Metso

1st edition

# Rotary kiln handbook:

## Aftermarket care for lasting reliability

Version 1.0

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# Preface to the First edition

The following handbook describes the fundamental components and uses for rotary kilns as designed and sold by Metso. Rotary kilns are the cornerstone of many processes that were developed and marketed by legacy companies Kennedy Van Saun corporation, Svedala Industries and Allis Chalmers corporation. Some of these processes include limestone calcining, iron ore pelletizing, coke calcining and many others. Although the processes vary, the use of the rotary kiln is common to all and the kiln design and components are nearly identical.

This handbook will serve as a technological resource for rotary kiln owners, operators and maintenance personnel. It will help identify the different parts that comprise a rotary kiln, the alignment and maintenance required for achieving high reliability from a rotary kiln and some insight on more recent rotary kiln developments and improvements.

The information contained herein is general in nature and is not intended for specific construction, installation or application purposes. Predictions of actual performance of a given piece of equipment should take into account many variable field factors the machine is liable to encounter. Because of those factors, no warranty of any kind, expressed or implied, is extended by presenting the generalized data herein.

We reserve the right to make changes in specifications shown herein or add improvements at any time without notice or obligation.

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# Rotary kilns are the cornerstone of many processes.

First developed in the 1800s, rotary kilns have been and continue to be instrumental in a wide range of processes. They share common components across manufacturers and intended processes. Using heating methods such as convection, conduction or radiation, material change processes are driven inside the kiln.



## History

The rotary kiln was first developed in the 1800s for use in cement production. Thomas Crampton, Frederick Ransome and Alfonso Navarro all played a part in early kiln designs both in the United Kingdom, and later, in the United States. The Coplay Cement Kiln in Coplay, Pennsylvania, was the first American-based kiln installation in 1889. Allis Chalmers, which formed shortly after Coplay, sold its first kiln to a Spanish cement company in 1901. Kennedy Van Saun later followed with their first cement kiln in 1909. Metso acquired both Allis Chalmers and KVS at a much later date.

# What is a rotary kiln?

A rotary kiln is a thermal processing instrument used for treating different types of solids to produce a chemical or physical change to the feed material. These changes can be instigated by exothermic or endothermic reactions with heating through direct flame or indirect heat methods, using solid, liquid, gas or electric heating techniques.

Some common reactions include:

- Calcination
- Thermal desorption
- Organic combustion
- Reduction
- Sintering/induration
- Heat setting
- Decrepitation

Rotary kilns share common components across manufacturers and intended processes. These include:

- **Shell**
- **Seals**
- **Riding ring/tire**
- **Support rollers**
- **Thrust rollers**
- **Drive**
- **Feed spout**
- **Discharge housing**
- **Bearings**

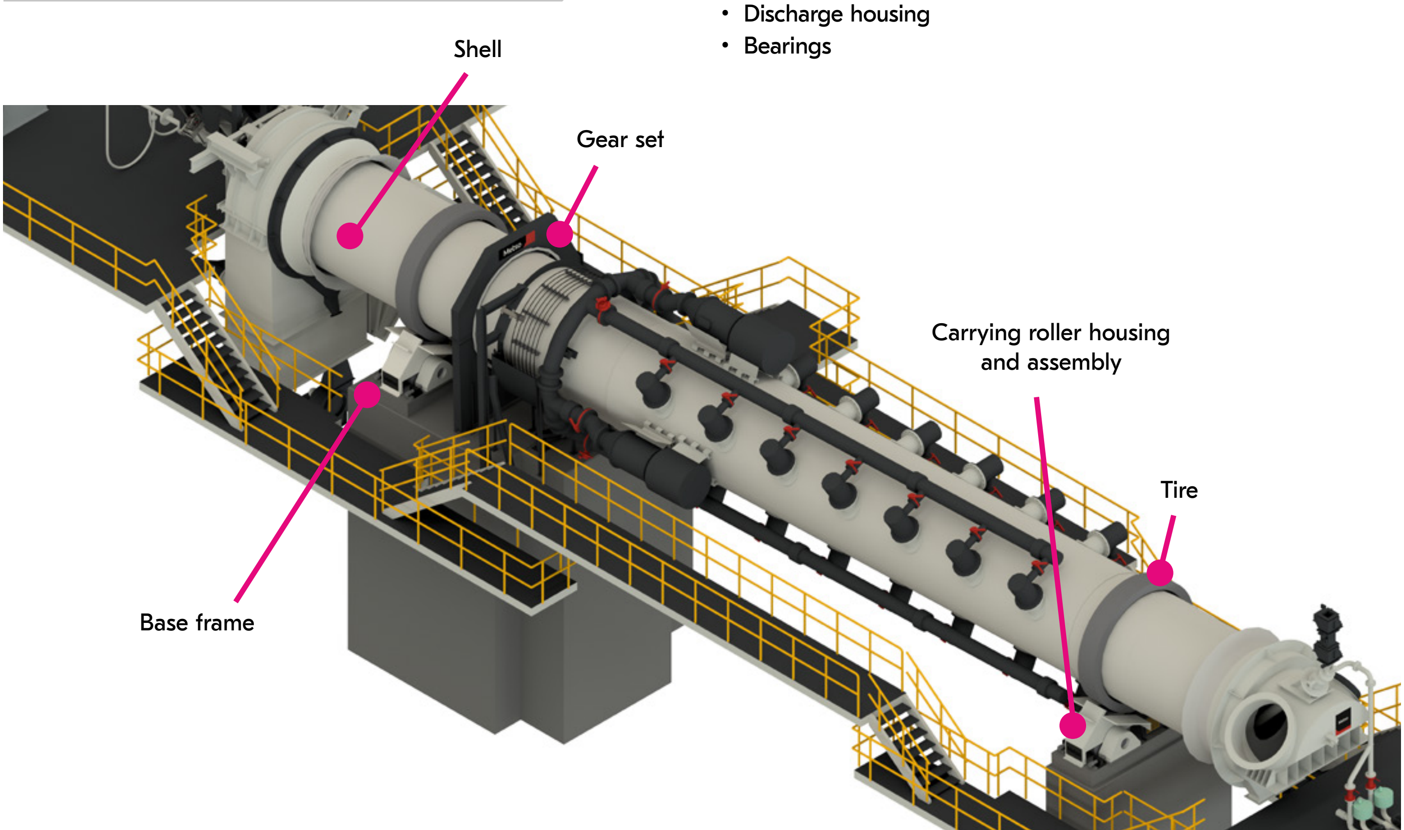



Figure 1: Basic kiln architecture


EASY MOLD

## Rotary kiln process

Although originally conceived for the cement industry, rotary kilns have found use in a wide range of processes, including:

- Mineral roasting
- Iron ore reduction
- Proppant sintering
- Gypsum and bauxite calcining
- Waste incineration
- Desorption of soil contaminants
- Upgrading of phosphate ores
- Lime recovery
- Catalyst activation
- Activated carbon production and reactivation
- Plastics processing/recycling
- Ceramics processing
- Petroleum coke calcining

Metso and our legacy companies have implemented rotary kilns for each of these processes. With such a long history of use, it could be incorrectly thought that the rotary kiln has run its course. Newer technologies that incorporate special heating methods to lower emissions (e.g., microwaves, electric heaters, plasma arc, etc.) and new mineral constituents are being developed. Direct reduction of iron ore, lithium baking, phosphate and various gasification and recycling techniques are now in vogue, as the world seeks to reduce our dependence on fossil fuels, recycle constituents once sent to landfills and develop the required materials for a sustainable future.

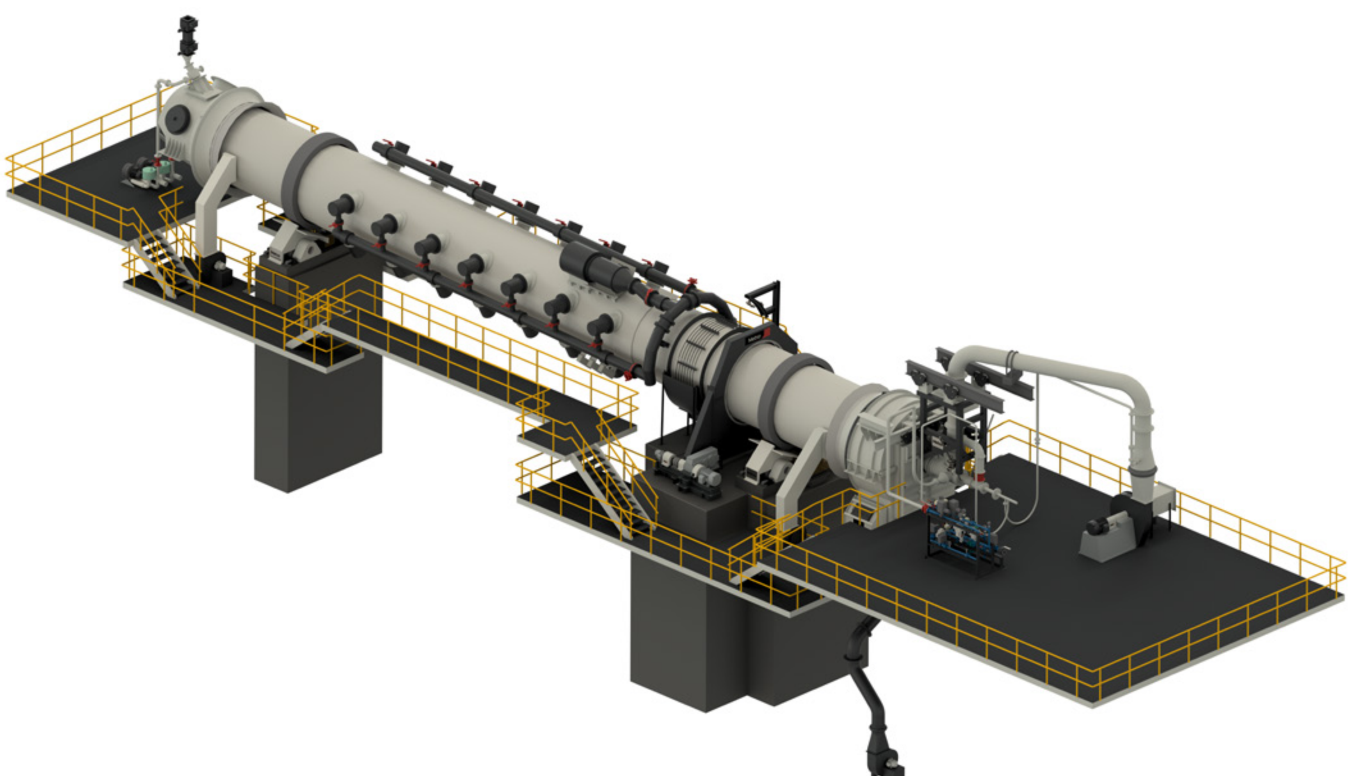


Figure 2: Direct fired phosphate kiln with air injection ports

## Heating methods

Rotary kilns require heat to drive the material change processes inside the machine. There are various heating method and flow path configurations compared to the material flow path.

Most kilns are direct fired, where the heating source is inside the kiln shell with the material. As the material migrates from the feed end of the kiln toward the discharge end (down slope) it is directly exposed to the heating source.

When the burner or heat source is at the feed end of the kiln and the heat travels in the same direction as the material, it is called co-current. This heat energy to material movement relationship is typically reserved for very wet materials (e.g., lime sludge recovery). The purpose is to drive as much temperature into the material at the beginning to remove moisture as rapidly as possible.

Counter current is when the burner is at the discharge end and the heat flows in the opposite direction of the material. For both process types, radiant heat is the main heat transfer method where the kiln flame radiates onto the material bed, with convection and conduction being minor constituents to the overall heat transfer model. Rotary dryers, on the other hand, use lifters to shower the material into the airstream. Convection and conduction become the primary drivers of heat transfer with radiation having little to no impact.

Some kilns are heated indirectly, where the heat source (e.g., flame, electric, etc.) is outside the shell and the heat energy enters the material indirectly through the kiln shell, such as in carbon regeneration. Most indirect kilns are configured to protect the material from oxygen exposure. On these types of kilns, conduction becomes the main method to transport heat energy into the material bed. These indirect kilns also allow more precise control of heat energy applied to the material and the rate at which it is applied (rate of temperature rise).

Other heating and energy transfer methods are combinations of the above. The material being processed determines the most appropriate method. Metso offers laboratory testing to determine best practices.

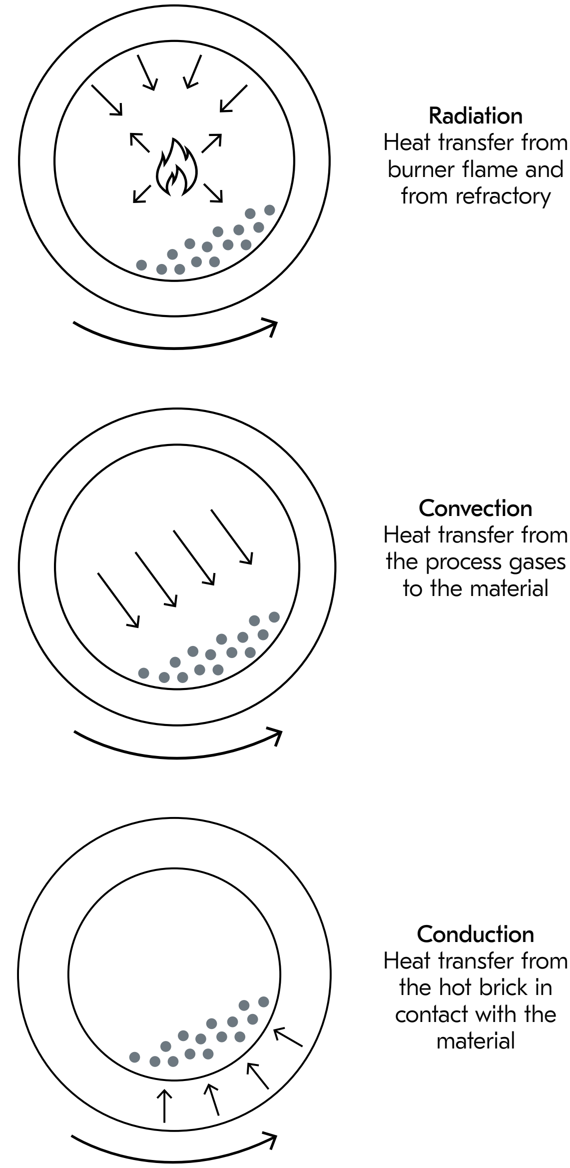



Figure 3: Modes of heat transfer

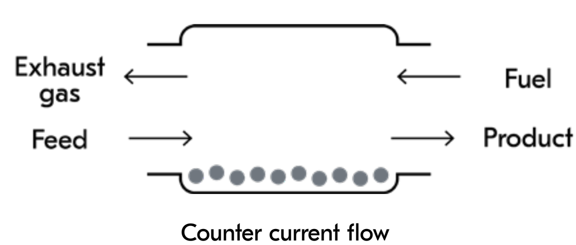



Figure 4: Kiln process flow

## Process example – limestone calcination

Calcium oxide (CaO), often called quicklime, is the product of calcination of calcium carbonate (limestone, $CaCO_3$). The product of calcination of dolomite ($CaCO_3MgCO_3$) is called dolomite or dolomitic lime. Heat input is required to drive this reaction, classifying this as an endothermic reaction. Endothermic reactions are energy intensive and typically require more time to satisfy (requiring longer kilns).

All lime kilns are heat exchangers and conveyors, as heat must be transferred from the flame and hot gases to the bed of stone in the kiln, and the material in the kiln must advance from the feed end to the discharge end. The basic modes of heat transfer in the rotary kiln are shown in Figure 3; the major amount of heat transfer in a rotary kiln occurs by gas radiation from the hot flame and combustion gases.

The second and much smaller amount of rotary kiln heat transfer is due to brick radiation. The hot brick radiates heat to the material, and transfers heat by conduction to the charge; temperature measurements of the brick lining in contact with the charge show that the temperature decreases by approximately 10° C (50° F) to 121° C (250° F) after the brick has passed underneath the charge due to the kiln rotation. Part of this cooling is also due to the absence of radiant heating of the brick from the gas or flame while the brick is covered by the material charge.

Another minor portion of rotary kiln heat transfer is due to convection when the hot gas stream comes in direct contact with the charge in the rotary kiln. This portion of heat transfer can be considerably increased mechanically, providing a higher degree of mixing, such as dams, internal recuperators, Trefoils and lifters.

Since most rotary kiln heat transfer is by radiation, it is necessary that the stone is exposed sufficiently to direct radiation from the hot gases and flame. Material movement in a rotary kiln and the path of a single particle in the material bed is a function of the kiln speed, slope, kiln material angle of repose, kiln length, and kiln diameter. With these parameters, the material retention time in the kiln can be described adequately, but the feed size distribution and the feed size ratio have a strong influence on the exposure of single particles to flame or gas radiation.

Although rotary kiln heat transfer is a very complex system, mathematical models have been developed that allow the accurate description, permit scale-up and kiln sizing from basic physical and chemical information, lab tests as well as extrapolation from small (or full scale) installations to desired operating conditions, such as more capacity, less fuel consumption or different product quality.

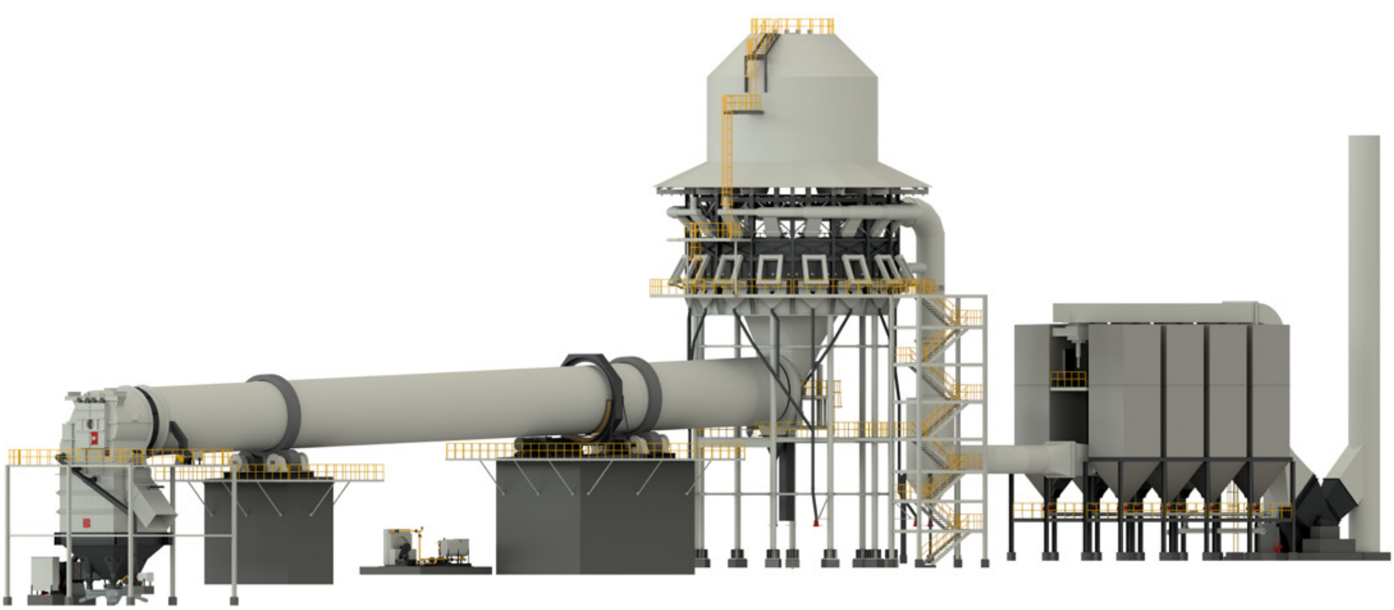


Figure 5: Lime plant

While rotary kiln heat transfer involves a highly complex interplay of physical and chemical phenomena, robust mathematical models have been developed to accurately characterize these systems. These models enable reliable scale-up and sizing of kiln operations by integrating fundamental thermophysical data, laboratory measurements, and extrapolations from pilot or full-scale installations. This approach supports kiln design that is optimized for specific performance targets, such as increased throughput, reduced energy consumption, or tailored product specifications.

To make sensible use of the significant heat energy input, the heated airstream leaving the kiln is used to preheat stored stone waiting to be fed into the kiln. The heat recovered from the cooler at the discharge end is used to preheat the combustion air while cooling the feed material.

Limestone heat conductivity is 0.005-0.006 $cal.cm^{-3}.sec^{-1}/°C$. The best limestone for making quicklime (CaO) has very specific chemical and physical characteristics because lime quality is directly tied to the stone quality and how it behaves in the kiln.

- High calcium carbonate ($CaCO_3$) content
  - >95% $CaCO_3$ is ideal
  - High-calcium limestone produces high-reactivity quicklime
  - Low MgO (typically <1–2%) unless producing dolomitic lime intentionally
  - High purity = higher available CaO and better performance in steel, environmental, and chemical applications
- Low impurities
- Good thermal decomposition behavior
- Favorable physical properties
- Low moisture and organics

High heat input is required to convert limestone to quick lime, and the last few percentages of conversion are extremely heat intensive. Thermal efficiency is of paramount importance to a successful plant operation.

The above holds true for many different processes. As moisture is removed from the feed material and drives the chemical reactions, the final few percentages of change are the most time and energy intensive. Metso uses computer modeling and laboratory testing to determine heating rates, exposure times and overall heat and mass balance with energy costs to help guide kiln design and system design.

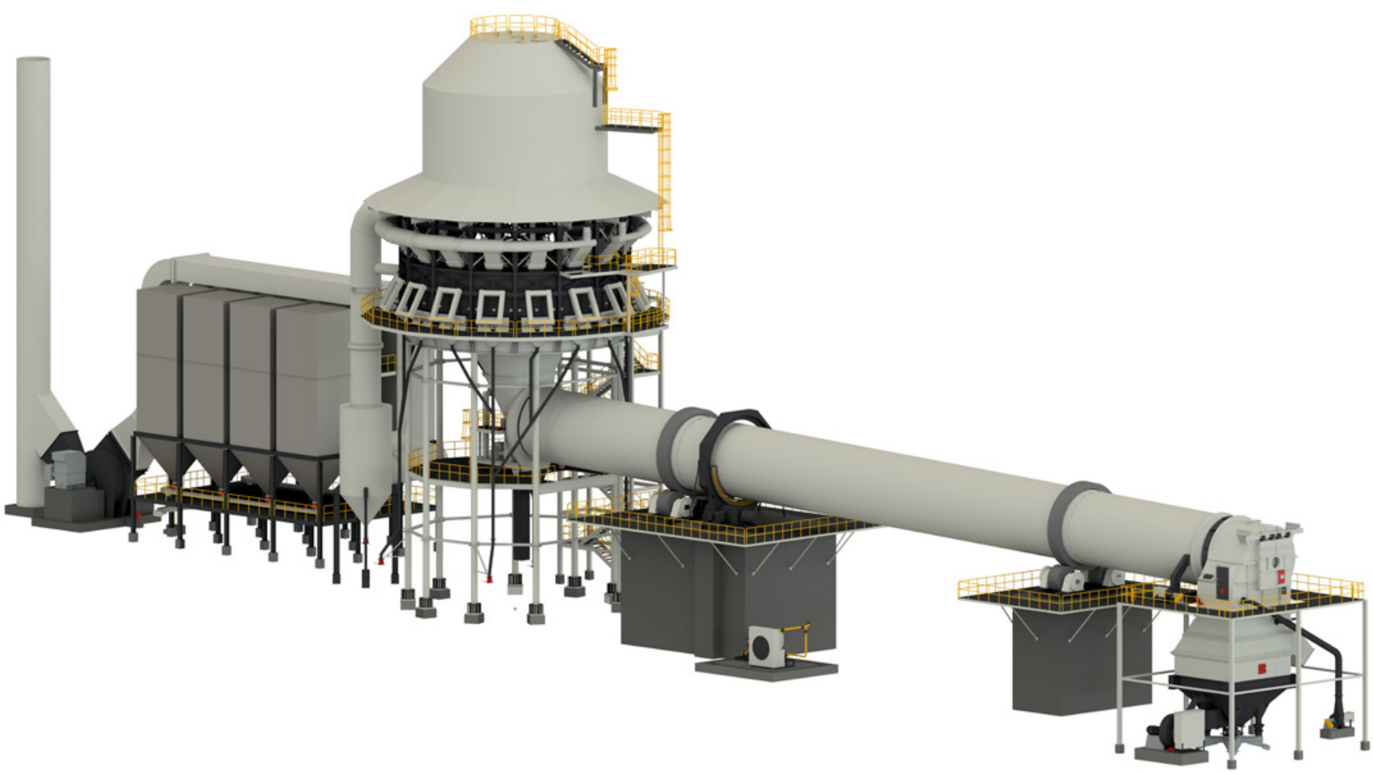


Figure 6: Lime plant, different view

# Different rotary kilns have a variety of features.

Metso kilns are designed and sized to meet specific parameters. Common components of a kiln include the shell, riding ring, carrying and thrust rollers, and the drive.

## Sizing

Metso kilns are designed and sized to meet specific parameters. The kiln length and slope work together to determine how long the material is exposed to the heating medium inside the kiln. The kiln speed also plays a part; however maximum and minimum "workable" speeds are constraining. Most refractory lined kilns rotate at a speed ranging between 0.5 and 2.0 RPM.

The kiln diameter prescribes its capacity to carry volumes of material and gas. Generally, the gas volume and velocity govern the kiln diameter. Most kilns, when running at full capacity, will only be filled with enough material to account for approximately 10-15% of the cross-sectional area. The rest of the area is used for kiln burner flame and gas volume.

The kiln design engineer's goal is to accommodate the length of the kiln with as few carrying stations (riding ring and roller combinations) as possible. There are several reasons for this approach: fewer carrying stations mean less capital equipment cost; fewer carrying stations are also easier to align and keep aligned, and fewer components minimize overall maintenance costs. Kiln designers strive to create kilns with only two carrying stations, but this is not always feasible. Very long and relatively thin (high length/diameter ratio) kilns require more than two carrying stations to minimize bending stress, deflection and the required plate thickness needed to accommodate the stress level.

Original kiln design is a factor when changes are made. Fuel type, burner type, exhaust fan and ductwork, and feed material changes together with other parameters affect the kiln process requirements. For example, due to changes in the filtering plant, the feed material has increased in moisture content. With a minor increase, a burner change may accommodate the change. This also increases gas volume, so off-gas speeds are faster, which increases the volume going to the gas cleaning system and must be checked for suitability. Major changes in moisture content bring additional issues. Higher moisture content often impacts the angle of repose (making it shallower), so the material moves through the kiln at a different rate. Wet material also tends to slide on the inside of the shell/refractory instead of tumbling. This affects mixing and average gas/flame exposure inside the kiln. Where speed and burner changes are made to accommodate increased moisture, the off-gas volume and moisture content will also increase. This can significantly impact cyclone and baghouse performance.

This section does not cover all process-related issues but is provided as a warning. Operators and end users experiencing process-related problems should contact their OEM. Select OEMs have math-based calculation tools to model equipment and processes and test labs where material can be tested and summarized in a report of conclusions drawn.

## Kiln shell

The kiln shell is the long, relatively thin tube that encompasses the main kiln body. The shell is responsible for carrying the weight of the material and refractory and providing room for heated gas and material flow.

Kiln shells are typically comprised of independent, rolled sections or "cans" welded together to form the overall shell length. While shells can be made from various materials, carbon steel (A36) is the most common. Indirect-fired shells operate at much higher temperatures and are typically comprised of stainless steel or a nickel-based alloy.

A rotary kiln can include internal features (internals) to improve heat transfer, material movement, reaction control and emissions performance. Not all kilns use them—lime kilns in particular are often lightly interned to avoid ring formation—but following is a structured overview of what can be designed into a rotary kiln.

- Lifters/flights
- Dam rings (retention rings)
- Lifting shelves/heat exchange shelves
- Internal chains
- Internal refractory shapes
- Internal baffles
- Dust scoops/drop-out pockets
- Feed-end internals

Flexibility is beneficial to kiln shell design. Gravitation will compress the shell (the top portion will sag towards the bottom portion) as it rotates, creating repeated and reversing stress cycles. This results in cracks and potential shell failure. Feed end plates and rings welded into or around the shell resist bending and create stress concentrations, which is also present in openings cut in the shell and reinforced with a door frame, external tube cooler, or other component. These features should always be inspected during maintenance stops.

Additional kiln shell-related issues include refractory loss, hot spots/blisters, shell pinching and deformity under the riding ring (coke-bottling), wear on the inside shell diameter from corrosion and material or refractory sliding and wear (see maintenance).

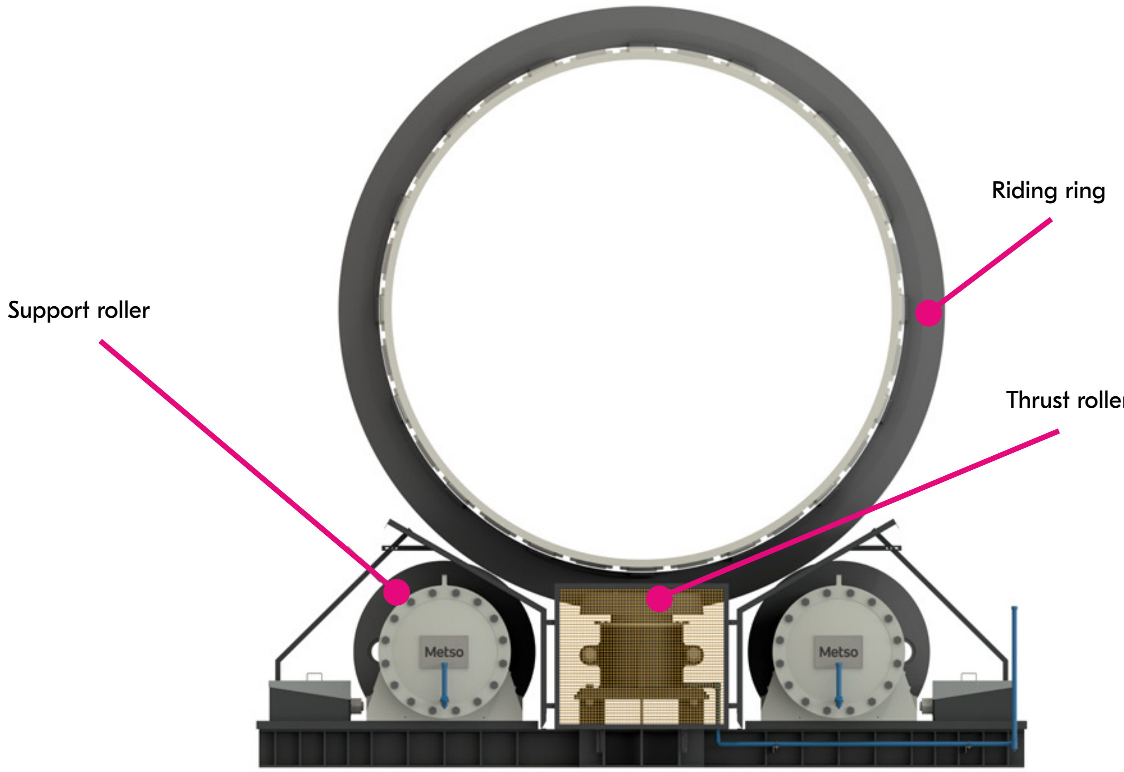



Figure 7: Thrust carrying station, front view

## Carrying station components

### Riding ring/tire

The kiln shell does not hold sufficient strength to directly act as its carrying surface. Large rings, called riding rings or tires, are provided as the carrying kiln surface. Although simple in form, the rings must account for rotational forces, carrying weight, thrust forces and thermal expansion. Many different approaches have been taken over the years to meet these design needs.  Metso kilns are a slip-fit on the shell, with wearing pads called filler bars between the shell and the inside riding ring diameter. The slip-fit decreases as the kiln heats and expands but should never become zero or less than zero, which will cause coke-bottling.

### Support rollers

Support rollers are a complimentary component designed to help support the kiln weight and ease rotation without translation, or linear movement. The rollers act as a rotating unit themselves. Roller shafts are typically carried in bearings that are mounted solidly to the supporting frame under the kiln. Occasionally, the rollers contain the bearings and the support shafts do not rotate (a dead shaft design), or the rollers are powered via motor and rotate the kiln. Component requirements are the same and maintenance-related issues are similar across the various designs.

### Thrust rollers

Since the kiln is positioned on slope and turning, gravity will pull it downhill. The rings are free to slide along the carrying surface of the rollers, so to prevent the rings from sliding off the rollers a thrust mechanism is provided to hold the kiln in place. The most common apparatus used today is a thrust roller. Older and/or smaller units use a stationary thrust pad; however, this is uncommon on rotary kilns. Metso machines use a pair of thrust rollers (one on the uphill side of the ring and one on the downhill side) and only one riding ring capturing thrust. The other rings are allowed to move and slide along the roller face as the kiln expands and contracts with temperature.

Gravity acts as the main engine for transporting material through the kiln shell. The slope is critical, and changes in slope affect material movement and impact the process. As components wear, the kiln may not lose elevation equally at all carrying stations, which can impact the slope.

Ideally, the kiln should float between the uphill and downhill thrust rollers or bear minimal pressure on downhill thrust rollers. In very particular design cases, the thrust roller takes the full kiln load, always thrusting downhill. Rollers and support bearings typically apply partial counterthrust to the downhill kiln movement.

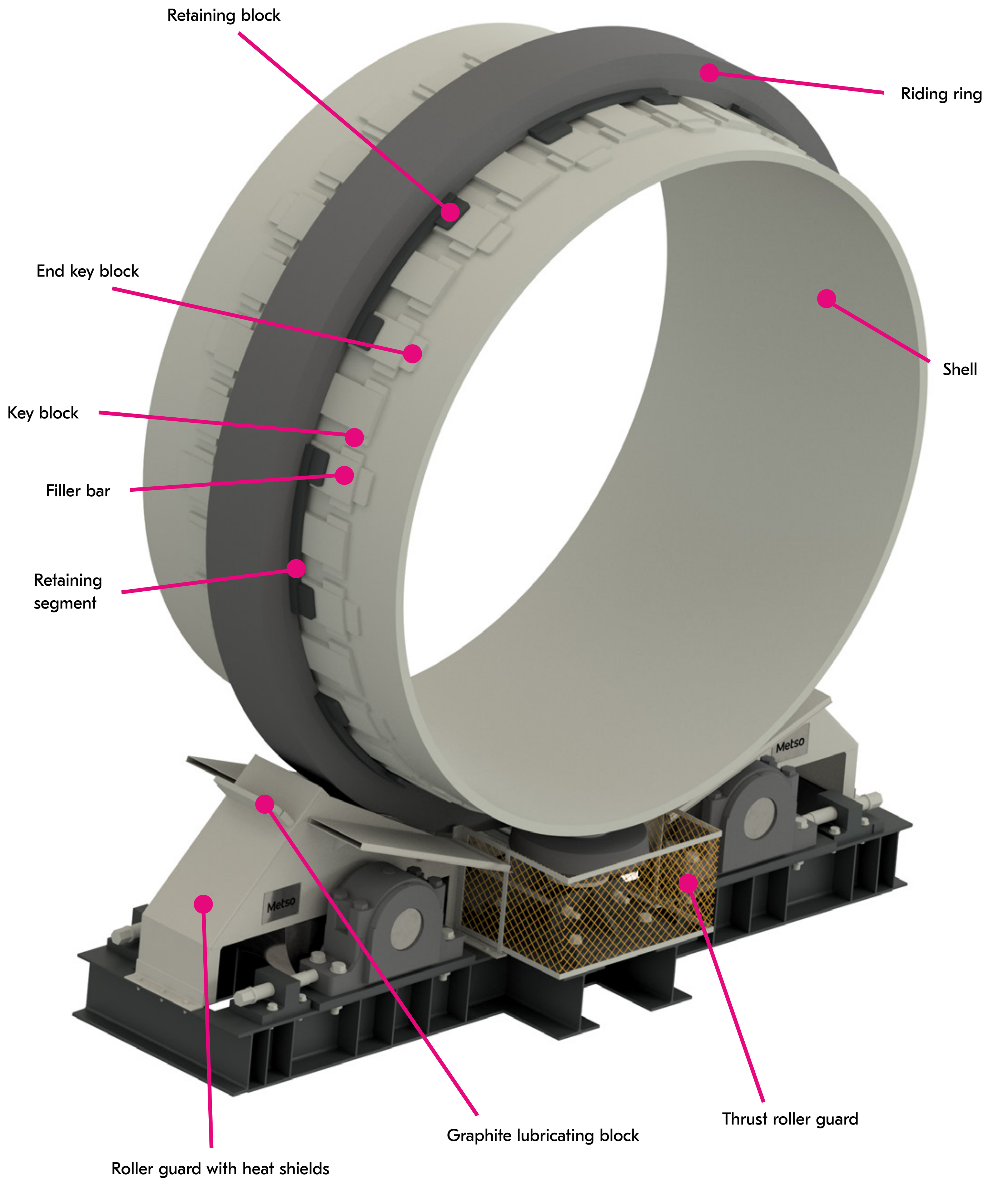



Figure 8: Thrust carrying station, side view

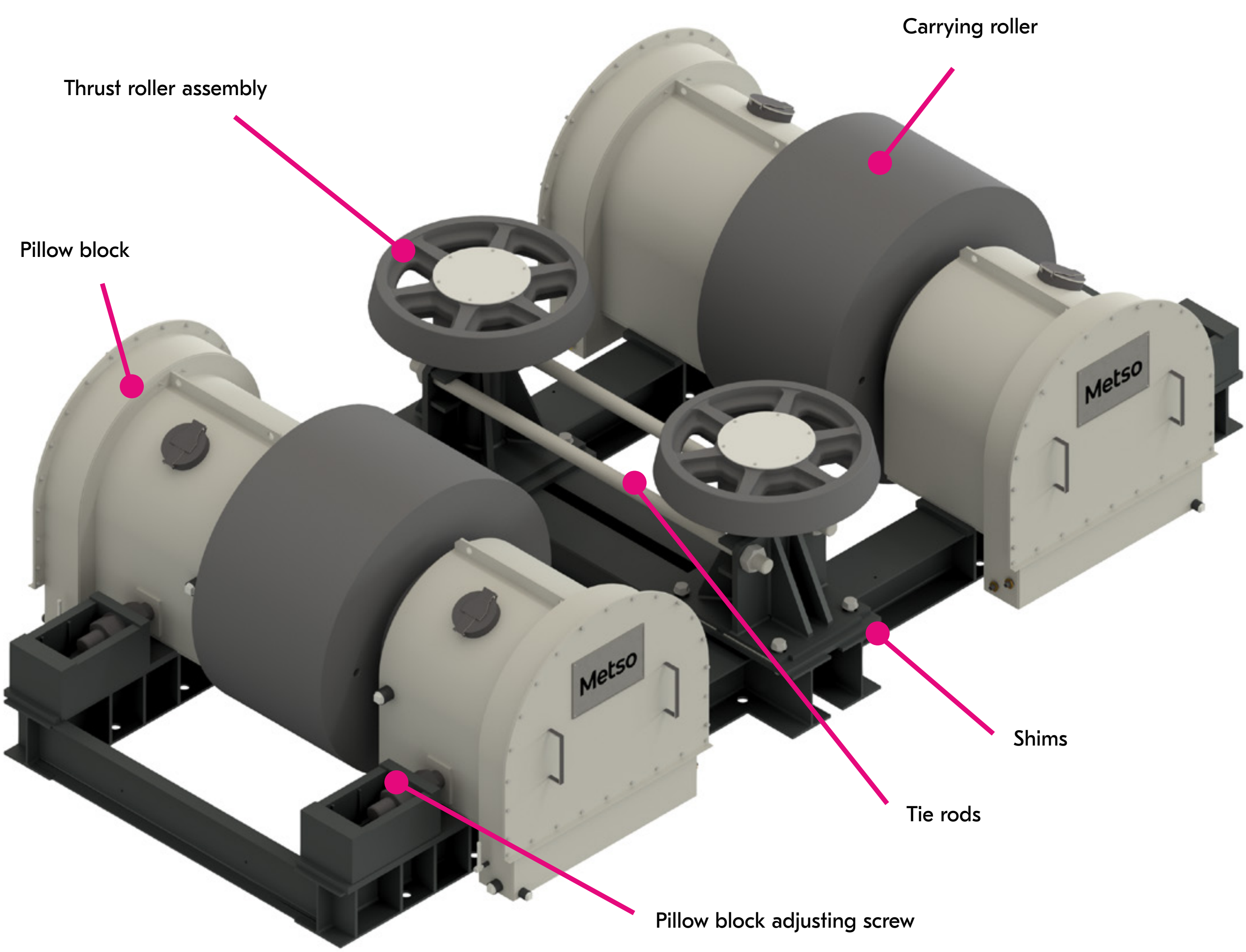



Figure 9: Thrust station (riding ring and shell not shown)

### Carrying frame

Most kilns are not located at ground level, but rather elevated, as the process uses gravity to transport material. Regardless of elevation, the carrying roller/bearing assemblies and drive need a support frame to connect with structural building steel or concrete support piers. These frames often play a critical role in the life of the machine due to alignment and vibration concerns. Fully exposed frames that are not buried in concrete or grout are preferred. Buried frames rely on the surrounding grout for shear resistance to the sloping kiln and frame. Buried frames also cannot be easily inspected, and issues may go unnoticed until bearings and rollers are impacted. Frames should be above grout and rely on keys and many foundation bolts to supply the shear resistance.

Frames and foundations are designed to handle local seismic conditions. Any changes to bolts, grout, etc. should not be made without consulting design engineers.

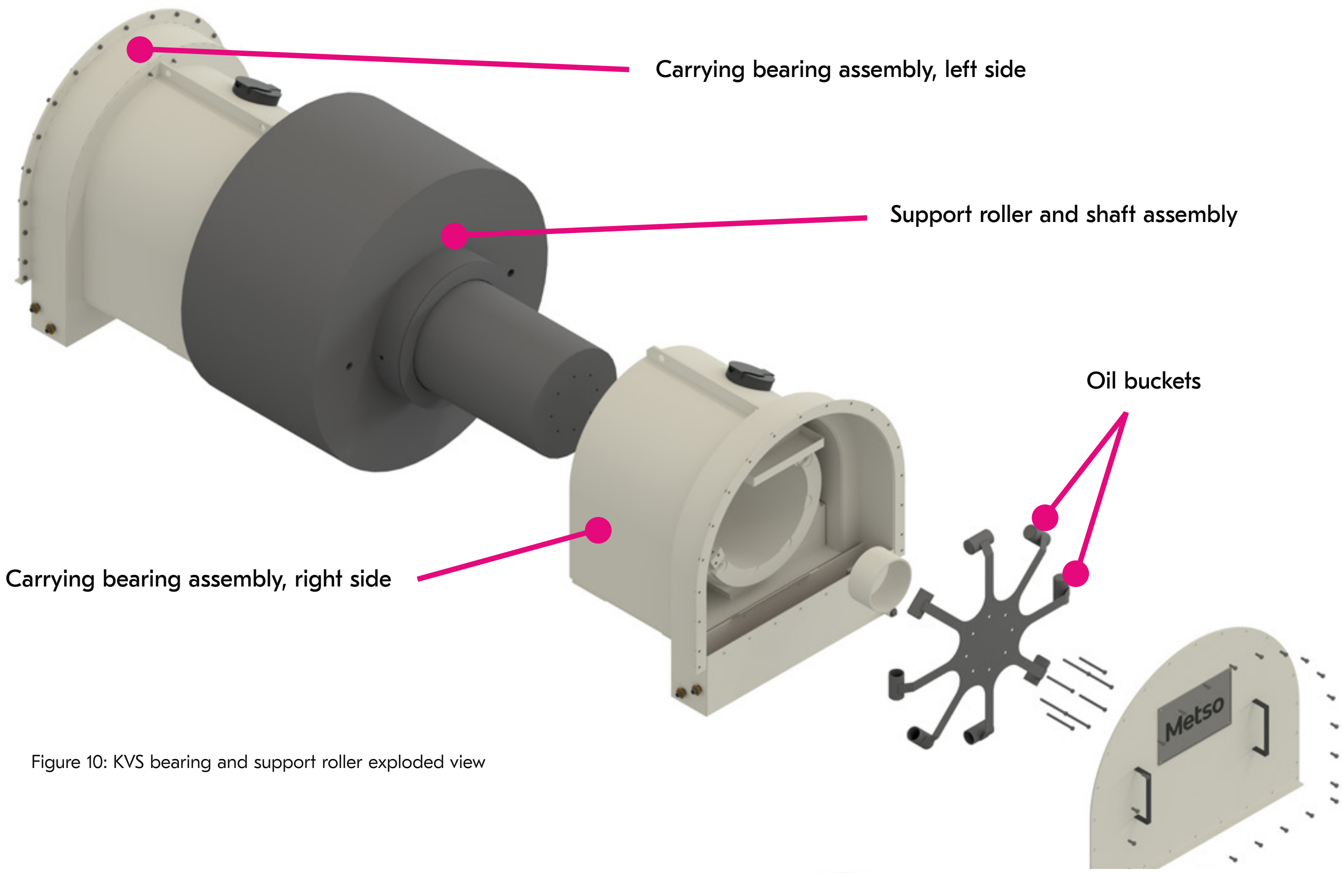



Figure 10: KVS bearing and support roller exploded view

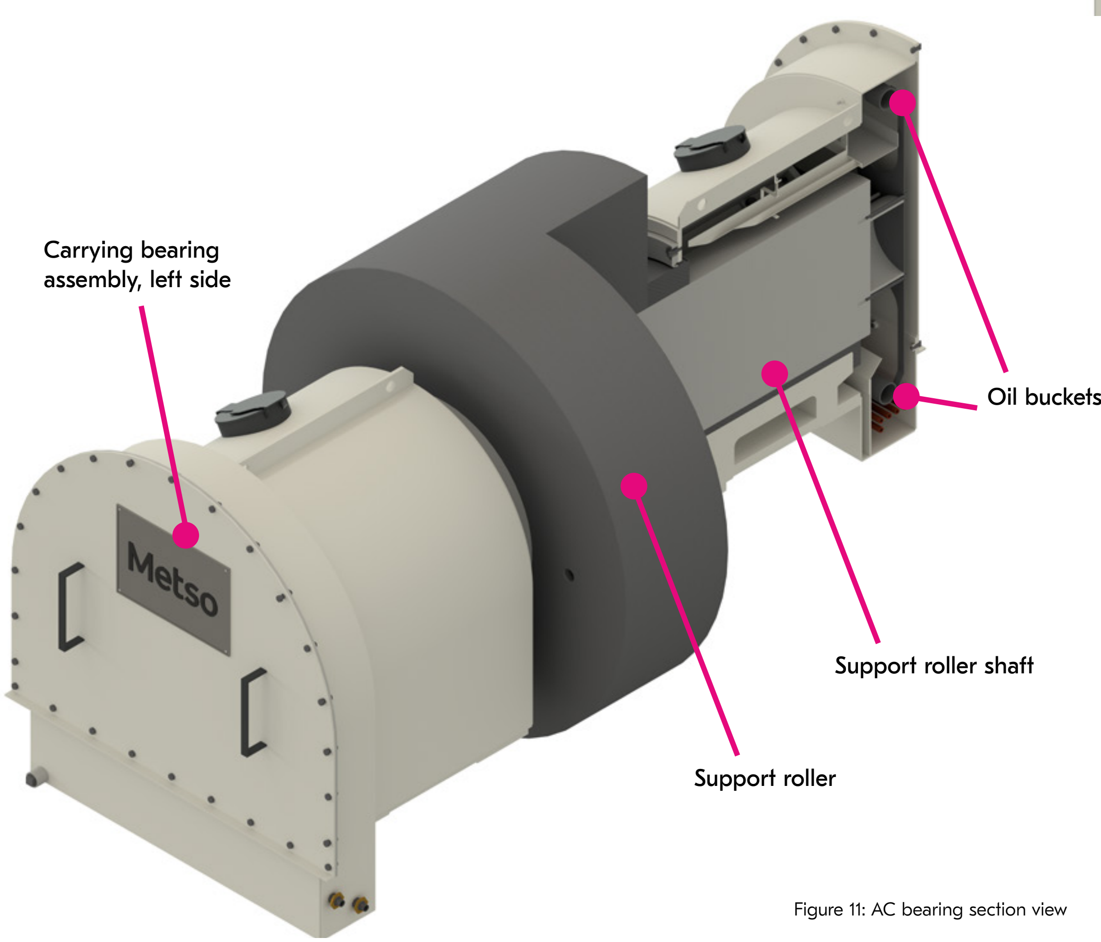



Figure 11: AC bearing section view

### Drive

A driving mechanism must be included to rotate the shell. Drive mechanisms can vary, but the most common type for Metso kilns is a large girth gear, attached to the shell, and rotated by a pinion mounted to the frame under the kiln. Rotation resistance comes from two sources: friction in the carrying and drive mechanisms and the torque generated by the offset material bed inside the kiln. Recall that the material crawls up the upturning side of the kiln and assumes an angle roughly equal to the material angle of repose. This offset pile creates a torque arm inside the machine and resists shell rotation. Additional drive forces/torque can be generated by kiln misalignment, seal friction, uneven build-up inside the kiln and other factors.

The most common mounting gearing arrangement includes a tangent plate, which is a type of spring plate. This acts as a buffer between the rigid gear and the flexible and expanding/contracting kiln shell. Some gears are solidly mounted via a heavy flange welded to the kiln shell.

Regardless of drive type, all rotary units contend with certain conditions to generate rotation: at start-up from an emergency stop where material remains in the kiln, the material bed must be raised up from bottom-dead-center to its offset position along the up-turning side of the kiln shell. This, combined with idle shafts and bearings, leads to high torque demands, which can be as high as 250% normal running torque. Conversely, if a kiln suddenly loses power during normal operation, the offset bed will cause the kiln shell to rotate backwards with an instantaneous velocity that can be significantly higher than the normal, forward rotational speed. The drive components must be able to handle these potential scenarios. Piston engines do not operate well when rotated backwards. Electric motors and most couplings should not be operated above recommended speeds, in forward or reverse. Gear and pinion teeth risk damage when shock loaded, as they are often made from hardened materials for wear resistance.

Kiln alignment components such as bearings, riding rings and thrust rollers can impart binding constraints that drastically increase the drive demand torque. Friction is a sizable consideration in drive demand torque. It is always best to maintain alignment and keep the drive gear/chain covered and well lubricated.

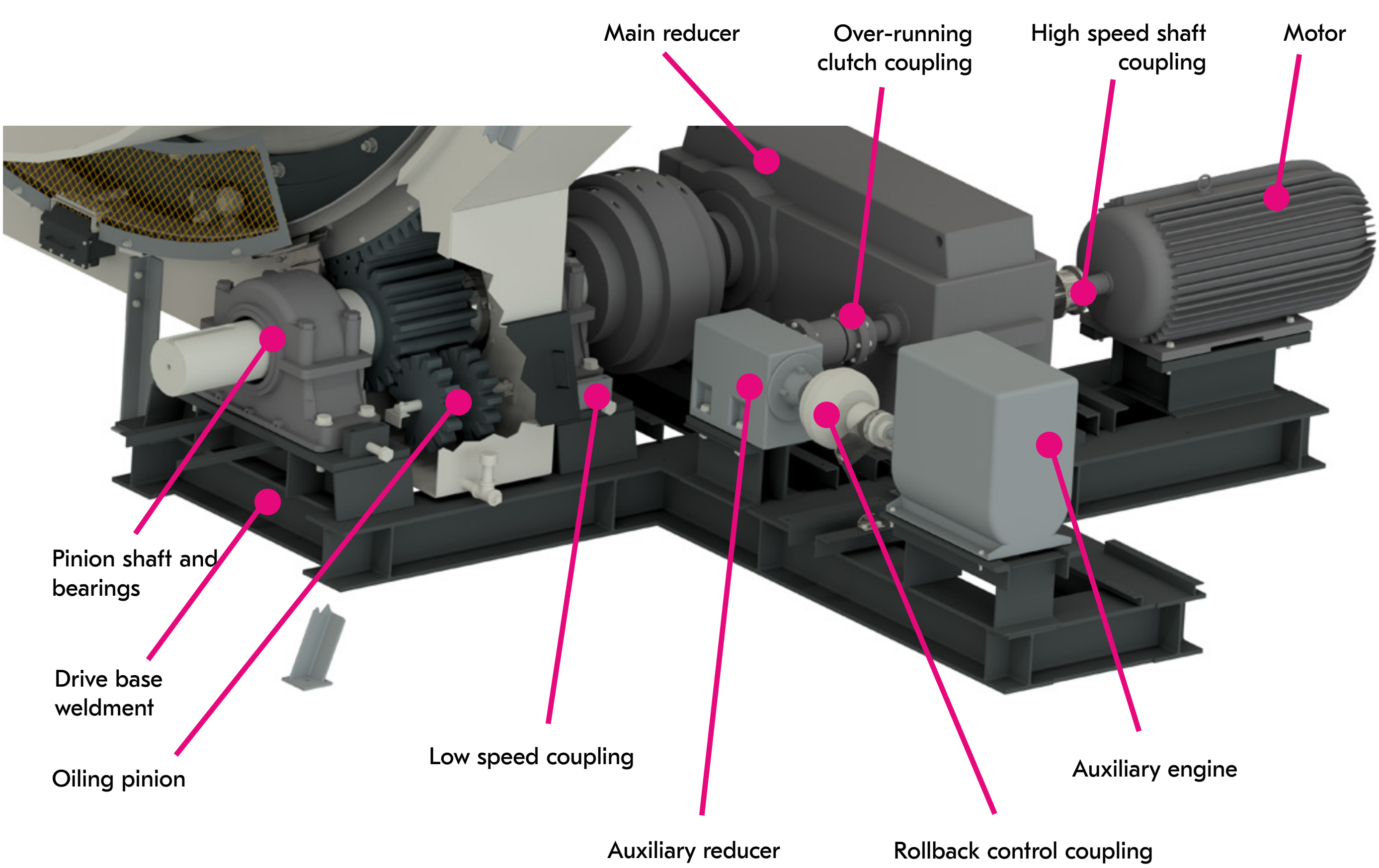



Figure 12: Girth gear drive components

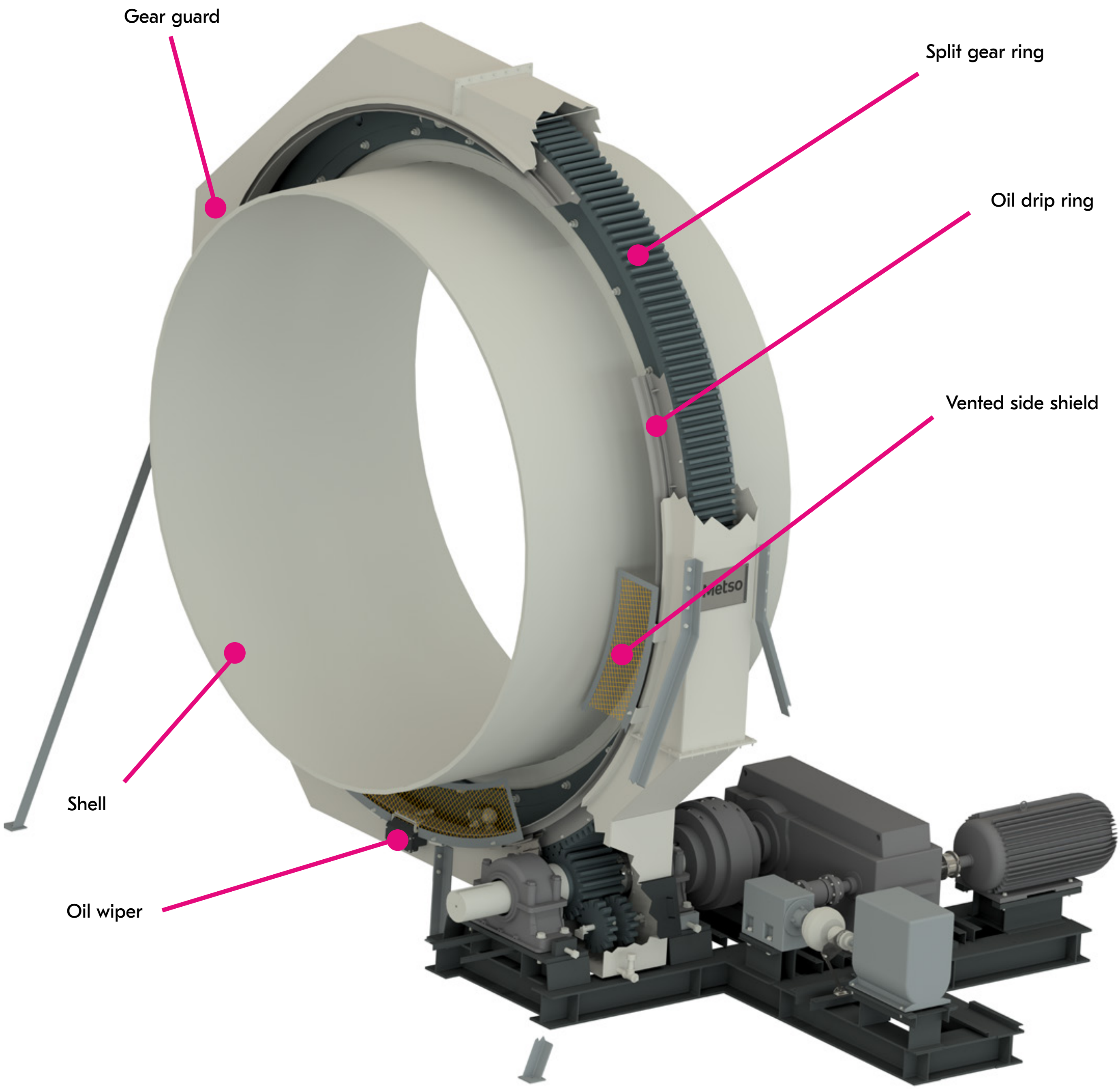



Figure 13: Flange mounted gear

**Feed and/or discharge housings**
Feed material needs to be introduced and removed from the kiln. Feed and discharge housings come in many different configurations but bear many similarities. The housings tend to be stationary with the kiln shell briefly piercing the housing wall. The interface between the rotating and stationary components normally requires a seal for dust mitigation and air ingress into the kiln. Most kilns operate under slight negative pressure so outside air will infiltrate the seal area. Kilns are designed for heat, and ambient air can reduce system efficiency.

The housings also manage air and material flow. Sizing must account for air speeds, dust loading and material movement. Some arrangements have separate pipes or screw feeders to convey material separately from the airstream.

Changes to the material insertion point, dams (intentional or from build-up on the inside of the shell) and other features can significantly impact material flow. Unintended dams from buildup, especially near the discharge end, are a considerable concern. The dam causes material to back up inside the kiln, increasing the loading percentage (drive torque) and lessens the open gas flow percentage area while slowing the average pile heating rate (more mass).

**Lubrication systems**
Kilns are comprised of many rotating parts that require lubrication to minimize wear and drive system torque demand. Consideration must be made for temperatures, construction materials and rotation speeds. Most support bearings and thrust rollers are grease lubricated. A high viscosity oil may be used on larger diameter kilns and bearings. In unclean or very hot applications, oil may be circulated so it can be cleaned and cooled.

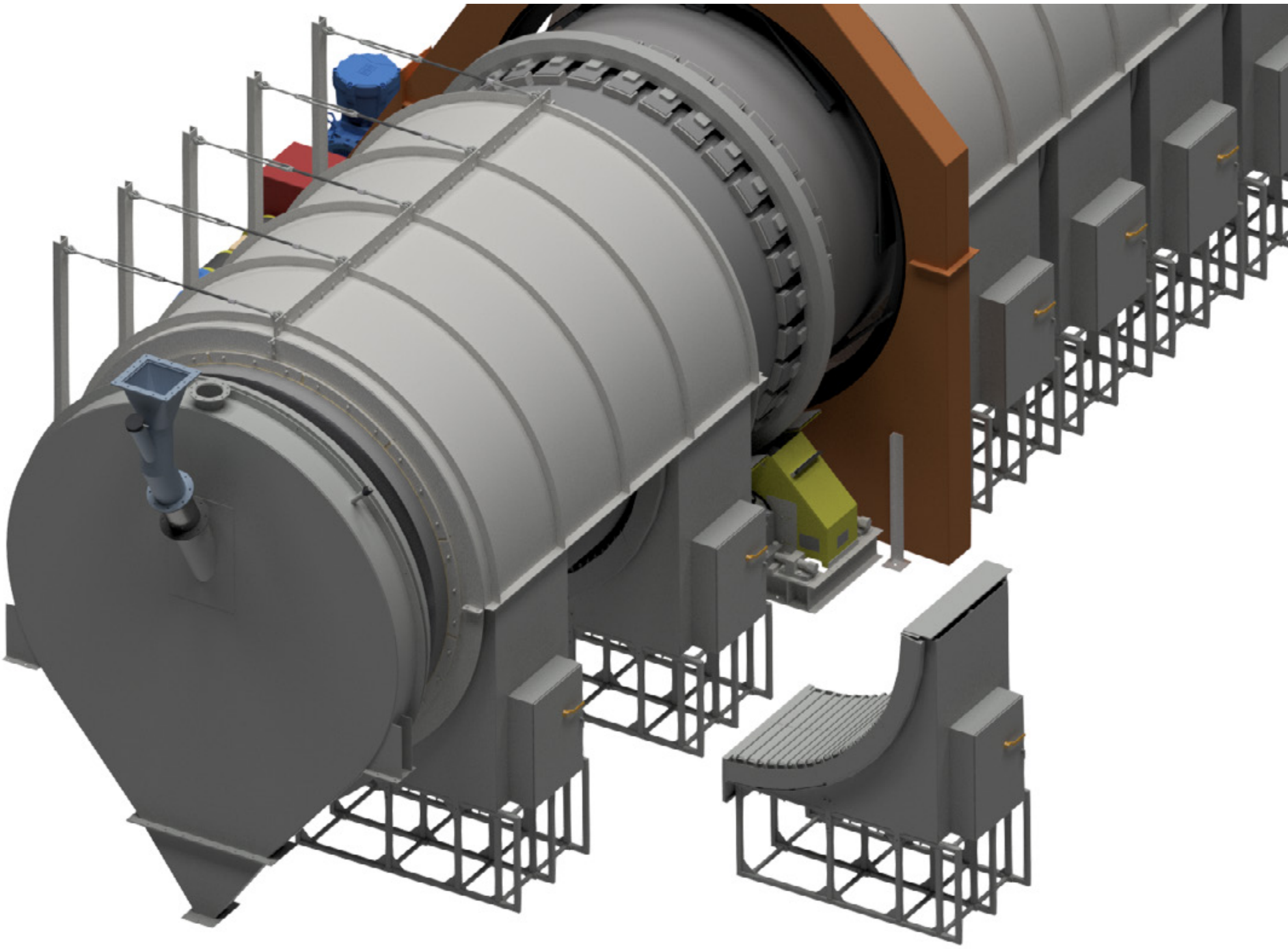
Gears and chain drives are often grease lubricated. As with kiln bearings, temperature and dirt intrusion can impact oil quality. The simplest lubrication method that meets the demands is often chosen for reliability. Lubrication loss in any component, even briefly, can be disastrous.

Many end users are unaware that riding ring-to-shell and riding ring-to-roller interfaces should be lubricated. The rings, due to the clearance with the shell or filler bars (welded to the shell), slightly rotate independently of the shell. This movement is critical. The rings are lubricated using a solid graphite bar that slips into the interface to melt and lubricate and maintain the independent movement (riding ring creep) while minimizing sliding wear.

Graphite bars are used to lubricate the carrying face of the carrying and thrust rollers to minimize wear on these large, costly and hard–to-replace components.

**Slope**
Gravity is the main engine for transporting material through the kiln shell. The shell is sloped from feed end to discharge end, on a downward angle. As the shell rotates, the material climbs the upward turning wall of the shell and slowly slides down, in the direction of the slope. This action leads to the material propagating along the major axis of the tube, all the way to the discharge end.

The action is controlled by kiln rotation speed, severity of the slope and the natural angle of repose of the material being processed. Some materials have a very shallow angle of repose (with powders and liquids approaching zero angle), so additional features inside the kiln may be required to propagate the material along the inside of the shell. These can include screw-shaped spiral flights, lifters, bed disturbers/agitators and other components that artificially increase the angle of repose and the material movement down the kiln's sloping axis.



**Miscellaneous**

Different rotary kilns have a variety of features. This section highlights common components. Engineers have devised various ways to handle loading conditions, material transport conditions, temperature conditions and efficiency needs. Some kilns are equipped with internal chains that act as a heat sink and transfer heat to the material when dragged through the material bed. Others use chains and various internal and external hammering devices to remove material buildup. Kilns may have internal heat recuperators that introduce hot gases at certain locations within the kiln. Indirectly heated kilns have recently experimented with electrical heating elements in lieu of solid/liquid gas burners.

Changes are also made to kilns throughout their service life that are not part of the original design and may hinder kiln strength, durability or process parameters. This includes changes to construction materials or shell plate thickness made during a repair. These changes should be studied to determine the overall impact.

## Knowledge of these terms is essential to understanding the kiln condition and future maintenance and upgrades that need to be performed to keep it in good running condition

**Air swept** A system that uses a hot air or gas stream to perform the fine particulate material drying and conveying functions simultaneously. This process is most often used for grinding coal before it is used as fuel.

**Baghouse** Filtering device used to remove dust and small particles from the gas stream. The filtering media is shaped like a sock or bag that collects the dust on the outside. There are many styles and shapes, and several ways to clean or remove the dust from media.

**Ball mill** Grinding mill with a rotating horizontal drum used to reduce coal to the fineness needed for efficient combustion. Hardened balls are used as grinding media. The grinding chamber has liners. Provides a low maintenance option for an air swept.

**Bearing assembly/arrangement** Multiple part assembly including a liner or rolling element, housing that contains lubrication and cooling, and lubrication distribution method; assembly transmits loading to the base frame.

**Booster fuel oil pump** Picks up the oil from the circulating oil loop and delivers it to the kiln burner at a pressure suitable for proper atomization (approximately 500 psig for No. 2 oil and in the range of 600 to 1000 psig for No. 6 oil).

**Bowl mill** Grinding mill with a revolving bowl or grinding chamber used to reduce coal to the fineness needed for efficient combustion. The most popular style mill used for lime plants. Also air swept.

**Burner pipe** The pipe through which the coal mill exhauster delivers the pulverized coal to the kiln coal burner.

**Burning zone** The hottest spot on the rotating bed of lime within the rotary kiln. The burning zone can shift up or down the kiln depending upon the shape of the flame. When reading the burning zone temperature, care must be taken to scan the bed for the hottest spot to prevent over-heating the lime and the kiln refractory.

**Bypass tempering air dampers** Admit ambient air to cool the preheat exit gas in the exit header from up to 427 °C (800 °F) to a nominal below 260 °C (500 °F). A thermocouple located downstream from each header automatically controls the bypass tempering air dampers. A secondary bypass valve, referred to as the tempering T, may sometimes be located before the baghouse.

**Carrying station** Located at load piers; includes base frame and all support mechanisms (bearing assemblies, trunnions, etc).

**Circulating fuel oil pump** A pump that delivers fuel oil from the main storage tank at relatively low pressure (i.e. 100 psig) to areas such as the grate and kiln. The circuit is called a circulating oil loop because unused oil is returned to the storage tank.

**Controller** A device used to detect a change in a particular process variable and then automatically utilizes an external power source to amplify the error. This energizes a mechanism that corrects the deviation until the process variable returns to a preset value. A controller normally has an automatic and manual mode; if the operator chooses, the error signal can be corrected manually through an adjusting knob on the controller.

**Creep** Additional kiln shell rotation relative to the riding rings.

**Diametrical clearance** Vertical distance measured from the kiln shell to the inner diameter of the riding ring.

**Eccentricity** An axial misalignment of the kiln shell centerline, also known as "dog-leg".

**Electrostatic precipitator** A dust collection device that operates based on the premise of ionizing dust particles. These particles migrate toward collecting electrodes due to the electric field between discharge and collecting electrodes. These are not normally used in the lime industry.

**Fan vibration** Shaft deflection during rotation. Deflection is measured in mill units (thousandths of an inch). For the main process fans, the fan manufacturer prescribes vibration limits by which the control room operator can judge whether or not to continue operation.

**Filler bars** Located under the riding ring, these provide a wear surface for the riding ring internal diameter and is an area to be considered for preventative maintenance.

**Firing hood** The chamber adjacent to the rotary kiln discharge end that receives hot air from the cooler's primary cooling section and discharges calcined lime from the kiln into the cooler load zone. The oil and coal burner pipes project through the firing hood face into the kiln.

**Flame impingement** The kiln burner flame directly contacting the lime bed or kiln refractory wall.

**Flame out** A condition where a burner has shut off due to some malfunction.

**Frame** Structural body that transmits loading to the pier, provides area for bearing assembly and thrust assembly placement.

**Heat and mass balance** A separate application of heat and mass conservation to physical system analysis. By accounting for material entering and leaving a system, mass flows can be identified that might have been unknown or difficult to measure without this technique. The exact conservation law used in the system analysis depends on the context of the problem, but all revolve around mass conservation. All mass and heat in must equal content leaving the system. A deep process understanding is required to perform this task.

**Hood draft** The pressure condition in the kiln firing hood. A normal hood draft is a slightly negative pressure to contain hot air and the burner flame within the kiln.

**Lime quality** The lime specification defined by our customers. These are stipulated by the lime use or application: LOI, $CO_2$, residual carbon, reactivity, CaO, available CaO, size distribution, brightness, color, sulfur.

**Neim's cooler** A highly efficient type of heat transfer equipment used for both cooling the lime and preheating secondary air for the kiln.

**Out of roundness** Permanent plastic deformation of kiln shell due to some operational abnormality, i.e. loss of refractory, hot shutdown emergency.

**Ovality** Non-permanent, elastic deformation of kiln shell at the riding ring locations due to loading.

**Pier** Constructed of concrete, these structural supports transfer kiln loading to ground elevations.

**Pressure** Termed positive if greater than atmospheric, negative if less than atmospheric, and neutral if equal to atmospheric pressure.

**Pressure differential** The absolute gauge pressure variance between any two points within a system. In the lime plant, this term is normally referred to when discussing pressure differences across the bed in the preheater and sometimes in a Neim's cooler.

**Primary air** The ambient air that is supplied to a burner from a fan. The primary air supports fuel combustion, helps to shape the flame, and cools the burner blast pipe.

**Radiation pyrometer** The temperature sensing device mounted in the kiln firing hood. This pyrometer measures the burning zone temperature to control the fuel input for maintenance of a specified temperature.

**Retainer blocks** Welded steel stops that contain the movement of both filler bars and riding ring along the axis of the kiln. Depending upon kiln arrangement these may include retaining bands as well.

**Riding ring** Commonly referred to as a "tire" and is located at every load carrying station; it wraps the kiln shell and provides radial stiffness and contact area for kiln rotation.

**RKI index** An established specialized test conducted by Metso. The test gives an indication of the dust that will be produced in a rotary kiln. The tumble test is on calcined lime.

**Rotary kiln** A rotating cylindrical furnace with a burner at its discharge end that receives preheated lime from the preheater on a short kiln. These are pyroprocessing devices used to raise materials to a high temperature, called calcination, in a continuous process. Most kilns are slightly inclined horizontally and rotated slowly about its axis. The process material is fed into the upper end of the cylinder. As the kiln rotates, material gradually moves down to the lower end, and may undergo stirring and mixing. Hot gases from a burning source pass along the kiln.

**Scrubber** A wet dust collection device based on the principle that a dust particle with a relatively high velocity collides with a water droplet that has a lower velocity. As a result the dust particle and the water droplet agglomerate into a bigger particle. By adding correctly-sized water drops to a dust-laden gas stream the dust will be made to agglomerate with the water, and be separated from the gas.

**Secondary air** Recuperative air entering the kiln through the heat recovery cooler.

**Set point** The particular value at which a process variable is to be maintained.

**Shell** Assembled sections of rolled steel also known as "can sections;" overall length and diameter is determined by process needs.

**Support roller and shaft assembly** Commonly referred to as a "trunnion", located at each carrying station; the support roller provides contact and load carrying area for the kiln and the shaft provides two pivot arms for rotation and load transfer to the bearing assembly.

**Thermocouple** A temperature sensing device.

**Thrust assembly** Comprised of an uphill and downhill thrust face this prevents the kiln shell from over traveling along its axis.

**Vacuum** Pressure less than atmospheric; suction is also commonly used in this reference.

**Waste gas temperature** An off-gas temperature as it enters a stack for disposal to the atmosphere. Sometimes also used when talking about air to pollution control.

# Good maintenance habits go a long way toward keeping your kiln healthy and minimizing operating expenses.

Performing regular inspections and maintenance are vital for kiln health and can prevent breakdowns and eliminate related safety concerns, inconvenience, and costly repairs.

This section addresses typical maintenance and reliability concerns within a rotary kiln. It is not intended to replace or supersede the specific maintenance and operations manual provided by Metso with the original kiln supply. The intent is to give the owner/operator an understanding of the "what and why" behind rotary kiln maintenance and how this impacts unit reliability.

## Alignment

A regular preventive maintenance routine impacts the reliability of most (if not all) rotary kiln subcomponents. Ensuring that the carrying and drive mechanisms are properly aligned with the rotary kiln is critical for minimizing wear and frictional forces.

Alignment may mean different things to different users, but should include:

- Kiln rotation axis as it passes through each riding ring
- Pier elevations and the kiln shell axial centerline impact
- Kiln slope regarding initial design slope
- Support roller/shaft axis compared to kiln shell axis
- Riding ring runout (radial and axial)
- Gear and pinion per supplier's specification for root clearance, backlash, axial and angular alignment, axial and radial run-out
- Thrust roller offset compared to kiln centerline (thrust rollers are generally offset to the kiln down-turning side) and roller placement (uphill and downhill) with respect to the riding ring centerline

Overall alignment is identified by two types: hot and cold. Cold alignment is the kiln in a non-processing condition (no material load and no elevated temperature) and is a baseline for the kiln condition. Hot alignment refers to checks and measurements that can be made while the kiln is in operation (full material load and normal operating temperature).
Due to thermal expansion, temperature variations among components, offset material loads, and other conditions, the kiln alignment will vary when hot (sometimes substantially) from the alignment cold. The alignment objective is to use the cold condition as the starting point with the hot condition the ultimate goal. Changes should be made slowly and deliberately, with only one or two changes made at a time.

Although the kiln is aligned shortly after installation and commissioning, wear and temperature changes may require subsequent realignment. Normal tire, filler bar and support roller wear creates kiln axis misalignment. Other components subject to wear include the gear and pinion, thrust rollers and bearing liners. The accepted definition of good kiln alignment is that the kiln shell center of rotation at the kiln supports should lie on a straight line within a specific tolerance (usually +/- 3 mm [1/8"] for most kilns).

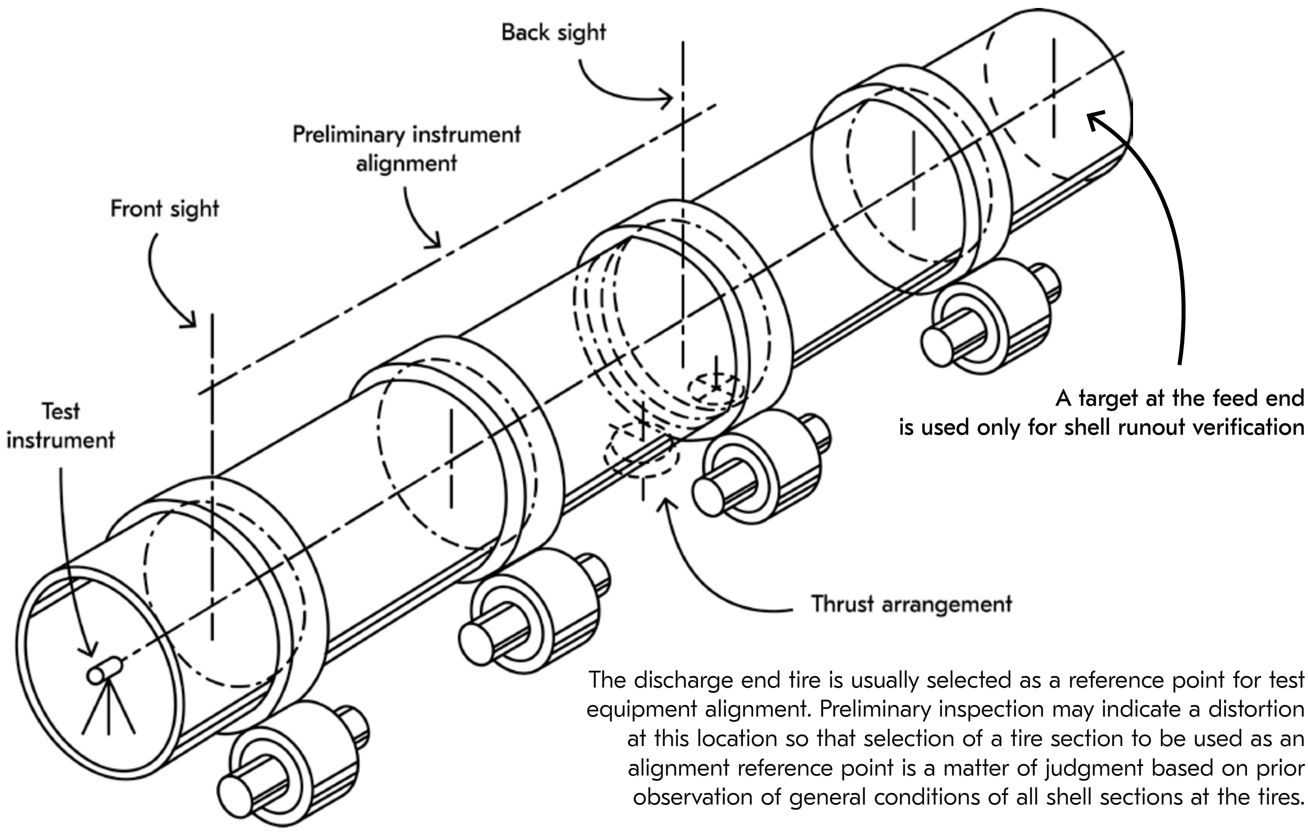



Figure 14: Internal alignment test (operational kilns)

The discharge end tire is usually selected as a reference point for test equipment alignment. Preliminary inspection may indicate a distortion at this location so that selection of a tire section to be used as an alignment reference point is a matter of judgment based on prior observation of general conditions of all shell sections at the tires.

The thrust tire is a reference point for aligning the test instrument because of its proximity to the drive arrangement.

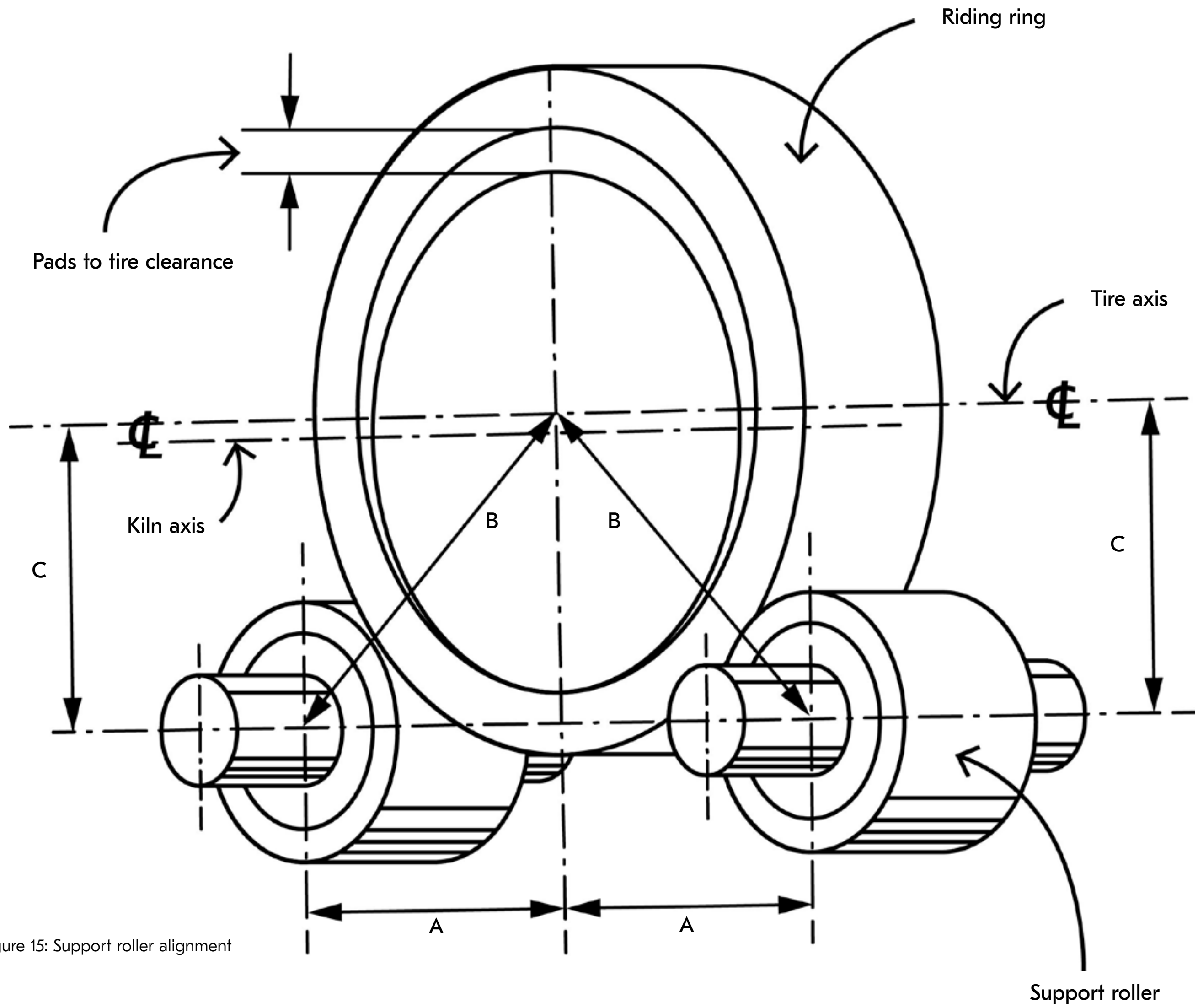



Figure 15: Support roller alignment

**A** - Dimension between vertical riding ring and support roller centerlines

**B** - Tire radius plus roller radius from actual field measurements

**C** - Dimension between horizontal riding ring and support roller centerlines

When dimension **C** must be adjusted to compensate for deviation in slope elevations between support frames, or to raise the kiln shell working axis to compensate for excess clearance between spacer pads and the tire, original dimension shown as **C** must be changed accordingly.

One-half of hot clearance must be considered for kiln shell axis alignment when in operation.

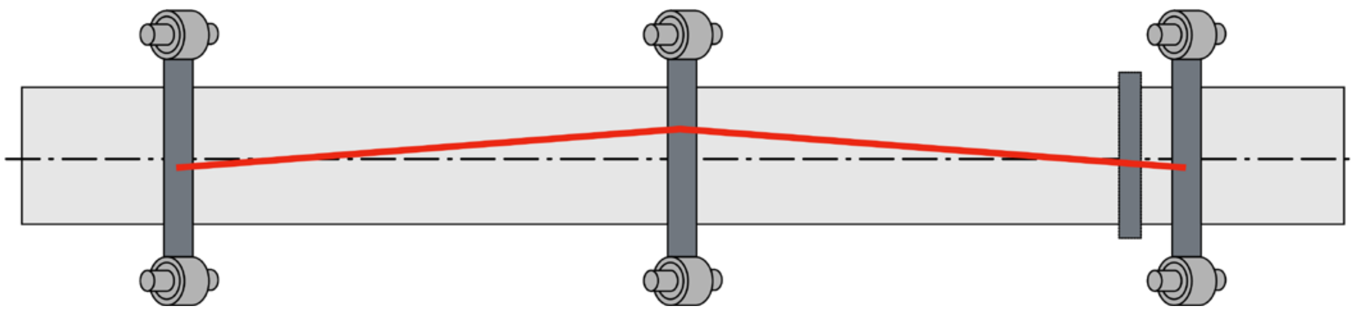


Figure 16: Centerline position in plan view

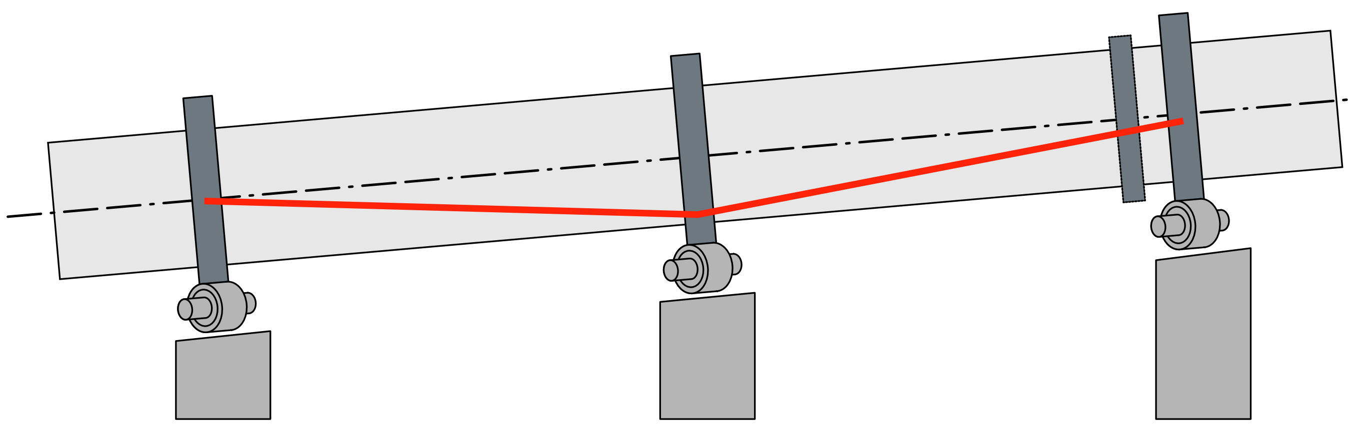


Figure 17: Centerline position in elevation view

Alignment should be considered in several ways:

**Pier to pier alignment**
(Especially crucial with long kilns of more than two piers/ carrying stations).

An inconsistent kiln centerline can impact lateral and vertical loads at each carrying station. The net result will be overload at some stations and/or one station resisting movement/ rotation with higher than normal drive forces and wear rates. Other factors may include overheated bearings at an overloaded station, rapid ring and roller wear, or the ring may try to force itself uphill or downhill along the kiln shell.

Viewed as a straight beam, misalignment effects include:

- Increased radial support roller bearing load on on one side
- Increased hertz pressure on rollers and tires leading to higher wear
- Increased shell stresses resulting in higher ovality and potential brick instability

Elevation view misalignment is partially offset by shell flexing:

- When treated as a structural beam, the shell naturally sags in the middle
- Unlike plan view alignment, the load is concentrated on one side only (at the bottom), allowing the shell to absorb the increased load by flexing/bending.
- The shell elevation position changes with different thermal kiln profiles day to day. Higher temperatures at one pier mean greater thermal expansion and a change in center position. It is not unusual to see changes between 3-4 mm in height.
- Plan view alignment is considered more critical to bearing loads than elevation view due to support roller placement. Elevation changes impact the vertical load, but plan-view changes cause lateral forces that would otherwise not exist.
- Plan view alignment remains steadier than in elevation view. Due to access and the uniform riding ring and shell shape on both sides of the kiln, it can be measured more accurately.

**Roller and riding ring alignment**
The ring to ring (centerline) alignment is relevant only to multi-support pier units with three or more support piers/ riding rings. Units with two riding rings establish a natural alignment (although the centerline established here may not be congruent with the originally designed centerline).

In addition to the ring-to-ring centerline, there is also shell/ ring centerline to support roller/shaft centerline alignment. The baseline starting point for this alignment is to locate the shaft centerlines parallel to each other and the riding ring centerline. This is the neutral position. The goal is to generate best contact between the outside diameter (face) of the ring to the face of the rollers.

As previously mentioned, skewing the support rollers' center line as compared to the riding ring will create a thrust force into the kiln and push it uphill or downhill (depending on the direction of the skew). This is often used to control the kiln position when hot and alleviate thrusting forces in the thrust rollers when they become too high. In this skewed position, the roller pairs are still parallel to each other and not directed toward one another.

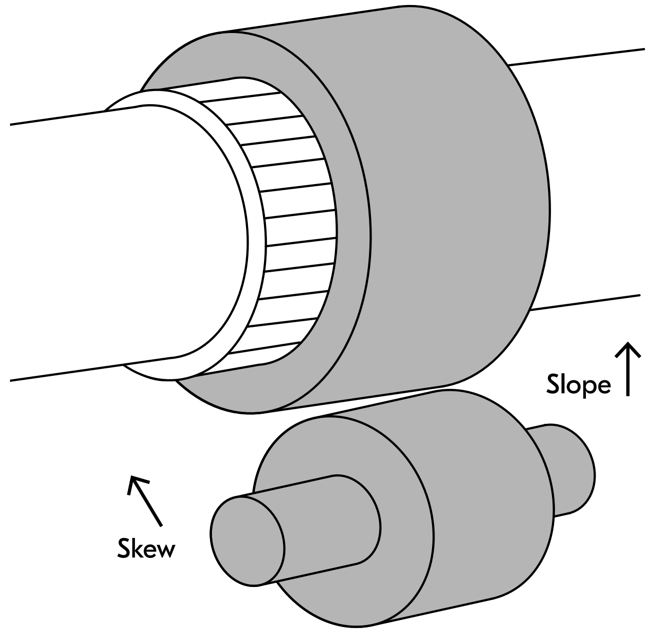



Figure 18: Riding ring face to roller face

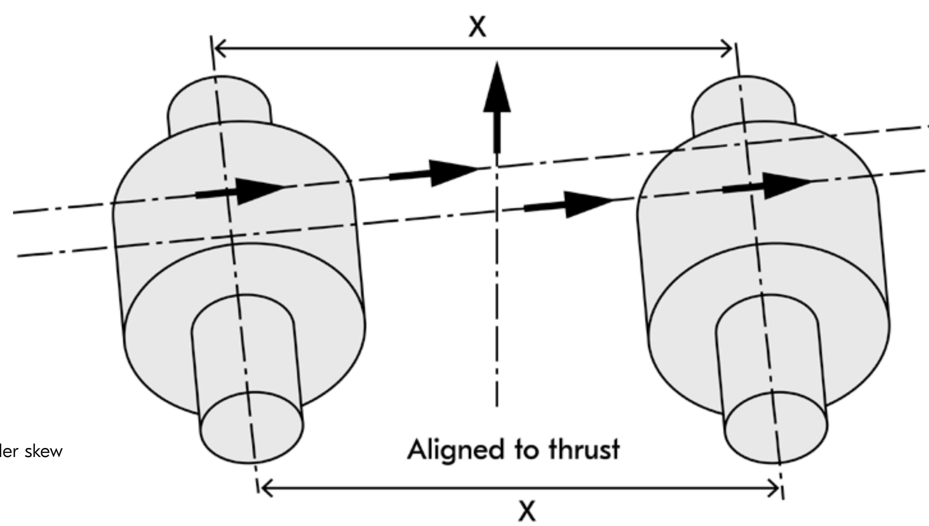



Figure 19: Proper roller skew

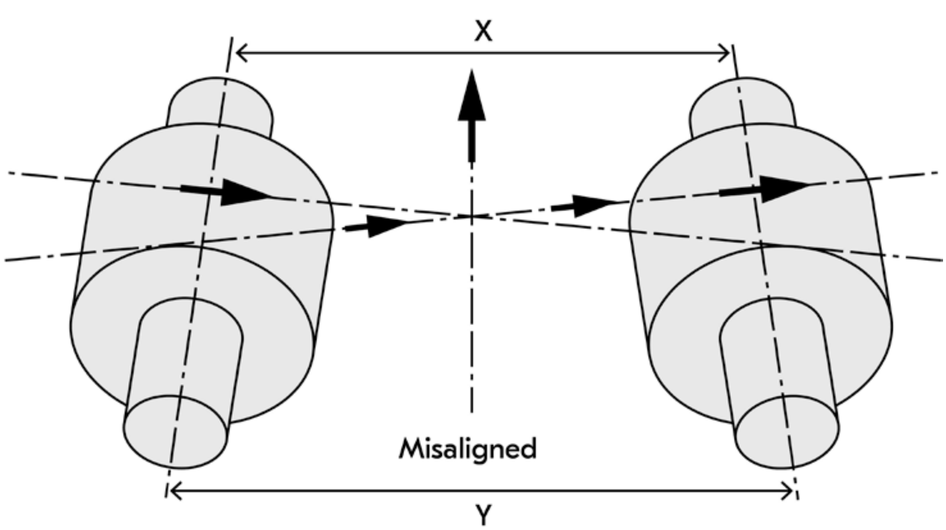



Figure 20: Incorrect, "pigeon-toed" rollers

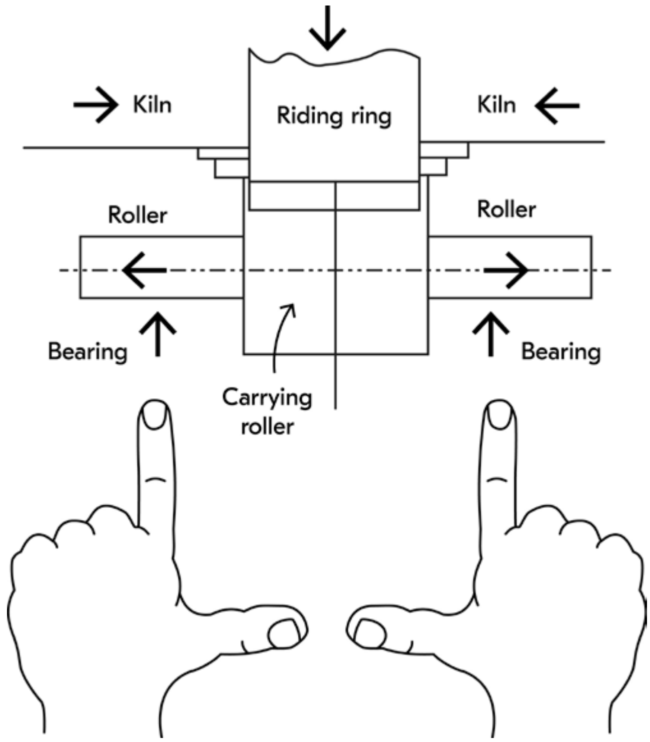



Figure 21: Skewing the down-turning side

## Facing kiln down running side

- Hands out, palms down
- Index fingers and thumbs as shown
- Index finger indicates bearing and direction to move
- Kiln moves in direction indicated by thumb of the same hand
- Roller shaft moves opposite kiln direction

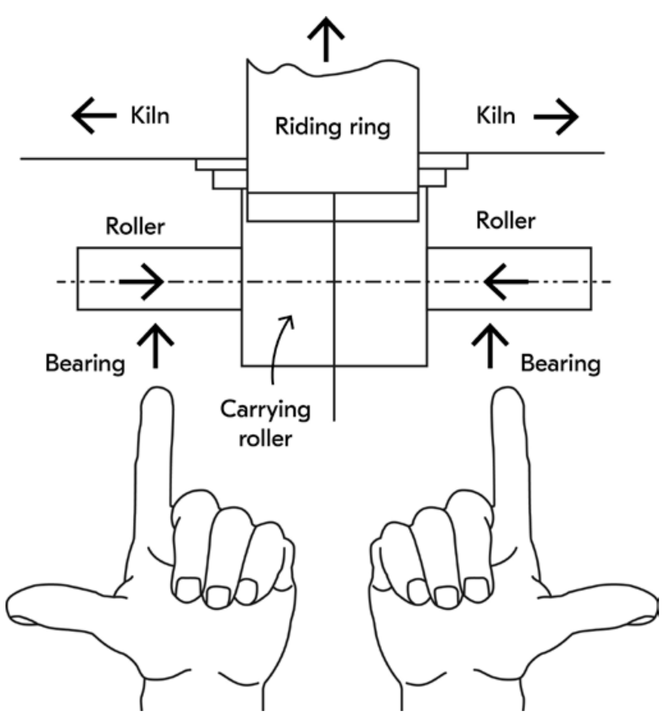



Figure 22: Skewing the up-turning side

## Facing up running side of kiln

- Hands out, palms up
- Index fingers and thumbs as shown
- Index finger indicates bearing and direction to move
- Kiln moves in direction indicated by thumb of the same hand
- Roller shaft moves opposite kiln direction

Skewing drives the kiln shell uphill (towards the feed end) or downhill (towards the discharge end). The force is generated by the rings rolling resistance to the rollers. The rotation direction affects the direction of the force, so the skewing rules are different for the up-turning side of the riding ring compared to the down-turning side.

NOTE: The shafts of the support roller pair (at one carrying station) must remain parallel to each other. Kiln movement in one direction will be accompanied by a movement of the carrying shafts/rollers in the opposite direction.

Purposeful skewing to control kiln shell thrust is most often done on kilns that have roller shafts supported in bushing-type bearings. These bearings can absorb thrust forces (to a certain point) and remove some natural, downhill kiln thrust from the thrust rollers. Some rotary kilns and dryers are supported on spherical roller bearings. These bearings do not like axial thrust forces, as those forces carry directly through the bearing cage. On these types of machines, the shafts are normally set parallel to each other and the kiln and the downhill thrust roller take the full downhill force (from gravity and slope). It is not uncommon for such rotary units to have no uphill thrust roller or a stationary pad/backstop on the uphill side in lieu of a thrust roller.

As the kiln shell moves, the pads and/or blocks holding the riding ring to the shell will also be impacted. As the shell moves to the left, the ring will stay stationary, but the locating blocks will force into the side face of the ring. This can lead to wear problems for the side face of the ring and blocks or weld failure where the thrust blocks connect to the shell. Metso recommends that a minimum of changes be made at any one time when performing hot alignment changes. Watch and record movements before making more adjustments.

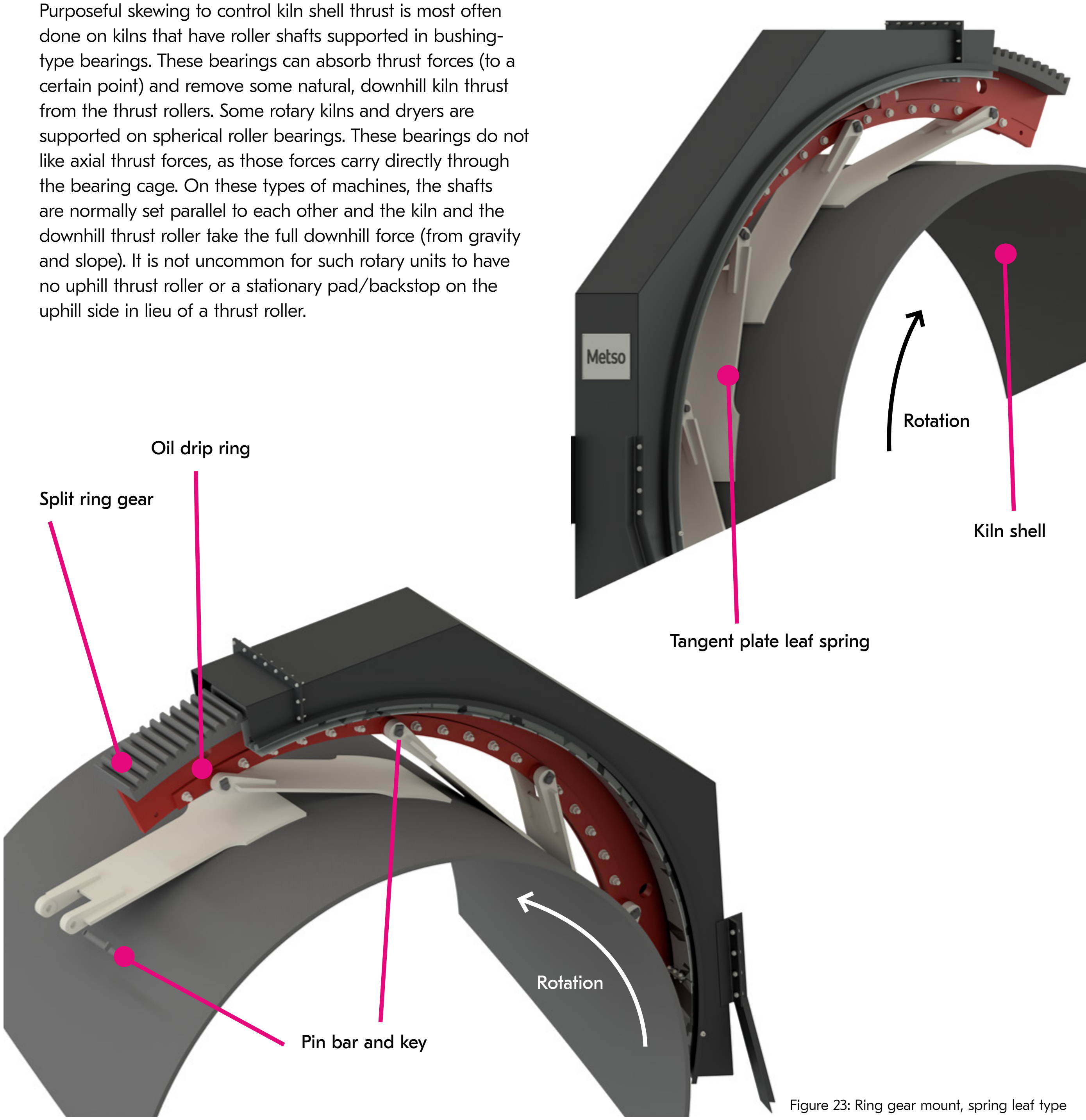



Figure 23: Ring gear mount, spring leaf type

**Roller and riding ring alignment**
As with the rings and rollers, the gear and sprocket will need to be aligned to the kiln centerline and the driving pinion centerline.

The gear or sprocket centerline should be in line with the kiln shell centerline. The pinion centerline should be aligned parallel to the gear/kiln shell centerline. This provides best contact and wear and will also minimize thrusting forces in the shell or the pinion support bearings.

Excessive changes to the original kiln alignment (in plan and elevation view) will cause a deviation in gear slope and skew relative to the pinion. Elevation changes can cause heavier gear meshing into the pinion. In other words, the theoretical gear pitch diameter drops below the pinion pitch diameter. For most kiln and dryer applications, this should be avoided and best contact is achieved by having the gear pitch diameter slightly above the pinion pitch diameter. The relationship is restored by adjusting elevations either by moving the support rollers inward/outward or adjusting the pinion bearing elevations.

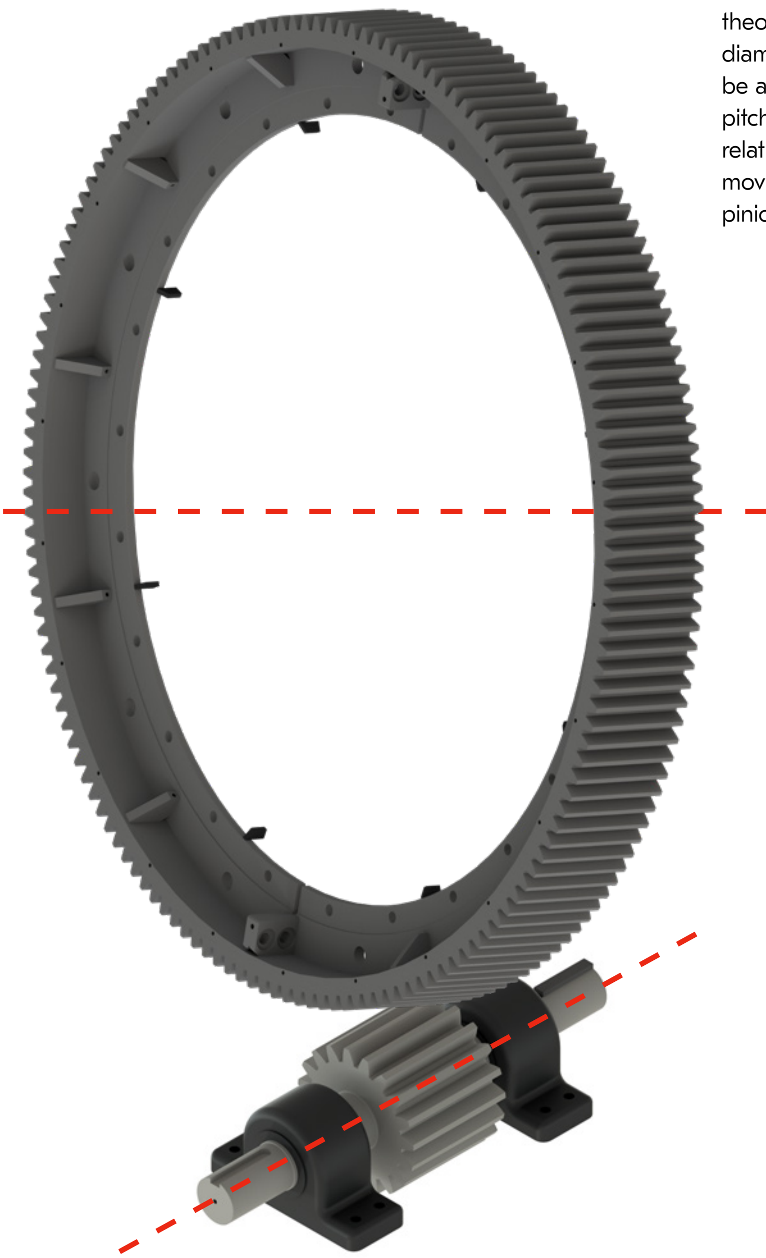


Figure 24: Gear alignment

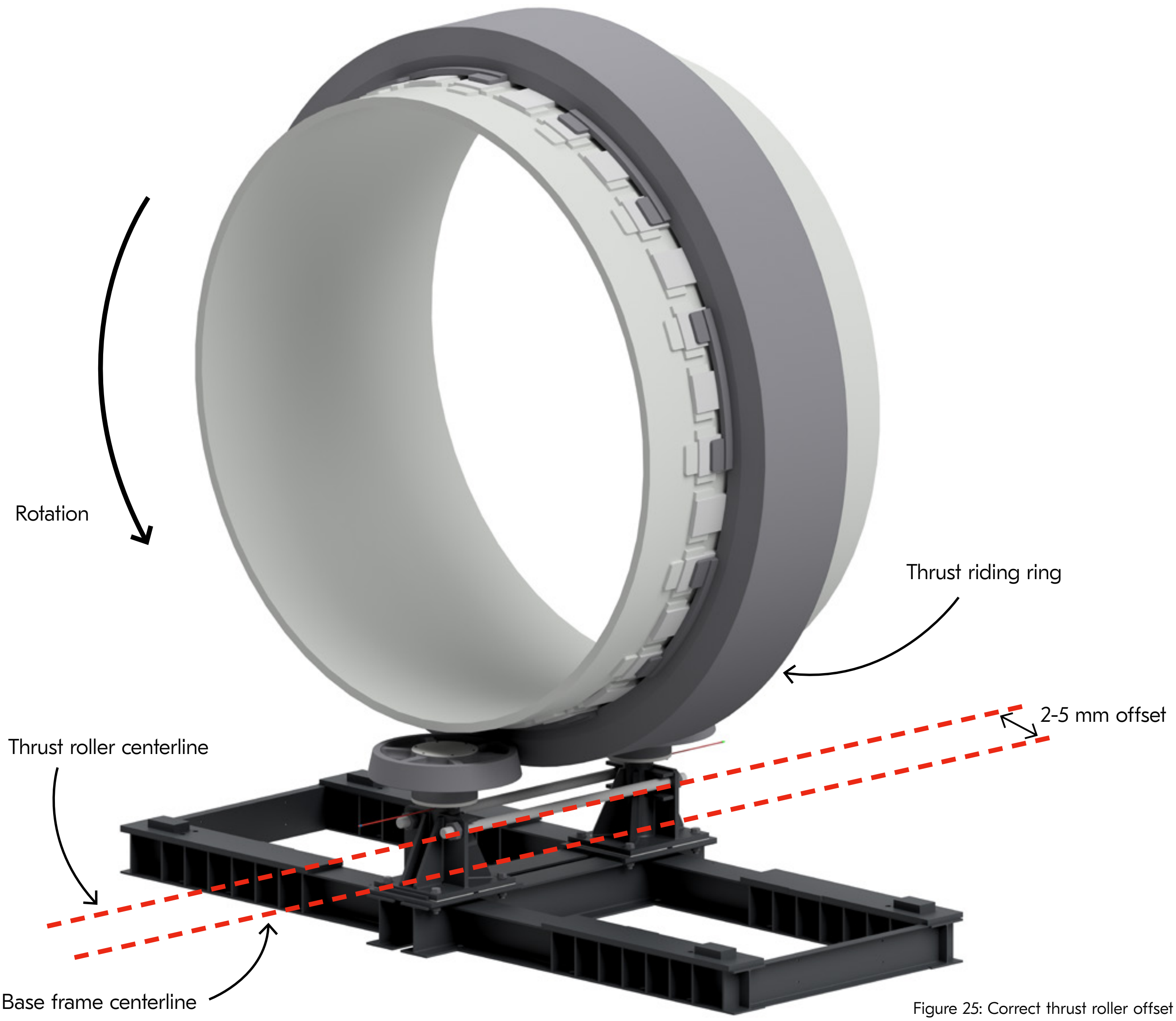



Figure 25: Correct thrust roller offset

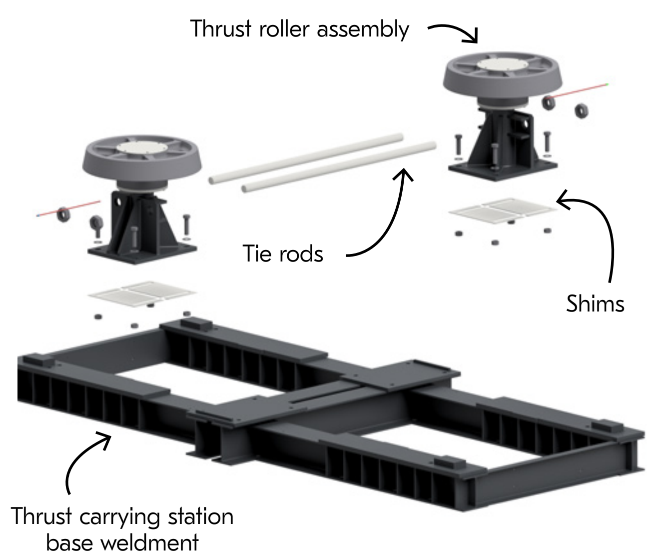



Figure 26: Thrust carrying station exploded view

**Thrust roller alignment**

Much has been mentioned about controlling the kiln thrust and how the thrust rollers capture the riding ring between the roller pairs. A cold alignment determines the correct, overall position of the riding ring and, consequently, the thrust rollers. The thrust roller centerline offset needed compared to the riding ring centerline is sometimes overlooked. Where the forces generated by the rotating ring face as it contacts the thrust roller face, the upturning side of the ring will want to lift the thrust roller. This is highly problematic. The correct positioning is for the thrust rollers to slightly offset to the down turning side of the kiln to minimize uplift during normal operation.

Backwards kiln rotations (purposeful or otherwise) will have the opposite effect.

The previous items are set during cold kiln alignment, where the process begins with positioning the original kiln design parameters. In hot alignment, kiln components are adjusted in the beginning of the process to achieve certain objectives. Depending on the alignment type, the process will change. The primary factor in hot alignment is in the name: hot. Much of the hot alignment moves depend on the temperatures in different parts of the system. The concept of temperature as the controlling factor must be kept in mind at all times. Process changes, weather changes such as temperature, wind, and precipitation, sunlight and other heat source exposure can all impact hot alignment.

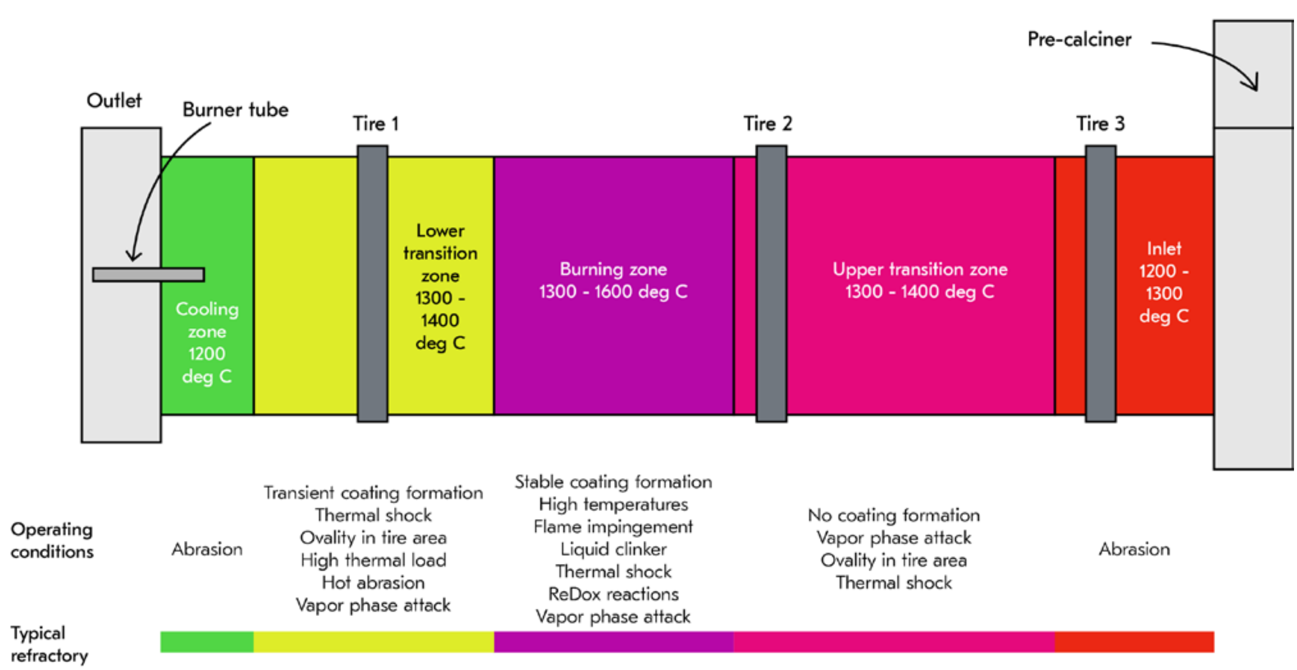
**Shell temperature**

Because thermal expansion of shell changes are temperature driven, the first step is to establish the kiln shell and mounted component operating temperature through a shell scan using a FLIR or similar camera. The kiln is designed with a lining/refractory system. It may be incorrectly presumed that the refractory is chosen to provide the lowest shell temperature possible for best thermal efficiency. For most refractories, insulation properties are indirectly proportional to wear resistance. The driving factor for the insulation system design is the balance of temperature resistance to thermal efficiency.

Over time, temperatures change due to a reduction in refractory thickness, abrasive wear, brick spalling, etc., process and burner flame changes, and material loading changes, among other factors. It is important to remember that temperature changes cause dimensional changes, which lead to alignment changes.

Understanding kiln operating temperatures will help to diagnose alignment problems that appear when the kiln is hot. Operating temperatures can affect the kiln elevation, the riding ring inside diameter tightness compared to the shell outside diameter, gear to pinion alignment and several other conditions.

**Typical operating conditions and temperatures in a 3-pier cement kiln with 4-stage suspension preheater and calcining furnace**



**Elevation changes**

Elevation changes can occur for several reasons such as temperature differential between the riding ring and rollers/ support frame (the kiln tends to increase in elevation at temperature due to the riding ring diameter increase), component wear, foundation settlement and carrying frame rust/decay.

The operator's main concern is how the elevation changes impact the meshing of various kiln components. Specifically, the riding ring to roller contact on kilns with three or more piers, the gear to pinion alignment (chain and sprocket drives do not have such concerns), the thrust roller to riding ring, and the kiln end seals.

The proper time to check elevation is when the kiln is cold. The elevation gain from temperature is normally minimal with minimal impact on overall alignment. Cold alignment is changed by moving the carrying rollers into/away from the kiln axial centerline. The original installation elevations should be the main reference. After setting the elevation to the original design, check the gear to pinion mesh, the end seals and the thrust roller face to riding ring side face.

The kiln feed end elevation as compared to the discharge end sets the kiln slope. This slope is critical to material movement and component alignment. The drive, support rollers and seals are typically set on the same slope as the kiln. Drastic changes to the kiln slope can result from foundation and frame settlement or uneven ring and roller wear. Compare existing slope to the original design slope and adjust as required.

**Gear and pinion alignment**

Alignment is critical to maximize component life on units driven by a large girth gear mounted to the kiln shell and a pinion mounted to the support frames under the kiln. Because the rotary kiln is on a slope and the pinion is mounted so the face of the pinion teeth are on slope matching the gear teeth, this maximizes the contact surface and minimizes wear and bending stresses in the teeth on both the pinion and the gear.

Additionally, the kiln elevation plays a critical part in the gear to pinion alignment. In cold alignment, the pinion teeth pitch diameter is generally outside the gear teeth pitch diameter (away from the root). As the kiln heats, the separation increases. This type of alignment provides maximum protection against teeth bottoming out and breaking at the expense of some loss in contact pitch. In all cases, reference the original installation drawings to make sure that this arrangement is intended.

Axial teeth alignment between the two driving components is the final consideration. When cold, the gear is in one position and moves uphill or downhill when the kiln is hot. The goal is to have full and centered contact between the pinion teeth and gear teeth when the kiln is hot. This means that there could be some offset when the kiln is cold.

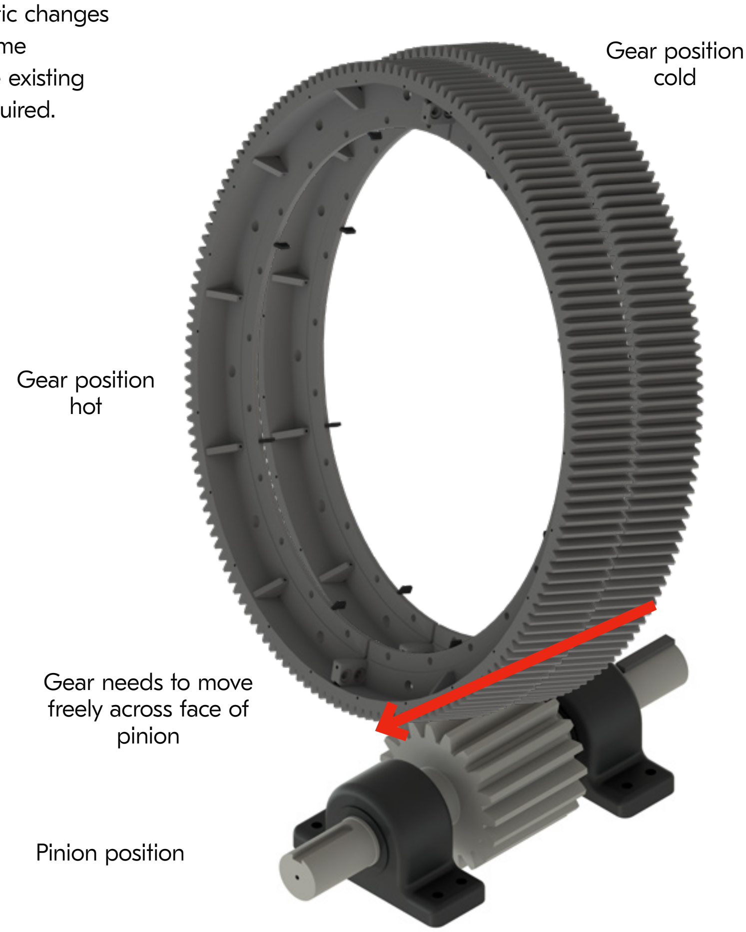



Figure 27: Gear position change, hot vs cold

## Shell damage

Rotary kiln (or other rotary unit) shell damage is a common problem. There are varying reasons for the damage and ways to handle repair work, depending on the type of damage. The following discusses the causes and repair approach.

| What causes rotary shell damage and how is the issue solved? | |
|---|---|
| ⚠ Upset burner conditions cause brick stripping and premature refractory failure. | ✓ Maintain good burner flame shape and burner positioning. Monitor and log shell temperature profile frequently. |
| ⚠ High kiln shell ovality due to excessive riding ring/filler bar clearance causes premature refractory failure. | ✓ Maintain minimal clearance between riding ring inside diameter and filler bar (or wedges/chairs) outside diameter and check kiln shell ovality frequently. Consider increasing riding ring bore lubrication to reduce filler bar wear. |
| ⚠ Overload conditions due to kiln misalignment causes high kiln shell ovality and subsequent premature refractory failure. | ✓ Maintain the kiln alignment to original design specifications and equally distribute the kiln pier to pier loading. |
| ⚠ Upset process/operating condition cause ring buildups, excessive coatings that damage refractory when they break free. | ✓ Maintain a close watch on kiln shell temperature profile for hot spots or cold spots. Record temperatures and watch for changes during kiln operation process changes. |
| ⚠ During upset operating conditions, weld seam cracks develop from high stress loads and/or hot spots. | ✓ Monitor kiln operations and shell temperatures. If hot spots develop, keep a close visual observation of the kiln shell in the surrounding area. |
| ⚠ Cracks develop in the shell plate due to weld cracks on filler bars from thermal kiln expansion. | ✓ Install new free-floating style filler bars to replace obsolete welded designs. During the free-floating filler bar installation, weld repair shell. If cracks are extensive, install a new kiln shell section. |
| ⚠ Kiln does not have an adequate pre-heat prior to startup and the kiln shell buckles under the riding ring in the kiln burning section. | ✓ Follow start-up and heat-up schedule procedures as outlined by OEM and refractory guidelines. |
| ⚠ Inadequate clearance between riding ring inside diameter and filler bars outside diameter causes the kiln shell to buckle in the kiln burning zone. | ✓ When new filler bars are installed, make sure the clearance is calculated correctly based on the kiln operating temperatures. |
| ⚠ The kiln is stopped due to a mechanical, electrical or equipment failure with a full load causing the shell to form a "dog-leg" condition. | ✓ Ensure the auxiliary motor is serviced and able to rotate the kiln within a short period of time. If shell damage is unavoidable, replace the damaged kiln shell section with a new section. |

## Plastically deformed shell

Plastically deformed shell section damage (often referred to as blisters, coke bottling or wrinkles) cannot be repaired by kiln alignment changes or by removing section loading (heat, weight or stress). This damage is permanent and can only be remedied by replacement (if damage is severe enough to warrant). Damage must be repaired if it affects mechanical kiln performance, negatively impacts refractory life or causes kiln or drive component misalignment.

**Repair**

Cut out the offending section and replace. If deformation is minimal and has no impact on kiln performance, monitor section frequently and look for deformation changes.

NOTE: Circumferential cracking is the most critical and can quickly lead to catastrophic shell failure.

If a crack is present, grind crack edge to solid metal and prepare V-groove weld. Drill crack ends to remove stress riser and prevent spread post-weld repair.

| Elastic (temporary) shell deformations | |
|---|---|
| Although not as severe as plastic (permanent) deformations, elastic deformation can lead to serious rotary shell damage. Elastic deformation is generally caused by carrying roller misalignment that causes the shell to sag or crank or "dog leg" between supports on multiple (more than two) support kilns. The shell bending can be remedied by proper carrying roller alignment to the theoretical kiln centerline. | |
| ⚠ The kiln centerline does not match the support roller design slope. This is a common occurrence when kilns are aligned in the operating condition. | ✓ Measure the riding ring and support roller diameters, check the gear and pinion alignment and restore the kiln centerline to the design elevation slope to match components. |
| ⚠ Failure to keep adequate records of support roller adjustment moves. This enables the plant personnel to evenly distribute the kiln loading to all support rollers. | ✓ Create a support roller adjustment log book after kiln alignment has been restored to original design specifications. |
| ⚠ Pier-top settling causing the structural steel base frames to tilt out of design slope. | ✓ Monitor the base settling and make sure settling has ceased. Break loose the structural steel base frames and reset to design specifications, if base frames are not bent or damaged. Install new base frames if the original frames are damaged. |

## Conclusions

Steps to take when visual inspection reveals shell damage:

- Some, but not all, shell deformations warrant repair or replacement
- Severe shell damage may not accommodate proper brick refractory lining
- Consider a permanent (plastic) deformation as a structural weakness, the steel included in the deformation has yielded, but more importantly this may introduce shell eccentricity
- Kiln shell eccentricity will cyclically load the carrying components on kilns with more than two piers and introduce a fatigue condition to these components
- Always have qualified and certified welders /procedures (AWS) complete any shell repair
- All deformities should be inspected and addressed. Deformation can lead to shell cracking and cracks that begin to travel circumferentially around the shell can lead to rapid and catastrophic shell failure.

## Filler bar wear and cracking

Filler bars are a sacrificial wearing surface provided between the kiln shell outside diameter and the riding ring inside diameter. To prevent the ring from pinching and constricting the shell when hot a running clearance is provided between the bars and the ring inside diameter. This clearance allows the ring and shell to rotate at slightly different speeds (creep), which leads to filler bar frictional wear.

On Metso designed kilns, the filler bars float (not welded directly to the shell) and can be replaced when wear causes riding ring creep to become excessive.

Allowable wear depends on the refractory type and overall kiln diameter. Excessive clearance from filler bar wear allows the shell to flex and sag. This cyclical flexing can lead to shell cracking near the filler bar stop blocks and damage refractory bricks.

Thrusting forces cause the ring to move uphill or downhill against the retaining bars. Excessive thrust from roller and drive component misalignment can cause retaining bar wear and weld failure between the retaining bars and the filler bars. Replacing retaining bars when replacing filler bars is highly recommended.

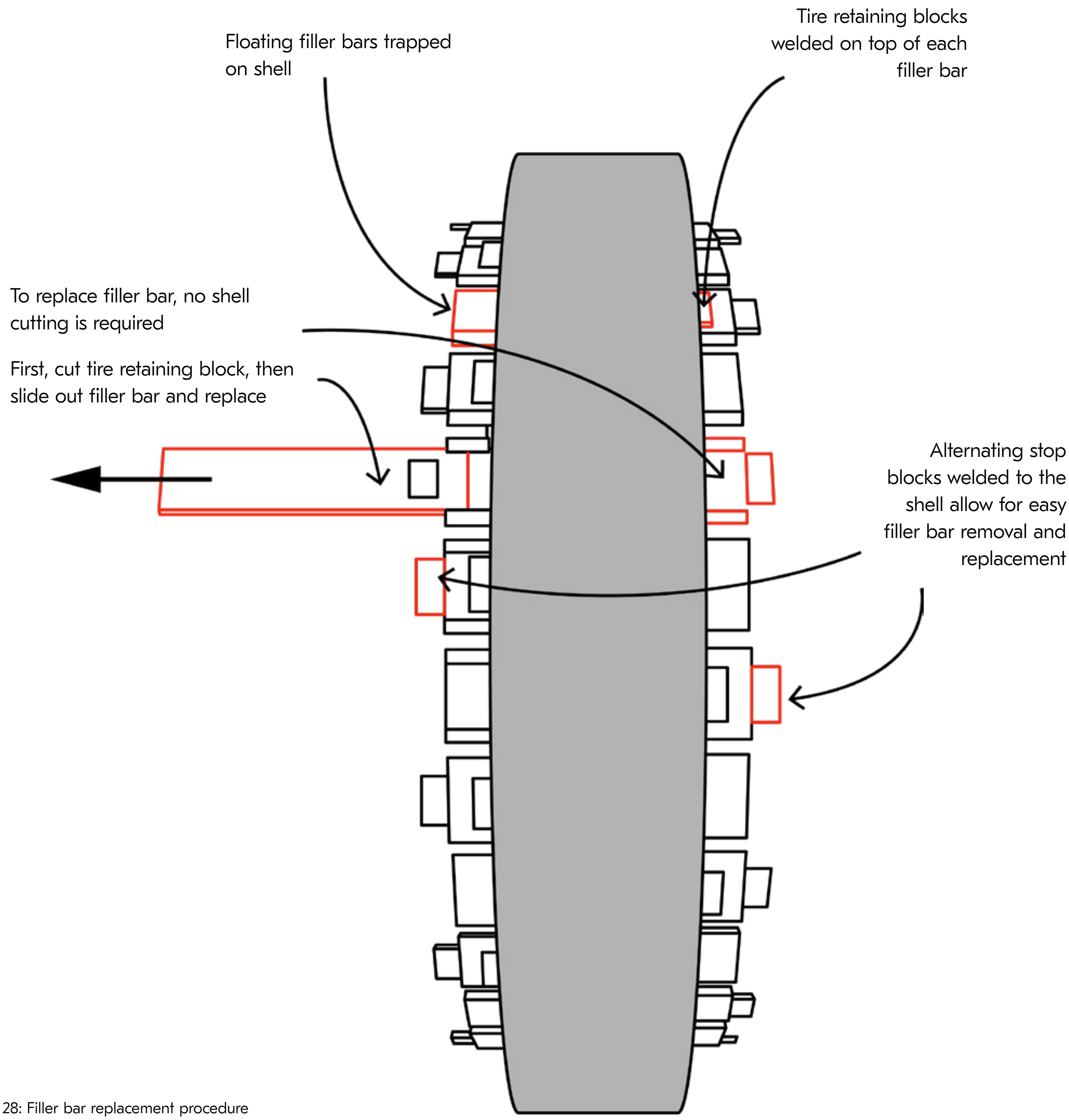



Figure 28: Filler bar replacement procedure

## Riding ring and support roller wear

The riding ring and carrying roller interface is also subject to frictional wear. Maximize face contact by keeping the roller face parallel to the ring face. In cases where the faces are not parallel, roller and ring wear can be dramatic.

Incorrect alignment can lead to conical roller or ring face wear. If the ring is not centered over the roller or if the ring does not float and rides in the same spot on the roller, a ridge can form on the roller or the ring. These highspots become a failure point when loading shifts and the full face contact pressure comes to bear on the raised edge. This causes the roller or ring edge to crack and break away.

The roller face is wider than the riding ring face to accommodate thermal kiln expansion as it elongates when it heats. A floating kiln allows the riding ring to move back and forth across the full width of the roller face thereby maximizing wear. If the kiln does not float and is held in one position for a long period of time, a groove can wear into the roller. If the kiln suddenly changes position and the ring climbs onto the raised area, the small, raised face will carry the full kiln weight and fracture.

The kiln float (small movements uphill and downhill during normal operation) is called kiln "training". This is controlled by the alignments discussed in section 2. The roller and associated bearing movement thrusts into the bearings and roller shafts to train the kiln.

**Thrust load taken by bearing housing end caps. The roller position would either sit against the uphill or downhill bearing housing cap. The position can be found where a Metso align guard is in place, or by sounding with a hammer to test for a hollow or solid noise.**

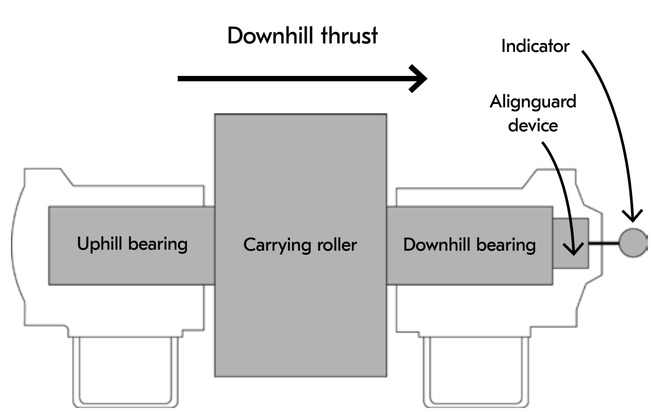



Figure 29: Thrust forces and kiln training with kiln bearings

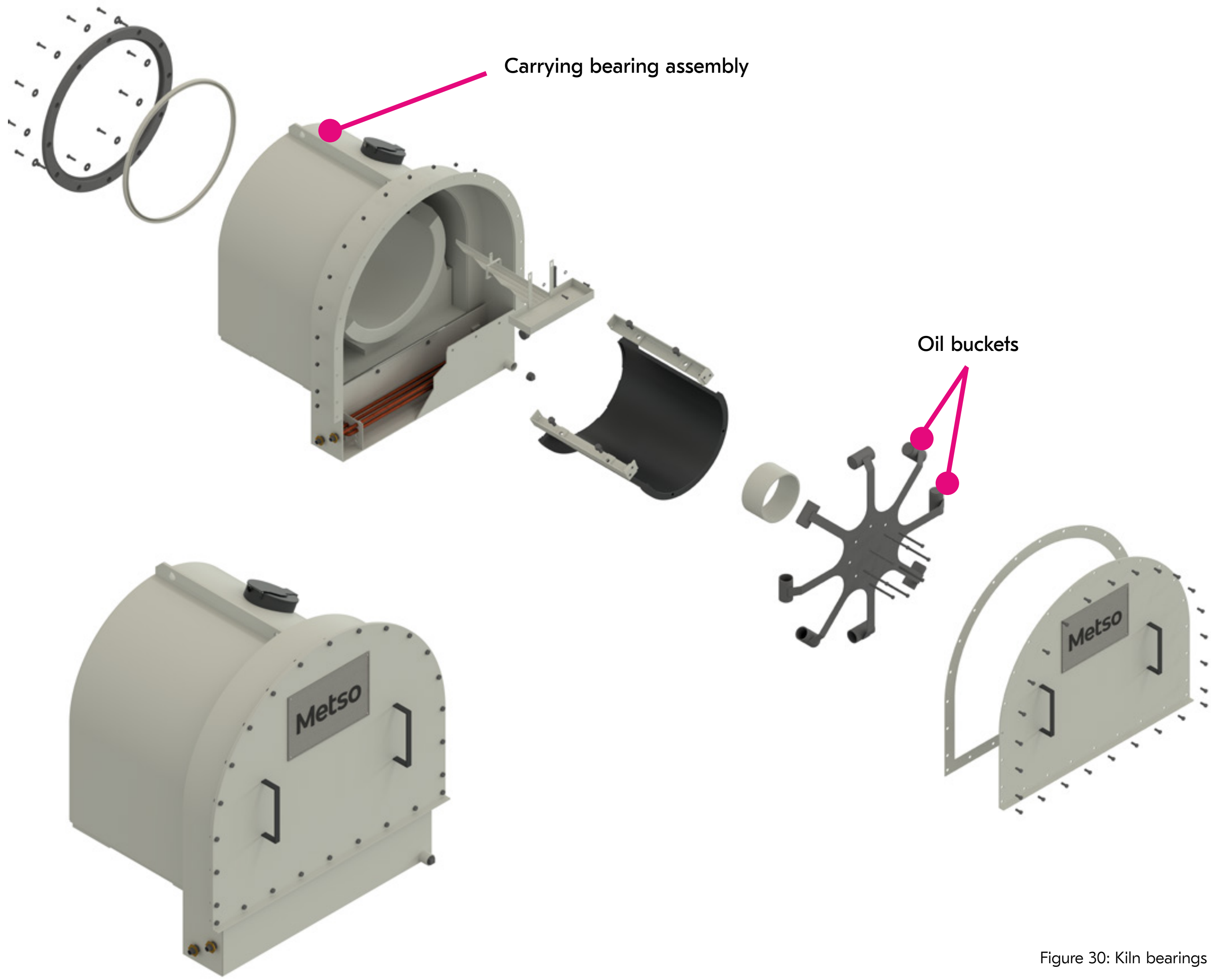



Figure 30: Kiln bearings

Thrusting is independent of the thrust rollers. The thrust rollers trap the kiln from moving too far uphill or downhill. Kiln-style bearings are designed to handle shaft thrust forces. There is a thrust plate in the bearing cap that will contact the end of the shaft. If the kiln rollers are mounted on spherical roller bearings, the thrust handling is diminished, and the shafts/rollers should not be used to train the kiln. In these circumstances, the thrust rollers are oversized and able to handle the full, downhill kiln force.

Generally, one-inch of outside diameter riding ring and roller wear indicates when to consider replacement. On smaller machines (10′ diameter or less), a half-inch of diameter wear indicates when to consider replacement. All rings and rollers behave differently and past exposure to high thrust loads, high temperature, overloading, weld repairs, and other changes  will impact wear life. Inspect rollers and rings at every cold maintenance stop or at least once a year.

## Carrying frame and foundation concerns

Although the kiln journal-type bearing can handle substantial thrust loads, it cannot handle poor parallelism between the bronze journal and the carrying roller shaft

Support frame and concrete settlement, distortion or rust and corrosion can lead to issues. A slight angular deviation will lead to bushing point loading. This angular movement may occur slowly over time, and may not manifest until a new bushing is installed. This may become visible when  a bearing that has operated at normal temperature becomes hot and no load shifting can correct the situation. Always check parallelism and the wear pattern when bushings are removed for replacement.

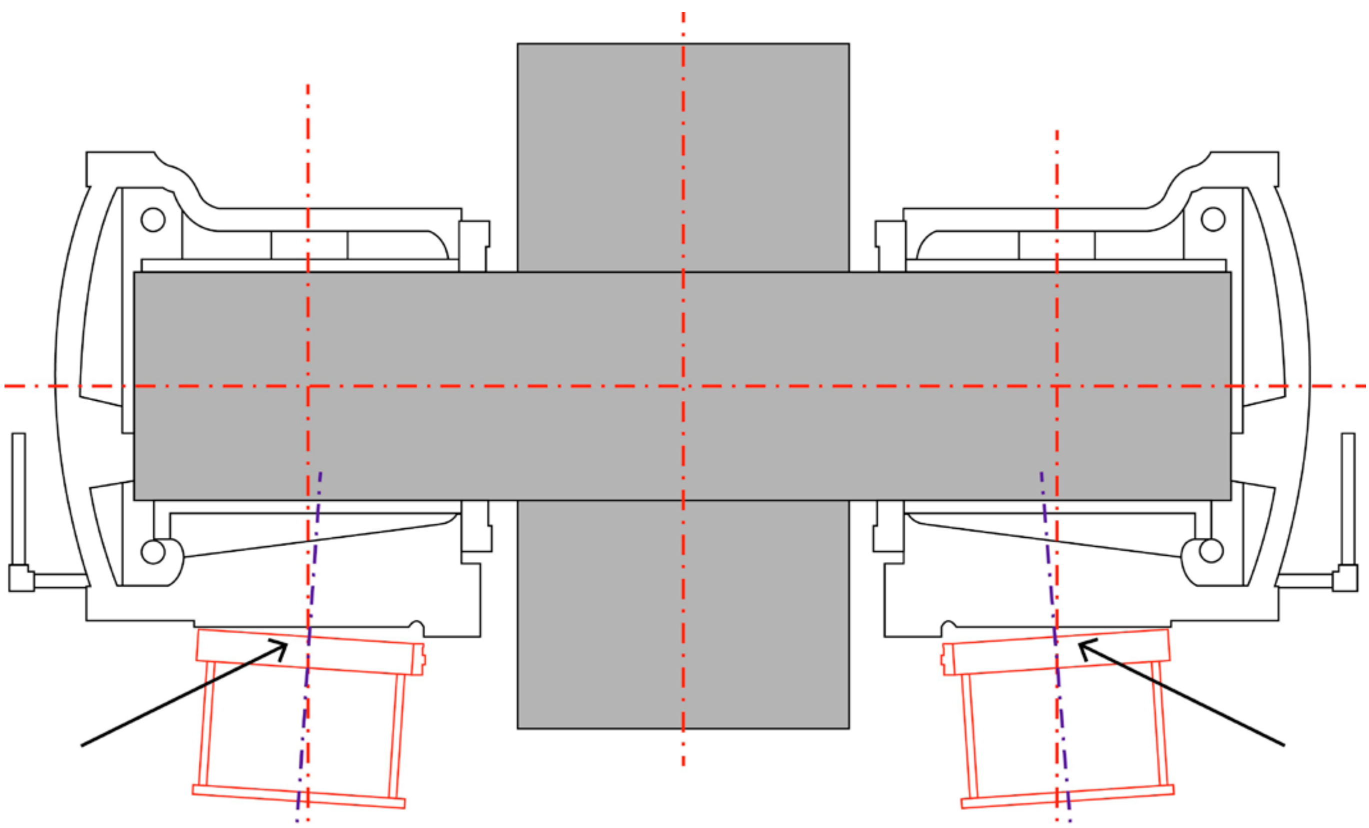


Figure 31: Poor baseframe alignment

## Miscellaneous components

Lubrication systems are an often-overlooked area of the rotary kiln. Liquid grease or oil lubricant is used in the support roller bearings, thrust rollers and the drive components such as the gear and pinion, gearboxes, associated bearing housings, and other components. In all cases, follow the recommendations in the supplied manuals. Regular oil sampling for particulate analysis is highly recommended. This is especially true for the kiln bearings.

Dry lubricants are also used for contacting faces between the rollers and riding rings and between the riding rings and thrust rollers. The riding ring bore is most often lubricated with graphite blocks engineered to slowly melt when inserted into the riding ring bore. Liquid lubricants should never be used in place of dry lubricants. Liquid lubricants or cooling water can damage the riding ring, thrust roller and carrying roller contacting faces.

Kiln end seals also require frequent inspection and maintenance. Most Metso supplied kilns have a leaf seal at each end that will ride against a wear band. Leaves and wear bands are wear items and need to be replaced every one to two years. Other types of contacting/rubbing seals have similar needs.

Figure 32: Metso patented leaf seals

# Maintenance inspection schedule

Performing regular inspections and maintenance are vital for kiln health, and can prevent breakdowns and eliminate related safety concerns, inconvenience, and costly repairs. Overall, good maintenance habits go a long way toward keeping your kiln healthy and minimizing operating expenses.

| Daily maintenance schedule | |
|---|---|
| A walk-by inspection should be performed daily | Check carrying roller lubrication levels |
| | Check gear lubrication levels |
| | Verify kiln shell axial position |
| | Ensure carrying roller cooling water flow |
| | Verify the burner's fuel and air connections for leaks |
| | Visually check the flame shape |

| Weekly maintenance schedule | |
|---|---|
| These inspections should be performed weekly, in addition to the daily checks. | Measure kiln tire creep |
| | Note major component wear |
| | Check the kiln drive amperages for fluctuations |
| | Check kiln seals and shell run-out on feed and discharge ends |
| | Check drive bolt tightness – visually check for loose bolts |
| | Verify the kiln shell temperature profile for operating temperature fluctuations |
| | Survey general pilot and burner settings including operating pressures and flow rates |

| Monthly maintenance schedule | |
|---|---|
| These inspections should be performed monthly, in addition to the daily and weekly checks | Check the auxiliary drive motor to ensure availability in an emergency |
| | Check the drive gear and pinion pitch line separation for gear mesh changes |
| | Inspect gear reducer oil levels and all drive bearings for high operating temperatures |
| | Perform gear and pinion, gear reducer, and drive system bearings vibration analysis |

Life Cycle Services takes the entire range of Metso services and conveniently bundles them into tailored and easy-to-manage packages. These can range from basic services to more complete solutions. Packages are equipped to cover single-event shutdowns or span multiple years, measured against strict KPIs.

**Addressing aims and challenges head-on**
As production rates increase and fluctuate, mechanical and alignment issues can creep up. If potential problems are not caught early, they can lead to unplanned shutdowns and breakdowns that have significant operational and financial impact.

**The value of accurate diagnosis**
Accurate condition information can improve pyro equipment life cycle decision-making. Service professionals can share OEM knowledge and process and technology experience through clear reporting. This information can assist in minimizing unscheduled downtime and reduce long-term operating expenses.

Metso is the OEM for Allis Chalmers, Kennedy Van Saun, Stansteel, Svedala and other legacy kiln designs. Our team of professionals can ensure rotary kilns are functioning properly and efficiently regardless of make or model.

## Packages:

### 1. Visuals and vitals
For improved equipment availability and maintenance planning.

### 2. Mechanical verification
For improved operational effectiveness, enhanced fuel efficiency and throughput.

### 3. Comprehensive/customized
For long-term reliability, increased the overall life of your equipment.

## Benefits
- Reduced downtime
- Extended lifetime
- Increased reliability
- Improved safety
- Minimized plant downtime
- Better maintenance requirement visibility

An annual inspection is recommended for pyro rotary equipment to identify concerns with improper lubrication, axis misalignment, carrying roller thrust balance, shell crank effect on carrying stations (dogleg) and shell flex at each pier (ovality).

| | | | Package 1 | Package 2 | Customized |
|---|---|---|---|---|---|
| Component | Task | Status | Visuals and vitals | Mechanical verification | Comprehen-sive |
| Satellite cooler/tube cooler condition | Inspect product cooling equipment external components | Operating | ● | ● | ● |
| Carrying roller face condition | Visual inspection of contact and wear pattern | Operating | ● | ● | ● |
| Riding ring/tire face condition | Visual inspection of contact and wear pattern | Operating | ● | ● | ● |
| Carrying roller station condition | Visual inspection of grout, base frame, carrying roller bearing housing and thrust roller at drive pier | Operating | ● | ● | ● |
| Gear condition | Visual inspection of tangent plates, welds, and bolts | Operating | ● | ● | ● |
| Feed and discharge air seal condition | Visual inspection of air seal components | Operating | ● | ● | ● |
| Shell condition | Visual inspection of shell profile | Operating | ● | ● | ● |
| Filler bar assembly condition | Inspection of riding ring/tyre retaining block, side and end key blocks condition and the filler bar for wear and cracks | Operating | ● | ● | ● |
| Roller bearing housing internal condition | Verify condition of internal components | Not operating | | ● | ○ |
| Carrying roller shaft condition | Inspect shaft for any scoring (excluding UT) | Not operating | | ● | ○ |
| Carrying roller bearing house bronze liner wear | Inspect liner for major wear | Not operating | | ● | ○ |
| Drive component condition | Verify all major components of kiln main drive and emergency drive | Not operating | | ● | ○ |
| Gear and pinion pitch lines | Verify pitch line separation | Not operating | | ● | ○ |
| Kiln internals (lifters, chains, feed spirals) | Inspect components for wear and damage | Not operating | | ● | ○ |
| Discharge castings | Inspect grizzly lump breakers, discharge end castings and port grate castings | Not operating | | ● | ○ |
| Burner condition | Inspect burner assembly | Not operating | | ● | ○ |
| Gear profile | Profile 2-3 teeth at four locations | Not operating | | ○ | ○ |
| Ovality | Collect and analyze data at each pier | Operating | | | ○ |
| Shell profile (runout) | Collect and analyze data along length of kiln | Operating | | | ○ |
| Roller shaft deflection | Collect and analyze data at roller shafts | Operating | | | ○ |
| Roller and base slope | Verify slope of roller and base | Operating | | | ○ |
| Gear axial and radial runout | Collect and analyze runout data | Operating | | | ○ |
| Tire wobble (axial runout) | Collect and analyze runout data | Operating | | | ○ |
| Kiln alignment measurements | Collect and analyze measurements to define hot kiln axis of rotation | Operating | | | ○ |

● Included in package ○ Optional

A detailed inspection report outlining the data taken and assessment of the condition of the components is provided with each package. The above represents standard recommended packages from Metso. Customization is possible within each package, allowing you to add or remove services to meet your specific needs. Note that some services are subject to availability, depending on region and operating condition. All details, specific to your operations, will be provided in the proposal.

| Section | Installed qty (Two kilns) | Description |
|---|---|---|
| Kiln feed hood | Complete set | Leaf segments, large, radial |
| Rotary kiln | 2 | 335 mm width kiln seal wear plates for 360 degree coverage (plate 10 x 335 x 12127, Astralloy eb450) |
| | 1 | Filler bar set - free riding ring |
| | 1 | Filler bar set - fixed riding ring |
| | 2 | Carrying roller and shaft |
| | 4 | Carrying roller graphite blocks |
| | 4 | Carrying bearing bushing and lug |
| | 12 | Carrying bearing oil seal (split) |
| | 48 | Brass screws for end thrust wearing plate |
| | 2 | Carrying bearing housing |
| | 4 | Carrying bearing end thrust wearing plate |
| | 1 | Thrust roller with shaft |
| | 1 | Roller bearing (upper) |
| | 1 | Roller bearing (lower) |
| | 4 | Thrust roller shaft seal |
| | 4 | Thrust roller graphite blocks |
| | 1 | Wheel |
| | 1 | Cooling fan motor |
| | 4 | Gear guard oil seal assembly |
| | 2 | Pinion bearing assembly - held |
| | 2 | Pinion bearing assembly - free |
| | 2 | Breather plug W4086 V-NPT1-206, 4 |
| | 2 | Flex grid - coupling |
| | 1 | Main drive motor |
| | 1 | Main drive reducer |
| | 1 | Main drive backstop/over-running clutch |
| | 1 | Drive pinion |
| | Complete set | Gear mounting hardware |
| Kiln firing hood | Complete set | Leaf segments, large radial |

# Critical spares

| Section | Installed Qty (Two kilns) | Description |
|---|---|---|
| Rotary kiln | 12 | Carrying bearing oil seal (split) |
| | 1 | Roller bearing (upper) |
| | 1 | Roller bearing (lower) |

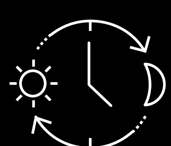
The following section discusses typical repairs and refurbishments associated with rotary kilns. Much of this has been mentioned briefly in preceding sections; additional clarity will be provided in this chapter.

## Shell section replacement

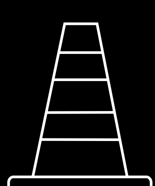
Kiln shell section replacements are the most common of all typical kiln repairs. Permanent kiln shell deformation and/or cracking can occur for various reasons. Regardless of the reason, the only viable repair option is to remove and weld in a new shell section. Careful planning must be taken for this replacement.

With the above considered and careful planning carried out, the actual shell replacement is a relatively simple, but time consuming, process. The cut marks will be planned, supports for the free hanging shell ends put into place and weight removed from the portion to be cut and removed.

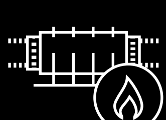
## Things to consider:



**Timeframe**
A cold stop is needed to perform a shell section replacement. Most site preparation work can be done ahead of time to afford minimal impact on the production schedule. Cranes, replacement sections, temporary utility moves, scaffolding and platforms can all be mobilized so the procedure is ready to begin as soon as the kiln is cooled down and emptied of product.

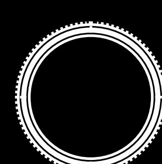


**Kiln supports**
The location of the removed section will dictate the type of temporary supports needed for the shell. Metso strongly recommends the use of APPROPRIATELY designed saddles to support the remaining shell. These saddles will be rigid enough to hold the shell and refractory weight , but flexible enough to not cause damage to the shell plate.

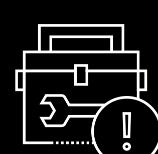


**Refractory**
A refractory section will need to be removed from the damaged kiln shell and from uphill and downhill of the repair site. This is necessary to allow the new section to be clamped while it is welded into place.

**Existing weld seams**
The kiln shell is normally comprised of multiple rolled sections (cans) that are welded together. The repair section must not interfere with the existing seams or the heat affected zone (HAZ) from previous welds. Metso recommends a minimum of 150 mm (6 inches) between old welds and new welds.



**Riding ring section**
If the damaged shell is located in the thicker riding ring section of the kiln, plans must be made to move and support the riding ring if the existing ring is to be salvaged.



**Parallel maintenance operations**
The kiln will be stopped in the cold condition for several days while the repair is being carried out. Maintenance should be performed on other parts of the system at this time.

Once removed, the existing shell ends will need to be prepared for welding with the correct bevel and joint hardware installed. This hardware is used to draw the new and old sections together and control the radial runout.

It is also common for an internal radial stiffener to be supplied with new shell sections, especially heavier sections that go under the riding ring. These stiffeners, often called “spiders”, should remain in place until the new section is completely welded to the existing shell.

A word of caution: Plan to have an adequate amount of joint hardware available. Most joint welds are performed while slowly rotating the kiln. While rotating, the shell will flex, which can cause the new weld to crack. Circumferential cracks propagate quickly and welders may find themselves chasing the crack around the shell. Using the correct joint hardware and spiders will prevent this from happening.

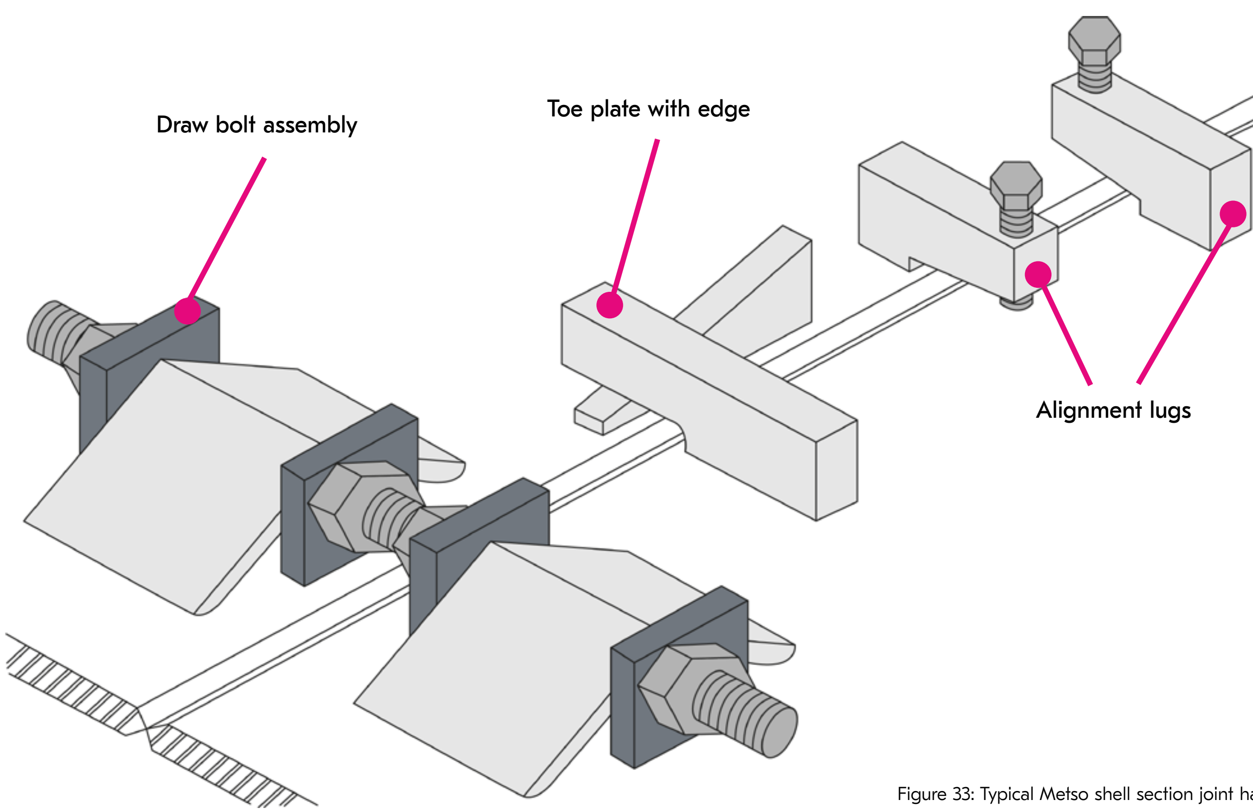



Figure 33: Typical Metso shell section joint hardware

## Resurfacing carrying components

Carrying component (rings and rollers) resurfacing is another common rotary kiln refurbishment. Component misalignment was discussed at great length in previous sections. This misalignment often causes uneven wear or face gouging of the riding rings and/or carrying rollers. To allow correct kiln alignment and remove float from uphill or downhill thrust, the contacting surfaces must be returned to a smooth condition with the faces parallel to each other and parallel to the axis of rotation.

Resurfacing involves grinding of the ring and/or roller faces.

Special care must be taken during the operation as the kiln will be rotating. Steady alignment and speed are important. Cutting is performed slowly and deliberately, with minimal material removal as the goal.

Over time, the outside diameter of the rings and rollers will diminish. This is caused by normal wear and resurfacing actions. The amount of removal depends on the specific kiln load and the carrying components dimensions. A general rule of thumb is:

| Permissible diametrical reduction of carrying components | | |
|---|---|---|
| Kiln diameter | Riding ring | Carrying roller |
| Under 3 m (10') | 12 mm (1/2") | 38 mm (1.5") |
| Over 3 m (10') | 6 mm (1/4") | 20 mm (3/4") |

In all cases, Metso should be consulted to perform a load study of the existing kiln and carrying components. Changes may have occurred over time that may have impacted the loading at any carrying station. These changes could increase or decrease the permissible diametrical reduction.

After resurfacing is complete, the kiln should be re-aligned and elevation and slope restored.

## Kiln load study

The term "load study" is not a physical kiln refurbishment, but a tool that is used to analyze and restore the kiln to proper operating condition.

The kiln is designed to perform a specific duty, which is constrained via process requirements and the physical kiln dimensions. Airflow through the kiln (or dryer), material retention time inside the dryer and thermal load all govern the kiln shell dimensions. These dimensions and the associated refractory and material loads govern the carrying component design. Process changes and refractory changes can impact the kiln component loading and degrade their suitability for service. A kiln load study will determine suitability and govern changes that may need to be completed in the future.

Metso will provide a questionnaire to the user. The more accurate the information, the more reliable the loading simulation. Metso engineers will take the provided information and use it to model the kiln in its proprietary "Kiln Mechanical" software.

During the study, Metso engineers will look for shell stresses (bending and shear), riding ring and roller contact pressures (hertz pressure), ovality, ring bending stress, roller rotational speeds, bearing loads and load imbalance from carrying station to carrying station.

INFORMATION TO BE SUPPLIED BY OUR CUSTOMER
FOR ENGINEERING STUDY
(DRAWINGS CAN BE FURNISHED IN LIEU OF THIS FORM)

1.0 General Information

Shell inside diameter (Ft.) : ____________
(Specify if multiple diameters)
Shell length (Ft.) : ____________
Shell slope (In./Ft.) : ____________
Shell speed on main drive:
Maximum: : ____________
Normal : ____________
Material being processed: : ____________
Feed rate (short tons/day) : ____________
Product rate (short tons/day) : ____________
Feed density/angle of repose : ____________
Product density/angle of repose : ____________

2.0 Support Locations

| Support Number | Distance from D.E. (Ft.) |
|---|---|
| 1 | ____________ |
| 2 | ____________ |
| 3 | ____________ |
| 4 | ____________ |
| 5 | ____________ |
| 6 | ____________ |
| 7 | ____________ |

3.0 Shell

NOTE: D.E. = Discharge End of Shell.
Also describe the diameter and length of any tapered feed or discharge end shell section.

| Distance from D.E. (Ft.) | Shell Plate Thickness (In.) |
|---|---|
| ________ to ________ | ____________ |
| ________ to ________ | ____________ |
| ________ to ________ | ____________ |
| ________ to ________ | ____________ |

Figure 34: Typical load study questionnaire

Armed with this information, needed changes can be planned and carried out to maximize kiln longevity. Kiln Mechanical can also be used to model the joint loads when a section of the shell is cut for replacement. This is useful information for designing saddles, joint hardware and determining jack sizes for lifting the shell.

## Filler bar replacement

Filler bars are a sacrificial wearing surface between the inside diameter of the riding ring and the outside diameter of the kiln shell. Eventually, the filler bars will need to be replaced as determined by the riding ring creep measurement.

Original OEM filler bars are fitted and machined in the shop. Replacement bars will go onto a worn shell and mesh with the outside diameter of a worn riding ring. In addition, the operational temperatures and thermal expansion at the riding ring will determine the cold clearance between the filler bar outside diameter and the riding ring inside diameter. Temperatures and expansion may have changed from original installation and will need to be considered.

Metso will come to the site and measure temperatures, creep, riding ring inside diameter and monitor the shell condition. Armed with this data, replacement filler bars and field shims can be designed and supplied. The replacement procedure is straightforward on Metso kilns with floating or semi-floating filler bars. End blocks and/or end welds are removed and the old bar is pushed out from under the riding ring. The new filler bar and shims are then slid into place. This is done at the top of the shell, where the gap between ring and bars emerges. The shell is slowly indexed and each bar replaced in its turn.

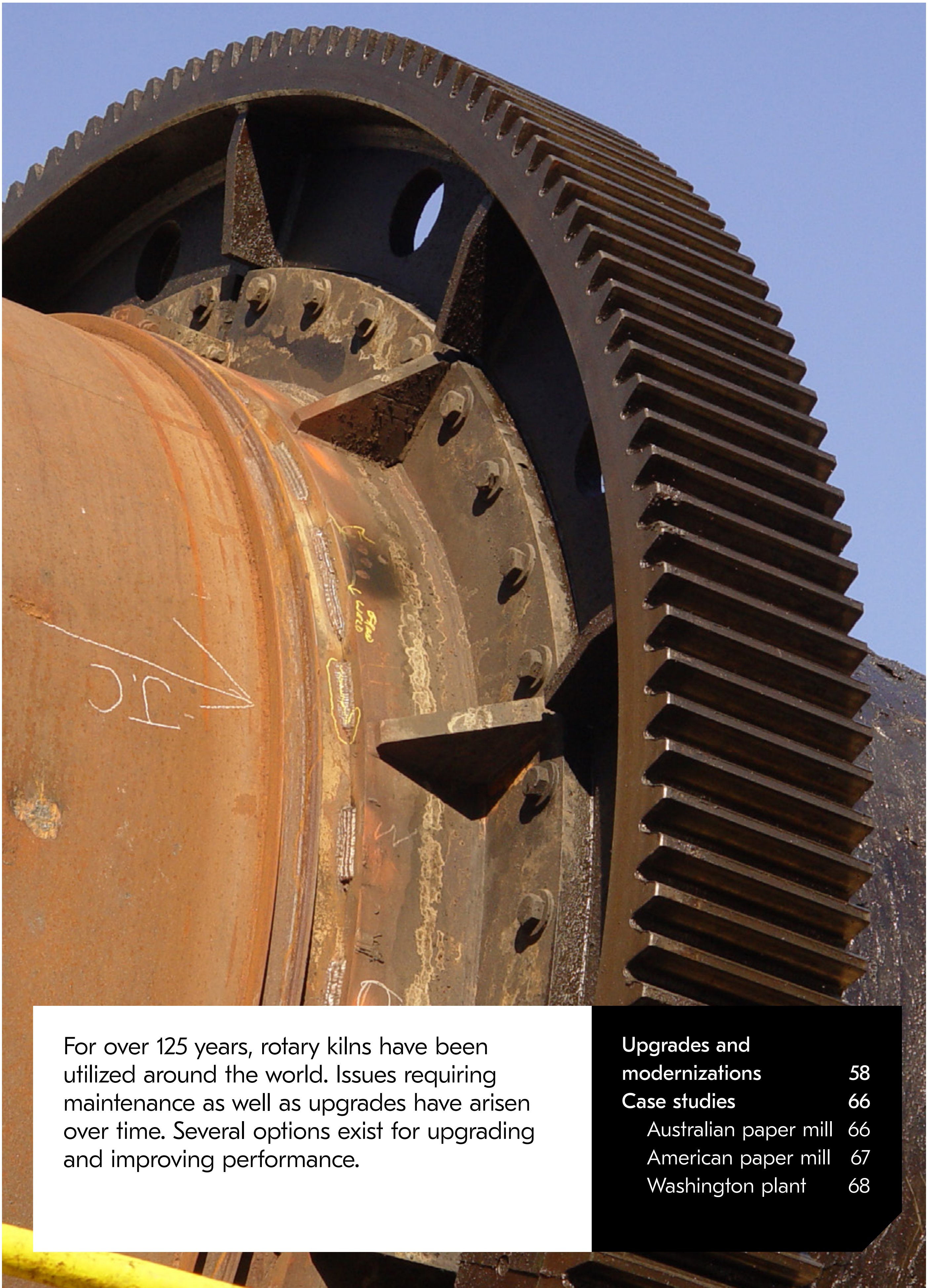
Some older Metso and many non-Metso kilns have welded filler bars. In this setup, the bars are welded directly to the shell. The replacement procedure is more involved and often the riding ring needs to be slid out of the way to allow replacement. Transitioning to a floating filler bar design during the replacement is usually possible to facilitate future maintenance.

## Miscellaneous

There are many other refurbishment activities that are far less common than those mentioned above. These include carrying frame replacement, whole shell replacement, new riding ring and roller installation, kiln shortening or lengthening (done for process reasons and only when possible), gear reversal and others. They are not covered here in detail; however Metso has engineered and performed these types of repairs and can assist kiln owners when the need arises. In all cases, loading and process requirements must be considered. In special cases, Metso may use finite element (FEA) software to model special features that fall outside the scope of our Kiln Mechanical program.

Modernizations for improved reliability and performance

# Kiln upgrades and modernizations improve system efficiency and reduce maintenance intensity.



For over 125 years, rotary kilns have been utilized around the world. Issues requiring maintenance as well as upgrades have arisen over time. Several options exist for upgrading and improving performance.

Rotary kilns have been in use for over 125 years, and Metso and its legacy companies have designed and supplied kilns since the 1910s. Given this longevity, the belief "everything that can be done has been done" could be thought to be true. However, Metso continues to offer kiln upgrades and modernizations that help improve system efficiency and reduce maintenance intensity.

## Kiln air seal

Oftentimes, the simplest improvements offer the most impactful changes to the system. Kiln seals are a simple modernization that offers significant efficiency and maintenance improvements. A kiln's main purpose to heatmaterial. Heating requires energy input (usually through the burning of a solid or liquid fuel). The burning fuel creates emissions that need to be considered as part of the process's environmental impact. In addition, high internal temperatures require the kiln to operate under slightly negative pressure to keep heat and dust inside the kiln. The downside of heat and dust retention is the introduction of external or "tramp air" into the kiln atmosphere at the feed and discharge ends. Tramp air is much cooler than the internal kiln, resulting in a cooling action. To overcome the tramp air effect, increased heat energy is required. A good seal between the rotating kiln and the stationary feed and discharge housings can offer many advantages:

**Reduced ambient air ingress**
- Reduces fuel consumption
- Increases thermal kiln and cooler efficiency
- Aids control system response

**Reduced gas volume**
- Lower gas velocity
- Reduced demand on inside diameter fan and electrical energy

**Increased production potential**

**Minimized nuisance dust loss**
- Reduces maintenance and housekeeping
- Improves safety

**Reduced maintenance cost**

Traditional seals are normally a rubbing-type seal where a seal material is pressed into a wearing surface. These seal types are maintenance intensive (high, frictional wear) and do not handle runout or distortion of the wear surface or the seal material. For decades, Metso has favored an overlapping leaf seal arrangement (often referred to in the industry as "fish plates").

The leaf seals and associated mounting rings and dust hoppers (where required) can be arranged in various configurations to accommodate process and physical constraints.

## Typical Metso leaf seal advantages

- Flat leaves, overlapped and mounted at a 45 degree angle
- Leaves are special spring steel or stainless steel that maintain elasticity
- Self-compensating for runout and expansion
- Sacrificial wear plate
- Seals effectively
- No lubrication
- No wrapper cables
- Low capital cost
- Simple installation; four days average
- Low maintenance cost
- Easy to maintain
- Optional dust hopper

**Leaf seal arrangements**

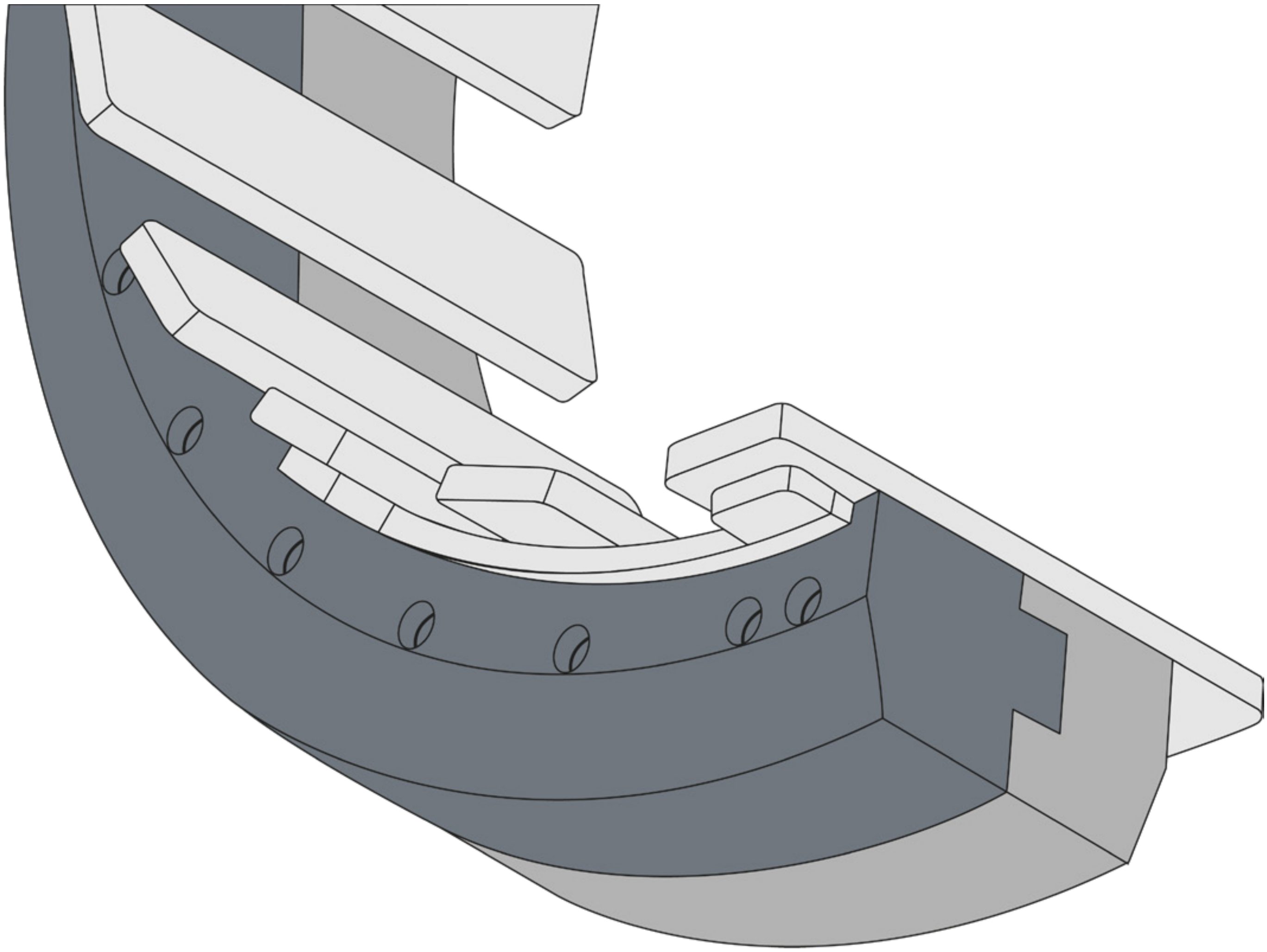
Superdeal® and Goodeal™ seals can be installed in a wide variety of configurations:

- Radial seal with stand off wear ring
- Radial seal (typical feed end of preheater cement kiln)
- Inward axial seal installed inside dryer to minimize material and air leakage
- Radial seal discharge end with air cooling, dust hopper and heat shield
- Inverted axial seal
- Inward radial seal
- Axial seal
- Double radial seal with purge gas

Metso has hundreds of installations with associated process data used to design new leaf seal retrofits. Calculations predict potential fuel savings and return on investment (ROI) based on the data. Airflow volume, emissions-related system improvements and maintenance costs are part of the ROI calculation.

Special sealing arrangements are required in these instances. Leaf seals experience some ambient air ingress, and certain processes cannot tolerate oxygen ingress into the system. Other products cannot be contaminated with metallic flakes that are generated as the leaf wears against the kiln shell. Metso has experience with these types of challenging requirements and can draw on our vast seal installed base to design the best solution.

Figure 35: Metso seal test rig



## Split riding ring

For smaller and lighter duty kilns and dryers, Metso offers a replacement riding ring design that can drastically minimize installation cost and time. The normal ring replacement method is to section the shell where the ring is located, remove the shell and ring and install new components. Certain emergency situations, space constraints and overall shell design (for example, rotary steam dryers) make the traditional replacement route undesirable. In these instances, the Metso split riding ring is a good option.

The ring is made in multiple, precision machined pieces that interlock around the shell. With this design, the shell and any internal or external components will not need to be removed or modified. The sections of the ring are also much smaller than a full ring, so installation costs and timeframe are optimized.

The split ring concept has been around for decades, but the legacy design had limitations. The current Metso split ring design offers performance and life that exceeds legacy designs.

## Floating filler bar retrofit

The advantages of the floating-style filler bars were mentioned previously. Many existing rotary kilns are fitted with non-floating (welded or bolted) filler bars, wedges, splines and other types of mounting arrangements that hinder thermal expansion and make normal worn part replacement difficult. Metso has a long history of designing replacement filler bars for existing kilns and dryers.

# Burners for kilns and pyro processing applications

**Features**

- Engineered to ensure consistent performance is available over the full equipment life
- Proprietary design avoids the complex mechanical adjustment mechanisms essential in most standard burners
- Avoids incorrect adjustments by local operations or maintenance

## OptiMix™

A design that uses well established and proven changes in fuel/air mixing intensity to provide flame control. The primary air is split between axial air for flame length and heat flux control, and swirl air for flame anchoring. A highly efficient aerodynamic swirler provides excellent flame stability.

The OptiMix™ range is custom-designed for firing all fuel types, either individually or in combination. Each OptiMix™ burner is supplied with an integral pilot, including the extremely reliable natural gas or propane model.

**OptiMix G-X**
Designed to operate on a wide range of gaseous fuels including hydrogen. Dual gas discharge locations in the patented G-X technology ensures fine control on gas firing applications and turndowns of over 20:1 enabling cold kiln starts for refractory curing.

**OptiMix L**
Whether operating on conventional liquid fuels such as #2 to #6 oils, waste oils or biofuels, the proprietary CM™ atomizer offers excellent atomization for good combustion with large turndowns of at least 8:1 using either steam or air atomization. The PJ™ atomizer is also available for pressure jet applications along with the WS™ waste oil sprayer designed specifically for liquid fuels with higher solid content.

**OptiMix S**
Used traditionally for pulverized coal and petcoke, the OptiMix S can be developed to accommodate all types of solid fuels including alternative and biofuels such as engineered fuels, sawdust, wood chips, lignin and cocoa hulls.

**Features**
- Potential upgrade for existing OptiMix burner users
- Suitable for retrofits and new installations
- Designed to meet current and future emissions legislation and targets
- Has no internal moving parts, providing reliable operation and simple maintenance

## OptiMix™ low NOx rotary kiln burner

The OptiMix™ low NOx rotary kiln burner is specifically designed to meet current and future emissions legislation and targets.

The OptiMix low NOx rotary kiln burner offers simple construction using high-grade stainless steel materials for key components without internal moving parts for reliable operation and simple maintenance.

The burner design provides flexible control with split primary air adjustment between axial air for flame length and heat flux control, and swirl air for flame anchoring. The flexible adjustment also offers control and NOx tuning. A legacy KFS aerodynamic swirler provides reliable flame stability.

OptiMix burner users can upgrade and retrofit a current burner to provide low NOx rotary kiln burner performance. The OptiMix low NOx rotary kiln burner premix design is combined with automated control functionality for consistent and repeatable optimized burner performance across variable kiln operating conditions over the burner lifetime.

The OptiMix low NOx rotary kiln burner is targeted at maximum NOx reduction for 100% gas fired applications and adaptable for multifuel systems across a wide range of kiln and calciner applications.

Due to potential implications of individual material processing requirements on emissions, every low NOx rotary kiln burner design is analyzed on a case-by-case basis to optimize potential NOx reduction for the specific process application. This is done through in-house process design models and expert CFD modeling.

Features

- Ideal for existing rotary kiln operations based on straight pipe burner technology
- A proprietary design fuel nozzle provides a dependable source of ignition, plus a high efficiency air swirler for easy light-off and a stable flame under variable kiln conditions

## HSB warm-up burners

The Metso KFS warm-up combustion system is a safe and effective method to heat a rotary kiln from cold start to main fuel firing.

A stable flame with an effective and controlled heat release profile is key to safe kiln warm-up. The HeatSafe Burner (HSB) design is based on the OptiMix™ integrated kiln burner design and easily replaceable without dismantling the burner.

The HeatSafe burner system can be designed for a range of heat inputs to suit the kiln size and process, but is typically sized in the range of 6-15 MW (20-50 MMBtu/h).

The Metso HeatSafe kiln warm-up systems are designed to meet the latest combustion safety standard requirements. The valve skids and BMS panel are designed to fit existing plant layouts and specific customer specifications.

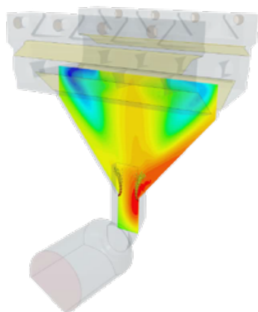
Features

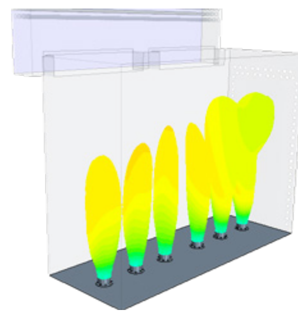
- Each DFN burner is custom-designed for kiln process performance and mechanical installation
- Developed using CFD modelling, the DFN burner has delivered improvements in production, fuel consumption, NOx emissions, and ash ring formation

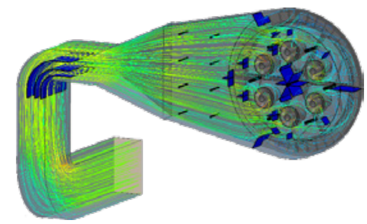
## Direct-fired nozzle (DFN)

Focused primarily in the lime and minerals industries, the direct-fired nozzle burner technology provides a straightforward retrofit to upgrade direct-fired system or straight-pipe burner performance. Bluff-body and swirl techniques provide high performance to enhance fuel/ air mixing combined with greater flexibility than traditional straight-pipe.

The DFN range is custom-designed for firing all solid fuel types, as well as gas, liquid and alternative fuels.







## Computational fluid dynamics (CFD) modeling

CFD is an integral part of combustion system design. Whether as a stand-alone consultancy service or a part of a standard combustion offering, CFD allows detailed examination of flame and temperature profiles, as well as their impact on process conditions and emissions.

**Rotary kiln – Lime and cement**

Metso has developed a proprietary lime bed chemistry module to be fully coupled with CFD.  This has been extended to cement bed chemistry which is more complex and involves multiple reactions for clinker formation.

**Rotary kiln – Pulp and paper, LWA, clay, etc.**

From material feed through combustion, processing and material discharge, CFD is used extensively to help understand the process and provide guidance on combustion equipment and kiln design.

**Preheaters and Calciners – Lime and alumina**

System modelling is used to optimize system performance and reduce NOx emissions, as well as operating issues such as refractory damage and material build-up.

# Getting to the root cause of issues

The aging, 3-pier, 70 m long kiln at an Australian paper mill was experiencing a range of issues that were severely impacting availability and thermal efficiency. Numerous issues were visible to the eye; however, the root cause had not been determined and a repair plan was not in place.

## Results

A comprehensive mechanical inspection and detailed alignment brought the true cause of numerous issues to light. With this information in hand, the customer opted to work with Metso to implement interim repairs right away, followed by major refurbishments. Refractory lining, and discharge seal repairs and upgrades and a shell replacement resulted in a significant reduction in fuel consumption, improved kiln mechanical reliability and a distinct reduction in unplanned mechanical issue stoppages.

## Metso solution

After a visual inspection, it was clear that breaking tangent plates and the resulting gear and pinion wear were the biggest issue impacting kiln availability. These types of issues can be caused by numerous factors such as poor welding procedures, material quality and lubrication, among others. The operator tried multiple tangent plate repair methods over the previous two years, to little result, except an unfortunate waste of time and money. This is a very typical scenario especially among large mechanical installations, where a lack of resources affects the ability to do a true root cause analysis.

At that point, the kiln was subjected to Metso's hot kiln alignment and mechanical inspection program to identify the major causes of the various issues. Metso then worked with the client to develop the most cost-effective solution. High kiln shell run-out was identified as one of the main problems causing high gear and pinion wear and continual tangent plate breakage.

Using a shell profile analysis as part of Metso's standard package, the most critical areas of kiln shell deformation were identified and recommended for replacement. Further detailed measurements indicated that the wear on the gear teeth was close to the limit and gear/pinion replacement was also advised.

# Kiln shell in need of maintenance

A paper mill in South Carolina, USA, was facing issues with one of their kilns. A section of the kiln's shell was in need of urgent attention as it was losing refractory due to overheating. Multiple blisters had also formed near one of the riding rings. Ahead of its annual planned shutdown, the decision was made to address the maintenance issues.

## Results

All the repair and replacement work was completed on schedule by Metso and its team of Metso preferred contractors, including the final kiln realignment. After the work was completed, the plant was able to return to full production and the likelihood of unplanned downtime in the future was minimized.

## Metso solution

Metso was responsible for removing and installing a 29′ section of the 375′ long kiln as well as aligning riding rings and installing new retaining blocks on piers 1 and 3. This complex task involved using heavy duty cranes, kiln support saddles and kiln joint hardware, as well as a Metso Field Services team to carry out the actual on-site work along with the plant's staff.

Metso also replaced two tube coolers and replaced the leaf seals on the discharge end of the cooler housing. In addition, repairs were done on the tube cooler leaf seal wear plate, as the wear plate had two spots on it where there were gaps between the sections. These gaps could potentially catch the leaf seals as they turned and either pop them out of the flange or tear them off completely.

Recommendations were also provided for preventive maintenance steps that could be put in place for the riding ring retaining blocks and other components.

# Tight timeline for kiln service work

A plant in Washington, USA, needed major maintenance work on one of its kilns and had an extremely tight timeline for the project to be completed.

## Results

This was an extremely challenging project with many logistical and access constraints. Metso was able to complete the complicated project 10 hours ahead of schedule. The team successfully changed out the components and also provided many preventative maintenance recommendations to help avoid future surprises and unplanned stoppages.

## Metso solution

The Metso solution involved installing a new thrust riding ring shell section, a thrust riding ring, and a thrust riding ring full floating filler bar assembly, as well as reversing the gear with new tangent plates and pinion.

The project also came with the additional challenges involved in safely manipulating the large and heavy components needed for the change-out. In addition to changing out the designated components, Metso was also able to point out several potential future issues that could be problematic if not addressed.

Many preventative maintenance recommendations were provided. In particular, a hot kiln alignment and mechanical survey, including an ovality study, was recommended to determine the proper elevation, spacing, and orientation of all carrying rollers and riding rings. Other recommendations were to put in place weekly riding ring bore lubrication and plan for the resurfacing work needed on one of the pier's carrying rollers, as it was showing signs of poor contact with the riding ring.

# Address problems early, boost efficiency, and build lasting confidence.


The following information is intended to serve as an aid in locating and eliminating defects and faults. This list is not exhaustive, but can be used as a reference to help identify and resolve common issues.

| Retaining/stop block or band wear | |
|---|---|
| **Cause** | **Solution** |
| Riding ring/tire misalignment with shell/filler bars as a result of kiln alignment | Align the kiln so riding rings, support rollers and kiln shell are the design axis/centerline |
| Riding ring/tire misalignment with shell as a result of improper support roller slope | Restore correct roller design slope by shimming self-aligning bearings or correcting the structural steel base position |
| Tapered wear on the riding rings and/or support roller surfaces | Resurface the riding ring and support roller contact surfaces with a grinding machine specifically designed for rotary kilns |

| Excessive axial kiln thrust | |
|---|---|
| **Cause** | **Solution** |
| The kiln is not aligned to original design specifications | Restore all kiln components to original kiln alignment design specifications |
| The support rollers are improperly adjusted | Perform a kiln alignment to restore to design specifications and stabilize support roller adjustments |
| The riding ring support roller surfaces have wear patterns that don't allow for proper roller adjustments | Resurface the riding ring and/or support roller contact surfaces and perform a kiln alignment to restore kiln components to original design specifications |
| The support roller surfaces are contaminated with oil from leaking bearing seals causing downhill kiln thrust | Replace worn bearing seals or adapt to a more modern sealing system |
| Dust, product or debris on the support roller surface, causing the kiln to thrust uphill | Install better discharge and feed end seals to reduce nuisance dust. Use good housekeeping to keep product or dust off the pier tops. |
| Presence of an upset process condition causing the kiln to heat up and change the axial thrust | Contact the production supervisor to determine the cause of the upset conditions and make process modifications to stabilize the kiln |

## Rough gear operation or vibration

| Cause | Solution |
|---|---|
| The kiln is not aligned to original design specifications, causing angular misalignment between the gear and pinion | Restore the kiln alignment to original design specifications |
| The support rollers and/or the riding ring are diametrically worn and have caused the gear to bottom in the pinion | Restore the correct kiln alignment by moving the support rollers to compensate for the wear. Replace worn compo-nents as needed. |
| The kiln shell is damaged because of refractory failures and is causing radial and axial run out, creating gear and pinion misalignment | Determine the area of kiln shell damage and replace the damaged shell with a new kiln shell section |
| The gear and/or pinion are worn and do not have proper gear to pinion contact during operation | On the appropriate gear set, reverse the drive gear to provide a new contact face. Install a new pinion or reverse the existing pinion. If wear is excessive, purchase and install a new gear and pinion. |
| The drive gear has been reversed and there is wear on the contact surface and excessive backlash | Replace the gear and pinion set with new design criteria. Use tangent mounting systems rather than flanged mount-ed and better rated gears if appropriate. |
| A new pinion has been installed on a worn drive gear, creating a contact surface mismatch | If the drive gear cannot be reversed or replaced, use a run-in compound to remove contact points causing gear to pinion mismatch |
| The gear mounting components are loose or missing | On the appropriate gear set, inspect flange to kiln shell welds, flange to gear mounting bolts, tangent plate to kiln shell welds, tangent pins, tangent pin retainer welds and gear joint flange bolts. Perform visual inspections monthly and closely inspect all gear components at every outage. Replace loose/missing bolts and weld repair any cracked welds. |

## High kiln shell ovality/premature refractory brick failure

| Cause | Solution |
|---|---|
| Excessive clearance between the filler bars outer diameter and the inner diameter of the riding ring. Filler bar wear is caused by lack of lubrication, misalignment between riding ring and the shell and product/dust contamination. | Install new free-floating filler bars to allow future shimming and maintain good kiln/component alignment |
| Misalignment of the kiln that generates high pier to pier loading at the riding rings | Maintain good kiln/component alignment and measure kiln shell ovality on a frequent basis |
| Damaged kiln shell causing loading transfer on a cyclic basis as the kiln revolves | Perform a shell run out study to locate the area of the kiln shell where the damage is. Remove the damaged shell section and install a new kiln section. |

## Concave/convex wear patterns on riding rings and support rollers

| Cause | Solution |
| --- | --- |
| The support roller design on many kilns requires adjustment or skew to control the axial thrust of the kiln. An excessive amount of roller adjustment will create high stress on the edges of the riding ring and result in concave/convex wear patterns. | Ensure kiln alignment is to the original design specifications and support rollers evenly distribute the axial loading as a result of kiln thrust. If surface wear is severe, resurface the contact surface using a grinding machine specifically designed for rotary kilns. |
| High pier loading on the support rollers exceeds design hertz pressures, and the riding ring displaces metal at an accelerated rate. As a result, the contact surfaces of support rollers become concave. | Ensure kiln alignment is to the original design specification, and pier to pier loading is distributed per design. Increased throughput in the kiln will generate higher loading, and design modification to kiln components may be necessary. |
| On feed and discharge ends of kiln, there is an excessive amount of product dust and contamination deposits on the contact surface of the riding rings and support rollers. Accelerated wear results in concave/convex wear on the surfaces of riding rings and support rollers. | Ensure the air seals on the discharge and feed piers can adequately handle high positive pressures to minimize dust emissions. If damaged surfaces exist, resurface the riding rings and support rollers with a grinding machine specifically designed for rotary kilns. |

## Kiln misalignment

| Cause | Solution |
| --- | --- |
| The kiln centerline does not match the support rollers design slope. This is a common occurrence when kilns are aligned in the operating condition. | Measure the diameters of the riding rings and support rollers, check the alignment of the gear and pinion and restore the kiln centerline to the design elevation slope to match components. |
| Failure to keep adequate records of support roller adjustment moves | Create a support roller adjustment log book after kiln alignment has been restored to original design specifications. This enables the plant personnel to evenly distribute the kiln loading to all support rollers |
| Settling of the pier tops causing the structural steel base frames to tilt out of design slope | Monitor the base settling and make sure settling has ceased. Loosen the structural steel base frames and reset to design specifications, if base frames are not bent or damaged. Install new base frames if the original frames are damaged. |

## Tapered/conical wear patterns on riding rings and support rollers

| Cause | Solution |
|---|---|
| Kiln axis misalignment compared to the original design specifications for correct kiln alignment | Restore kiln shell alignment to the original design specifications as outlined in OEM drawings and to specified tolerances |
| The support rollers structural steel base frames have settled and are causing the contact surface to misalign the riding ring when kiln is aligned to the design specifications | If the structural steel bases are not damaged or twisted, remove grout, loosen anchor bolts and reset the base to the correct elevation/slope. If the structural steel bases are damaged or twisted, install a new base frame according to original design specifications for correct kiln alignment. Note: On some types of kilns with self-aligning bearings, it is possible to shim under the bearing housing to restore to the correct design slope/elevations. |
| Excessive support roller maladjustment with the riding ring contact surface. This is most common when plant personnel try to thrust a riding ring in a direction to relieve high axial loading against retaining blocks, bands, or rings. | Ensure the kiln alignment is set to the original design specifications and support rollers are adjusted to distribute the axial thrust of the kiln equally. Correcting component alignment decreases axial loads on retaining blocks, retaining bands, retaining rings and excessive skewing of support rollers. |

## High support roller bearing temperature

| Cause | Solution |
|---|---|
| Excessive support roller axial thrust against the internal thrust plate/collar of the bearing housing assembly | Align the kiln to original design specifications and distribute the support roller adjustments equally to all support roller bearing housings |
| Support roller shaft misalignment with the bearing liner in the housing | At the earliest convenience, correct the structural steel base alignment to allow the housing to sit at original design specifications |
| Inadequate lubrication to maintain oil film strength or inadequate oil levels in the support roller housings | Check oil levels consistently and visually check that oil is properly distributed on the support roller shaft. Use a lubricant as outlined in OEM design specifications. |
| High loads resulting from kiln misalignment and/or high load transfer as a result of kiln shell damage. The kiln loads can exceed oil pressure limits and generate metal to metal contact. | Maintain the design kiln alignment specifications to equally balance pier loading. If kiln shell damage exists, determine the damaged area and replace the damaged section. |
| Oil/lubricant contamination has caused scoring or damage to bearing liners and/or the support roller shaft | Filter the oil in the bearing housing to maintain cleanliness. Ensure oiling cups are free of buildup and allow adequate application of lubricant on the roller shaft and bearing liner. |
| Bearing housings are not receiving adequate cooling to maintain normal operation | Ensure the cooling water system is turned on and cold water is flowing through the bearing housings. Inspect and clean bearing housing water jackets annually. |
| Previously damaged support roller shaft and/or the bearing liner are generating heat due to support roller axial movement | Use higher strength synthetic lubricant to maintain oil film pressure. Adjust support roller to limit axial movement. Replace worn bearings and support roller if needed. |

| Kiln shell damage | |
|---|---|
| **Cause** | **Solution** |
| Incorrect burner conditions cause brick stripping and premature refractory failure | Maintain good burner flame shape and burner positioning. Monitor and log shell temperature profile frequently. |
| High kiln shell ovality resulting from excessive riding ring/ filler bar clearance causes premature refractory failure | Maintain minimal clearance between riding ring/filler basis and check kiln shell ovality frequently. Lubricate riding ring bores with graphite to reduce filler bar wear. |
| Overload conditions caused by kiln misalignment results in high kiln shell ovality and subsequent premature refractory failure | Maintain kiln alignment to original design specifications and distribute the pier to pier loading equally on the kiln |
| Incorrect process/operating conditions cause ring buildup, excessive coatings that damage refractory when they break free. | Maintain a close watch on kiln shell temperature profile for “hot spots” or “cold spots.” Record temperatures and watch for changes during process changes to kiln operation. |
| During incorrect operating conditions, weld seam cracks develop from high stress loads and/or “hot spots” | Monitor kiln operations and shell temperatures. If “hot spots” develop, keep a close visual observation of the kiln shell in the surrounding area. |
| Cracks develop in the shell plate as a result of weld cracks on filler bars from kiln thermal expansion | Install new free-floating style filler bars to replace obsolete welded designs. During the free-floating filler bar installation, weld repair cracks in the shell. If cracks are extensive, install a new kiln shell section. |
| Kiln does not experience adequate pre-heat prior to startup, resulting in the kiln shell buckling under the riding ring in the burning section of the kiln | Follow start-up and heat-up schedules and procedures as outlined by OEM and refractory guidelines |
| Inadequate clearance between riding ring internal diameter and filler bars outer diameter causes the kiln shell to buckle in the burning zone of the kiln | Ensure when new filler bars are installed, the clearance is calculated correctly based on the operating temperatures of the kiln |
| The kiln is stopped due to a mechanical, electrical or equipment failure with a full load causing the shell to form a “dog-leg” condition | Ensure the auxiliary motor is serviced and able to rotate the kiln within a short period of time. If shell damage is unavoidable, replace the damaged section of the kiln shell with a new section. |

# Notes

Metso is a frontrunner in sustainable technologies, end-to-end solutions and services for the aggregates, minerals processing and metals refining industries globally. We improve our customers' energy and water efficiency, increase their productivity, and reduce environmental risks with our product and service expertise. We are the **partner for positive change.**

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