

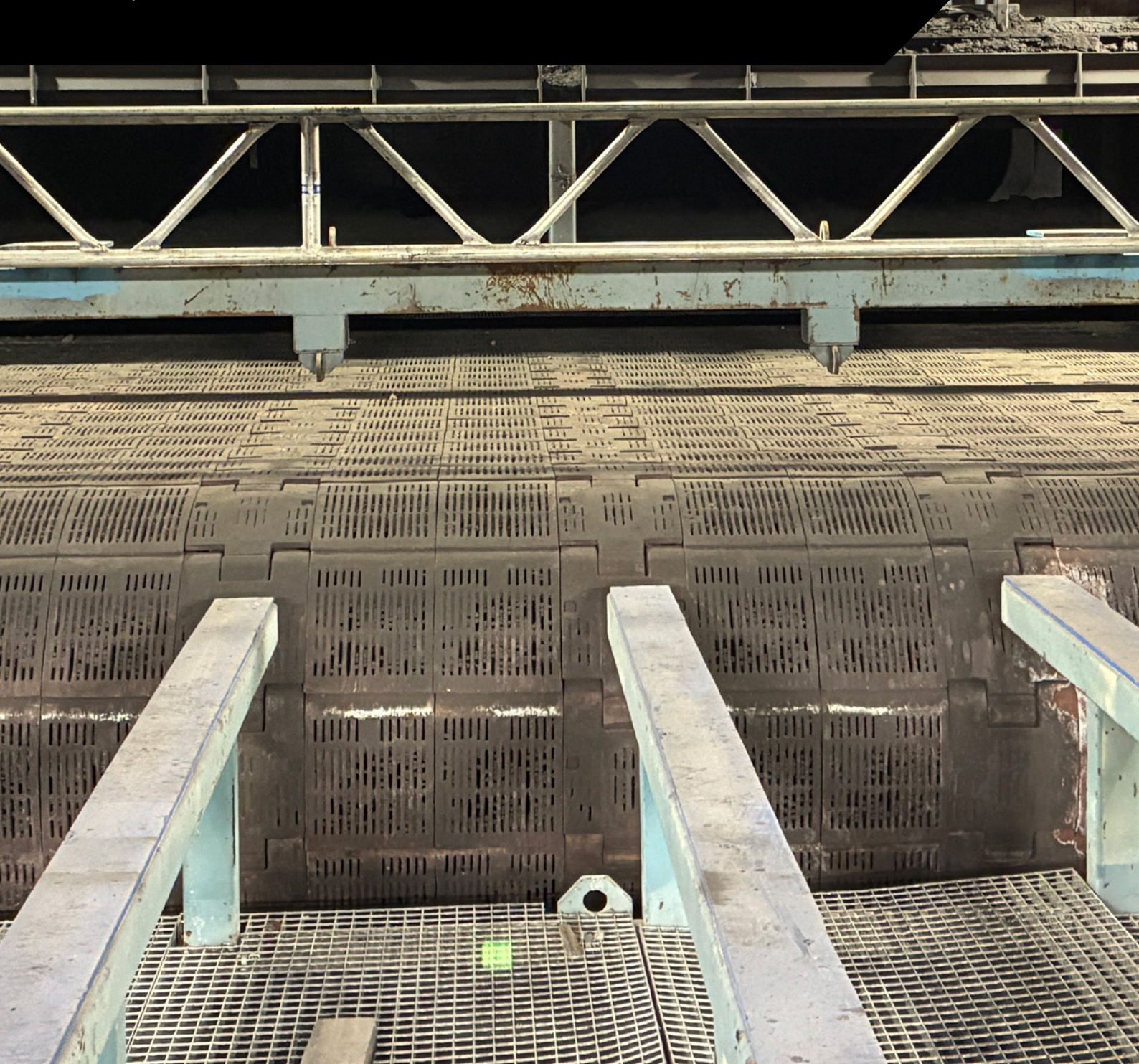
Metso

1st edition

Traveling grate handbook:

Aftermarket care for lasting reliability

September 2026



Preface to the First edition

Welcome to the Metso Traveling grate handbook: Aftermarket care for lasting reliability.

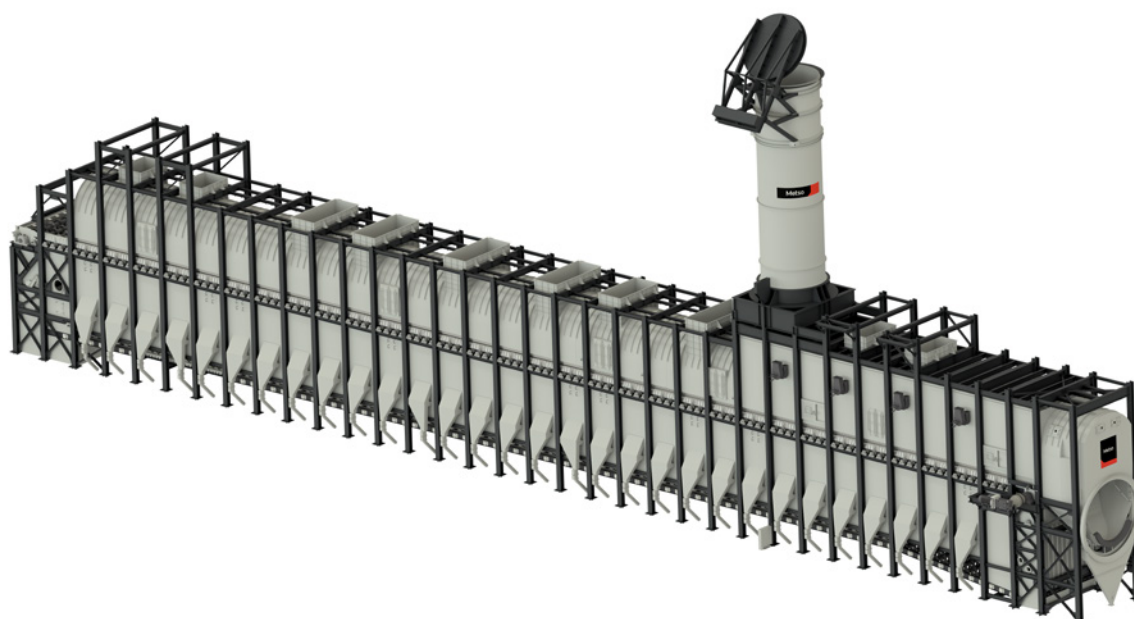
The following handbook describes the fundamental components and uses for chain style traveling grate preheaters as designed and sold by Metso. Traveling grates are a fundamental part of several processes that were originally developed and marketed by our legacy companies Allis Chalmers and Svedala Industries. Some of these processes are limestone calcining, iron ore pelletizing, ilmenite reduction, light weight aggregate and cement clinker production. Although the processes vary, the use of the traveling grate preheater/cooler is common to them all and the components are nearly identical.

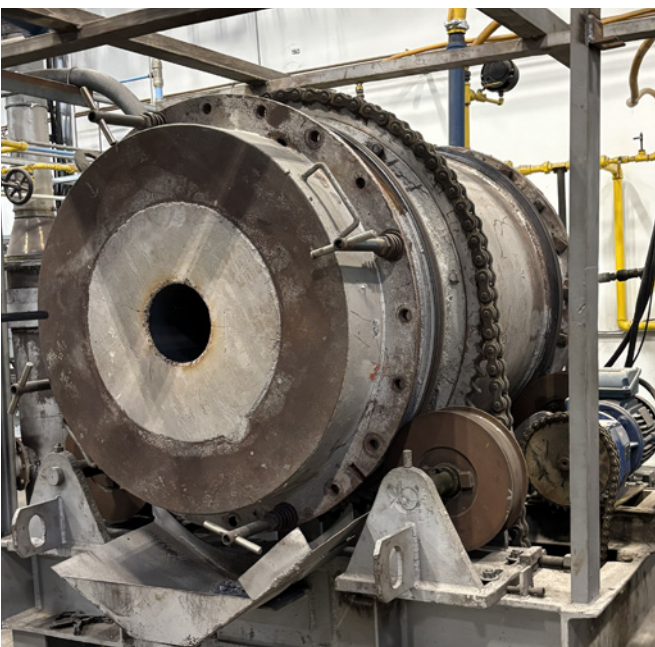
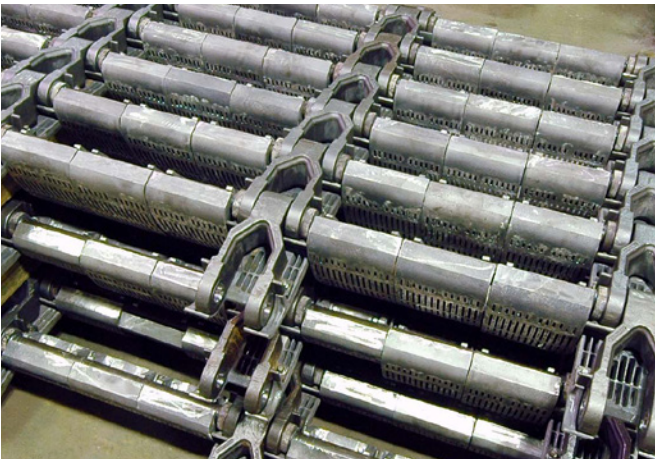
This handbook will serve as a technological resource to the owners, operators and maintainers of traveling grates. It will strengthen the reader's understanding of the different parts that comprise a grate, as well as aid in the alignment and maintenance required for achieving high reliability from the machine. Further, it should serve as useful insight on recent developments and improvements for traveling grate and controlled flow cooler machines.

When the grate chain is used as a cooler (located after the kiln instead of before) it is called a controlled flow cooler, but the components and overall design vary in minor ways. As a cooler, the grate is used on phosphate and cement kilns.

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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Originally developed for
the cement industry,

traveling
grates

have been used in various
mineral processing sectors
but are primarily used for
iron ore processing.



Pellet preparation

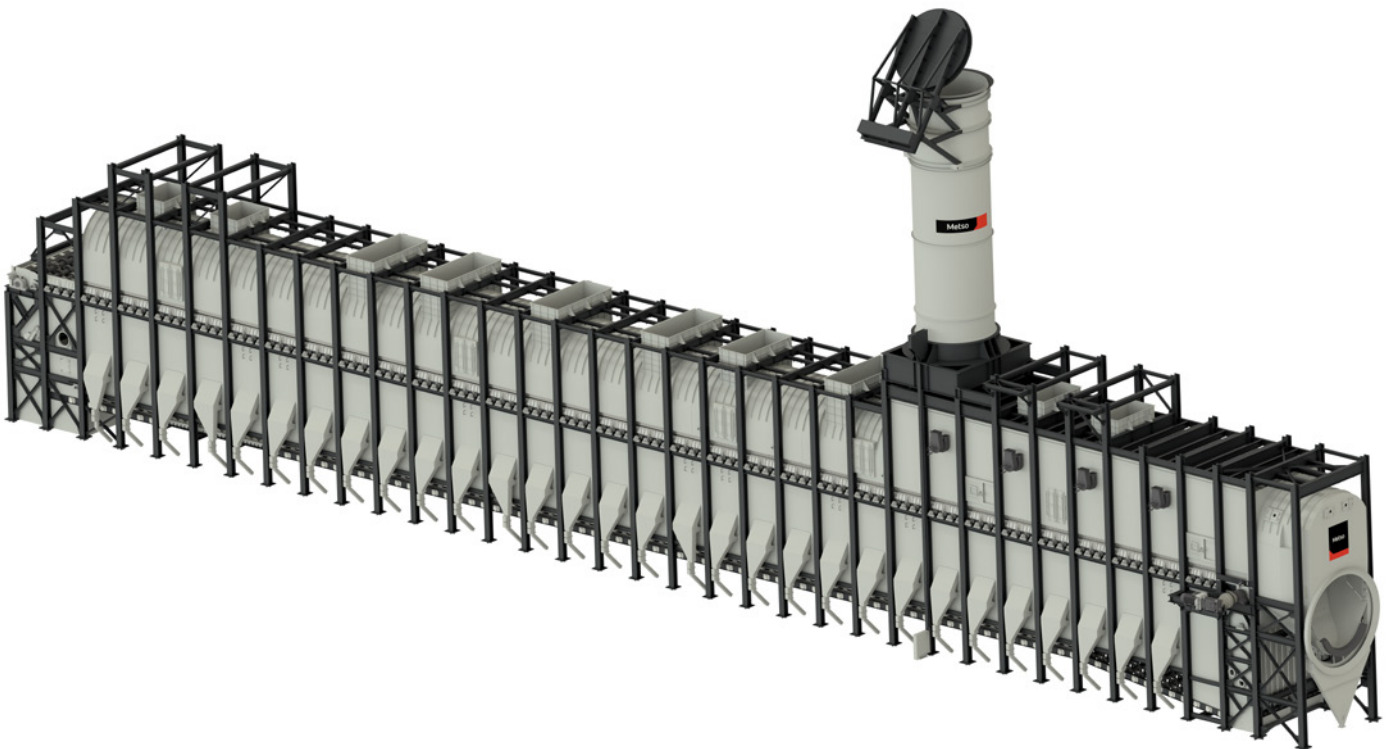
Traveling grates are used in iron ore pelletizing to continuously dry, heat, and harden green pellets before final firing. As pellets pass through controlled temperature zones, moisture is removed and strength is developed, supporting uniform pellet size, dust or breakage reduction, consistent quality, and reliable preparation for downstream processing in rotary kilns.

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What is a traveling grate?

A traveling grate is thermal processing equipment used for treating different types of solids to bring about a temperature and/or moisture change in the material. The machine is a gas to solids heat transfer device that relies on convective heat transfer between the static material bed and gas flowing through the bed (also called a grate). For most traveling grate machines, the gas flow is heated inside a rotary kiln (refer to the [Rotary kiln handbook](#) for more information) or other downstream device and then drawn through the bed of material using large exhaust fans located below the grate. In some cases burners may be added above the bed inside the traveling grate to increase the heat produced in addition to the convective heat transfer.

The traveling grate was first developed in the early 1900s for use in cement production. Otto Georg Lellep (September 29, 1884 – October 18, 1975) was an Estonian-born American metallurgical engineer and inventor best known for pioneering energy-efficient furnace designs, oxygen-enriched steel production and innovative processes in nickel smelting and cement manufacturing. In the 1950s, partnering with Allis-Chalmers Manufacturing Company, Lellep developed a pelletization method for cement production and an efficient extraction process for iron from low-grade taconite ore, contributing to resource conservation in mining. One part of his system was a chain-belt preheater called a “traveling grate”. This preheater was an adaptation of his LEPOL cement system (Polysius-Lellep) which used a similar traveling grate preheater to dry nodular cement clinker before the clinker would drop into a rotary kiln for final heating.





Process concerns

Although originally conceived for the cement industry, traveling grate preheaters and controlled flow coolers have been used in various mineral processing sectors. The primary use is in iron ore pelletizing as a preheater located upstream of the rotary kiln.

Iron ore pellets are indurated compactions of ground iron ore or related minerals. The grinding process seeks to liberate the desirable ore from the rock that it is encased in. This fine, liberated ore must then be transformed into a size fraction that is large and durable enough for transportation and further processing downstream, normally in a blast or electric arc furnace. The fine ore is mixed with a binder and rolled into uniform small pellets. These pellets are heated to sufficient temperature to remove water and indurate the fines into a rigid, roughly marble sized pellet.

The trapped water inside the moist pellets is the main reason a traveling grate is required upstream of the kiln. Temperatures inside the rotary kiln are sufficiently high and the moisture in the “green” unfired pellets would convert to steam and cause the pellets to rupture/break and turn to dust. However, slowly heating the pellets to remove moisture before sending them into the kiln is key to producing high quality pellets.



Process introduction

The main heat source for the drying of the pellets on the grate comes from hot gases recirculated from the kiln and the downstream cooler. The schematic shown below in Figure 1 is typical of a modern grate kiln system.

The exhaust fans, pulling air from below the material bed in the grate, route hot gases through the kiln, up into the hood of the grate and down through the bed of material and chain. The cooler forces ambient air up through the hot pellets that are mostly processed and leaving the kiln. The temperature needs to be reduced to a level where the pellets can be moved on conveyors and loaded into piles without fusing together. After the cold air passes through the hot bed, it reaches sufficient temperature that it can be used on the initial drying stage of the grate.

The key to a successful preheater operation is slow, linear heating of the pellets to remove moisture and impart enough hardness for the pellets to survive the trip through a rotary kiln. Within the kiln, final hardness is reached at extremely elevated temperatures (1400 °C/2500 °F).

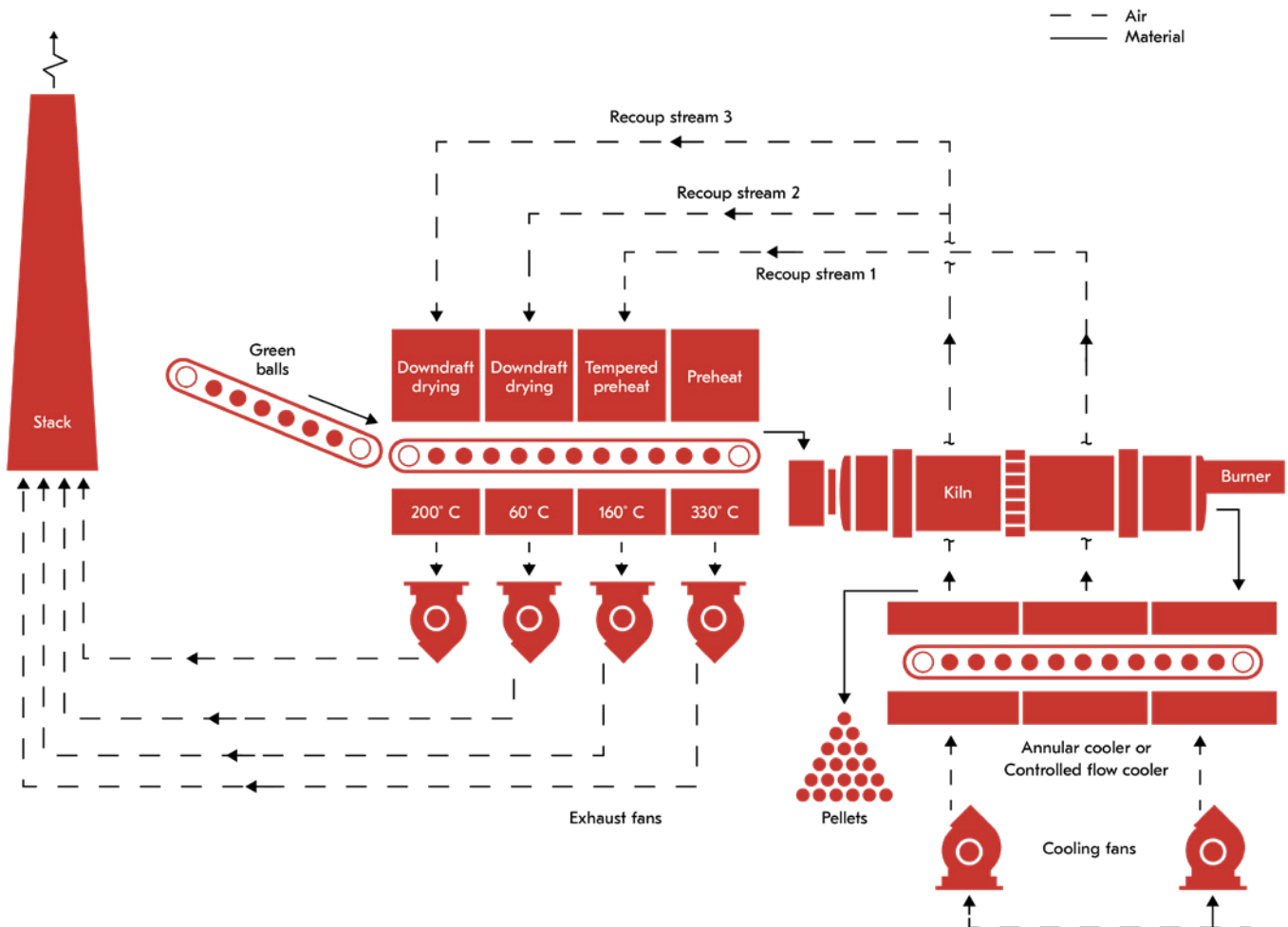


Figure 1: Grate kiln process schematic

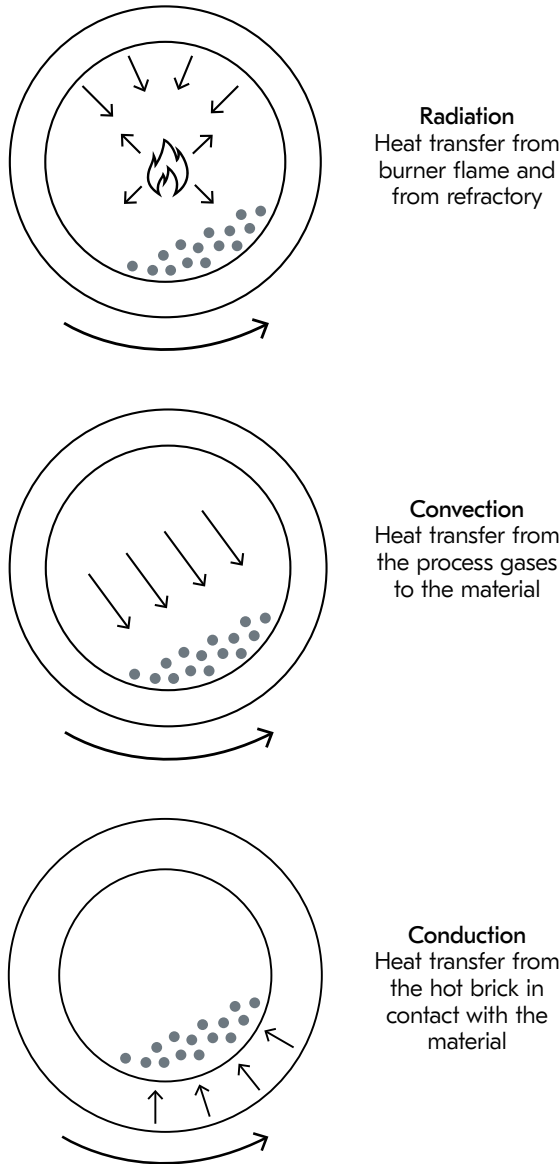
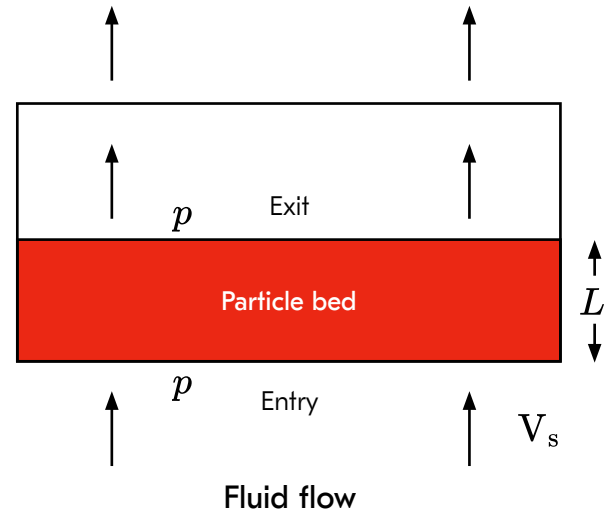


Figure 2: Modes of heat transfer in a rotary kiln

The grate relies on airflow and convective heat transfer. Airflow will always seek the path of least resistance. Pellet bed formation on the grate chain is very important to maintain even airflow through different sections of the bed. Sealing surfaces that are open to the outside atmosphere are a path for tempering air to enter the gas stream and lower the temperature of the process gas, hurting the drying process and driving up fuel costs.

In some processes burners are positioned in the furnace area of the grate to provide extra heat input into the gas stream. This is often required to calcine additives such as limestone, dolomite, coke breeze, etc. combined into the pellets. These burners increase air temperature.

Another consideration for the overall process and system efficiency is to maximize airflow through the bed of material, while using minimal pressure drop (fan power). The bed behaves like a semi-packed column of particles. Less compaction is beneficial and achieved by maintaining pellets that are of similar size (opening up void fraction space). A mixture of pellet sizes and broken pellets and dust will all increase the compaction of the bed by filling in the open void spaces between pellets.



$$f_p = \frac{150}{Gr_p} + 1.75$$

where f_p and Gr_p are defined as

$$f_p = \frac{\Delta p}{L} \frac{D_p}{pV_s^2} \left(\frac{\varepsilon^3}{1 - \varepsilon} \right)$$

$$\text{and } Gr_p = \frac{D_p V_s p}{(1 - \varepsilon) \mu}$$

where:

Δp is the pressure drop across the bed

L is the length of the bed

D_p is the equivalent spherical diameter of the packing

p is the density of the fluid

μ is the dynamic viscosity of the fluid

V_s is the superficial velocity

ε is the void fraction of the bed

Figure 3: Partially packed bed flow equations

About the traveling grate

There are some common components and attributes that traveling grates share, across manufacturers and intended processes. The following is a brief overview and important terminology. More detailed explanations are provided in subsequent sections of this handbook.

Metals grate

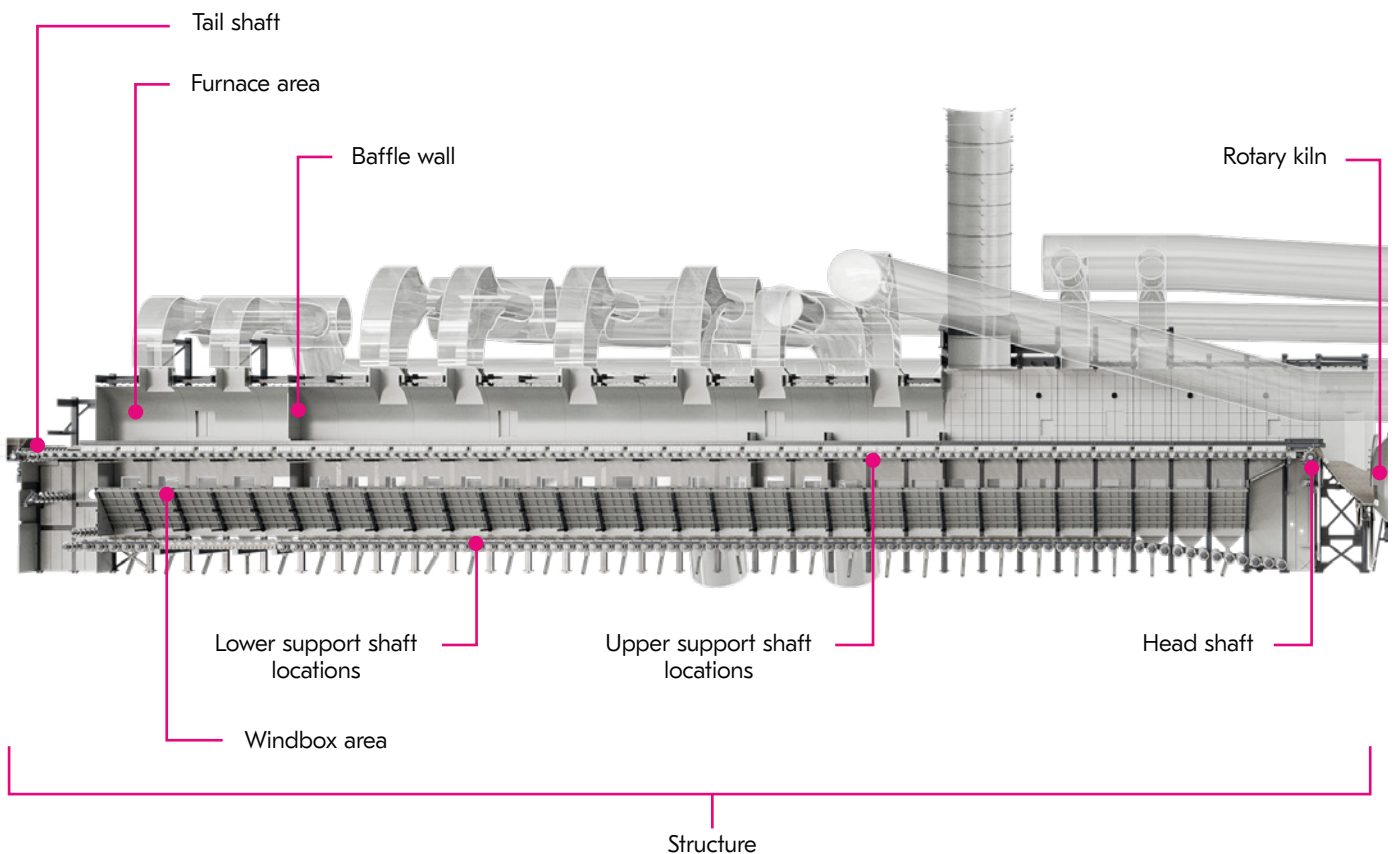
This refers to traveling grate machines used as a preheater upstream of a rotary kiln and used for processing metallic ores such as iron ore, titanium, etc. In these machines the windboxes, located below the upper strand of the grate chain, are independent of each other and the chain itself leaves the process flow and travels outside the windboxes along the lower return. The lower chain return and shafts are all outside the process gas flow.

ACL grate

This refers to traveling grate preheaters located upstream of a rotary kiln that are used for processing non-metallic ores such as limestone, cement clinker, phosphate, clay and nickel ores. ACL stands for "Allis Chalmers Lelap" and mimics the early LEPOL machines. In these preheaters, the grate chain stays within the process flow. All the supporting shafts (upper and lower strand) along with the head shaft are located within the process flow. The only area outside of the process flow is at the feed end of the machine. Most of these ACL grates have long been removed from service, but about 10 are still in operation in the US and abroad.

Structure

This refers to the skeleton of the machine. It comprises of the head shaft, tail shaft, upper and lower shaft assemblies, baffle walls and windboxes along with the columns, stringers, mainframes and other steel that support the moving parts of the furnace.



Deadplate assemblies

These are positioned below the bed of material and chain but above the windboxes. They serve as a gas flow seal which divides one process zone from another, along the length of the traveling grate machine. The assemblies consist of the deadplates (located underneath the grate plate areas of the grate chain) and skid bars (located beneath the chain link rows

of the grate chain). The skid bars contact the underside of the chain link and support the weight of the grate chain and material bed. Deadplate lengths are adjusted based on the pressure differential in zone A versus zone B. The deadplates should never contact the underside of the grate plates.

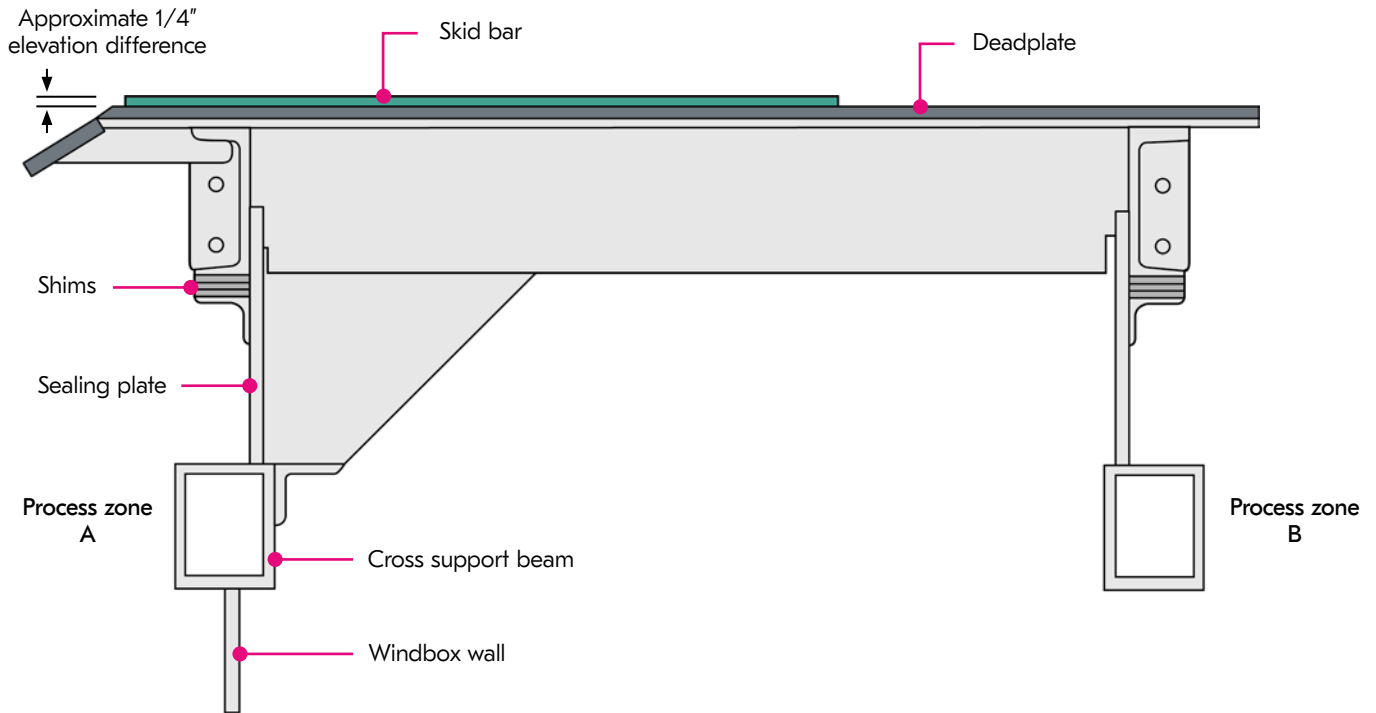


Figure 4: Cross-section depicting process zone division via deadplate assembly

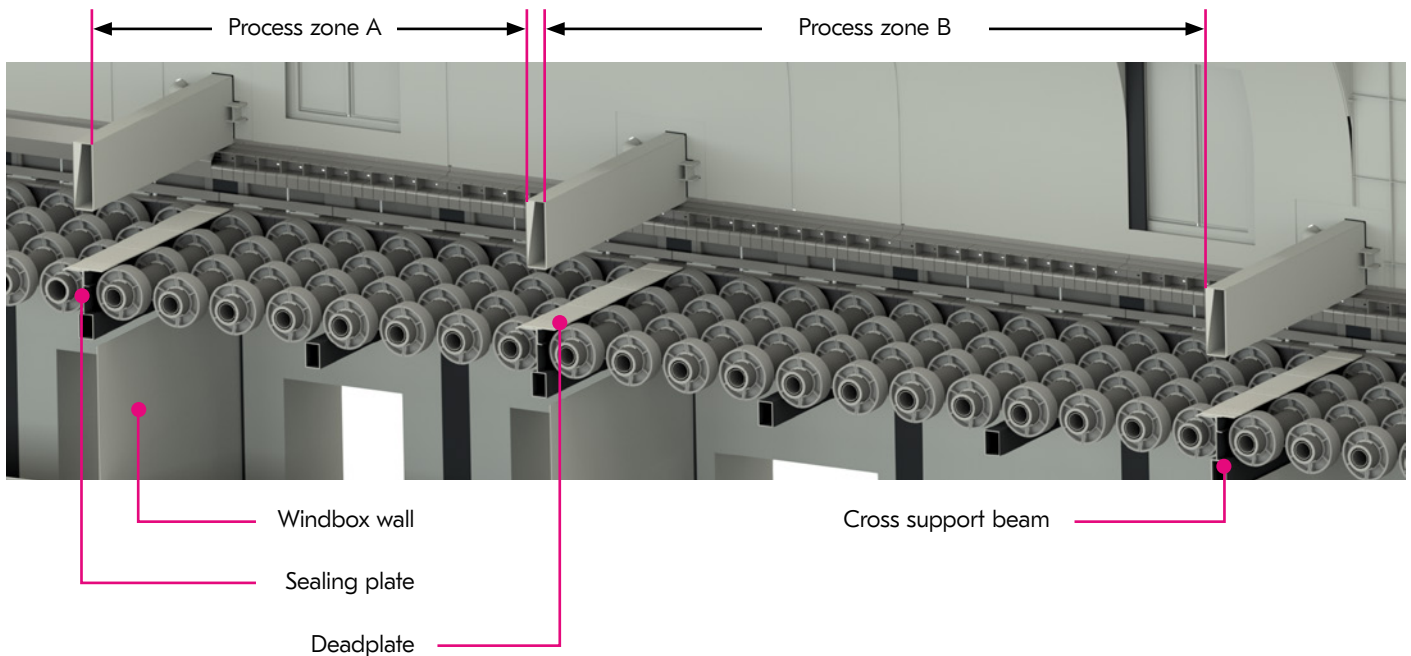


Figure 5: Process zones

About the traveling grate

Grate chain

The grate chain is the backbone of the machine, carrying the material through the various process chambers where it either loses or gains heat, depending on the application. In addition to transportation duties, the chain also permits air flow through the material bed. The chain forms a continuous loop within the machine, with the head shaft driving the chain and the tail shaft supporting the chain loop at the feed end.

The grate chain is comprised of grate plates and fasteners, chain links and chain link covers, thru rods, pipe spacers and end walls called sideplates.

These are large but critical components forming a wide belt that can carry large amounts of product in a high heat atmosphere. They also need to have longevity in a 24/7 continuous thermal cycling process.

There are three different variants of the 10" and 12" pitch chain that Metso offers.

Standard chain

The first variant is the standard chain with a one-piece chain link and grate plates which clip to pipe spacers which are slid over the thru rods. This design remains the most common 10" pitch chain in service.

This style chain removes the need for wear inserts in the bores of the chain links. In lieu of inserts or bushings, the bores are hardened to provide adequate wear resistance.

Two-piece chain

In this variant of the 10" pitch chain, the chain link is made in two parts, with the top part (cover casting) being made from a temperature-resistant stainless steel and the lower part being made from an alloy steel engineered for the tension forces imparted into the link. This variant is described in more detail on page 44 under the **Upgrades and modernizations** section.

Eco chain

This design is set to simplify the number of parts while providing for a shorter chain life with cost efficiency that fits into certain customer maintenance schedules. The chain consists of one-piece chain links without bushings, grate plates which slide onto the thru rods versus being clipped in place and no pipe spacers.

In this design, the grate plates cannot swing open as they do with the other variants, so letdown chains at the end strippers are not required. There is a need, however, to provide a collection trough for pellets that fall into the backside of the chain so they are not caught in an endless loop inside the chain. This collection trough is usually positioned under the tail shaft.

The end connections for the thru rods are also simplified on this version. A thick, threaded washer with a locking bar (which is field welded) is employed instead of the typical castle nut, washer and cotter pin connection used on the standard and two-piece variants.

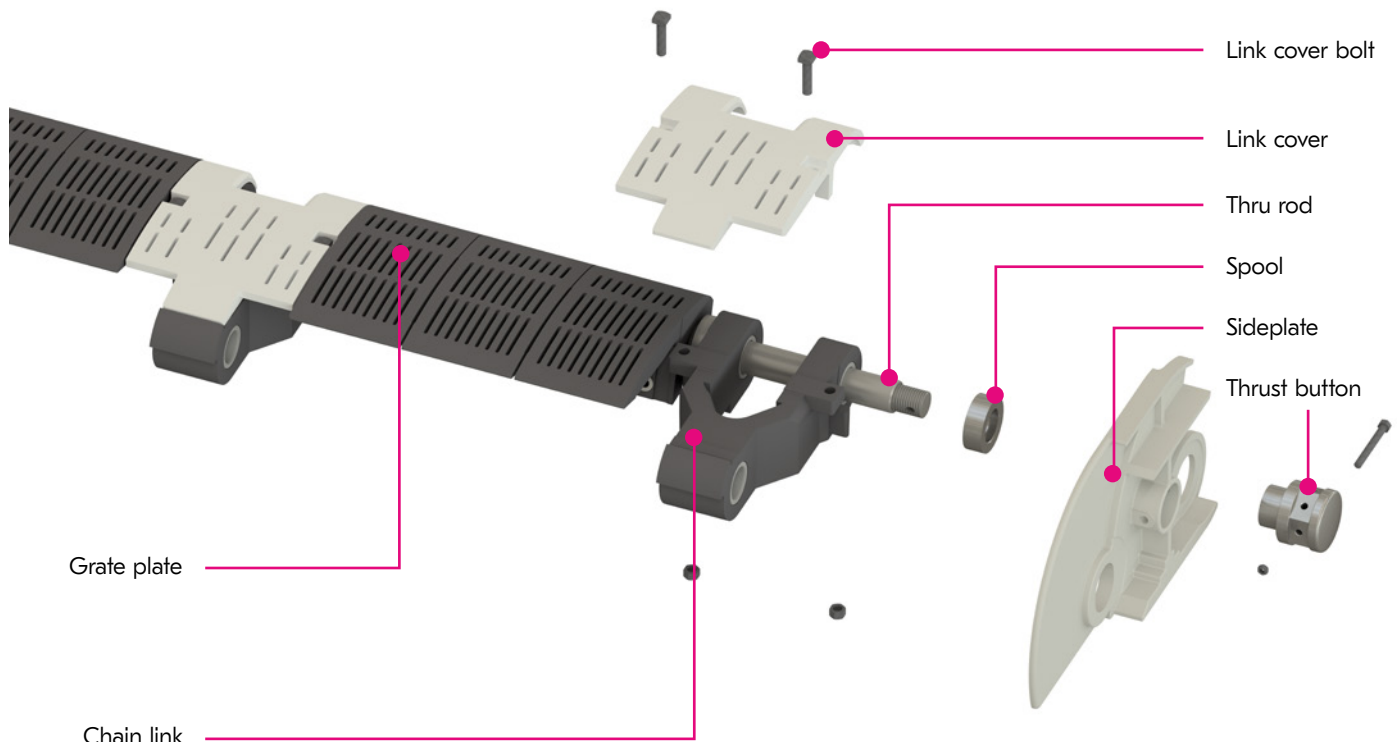
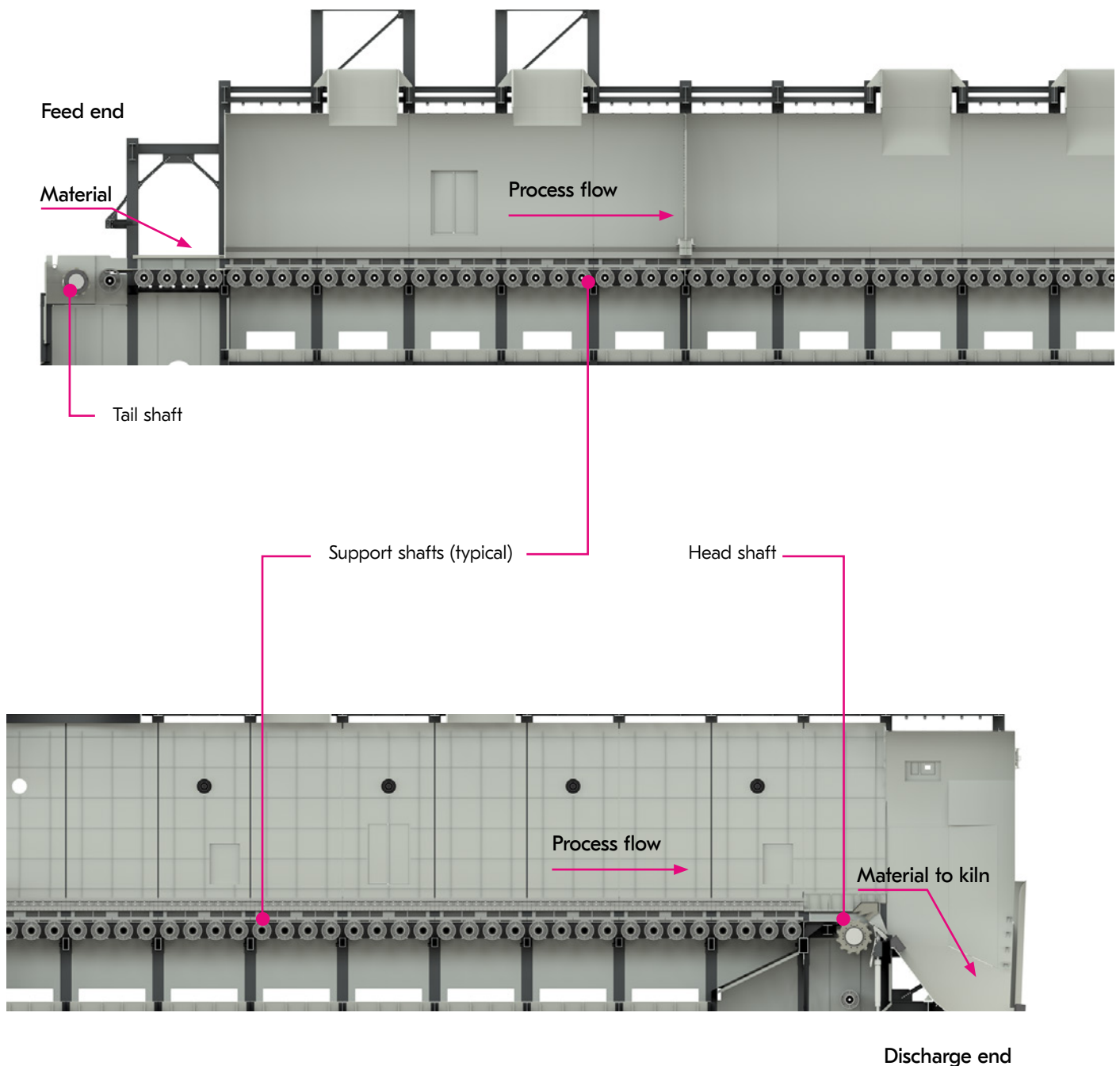


Figure 6: Two-piece grate chain assembly, exploded view

Upper chain support

This consists of the various shafts that support the grate chain conveyor, along the top strand of the chain loop, where the chain is carrying the bed of material. The upper chain support includes the tail shaft (feed end shaft), head shaft (driven shaft at the discharge end) and the intermediate support shafts. The support shafts are spaced evenly along the length of the machine and support the weight of the chain and material bed. This is to support the chain with reduced inflection.

The shafts are supported at their ends in bearings which are fastened to the grate structure. The dead loads on the shaft are taken into the structure through these bearing mounts. Since the upper support shafts pierce the furnace or cooling chamber, the shafts must be sealed at the machine walls to prevent gas leakage in or out of the machine. Air ingress can have large effects on the process.



About the traveling grate

The head shaft is the driven shaft which imparts movement to the grate chain. There are many different types of drive arrangements. Older machines and controlled flow coolers used large gears on the end of the head shaft; this gear was driven by a pinion attached to a foot mounted gearbox. Newer machines, to accommodate thermal expansion and movement of the structure, switched to gearboxes mounted onto the shaft end and supported by a torque arm.

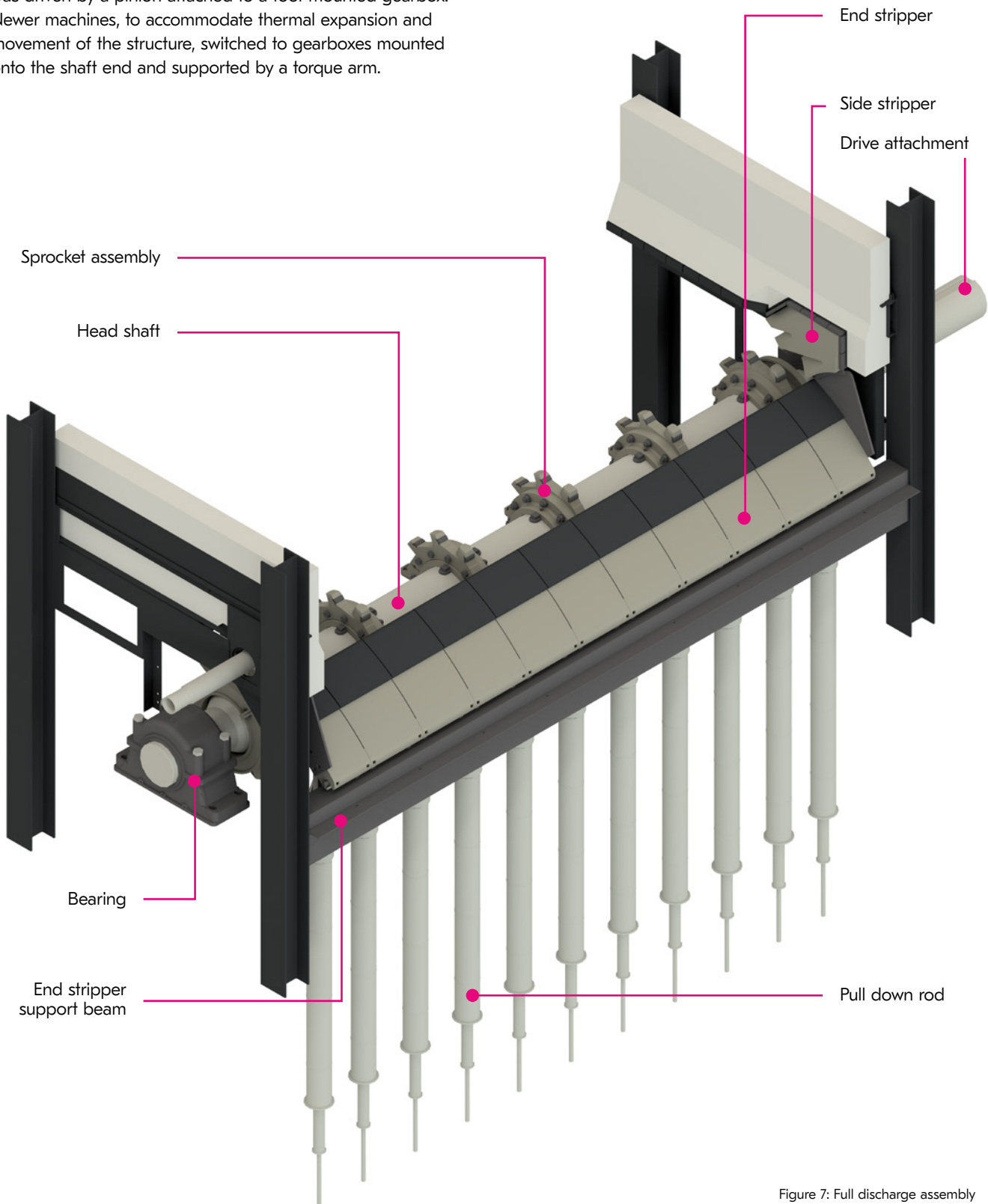


Figure 7: Full discharge assembly

Lower chain support

Similar to the upper chain support. On Metals grates, these supports are located outside the process flow, so no seals are required. On ACL and controlled flow cooler machines, these shafts are inside the windboxes and must be sealed at the machine wall as the support bearings are always located outside the process flow.

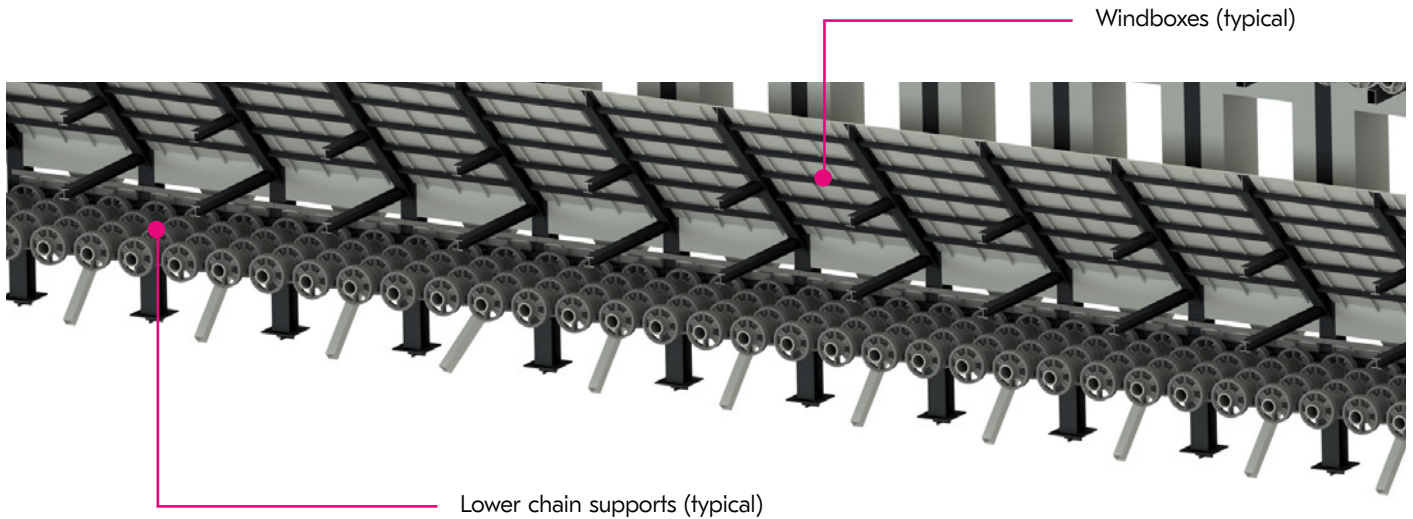


Figure 8: Windbox outlets

About the traveling grate

End strippers

Due to the configuration of the rotary kiln versus the grate chain shape, a device is needed to strip the material bed and send the material into the kiln. The plates which strip the material off the top of the chain are called end strippers. These plates ride against the top surface of the grate chain and direct the material into the transfer chute and down into the kiln. The strippers also serve as an air seal as the kiln and upper furnace are under negative pressure (suction) and the area under the chain and strippers is open to atmosphere. Preventing the introduction of ambient air into the furnace and associated gas stream minimizes fuel use. For applications using controlled flow coolers, they do not have this issue.

Side strippers

Similar to the end strippers, the side strippers ride against the inside surface of the chain end walls or sideplates and direct the material into the end strippers, down the transfer chute and into the kiln. As with the end strippers, they also serve as an air seal.

Letdown chains

A letdown chain assembly consists of a fully rollerized and counter-weighted chain strand connected to a wear resistant impact casting. One letdown assembly is positioned under each grate plate strand and is located below the end strippers. Because the grate plates are designed to rotate open as the chain passes over the head shaft and enters the lower return, the letdown assembly serves to control the rate at which the grate plates open. This prevents plates from swinging wildly and becoming interconnected and wedged open. Letdown chains also prevent pellet spillage, exiting under the stripper tips, from plugging the grate plate slots from the backside.

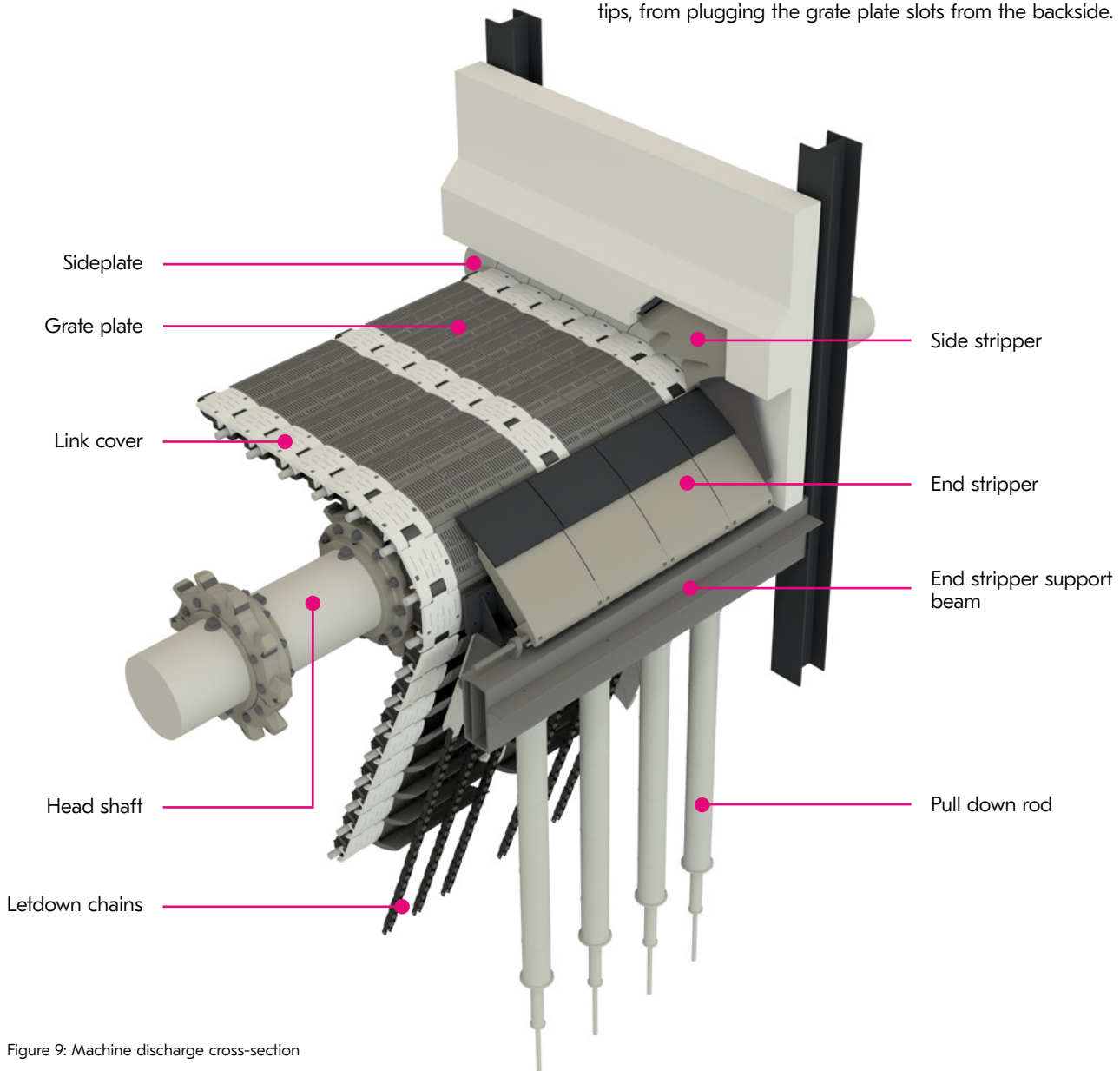
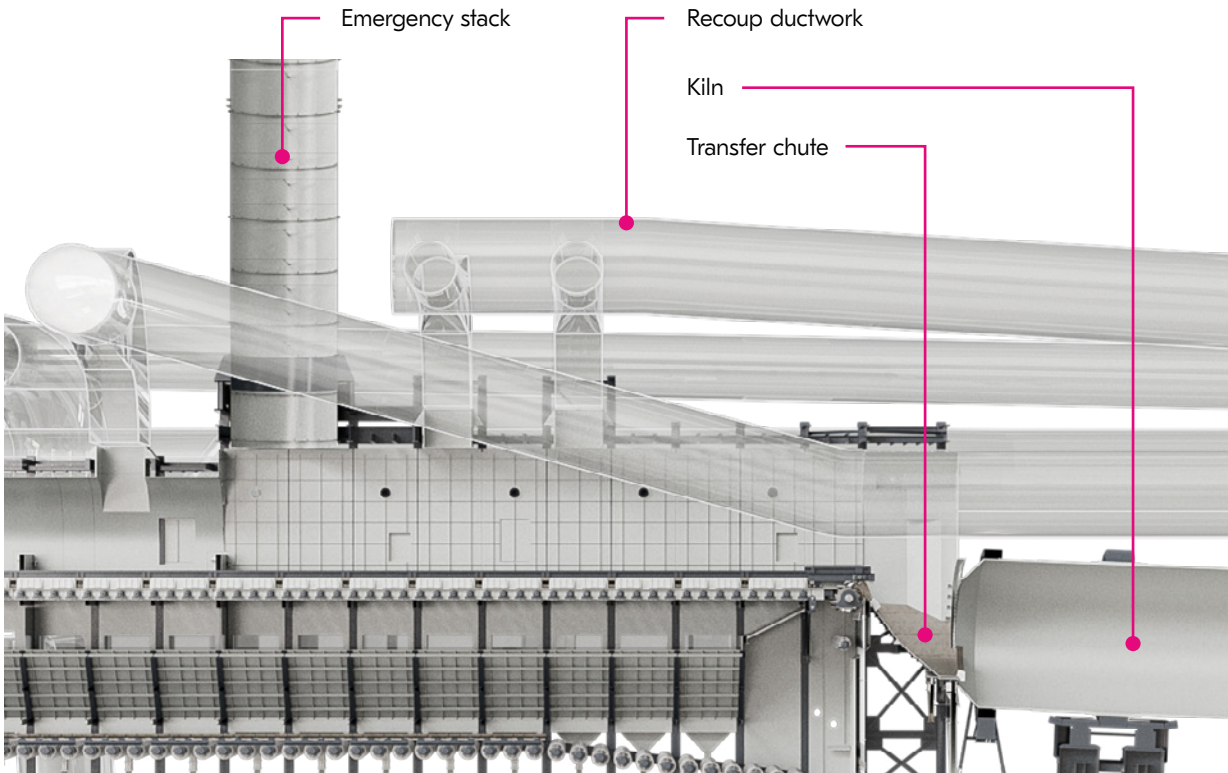


Figure 9: Machine discharge cross-section



Transfer chute/discharge housing

This construction is particular to Metals and ACL grates which are located upstream of a rotary kiln. The chute directs material into the kiln and directs kiln off-gas into the grate furnace to facilitate the drying/heating of the material bed.

Emergency stacks

The Metals or ACL traveling grate is always just one component of a system and never an independent processing machine. Most commonly it is feeding a kiln, then the kiln is feeding some type of cooler or hot discharge system. With independent systems comes the potential for independent failures. The most common is a power failure of the grate or one of the downstream machines. When a failure occurs in a hot machine, there is potential for the kiln off-gases to overheat the traveling grate chain and cause irreversible damage. This happens because the large exhaust fans, connected to the windboxes, continue to turn during a power failure due to their high inertia. As the spin down of the fans takes place, they continue to pull air through the system. A vent is needed for the system to allow kiln off-gas to bypass the chain and proceed to the stack. This vent is called the emergency stack. It is the round off-duct coming out of the roof of the traveling grate, near the head shaft. The cap on the stack is a fail-open design using counterweights and air cylinders. During a power failure, if movement of the grate stops, or the kiln off-gases pass a high temperature threshold, it will open.

Structure cooling system

Most traveling grates are preheaters and regulated high temperatures are desirable. Although the circulating gases should be kept as hot as possible to conserve fuel, not all components can handle the high temperatures. Structural cross beams and shafts which pass through the furnace or hotter windboxes at the discharge end of the machine need to be force-air-cooled to limit thermal expansion and mitigate thermally induced stresses. A fan and ductwork system directs cooling air into these components and a suction side draft is supplied on the opposite end to facilitate air movement with adequate velocity.



Figure 10: Emergency stack cap

About the traveling grate

Air blast systems/cannons

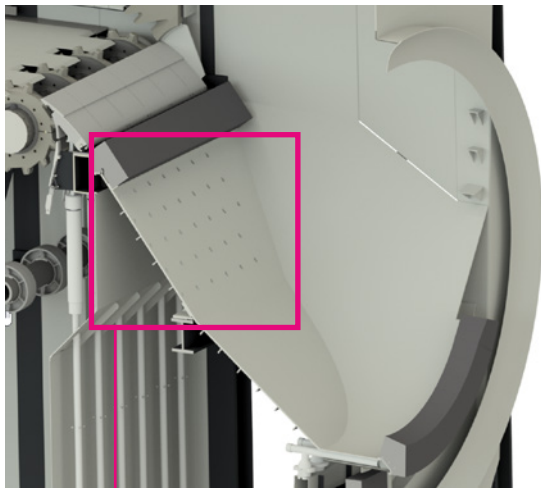
The transporting of the material from the grate into the kiln generates dust. This dust tends to build up in slabs on the walls and floor of the transfer chute and the furnace walls at the discharge end of the machine. To help mitigate this buildup and its associated problems, a compressed air blasting system blows air through ports in the chute floor and walls and in the walls of the furnace. The air blast system does not contain sufficient pressure to remove build-up. The goal is to prevent material stagnation and maintain continuous material flow. Determining where they are required can be different at every plant.

Lubrication systems

As with any machine containing sliding or moving components and bearings, lubrication is required to limit wear and extend the useful life of components. On the traveling grate, lubrication points are:

- upper and lower support shaft bearings
- furnace to shaft seals
- grate chain sideplates against the pressure bar supports
- drive system

These components all have grease and oil lubrication systems. The systems can become complex as there are hundreds of connections that all need to be serviced and monitored.



Holes representing where air blast pipes would be located (air blast system not shown in this rendering)

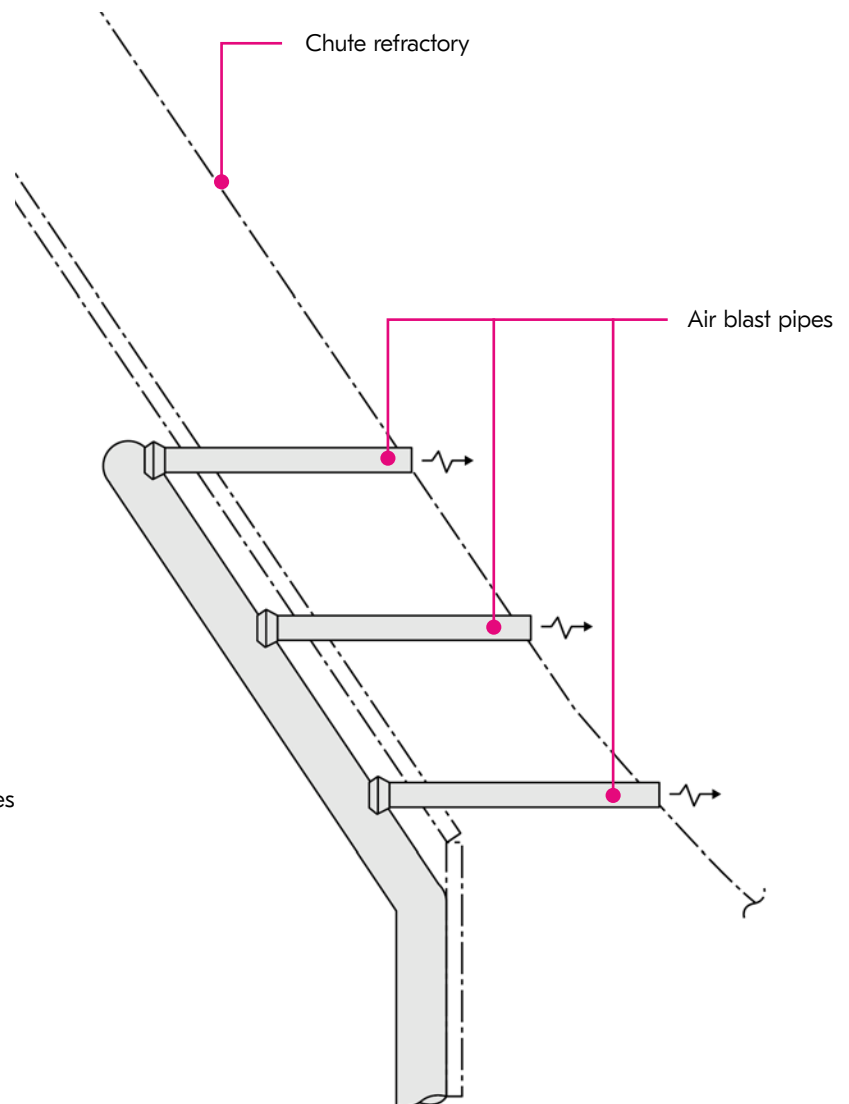
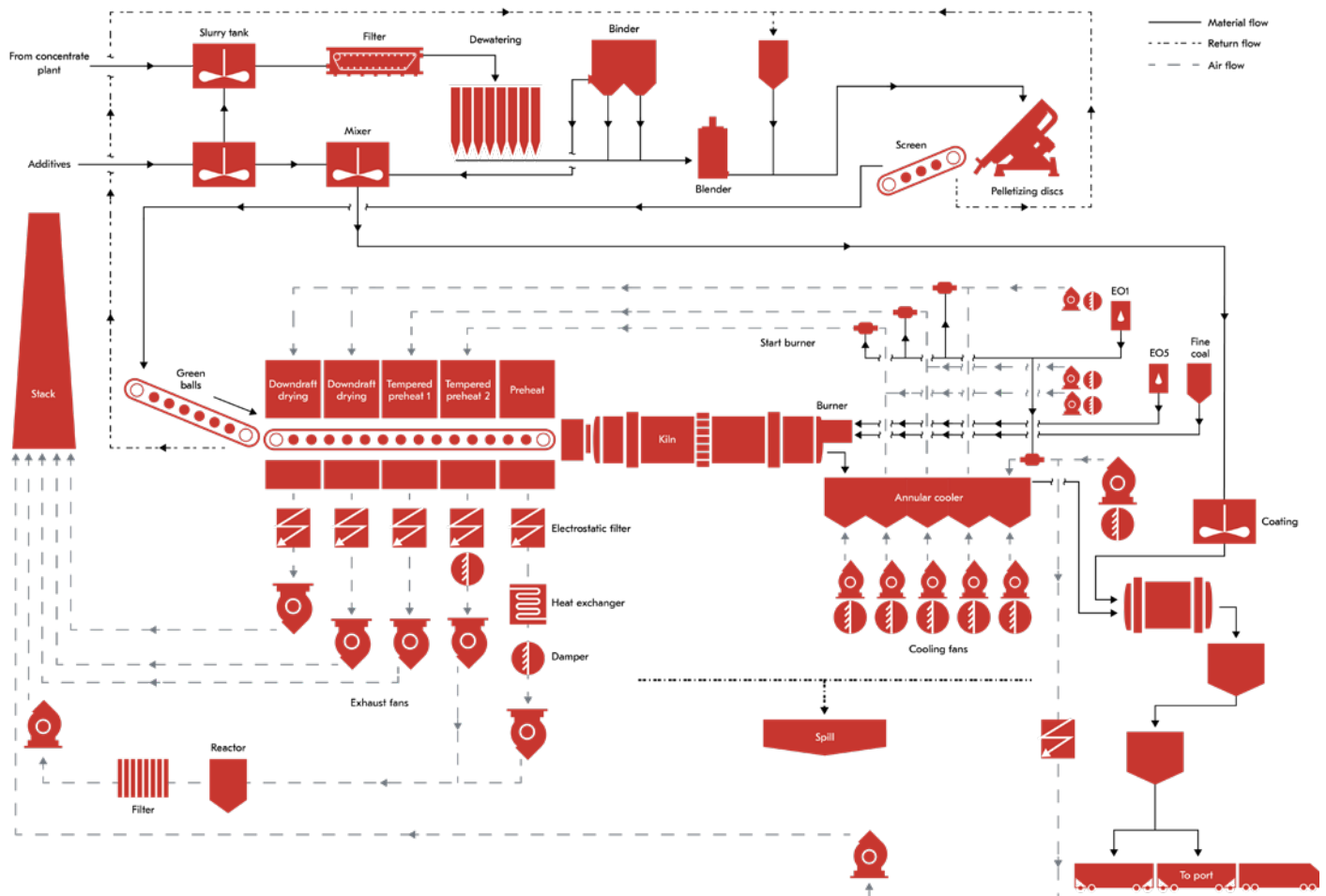


Figure 11: Transfer chute floor air blast arrangement

Process and machine sizing

Metso traveling grates are designed and sized to meet specific parameters. The traveling grate chain's speed of travel is limited to a range. Knowing this speed range and length determines the residence time of the material inside the traveling grate or controlled flow cooler. The airflow velocity through the bed of material and ductwork is also limited to a certain range. The final key to the sizing parameters is the rate at which the pellets can be heated or cooled without damage. If all ores behaved similarly, this would be a simple calculation. In reality ores behave differently from mine to mine and can even change within a singular ore body. Metso uses calculations based on historical operations as well as an in-house pot grate testing facility to determine the appropriate heat input. This rate of heat input is proportional to the volume of gas required to attain that heat transfer. From this relationship, the overall length and width of the machine is determined.

A typical overall system configuration for iron ore pellets including a traveling grate preheater is shown below.



About the traveling grate

Most traveling grate preheater machines operate with a bed of material on the conveyor chain that is between 150 and 250 mm in depth. This holds true for iron ore pellets, limestone, phosphate pellets and cement clinker/nodules. This relatively shallow bed depth provides for a low pressure drop across the bed therefore minimizing the power consumption by the process fans. The bottom of the material bed is also protected from crushing under its own weight.

Simulations for this system are carried out on a small scale in the Metso test lab.

Within this test system, air zone and ore changes can be modeled in addition to sizing new machinery. Common changes made over time include changes to the ore mix or body as well as changes to the burner and fuel, optimization of heat recuperation versus fan quantity and pellet sizing, and others. If concerned about the performance of existing machines, contact Metso for information about laboratory modeling and optimization.



Figure 12: Pot grate system at the Metso York Test Center, Manchester PA USA



ACL (Allis Chalmers Lellep) grate Traveling grate machines that are used as preheaters upstream of the rotary kiln and process non-metallic ores. Unlike the Metals grate, the grate chain stays completely within the process gas flow. The only area outside of the process flow is the feed end of the machine.

Air blast system A compressed air system that blows air through ports in the chute floor and walls of the furnace to prevent build-up of dust from the transport of material.

Catenary The natural, loose, hanging curve shape formed by the return loop of the grate chain as it travels back underneath the furnace.

Chain lifting rig A specialized lifting device used to safely lift, handle, and move preassembled traveling grate chain blanket sections during installation, replacement, or maintenance.

Chain links Join individual grate components into a continuous grate chain.

Chain link covers Protective cast components fitted to the grate chain and links that shield and streamline the chain assembly in high-temperature, abrasive applications.

Cold alignment Checks and measurements conducted while the machine is in a non-processing condition and is considered the baseline for machine condition.

Controlled flow cooler Term for when the grate chain is located after phosphate, cement or iron ore kilns.

Deadplate Located under the grate plate area of the grate chain at the division of each process zone.

Deadplate assemblies Consist of the deadplates and skid bars and are positioned below the bed of material and grate chain but above the windboxes. Serve as a gas flow seal that divides process zones from one another along the length of the traveling grate machine.

Dead load The static and unchanging weight of the structural and mechanical components of the grate chain conveyor system.

End strippers Plates that strip material from the top of the grate chain into the transfer chute and kiln. They also function as air seals.

Emergency stack A round off-duct coming out of the roof of the traveling grate that allows kiln off-gas to bypass the chain and vent to the atmosphere in the event of a power failure.

Grate chain Forms a continuous loop around the machine and transports the bed of material through the furnace. Permits the flow of air or gas through the material bed.

Grate plates Part of the grate chain. The perforated structural plates that form the traveling grate surface, support the material bed, and allow controlled upward or downward airflow through the furnace zones.

Grate plate fasteners Mechanical connecting elements used to secure grate plates and other chain assembly parts into a continuous and load-bearing traveling grate.

Head shaft Part of the upper chain support and is located at the discharge end of the traveling grate. The head shaft is driven and transmits movement to the grate chain.

Hot alignment Checks and measurements conducted while the machine is in operation; alignment will vary from cold alignment.

Induration The thermal process of hardening wet, green iron ore pellets into durable, fired pellets suitable for blast furnace or DRI (direct reduced iron) production.

Letdown chains Counterweighted roller chains located below the end strippers with one strand provided for each grate plate row, which prevent grate plates from swinging open too quickly and interlocking.

Lower chain support Consists of the various shafts that support the grate chain conveyor along the bottom strand of the loop. These supports are located outside the process flow on metals grates and do not require seals. On ACL machines the shafts are located inside the windboxes and require sealing at the machine wall.

Lubrication systems Provide lubrication to upper and lower support shaft bearings, furnace to shaft seals, grate chain sideplates against pressure bar supports and the drive system.

Metals grate Traveling grate machines that are used as preheaters upstream of the rotary kiln and process metallic ores. The lower chain return and shafts are located outside of the process gas flow.

Pelletization The process of transforming iron ore fines into spherical pellets through agglomeration and induration.

Pipe spacers Part of the grate chain. A sleeve-type spacing component installed around the thru rod within the traveling-grate chain assembly, used to maintain correct spacing and alignment of chain components while facilitating thermal growth of grate plates.

Pot grate A laboratory-scale furnace and pilot testing device used in iron ore processing to simulate the thermal treatment (induration) of green iron ore pellets on an industrial traveling grate or grate-kiln system.

Process gas flow The controlled movement, distribution, and velocity of gases through a bed of material to facilitate drying, heating, reduction, or calcination.

Pull down rods Rods connected to the underside of each end stripper casting. They provide a downward force to keep the strippers in near-contact with the grate chain, so as to minimize pellet spillage. The rods are also used to lift stripper castings into the open position (often using air cylinders) during a maintenance stop.

Pull type chain link Older version of chain link where the sprocket engages the link on the inside and pulls it through the furnace. This link was manufactured as all one piece.

Push type chain link Redesigned version of chain link where the sprocket engages the link on the outside, allowing for more surface contact. This version is also manufactured as two pieces: the link and the link cover.

Sideplates Chain end walls that are part of the grate chain. They support, align, and stabilize the grate assembly by connecting with grate plates, chain links, and thru rods to form the complete grate chain.

Side strippers Plates that ride against the inside surface of the sideplates (chain end walls) and direct material into the end strippers. They also function as air seals.

Skid bars Located beneath the chain link rows of the grate chain and support the weight of the grate chain and material bed.

Structure Consists of columns, stringers, mainframes and other steel that support the moving parts of the machine.

Structure cooling system A system consisting of fans and ductwork that directs cooling air into the structural cross beams and shafts that pass through the furnace or hotter windboxes at the discharge end of the machine. A suction side draft supplied on the opposite end facilitates air movement.

Tail shaft Part of the upper chain support and is located at the feed end of the machine.

Tail shaft guide sprocket An independently rotating (free-wheeling) sprocket on the tail shaft whose teeth work to keep the chain located centrally within the machine.

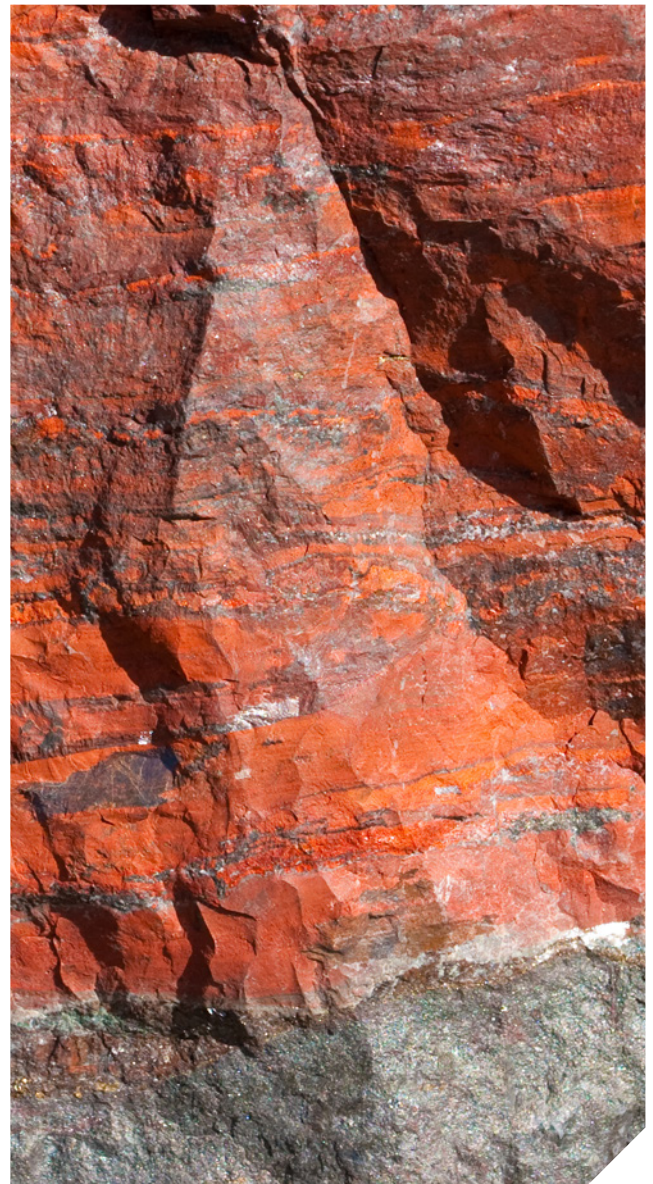
Thru rods Part of the grate chain. A long connecting rod that passes through the grate chain assembly and acts as a structural tie-member holding together the grate plates, chain links, and sideplates.

Transfer chute Directs material into the rotary kiln and directs kiln off-gas into the grate furnace. Applicable to metals and ACL grates that are located upstream of a rotary kiln.

Traveling grate A thermal processing instrument, first developed in the early 1900s, that is used to treat different types of solids by generating a temperature and/or moisture change to the material. This change relies on convective heat transfer between the static material bed and gas flowing through that bed.

Upper chain support Consists of the various shafts that support the grate chain conveyor along the top strand of the chain loop. The tail shaft, head shaft and intermediate support shafts are part of this system.

Windboxes Enclosed chambers located beneath the grate chain that manage process gas flow through the material bed, enabling zone-by-zone control of pressure and temperature.



Proper structure alignment and vigilant monitoring of the grate chain condition **are crucial** measures in preventing unscheduled and costly downtime in production.



Keep it running

Scheduled and consistent preventative maintenance on a traveling grate system helps preserve mechanical integrity and maintain process stability. Regular inspection, cleaning, and component servicing reduce the likelihood of unexpected downtime and extend equipment life. When preventative maintenance is neglected, issues such as uneven airflow, accelerated component failure, and unplanned shutdowns can disrupt production and increase repair costs.

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The following section will discuss typical maintenance and reliability concerns within a traveling grate or controlled flow cooler. It is not intended to replace or supersede the specific maintenance and operations manual that was provided by Metso with the supply of the original equipment. The intent is to give the owner/operator an understanding of the “what and why” behind maintaining a grate chain machine and how this will impact the reliability and efficiency of the unit.

Alignment

The first topic to discuss will be a preventative maintenance routine that is carried out regularly and impacts the reliability of most, if not all, of the subcomponents of the grate. Ensuring that the carrying shafts, drive mechanism, structure and chain sealing components are properly aligned with the centerline of the chain (coincident with the rotary kiln centerline) is critical for minimizing wear and frictional forces and maximizing the life of the moving components.

Alignment may have different understanding to different users, but it should include the following:

- All support and driving shafts should be perpendicular to the centerline of the machine.
- Elevational relationships must be maintained between the tops of support rollers, tops of pressure bars and deadplates, bottom of the upper sideplate seal and other critical relationships.
- The traveling grate chain centerline should be coincident with the machine's imaginary centerline.
- The imaginary axial centerline of the grate lies in-line with the centerline of the downstream kiln.
- Structural columns should be parallel to the centerline of the grate and equidistant from that line.
- The installation benchmarks, typically referenced from the kiln support base frames, should be the guiding feature for setting the cold, imaginary centerline of the machine.

The overall alignment comes in two options: hot and cold.

Cold alignment is the condition with the grate in a non-processing condition; no material load and no elevated temperature. It is a baseline for the condition of the machine and the main bullet points are described above. **Hot alignment** refers to checks and measurements that can be performed while the machine is in operation with a full material load and normal operating temperature. Due to thermal expansion, temperature variations amongst the components and offset material loads, the alignment of the grate, when hot, will vary from the cold alignment. This variance may sometimes be substantial. The alignment objective is to use the cold condition as the starting point and then the hot condition as a predictor of behavior (mainly chain tracking). Changes should be made slowly and deliberately, with only one or two changes made at a time. This is especially true when it comes to skewing shafts to control chain position.

The alignment established during initial installation is subject to change over time. Settlement of support structure, permanent deformation of structural and machine elements such as shafts and seals and differential thermal expansion all play a part in changing the alignment of the machine. In addition, spot repairs made in haste during a hot stoppage often lead to misalignment of the machine. Wear of moving parts has a substantial effect on elevation relationships which happen slowly over time and can easily be missed. The accepted definition of “good alignment” of the grate is that the machine operates with minimal power draw and minimal component wear of the moving and rotating parts. Metso recommends a bi-yearly alignment check on the structure and shafts with reference to the imaginary centerline along with spot checking of elevational relationships. Concise record keeping of failures and wear life of components is the most advantageous approach to diagnosing alignment issues.

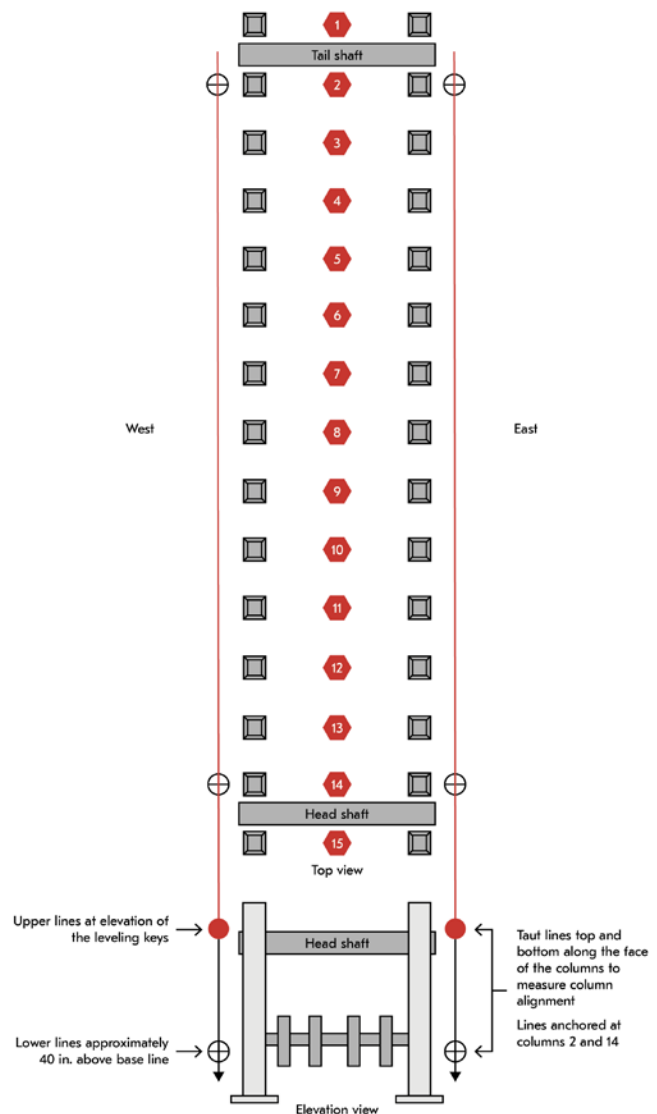


Figure 13: Structure alignment example

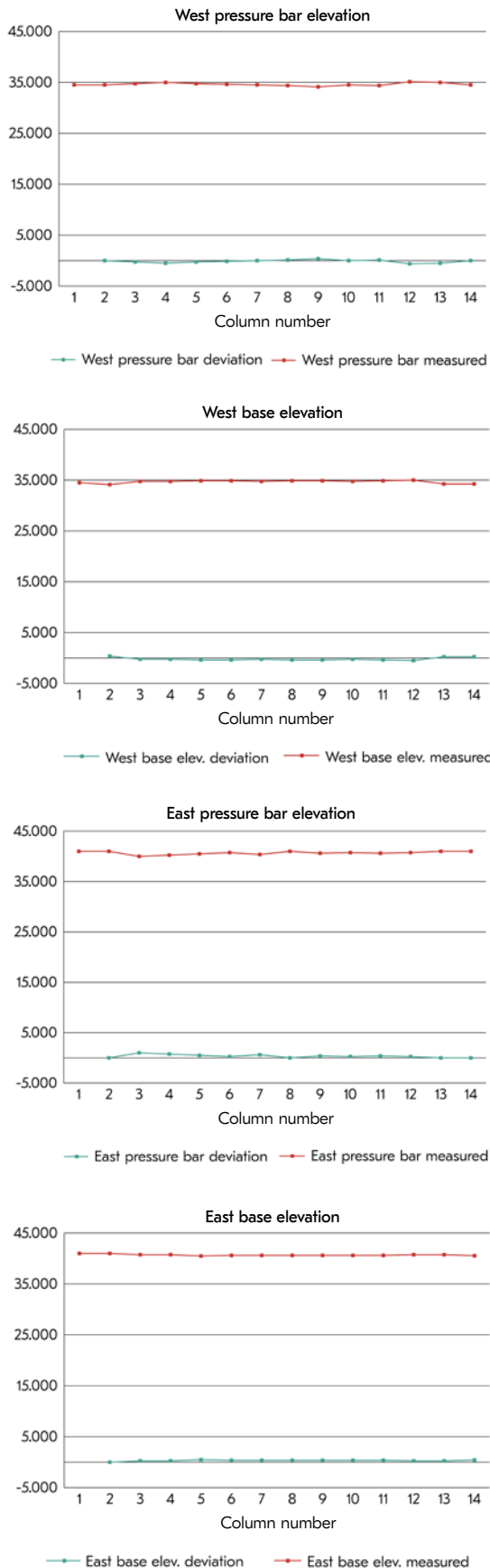


Figure 14: Graphs showing examples of measurements and deviations of structure alignments at different elevations on both sides of machine

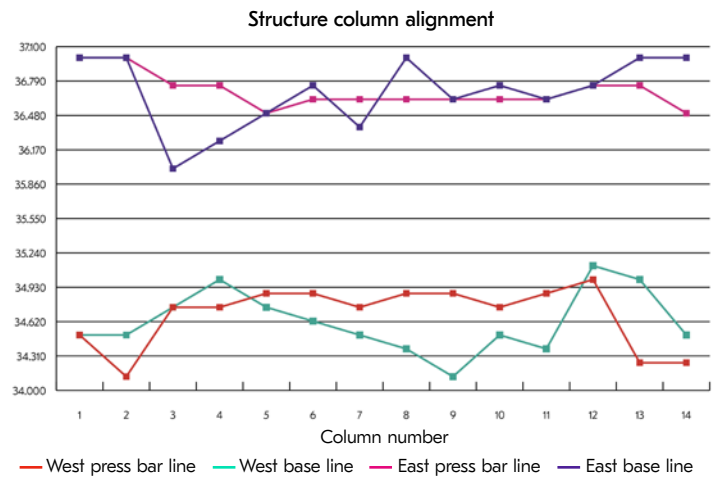


Figure 15: Example of a graphical representation of column (structure) offset from machine centerline measurements

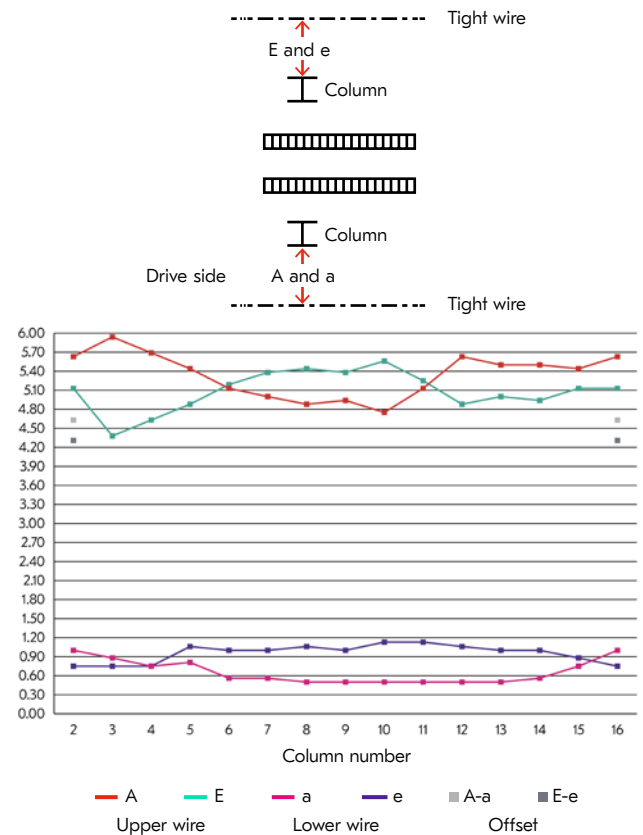


Figure 16: Example of results from a hot alignment survey for centerline offset measured at upper support shafts

The hot alignment graph can quickly demonstrate problematic areas through a rapid change in the slope of the curve. Ideally this would be a straight horizontal line for each separate measurement. This chart can be compared to a corresponding chart of cold measurements to weed out inherent misalignment and help identify alignment issues caused by temperature differentials.

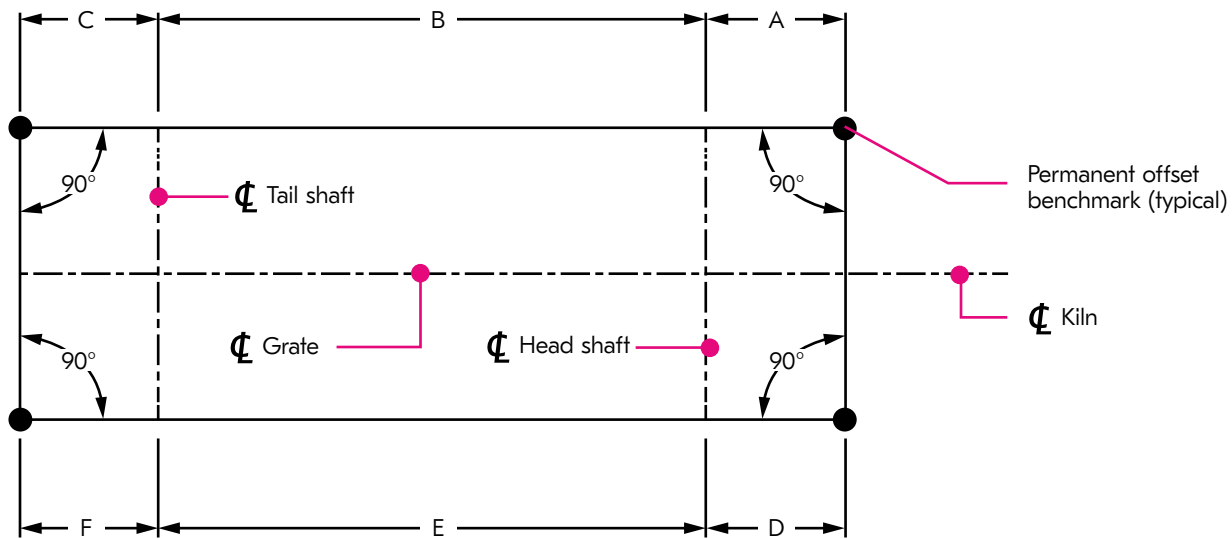


Figure 17: Main shaft alignment example

For shaft alignment, it is critical to remember that the head shaft or driving shaft controls the overall conveyor chain tracking to the greatest extent and is the shaft to which the other support shafts should be aligned parallel as a starting point. The head shaft should be set perpendicular to the centerline of the machine and the other shafts set parallel to the head shaft, working from the machine discharge back towards the feed end. It is critical that cross-corner measurements be carried out so that one doesn't align a rhombus instead of a square by accident.

Centerline offset alignment is important, but even more critical are the elevation relationships at the upper support shaft and grate chain sideplate locations. Vertical misalignment can quickly lead to process problems and acute wear of moving parts of the machine.

The chain elevation (centerline of thru rod) is critical to maintaining the relationship with the surrounding seals (sideplate seals and inter-zone deadplates). When these relationships deteriorate, the chain can drop, while the sideplates remain at their prescribed elevation. The sideplates rest on the pressure bars (lower seal plates) and are engineered to float on the thru rods. If the thru rod elevation continues to drop, the weight of the chain can come to rest on the sideplates when the thru rod bottoms out in the elliptical hole in the sideplate. When this occurs, the entire chain and bed weight are transferred through the bottoms of the sideplates and into the pressure bars. This converts the system from rolling friction, when the chain rolls along on the support shafts, to sliding friction. Negative results include high drive forces and sprocket wear, higher chain tension with wear on the thru rods and chain link bushings and wearing away of the bottoms of the sideplates and the tops of the pressure bars. In extreme cases, this can lead to a head or tail shaft failure.

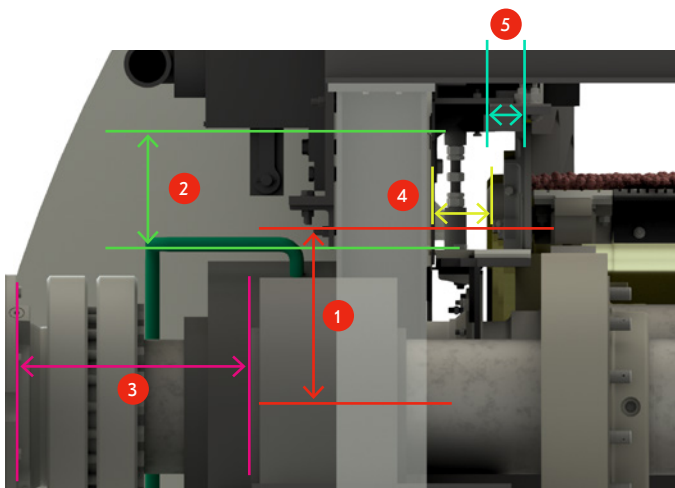


Figure 18: Critical elevation relationships at the upper support shaft location

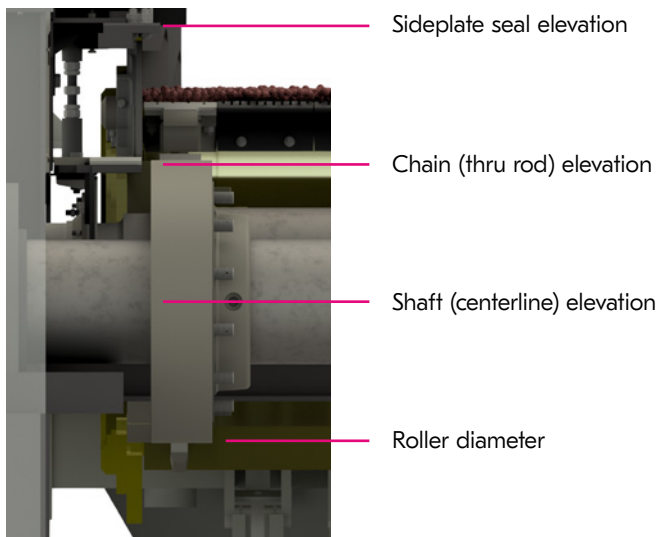


Figure 19: Critical components at the upper support shaft location

Elevation and misalignment can cause the bottoms of the grate plates to rub against the deadplates and the skid bars. Either condition will cause the plates to open and close rapidly; this is known as grate plate chatter. This up and down motion will destroy the pellets at the bottom of the bed and cause it to lose permeability. With lack of airflow through the bed, the pellets will enter the kiln in a softer condition and degrade, turning into dust and many fractured pellets coming out at the end of the process.

Lastly, this area at the upper support shaft location contains the sideplate seals, the main process gas seal between the moving chain and the outside atmosphere. Elevation and lateral location are paramount to the functioning of this seal. If the upper seal loses contact with the tops of the moving sideplates, outside (tramp) air will be drawn into the machine. This will temper the gases going through the material bed and slow down the drying process for the pellets. In addition, the area between the sideplate seals and the observation doors can act like a duct or channel for high temperature gases to be pulled down along the machine towards the feed end. This occurs because the exhaust fans in the feed end operate at a higher negative pressure than the discharge end exhaust fans. Hot kiln off-gas pulled into this artificial duct can overheat the structure. It can also create an acid dewpoint issue as the gas cools, leading to corrosion of the seal components and structural members.

Hot gases bypassing the bed and going over the tops of the sideplates can cause the edges to crack from overheating.

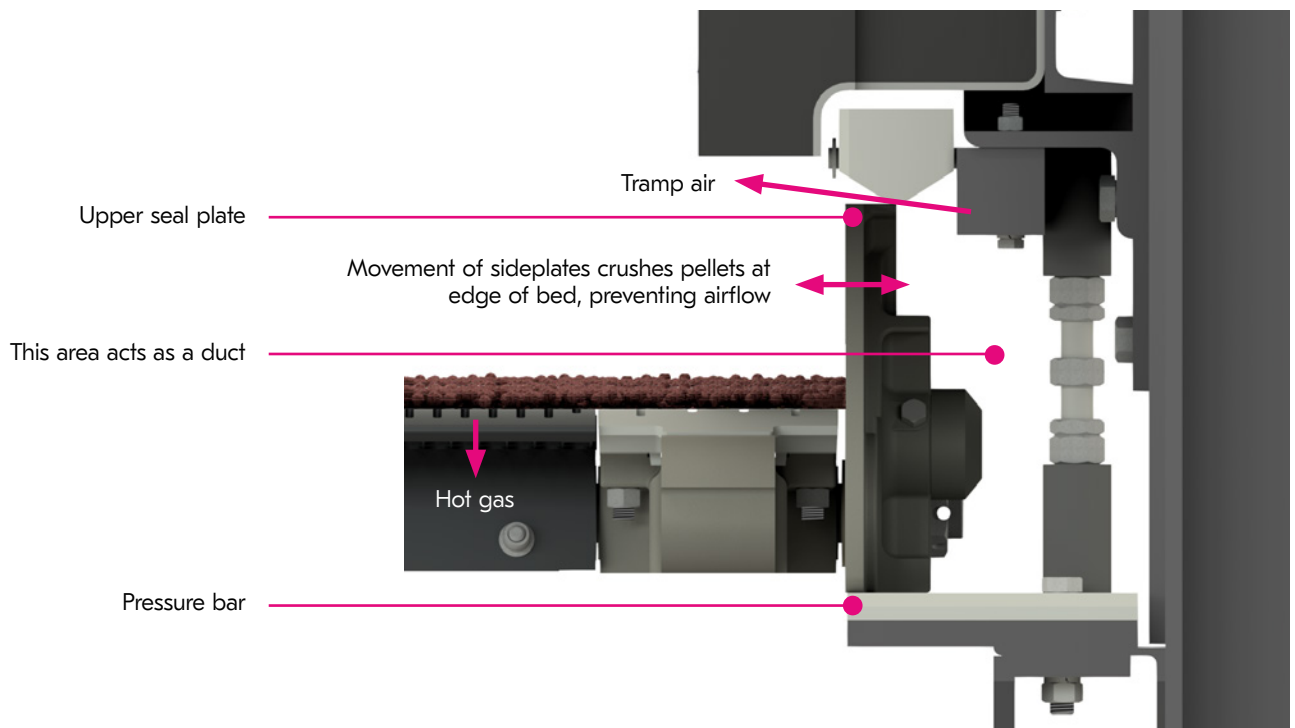


Figure 20: Gas flow concerns at the upper sideplate seal area

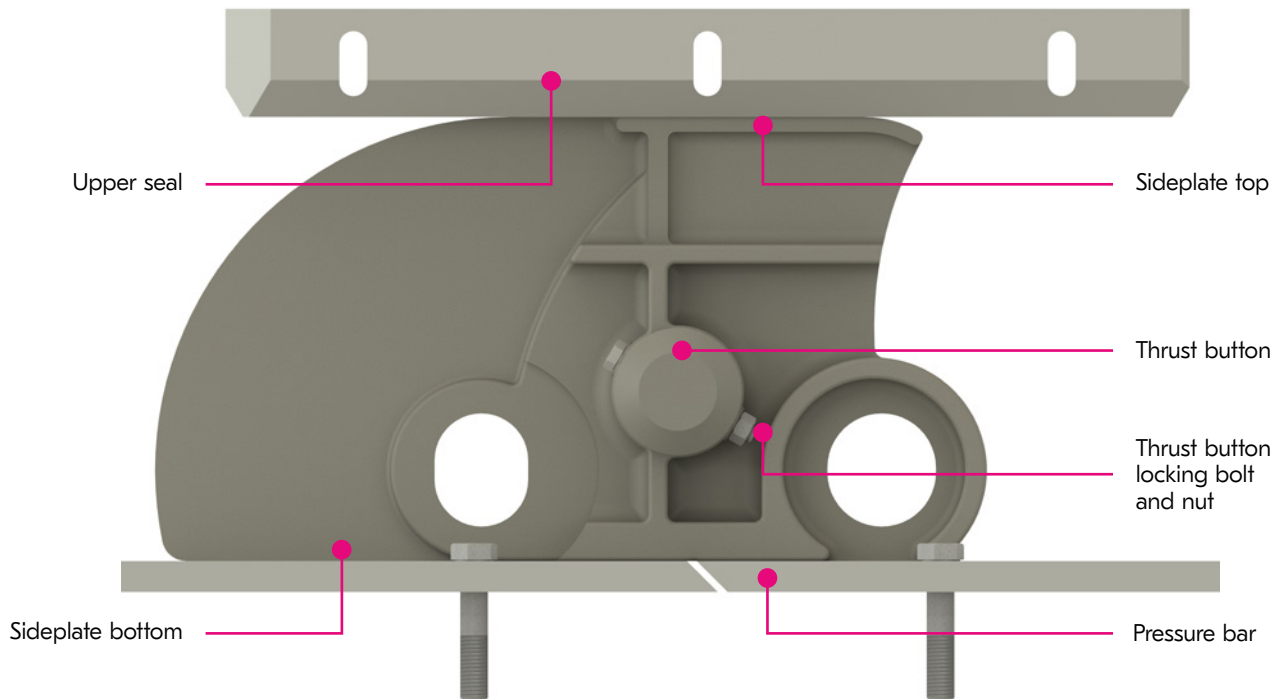


Figure 21: Sideplate and seal components

Corrective actions related to alignment often require a return to the cold benchmark conditions. This is true with some exceptions:

If the chain has worn more on one side versus the other (for example, chain pitch is longer on row one versus row six), then the overall chain belt will be longer on one side than the other. The only way to counteract this situation is to skew the tail shaft to make up this difference. For most machines, a skew of 50-100 mm is not detrimental to the bearings. In cases where extreme wear has occurred and the only recourse is to skew the shaft more than 100 mm, then accelerated bearing wear on the tail shaft is an assumed risk to maintain operation until the chain can be replaced.

If the chain is hotter on one side than the other, a similar condition will exist with the chain being longer on one side versus the other and tail shaft skew being the only recourse. With this condition it must be understood that, when cold, the chain will not have a differential length as it was all due to temperature differential. Operators must plan for the chain shrink when going down cold and move the tail shaft back to a neutral position to accommodate.

If the decision is made not to counteract the chain length distance on one side versus the other, the chain will sag between rollers on the longer side and green pellets will be damaged, airflow will be disturbed and sub-standard product quality and dust generation will be the outcome.

For many conveyor chains the chain will snake through the furnace, shifting from side to side as viewed from above. This

could happen for various reasons. Skewing the tail shaft will not correct this. The only corrective action for this condition is to purposely skew the support shafts to steer the chain back towards the centerline. Each individual shaft should not be skewed more than 10 mm or so. The opening in the furnace sidewall where the shaft passes through will be the ultimate limiting factor. When skewing a shaft, the process may be equated with the analogy of riding a bicycle. The cyclist is looking in the direction of travel, and turning the handlebars is analogous to turning the shaft in the direction the chain should go. For example, if the chain is moving left and needs to move right, the shaft should be turned to the right. Skewing one support shaft will make little to no difference. Skewing multiple shafts - several bays worth - a small amount will cause the chain to move. It may take several rotations of the chain for the movement to take place so patience is needed.

Lastly, elevation changes brought about by worn shaft bearings or worn rollers can only be corrected by shimming the support shaft bearings. The new elevation of the shaft centerline will not match the installed condition. In addition, if the worn bearings or rollers are replaced, the shaft must be returned to the neutral elevation. Shimming for wear would typically not exceed 8 mm; that is the maximum radial wear allowed on the support rollers before they should be replaced. Metso offers oversized and undersized rollers if adjustment is not possible.

General maintenance topics

General maintenance and replacement of worn parts is the next consideration. The following pages outline common ailments that could occur.

Worn grate chain

The single most critical component of the traveling grate is the grate chain assembly. The conveyor belt carries the material bed through the furnace and permits gas flow through the material bed to properly dry and harden the pellets before they are released into the rotary kiln. A well-cared for grate chain, with proper maintenance and alignment with good process control, will maximize the life expectancy of the chain. A critical process or alignment issue can destroy a chain in a matter of days. If a replacement is secured in a timely fashion, replacing the chain will take several days with lost production guaranteed. Chain inspection and maintenance are of critical importance.



During the annual cold stoppage, the chain pitch elongation should be measured. The measurements will need to be carried out on the top strand inside the furnace so that the chain is stretched under tension. Several measurements should be made along the length of the furnace and across the width of the chain. These measurements should be tracked over time so that outliers can be identified, the causes addressed and planned replacement of the chain scheduled. The typical wear rate of a chain, per pitch, can vary. Variations of 0.010 inches per 1000 hours of operation have been observed. This rate can vary over the life of the chain and with process upsets, but a long-term average around this value should be expected. The maximum allowable pitch wear from one thru rod to the next is approximately 10 mm. Different chain designs will have different limits, but all of them are in this general vicinity. Knowing the wear rate per 1000 hours of operation and the maximum allowable elongation can easily determine the remaining chain life.

What causes grate chain damage and how is the issue resolved?

 **Occurrence:** Upset or uneven bed leads to hot spots on the chain.

 **Solution:** Maintain a proper and even bed depth across the width of the chain and along its length. Remove obstructions in the system that are leading to bed unevenness.

 **Occurrence:** Chain hotter on one side as compared to the other, leading to persistent tracking problems.

 **Solution:** If bed depth is confirmed to be even across the width of the machine, look for secondary causes. Is build-up in the windboxes or on furnace walls directing airflow through one side of the chain? Is dust from the incoming kiln off-gas settling on one side of the chain and causing permeability issues? Is the pellet feed biasing smaller pellets to one side of the chain? Locate the airflow disturbance and correct.

 **Occurrence:** Premature failure of grate plates and/or entire grate chain assembly.

 **Solution:** Sudden changes in the wear life of chain components can be caused by localized overheating (localized damage) or general overheating (all components are damaged). General overheating is often an operational issue and typically results from running at reduced capacity (50% or less). If these issues are ruled out, changes in the ore body may be introducing halogens, most commonly fluoride and chloride, into the gas stream and leading to casting decay.

 **Occurrence:** Chain stretch or pitch elongation is occurring more rapidly than in the past.

 **Solution:** Overheating of chain links and thru rods will reduce the hardness of the components and lead to accelerated wear rate. Normally thru rod wear is 60% of the pitch elongation and the bushing inner diameter wear is the other 40%. If overheating is suspected, the thru rod will begin to wear much more rapidly than the bushings.

 **Occurrence:** Drive amperage demand is higher than normal.

 **Solution:** Look for increased wear on the sideplate bottoms and tops. This can be observed on the lower return. If wear is excessive, check the section above for elevation relationships and correct. Alignment can also cause higher than normal drive power draw. If the chain shifts hard to one side, the thrust buttons on the sideplates will contact the thrust plates, creating a large sliding friction force. Lastly, confirm that the structure and shaft cooling are operational. If the cross beams or shafts overheat and expand, the shaft support bearings can become pinched inside the housings and the rotational friction will increase. All these conditions will lead to faster chain wear due to higher tension forces.

Support shafts bending

Under normal loads and expected temperatures, the shafts are designed to produce a deflection of 6 to 8 mm at the middle of the shaft between the two bearings. The chain is flexible enough to handle this deflection and more without detrimental effects. It is possible, however, for the shafts to deflect more than this without failing outright. Typically this occurs at the discharge end of the machine, on the upper support shafts, where the temperatures can become quite high. The temperature spike needs to occur in the windbox on the exhaust side, under the chain where the shaft is located. Hot stops are the number one reason for bent shafts. During a hot stop, if the kiln stops rotating and the grate must stop, the emergency cap will open. If the opening is delayed, or the exhaust fans and dampers are not controlled, kiln off-gas will pull through the bed and the windbox temperature will begin to spike.

Replacing the shafts is the only solution for this permanent deflection. Temporary elevation changes can be made to minimize the dip in the chain, but that is often not required as the pellets in the preheat zone are typically strong enough to survive the crushing forces this dip generates.

 **Repair:** Remove and replace the bent shaft. Review operational procedures and alarm settings to prevent future overheating of shafts.

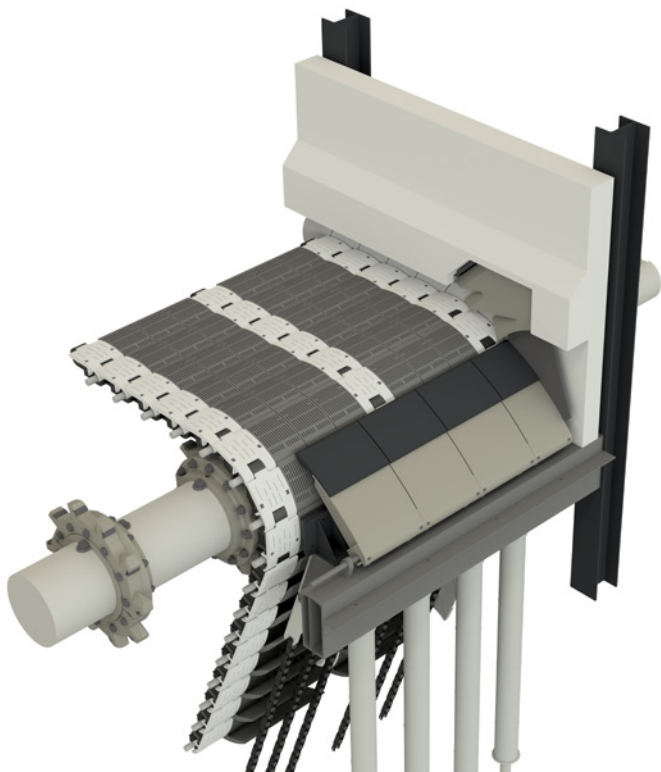


Figure 22: Head shaft, end stripper and letdown chain area

End stripper and letdown area failures

The head shaft area of the machine is the most common area for failures due to the location of many moving parts. It is also the most difficult area to carry out repairs. The difficulty arises due to high temperatures and the required long cool-down period. The entire kiln must be cooled before personnel can enter the machine in the preheat zone or under the head shaft. The most common failures include:

 **Occurrence:** Grate plates breaking off the chain and accumulating in the letdown area of the machine.

 **Cause:** If the machine is equipped with opening-style grate plates that swing open on the lower strand and letdown chains, the first suspect for falling plates will be letdown chains located too far away from the path of the grate chain as it travels from the head shaft to the lower support shafts. This allows the plates to swing open and the tips to become jammed into the letdown chains. This bends the clips and the clip mounting hardware. When the plates open fully at the bottom, near the first lower support shaft, they fall off.

Related to the previous is the tendency of the chain to creep backwards, up the letdown chains and around the head shaft, as the machine cools. The movement is minimal and depends on the total length of the chain and operating temperature, but one pitch of movement is quite common. If the plates are open too far because of misadjusted letdown chains, this backwards movement will bend the clips and clip mounting hardware and plates will fall off on restart. In this situation a small cluster of plates will fall, but continuous falling is not likely.

Inspect these points along with damaged clips, fasteners and plates to arrive at the causation.

 **Occurrence:** Pellet spillage at the end stripper is higher than normal.

 **Cause:** Normal pellet spillage rate for the traveling grate is around 3% of the total feed to the machine. Most of the spillage occurs at the discharge end of the machine at the end strippers.

Preventative maintenance

! Occurrence: Grate plate slots are plugged with full pellets and pellet chips.

! Cause: Spillage at the end strippers often finds its way into the backside of the grate plates where the slots are much wider than the top side. This occurs when the end strippers are not sealing against the chain adequately and the grate plates are opening slightly. Spillage under the end strippers will roll down the chain and directly into the partially open grate plate. The seal leg of the plate holds the pellets in place while they cool and the slots become full from the backside.

Diagnosing this problem is simple. Pellets which are bigger than the topside opening of the plates, around 6 to 8 mm, cannot squeeze through that opening and become jammed in the grate plate slots. They must be entering the slots from the backside.

This situation can also cause each individual plate to become much heavier, forcing the letdown chains to move out of position and the plates to open too early on the letdown. As mentioned previously, this will lead to damaged grate plate clips and plates falling off along the lower return shafts.

! Occurrence: Heavy pellet spillage at the outside edges of the chain as it descends the letdown area.

! Cause: The sidestrippers are meant to peel the pellets from the sideplates and direct the pellets into the transfer chute and onward into the kiln. The width of the chain as measured from inside of sideplate to inside of sideplate is not a constant. It changes over time with chain component wear. Legacy sidestripper designs struggle to compensate for these width changes. Metso offers an updated design which is actuated via pneumatic cylinders and can move in and out of the machine, automatically adjusting for chain width. In addition, the newer design has air cooling to limit thermal damage and expansion issues.

! Occurrence: Sudden loss in bed permeability combined with damaged or flipped grate plates.

! Cause: With damaged and flipped grate plates, the first point of inspection is the letdown area. Once this is ruled out, the deadplates or zone splits within the windboxes are the next most logical cause for flipped plates. If bed permeability is suspected due to quality issues and fan pressure changes, the deadplates are almost certainly the culprit.

When grate plate seal legs drag on the tops of the deadplates, the plates flutter open and closed. This fluttering or “chatter” damages the bottom of the pellet bed and causes a loss in bed permeability. In extreme cases, the plates will flip over and become jammed, ultimately shearing off at the end strippers.

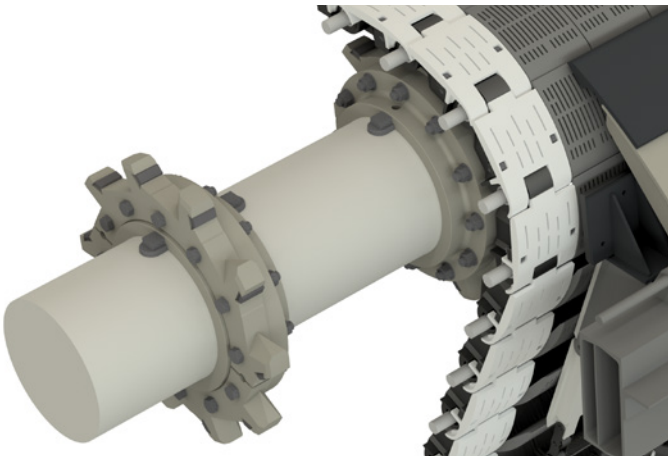
Correct adjustment of deadplates is known as elevation setting. Correct elevation setting of upper support shafts is critical. Over time, the support shaft rollers and bearings will wear, lowering the elevation of the chain which rests on the rollers. Wear will also occur at the deadplate assembly skid bars, the portion where the chain links ride. At some point, the wear and elevation changes will cause the grate plate seal leg to contact the deadplate or rub against the side of the skid bar.



Occurrence: Wear of slots in the castings. Due to thermal loading, dust laden gases and general corrosive elements in the gas stream and the pellets, the slots in the grate plates and cover castings will wear. Accelerated wear in the slots is a concern. Normally the majority of the cover castings are expected to last the life of the chain. The same cannot be said for the grate plates. However, either casting should last for two years. Inspection and replacement should be carried out during each major stop.

Cause: If the appearance of the castings changes dramatically in a short time span (days, not months), then there is most likely a thermal issue. The casting is overheating due to exposure to the kiln off-gases. If the appearance changes dramatically over a few months, it is most likely corrosion-related and not from direct exposure to the kiln off-gases.

It is imperative to monitor casting temperatures, windbox temperatures, chain tracking, etc. to diagnose these problems before they become catastrophic. Good record keeping and daily log books of visual inspections are a crucial part of maintenance.



Occurrence: As the chain rotates over the head and tail shaft there will be some independent rotation between the pipe spacers and the link bodies. This will lead to wear on the pipe spacers. Typically this wear rate is quite high in the first few months of the life of the chain and will then decrease dramatically. Shimming the thru rod castle nuts 3/8" in the first year would be considered normal. Accelerated wear, which can easily present as over an inch of wear per year, is cause for concern and will lead to many issues within the machine.

Cause: Dramatic wear between the pipe spacers and links is possible if high thrust loads are present in the chain or if the chain is overheated. It is a delicate balance between keeping the chain tight so gaps don't widen, leading to a loss of bed and overheating of the components versus squeezing the links closer together, resulting in the sprockets and rollers no longer aligning properly with the chain.

Occurrence: Sideplate bottoms or wear shoes will wear over time. This is due to the dragging of the plates over the pressure bars. The rate of wear should be such that it will not impact the useable life of the sideplates. As with other components, the wear rate will be higher with a new machine, but it should taper off quickly. Accelerated wear of sideplate bottoms and associated increase in drive amps is cause for concern.

Cause: Worn support rollers that drop the elevation of the links and thru rods. This can transfer the weight of the chain onto the sideplates. This will dramatically increase wear and power draw at the motor.

Cause: Lack of lubrication on the sideplate bottoms. Metso recommends using a colloidal graphite mixture such as Petron for lubrication. Grease should be avoided as it is a fire hazard, traps dust and turns into grinding compound.

Cause: Overheating of the sideplate bottoms. This can happen in the preheat zone if the support shaft rollers are too high and the plates lift off the pressure bars.

Occurrence: A sudden increase in kiln back spill of pellets, or a sudden increase in broken pellets and dust inside the kiln.

Cause: The transfer chute nose castings are stainless steel components that are air-cooled and refractory covered to protect them from heat and wear caused by the flow of pellets into the kiln. If the multi-piece castings become displaced either by bolt or structural failure, they may drag against the pellet bed inside the kiln. This will lead to back spill and pellet damage.

Maintenance schedules

Equipment	Procedure	Frequency				
		Each shift	Daily	Weekly	Monthly	Annually
Head shaft drive assembly	Unusual noise, vibration or movements		•			
	High temperature of motor housing or hydraulic fluid		•			
	Oil leakage from motor or lines		•			
	Adequate fluid level in tanks		•			
Main bearings	Lubricant showing at seals		•			
	Visual check of lubrication lines				•	
	Visual check of housing bolts		•			
Head shaft assembly	Visual check of head shaft sprockets and mounting hardware					•
	Visual check of sideplate support rollers for wear					•
Tail shaft assembly	Visual check of support rollers for wear or missing hardware					•
	Visual check of guide sprocket for wear, missing hardware and proper engagement of sprocket					•
Upper support, hold down and catenary shaft assemblies	Visual check for shaft rotation		•			
	Visual check of bearings for lubrication showing at seals		•			
	Check support roller wear					•
	Check lube lines and air cooling lines where applicable				•	
	Visual check of all mounting hardware				•	
	Visual check of catenary shaft position with relation to conveyor chain			•		
Shaft seals	Visual check of functionality		•			
	Visual check of alignment				•	
	Inspect mounting hardware					•
Lower chain support shafts	Visual check for shaft rotation		•			
	Visual check of bearings for lubrication showing		•			
	Check support roller wear and placement					•
	Check lube lines				•	
	Visual check of all mounting hardware				•	
Conveyor chain assembly	Visual check for bent, worn or broken thru rods		•			
	Visual check for loose or missing retainer nuts and bolts	•				
	Visual check for broken, missing, plugged grate plates		•			
	Confirm grate plates are swinging freely		•			
	Visual check of grate plate clip and mounting hardware					•
	Visual check of chain castings for wear (bottom and sprocket recess), broken or missing bushings, and broken or plugged cover castings					•
	Visual check for worn spools					•
	Visual check for missing or worn thrust buttons		•			
	Visual check for damaged sideplate assemblies		•			
	Visual check for wear on sideplate wear shoes					•
	Visual check of tightness of chain in the catenary areas	•				
Thrust brackets	Visual check for loose or missing bolts		•			
	Visual check for wear on thrust rails			•		
	Check clearance between sideplate thrust buttons and thrust rails			•		
	Check for thrusting of chain to one side of grate	•				
End stripper assembly	Check for excessive pellet leakage past the strippers	•				
	Visual check of pull down rods for bent rods, damaged cooling air lines or improper adjustment of assembly		•			
	Visual check of wear on stripper tips and mounting hardware					•
	Visual check for warped stripper bodies, support beam, or damaged letdown assembly					•

Equipment	Procedure	Frequency				
		Each shift	Daily	Weekly	Monthly	Annually
Side stripper assembly	Visual check of cooling air supply lines		•			
	Visual check for warped or cracked castings or shafts frozen on the bushings					•
	Visual check for worn or broken bushings					•
Upper seal assembly	Visual check of movement of sideplates through the seal area		•			
	Check for wear of pressure bars and alignment of the seal assembly with respect to the tops of the sideplates					•
	Visual check of structure, access doors and refractory					•
Water wash-down system	Verify operation and fan spray placement			•		
	Check for leaks, plugged nozzles and inadequate flow				•	
Dead plate assemblies	Visual check for worn or missing skid bars					•
	Visual check for loose or warped dead plates					•
	Check gap between dead plates and grate plates and also anti-flip rails with anti-flip noses on grate plates					•
	Check alignment of chain links with skid bars					•
Transfer chute	Visual check for warped, cracked or missing castings and refractory					•
	Visual check of air blast pipes					•
Structure cooling system	Visual check of shaft cooling inlet and outlet pipes for interference with shafts			•		
	Visual check of mounting hardware, flexible lines and valves				•	
	Check cooling fans for appropriate settings, unusual vibrations or high bearing temperatures		•			
	Visual check of manifolds for dust build up or leaks				•	
Emergency stack assemblies	Check the physical condition of:					
	• Stack cap refractory					•
	• Leaf seal segments				•	
	• Mounting hardware				•	
	• Cable system				•	
	Confirm fail-safe operation					•
Process ductwork	Check pneumatic cylinder, lines and valves				•	
	Visual check for:					
	• Broken welds		•			
	• Missing hanger hardware		•			
	• External/internal dust build-up					•
	• Damaged refractory					•
Access doors and observation doors	• Damaged expansion joints				•	
	Confirm ease of opening and closing of doors				•	
	Check for missing or damaged mounting hardware and locking mechanisms			•		
Traveling grate enclosures	Visual check of seals where applicable				•	
	Visual check for broken welds				•	
	Check for warped or cracked panels				•	
Lubrication systems	Visual check of furnace area refractory					•
	Check lubrication levels and condition of circulating lubricants				•	
	Check lines, fittings and valves for leaks			•		
	Confirm appropriate flow rates and greasing intervals			•		

Recommended spares

Equipment and item description	% of total installed for spares
Transfer chute assembly	
Chute castings	25
Dust valve	10
Superdeal leaf seals	100
Bays (lower chain support assembly and maintenance rollers)	
Lower shaft (machined)	10
Return roller half castings	2
Chain support bearings	10
Catenary shafts	1 shaft assembly
Roller halves	2
Holddown shaft feed end	100
Holddown roller halves	100
Holddown and catenary bearings held	100
Holddown and catenary bearings free	100
Wear shoes	20
Bays (maintenance rollers)	
Roller and seal assemblies	10
Return roller castings	10
Bearings	10
Head shaft assembly	
Pillow blocks	100
Sprocket assemblies	100
Tail shaft assembly	
Pillow blocks	100
Roller half castings	100
Guide roller assembly	100
Conveyor chain assembly	
Grate plate castings**	25
Grate plate clip castings**	25
Chain link assemblies**	15
Chain cover castings**	25
Thru rods**	15
Spacer tubes**	15
Sideplate spools**	15
Sideplate retainer washers**	15
Sideplates (right hand bottom)**	25
Sideplates (right hand top)**	25
Sideplates (left hand bottom)**	25
Sideplates (left hand top)**	25
Thrust buttons**	10
Wear shoes (right hand)**	25
Wear shoes (left hand)**	25

Equipment and item description	% of total installed for spares
Upper seal assembly	
Pressure bars (lower sideplate seal)	15
Proximity seals (upper sideplate seal)	15
Proximity seals (high temperature zones)	25
Sideplate stop angle	15
Upper support chain assembly	
Upper support shafts with diffuser	10
Roller half castings	15
Upper support shafts without diffuser	10
Roller half castings	5
Stub shaft	100
Stub shaft roller halves	100
Pillow block bearings held	20
Pillow block bearings free	20
Seal rings	20
End stripper assembly	
Center stripper body	100
Right end stripper body	100
Left end stripper body	100
Stripper tips (center replaceable)	100
Stripper tips (right and left replaceable)	100
Letdown bar weldment	100
Letdown chain assemblies	100
Side stripper assembly right hand/left hand	
Stripper blade right hand/left hand	100

** Denotes a critical spare part

Modernizations for
improved reliability and
performance

Invest in
uptime,
efficiency
and control.

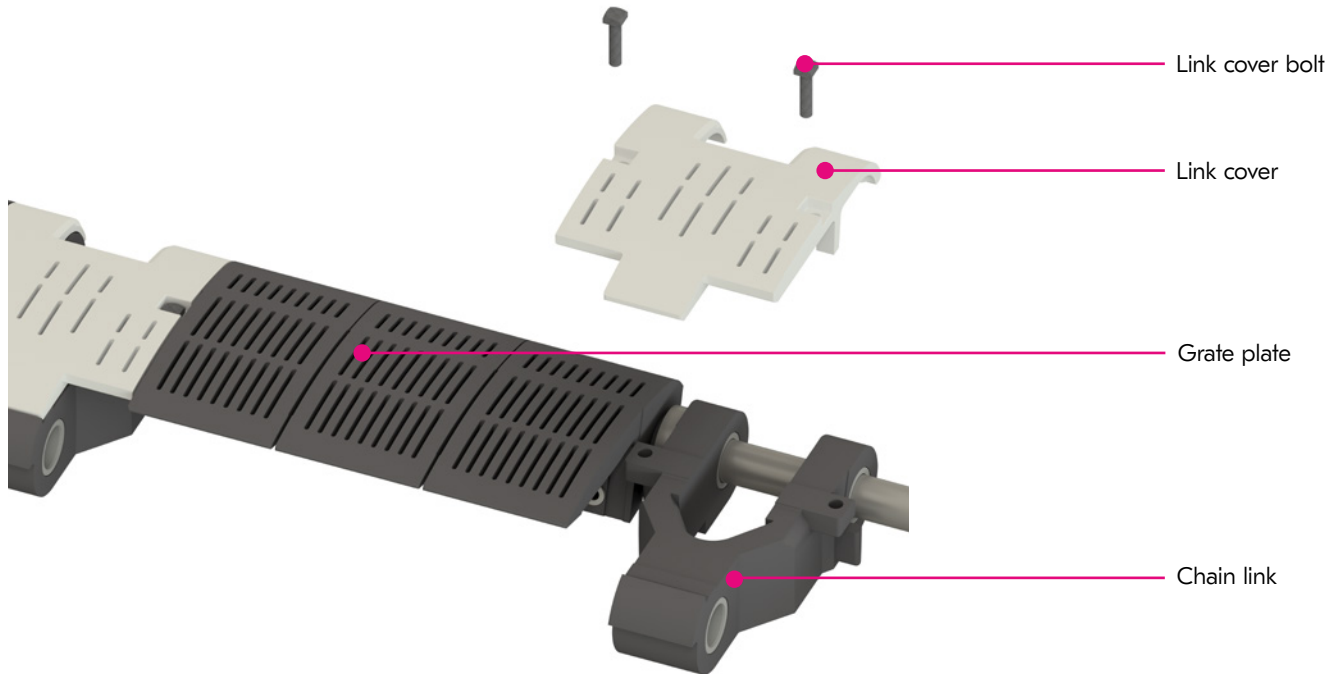


Improve process control

These upgrades improve process control by reducing wear, air leakage, heat loss, dust and pellet spillage. Their value depends on proper installation, monitoring, and plant-specific conditions, making ongoing maintenance and wear tracking essential.

Grate chain assembly	44
Drive shaft and support shaft	48
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Traveling grate chain assembly upgrades



10" chain assembly upgrade

There are two major upgrades available with the Metso style grate chain:

Update #1

The chain link is modified from a pull type to a push type chain link. The link is reversed so the sprocket engages the outside head of the male end of the link and pushes the chain through the furnace. Pushing the link creates compression versus tension (pulling forces) and allows the link to be redesigned for better strength. The original design pull style link requires the sprocket to contact the inside male end of the link. This also requires the surface to be rounded on the inside, reducing the wall thickness of the link versus the push style link that contacts the outside of the male end. The internal of the updated link has been redesigned to handle compression forces, increasing the life of the link.

Update #2

The chain link is now two pieces; the link and the link cover. With the change to the push style link, gaining a greater cross-sectional area on the link legs is possible. The strength of the link is improved versus the original pull style, where the sprocket fits on the male end on the inside of the link casting. The link cover is now made from a separate casting and of a material designed to handle the temperature of the furnace. This new design also offers the opportunity to increase and better distribute the gas flow through the bed of pellets. With the new link cover, approximately 21% more airflow goes through the bed versus a single slot chain link. The slots are more uniformly distributed across the width of the chain.

Challenge

- Excessive maintenance requirements and pellet loss from the existing chain blanket design
- Limited airflow through the one-piece chain link resulted in uneven bed heating and reduced pellet quality

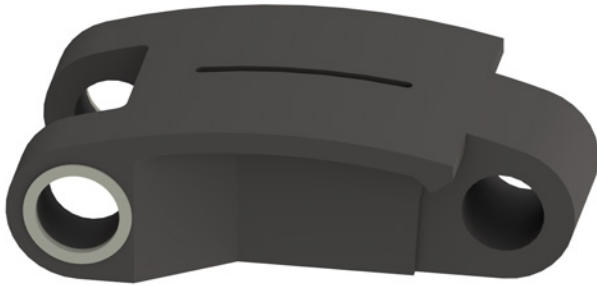
Solution

- Redesigned the chain blanket assembly with a modern two-piece configuration
- Added a cover casting and optimized airflow paths throughout the chain blanket

Results

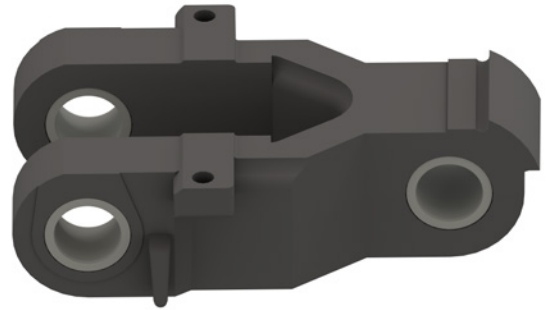
- Modern two-piece chain link and cover casting improved durability and serviceability
- Increased airflow promoted more uniform bed heating and enhanced pellet quality

The two-piece link and cover allow for other changes as well. The link is now robust enough to increase the diameter of the bore hole, accommodating installation of a larger diameter thru rod. The larger diameter is 1.75" versus the typical 1.5". This decreases wear on the chain link and thru rod through larger contact surface and lower bearing pressures. The enlargement of the thru rod diameter results in increased bending and shear strength.



Pull type single piece link
Sprocket engages and pulls link on inside

Bushings through each link bore are now standard on this variant. The bushings are designed for wear resistance and specially matched through laboratory wear testing to the material and surface finish of the thru rods. The bushings dramatically improve the life of the chain links and thru rods and extend the life of the chain by minimizing chain stretch (pitch length increase due to wear).



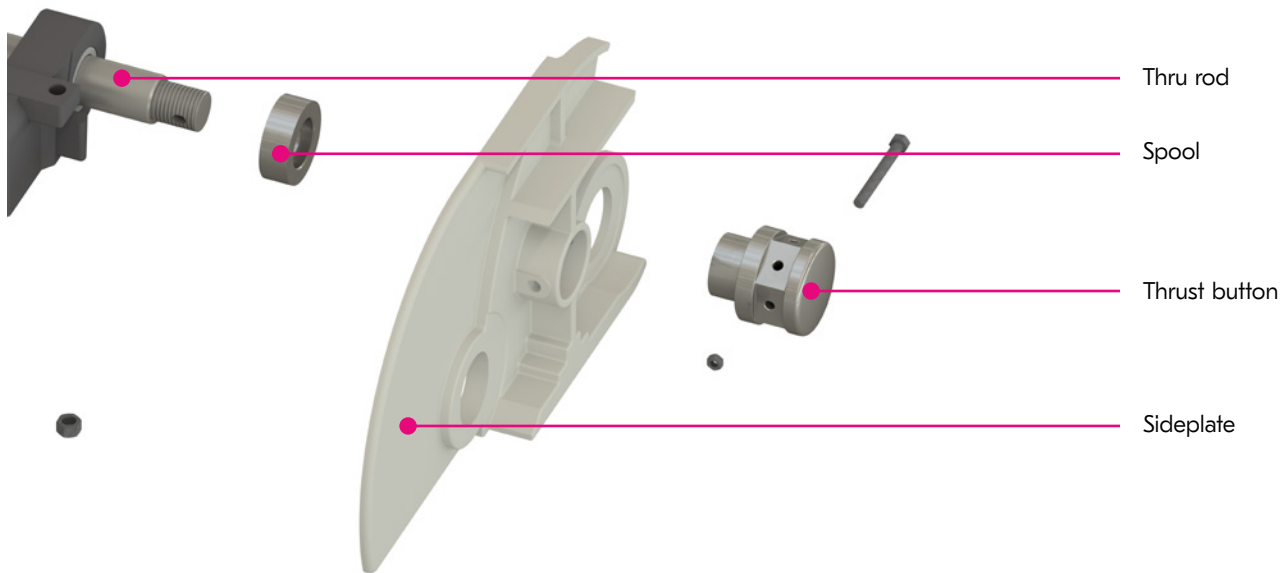
Push style link
Sprocket engages on outside of link and has more contact surface to engage; link is more robust and designed for compression forces



Metallurgy improvements to links and plates

Metallurgy of the link and link cover are now independent of each other. The link casting is designed to handle the forces applied to the chain assembly, while the link cover casting is designed for heat and process conditions. The link cover metallurgy can be formulated for specific process conditions present at the plant. For example, high sulfur content in ore and fuels, halogens in process water and ores, high temperature of the process (flux pellets) and dust loads are all considered when selecting the chain link cover casting and grate plate casting metallurgy.

Metso has a robust research and development initiative for examining failed components and for testing new materials.



Sideplate and thru rod end connection changes

Legacy sideplate designs exhibit deficiencies that are addressed and improved with the newest Metso design. One major issue with the legacy design is the upper sideplate sealing arrangement and the gaps that exist. Due to these gaps, super-heated air will egress from the furnace in the preheat zone, overheating the tops of the sideplates and causing them to crack and fracture. Many older chain designs use a C-clip to connect the sideplate to the thru rod and a thrust gusset/rib on the sideplate casting for controlling the side-to-side movement of the chain. The thrust gusset cannot be replaced, and the C-clip design makes it difficult to mitigate the side-to-side wear of the chain.

Transverse wear is a major concern as it leads to pellet spillage in the wind boxes. When gaps between chain links, sideplates and grate plates exceed 6 mm, there is a significant increase in pellet losses.

Along with changes to the chain link, Metso has also improved the design of the sideplate. The current Metso sideplates consist of a one-piece or two-piece upper and lower assembly, a replaceable thrust button, a cast in place wear shoe and a castle nut to adjust the transverse wear throughout the life of the chain assembly.

The two-piece sideplate design permits the high wear area of the sideplate top to be made from a different metallurgy than the lower sideplate, thus facilitating replacement during the life cycle. This also creates the opportunity for the upper sidewall piece to be made from a higher-grade alloy to combat the higher process temperatures.

The replaceable thrust button is an improvement from the original wear rib design. The thrust button is held in place by a single 8 mm bolt and nut. If the thrust button wears or breaks due to transverse forces, then it is possible to unbolt and replace versus installation of a complete new sideplate.

The wear shoe is now cast into the sideplate versus bolting. This design is more robust and adds life over the current bolted and welded designs.

The castle nut design enables the chain to be tightened throughout its life as it wears in the transverse direction. Wear between the pipe spacers, link sides, and sideplates create gaps that need to be controlled. With the legacy C-clip arrangement, the transverse forces cause the clip to bend and pop off the thru rod, resulting in the chain assembly becoming loose and falling apart. Adjustment with the castle nut, using washer shims, is simple and can be done relatively quickly.

Pipe spacers and thru rods

The original design had a straight cut pipe with no flanges. The flanges help with wear, but the material and hardening process are more important, especially if higher processing temperatures are encountered. High carbon steel or low alloy steel flanges tend to anneal and soften, and the wear rate can become quite high. This leads to transverse wear of the chain and gaps where pellets can spill through, leading to even higher temperatures and damage to components.

The Metso chain assembly uses a thru rod to lower the bearing pressures and wear, a chain link that is harder than regular cast stainless and pipe spacer flanges made from a material that does not soften with higher processing temperatures. This translates to less wear and lower pellet losses due to wear.

In recent years and in extreme conditions such as high processing temperatures, Metso has experimented with pipe spacer flanges made from two base materials, brazed together. The wear surface of the flange is made from a material similar to the chain link bushings. The base of the flange is made from carbon steel which can easily be welded and machined. The bushing material does not soften with exposure to high temperatures, making this a suitable choice for extreme situations such as processing high flux iron ore pellets or when the chain is used as a limestone preheater in a lime calcining kiln.

Expected life of components

Metso has observed a life span of 4 to 6 years for the chain assembly and 1.5 to 3 years for the grate plates and cover castings. The lifespan of equipment depends on process and operation conditions within the pellet plant. The life of sideplates, thrust buttons, wear shoes, thru rods, etc. varies from plant to plant since process, operations and maintenance are all different. It is recommended that a limited quantity of startup spare parts are purchased, and the wear rates tracked to better predict the life of the chain assembly and when spare parts need to be ordered and installed.

Chain lifting rig

Metso designs and supplies specialized lifting rigs that enable the safe movement of grate chain blanket assemblies. The Metso chain design permits pre-assembly of chain sections so that the overall chain change-out procedure is simplified and the timeframe required is shortened.

Proper lifting of the chain sections is critical to prevent damage to the components.

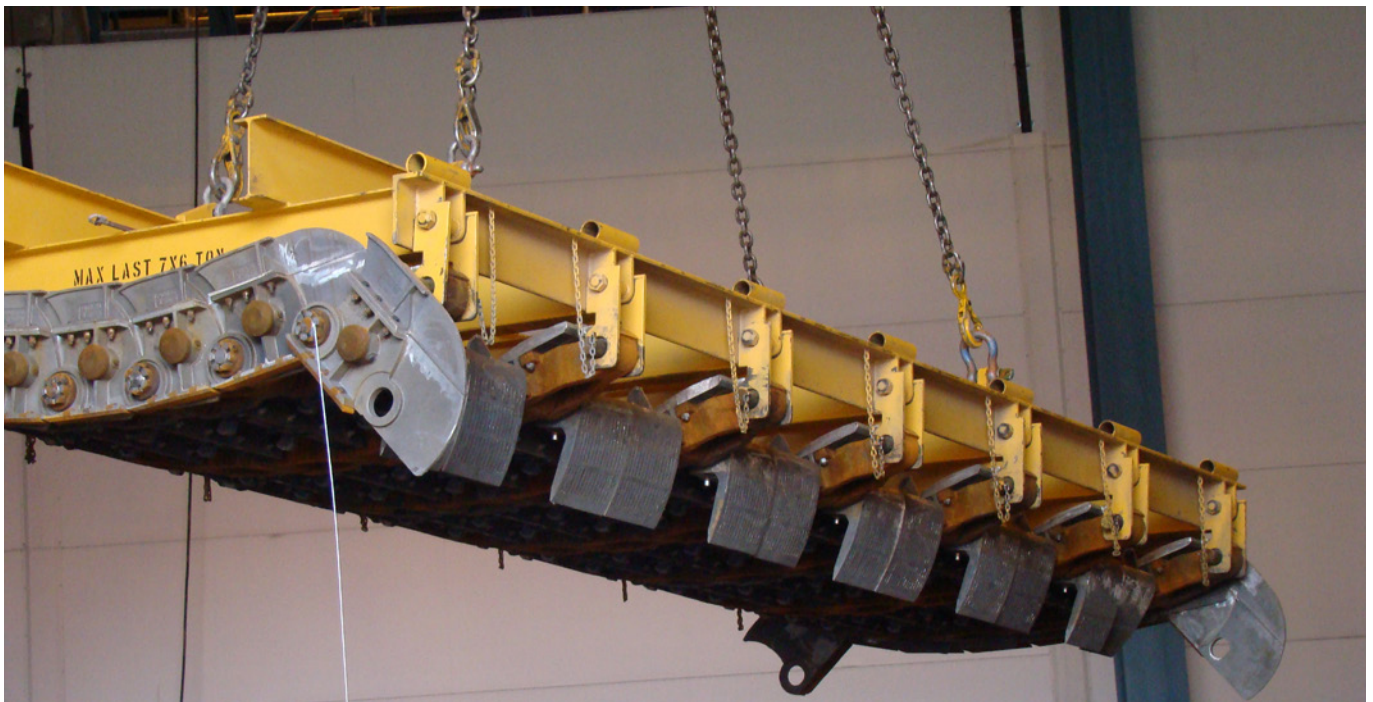
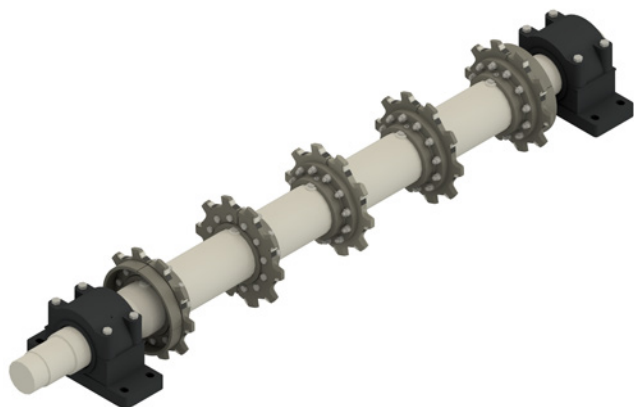


Figure 23: Chain lifting rig

Traveling grate drive shaft and support shaft upgrades



Free-wheeling tail shaft guide sprocket

Controlling the side-to-side movement of the chain is critical for addressing process issues as well as chain component life. The guide sprocket design implemented on the traveling grate tail shaft is another option to control transverse movement.

This free-wheeling sprocket rotates independently of the tail shaft and the teeth operate to keep the chain located centrally within the machine. When combined with the thrust button and thrust rail system, a reinforced mechanism for controlling chain position is achieved.

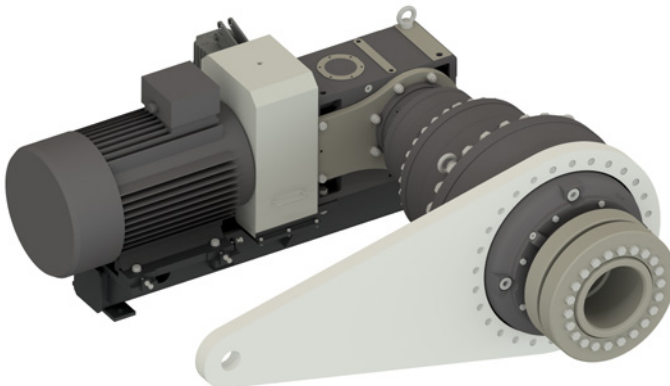
Modern head shaft drive system

Legacy drive designs typically consisted of a foot-mounted reducer, driving a pinion with a large girth gear attached to the outboard end of the head shaft. Similarly, the gear and pinion may be integral to a housing with the reducer and electric motor floating on the same housing. This is known as a bogi-flex drive.

Both systems suffer from poor management of differential thermal expansion. The structure, head shaft and drive components and support bases all reach different operating temperatures. The temperature differential leads to a variance in thermal expansion, which impacts the alignment of the gear and pinion teeth.



Figure 24: Head shaft bearing lubrication system



Metso upgraded head shaft and drive system

Current bogi-flex drives have the option to be replaced with an electro-mechanical drive that mounts directly to the head shaft with an integral torque arm.

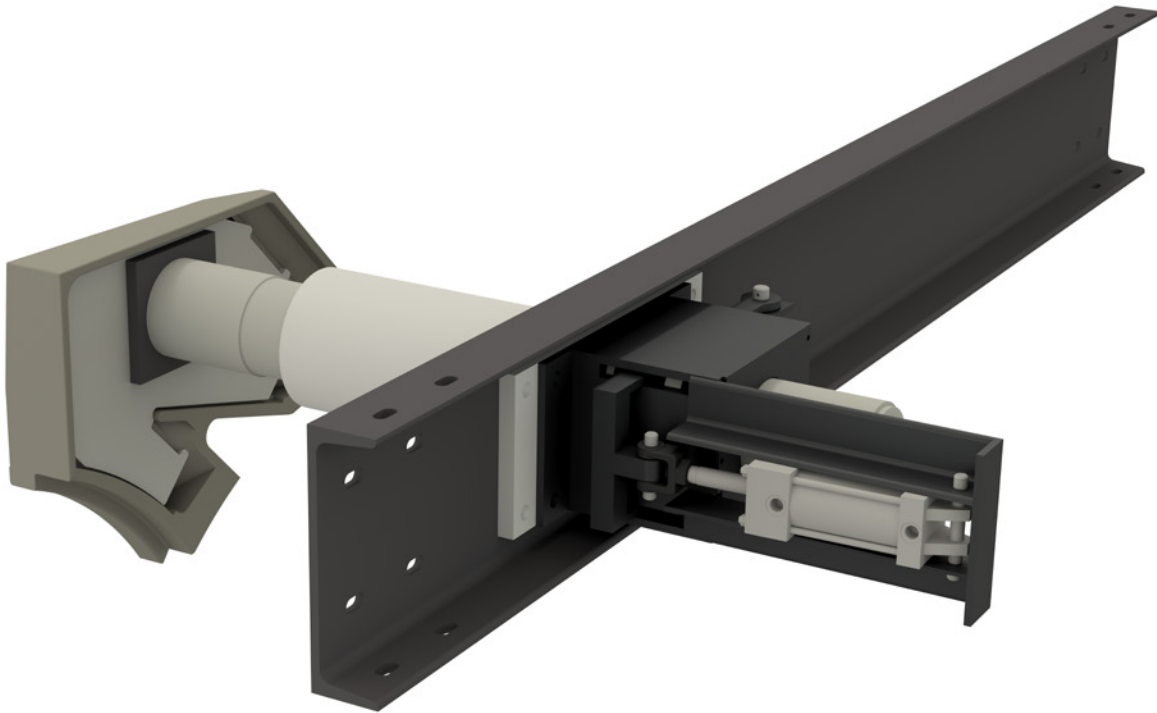
A typical drive system will consist of a motor, high speed cycloidal or similar reducer, lower speed reducer and a coupling assembly for shaft to reducer. The assembly will include a torque arm that mounts to the assembly and attaches to the furnace structure and a drum or disc brake to prevent movement of the head shaft during operational stops. For very large machines, a drive package is provided for each end of the head shaft.

Head shaft bearing lubrication system

Legacy head shaft bearings were grease lubricated, either manually or via a dual line pump system. Unfortunately, even modern synthetic greases struggle with the higher operating temperatures of the machines. To combat this and to increase bearing life, Metso has upgraded the head shaft support bearing lubrication in many machines to a circulating oil system.

This system provides two benefits: the flowing oil and large, remote reservoir act as a cooling agent for the bearings and bearing seals. Secondly, the oil can be filtered and dust and contaminants removed to help aid in extending oil and bearing life.

In some installations the head shafts may be redesigned to locate the support bearings further outward from the original locations which may be tight up against the sidewalls of the furnace. This relocation permits the installation of better furnace seals and moves the bearings away from the hot sidewalls of the furnace.



Side stripper upgrade

Some side strippers are counterweighted on the outside of the furnace. The counterweight provides pressure on the side stripper casting to move inwards which aids in stripping the pellet bed off the sideplate of the chain assembly. This outdated design does not provide sufficient pressure to remove the pellet bed. The mechanism to transfer the load from the counterweight to the casting has fundamental issues with jamming and locking in place due to the heat and process conditions of the traveling grate furnace.

Side strippers are a source of pellet spillage on the grate when they are not maintained properly. Any jamming or loss of functionality causes the side stripper to malfunction, resulting in pellets inadvertently spilling out of the machine versus entering the rotary kiln.

With this jamming effect, a large amount of air can also escape the furnace, reducing the efficiency of the plant and contributing to the overheating of the head shaft area and dust losses on the machine.

To address these issues, Metso has an updated version of the side strippers that have been installed in several traveling grates around the world.

Side stripper upgrade components

The side stripper castings are more durable than the original and provide teeth that assist in peeling the bed of pellets off the sideplate. The castings are also air cooled to help reduce cracking of the side stripper during operation.

A new support structure is provided with the new stripper design. The precision fabricated support is welded and machined and replaces existing brackets and assembly.

A pneumatic cylinder provides constant pressure to the side stripper. The assembly is less prone to jamming and as a result reduces the potential for pellet spillage.

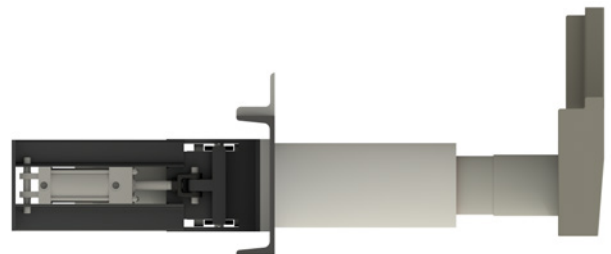
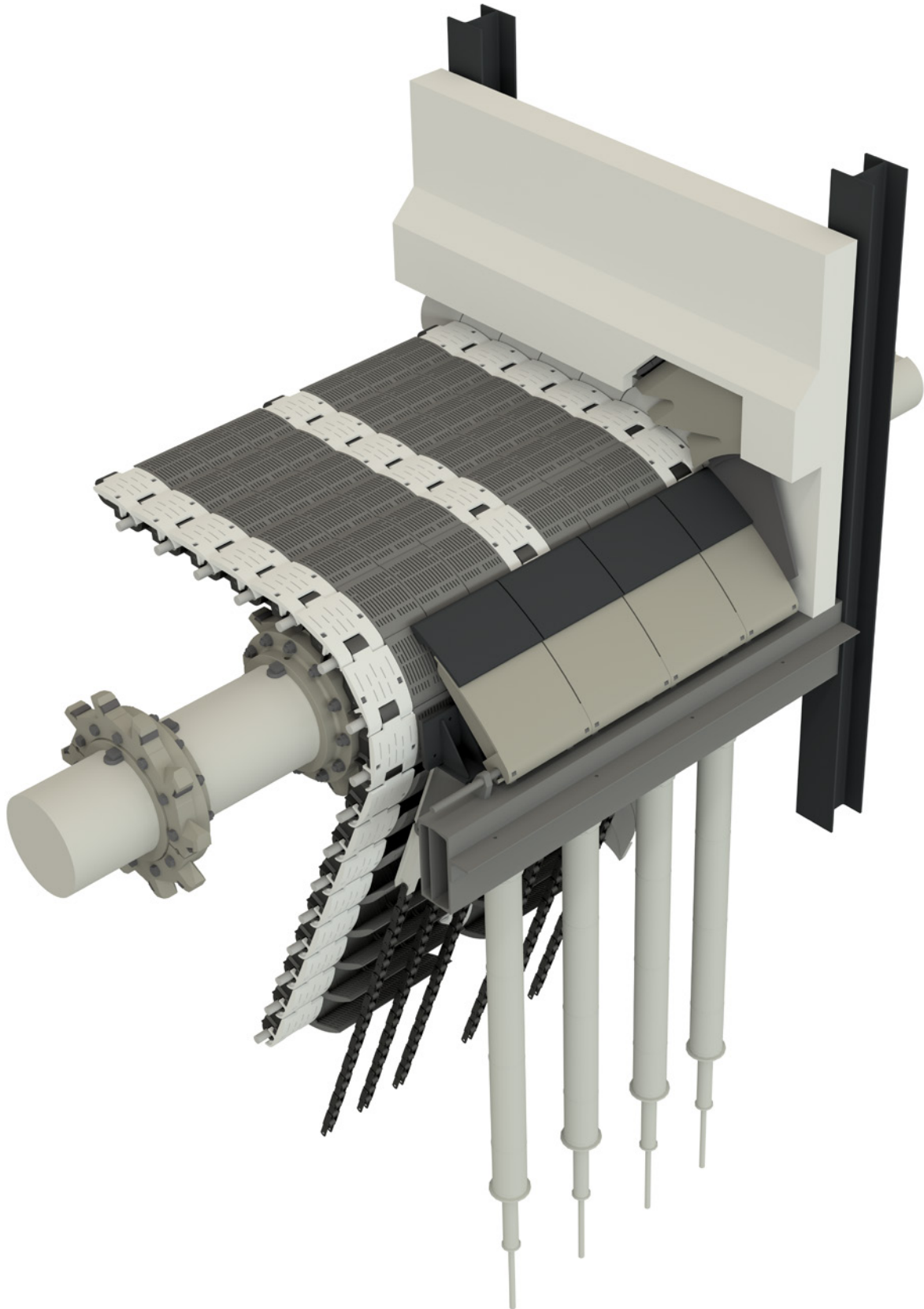


Figure 25: Upgraded side stripper, elevation view

End stripper, box beam, pulldown rods and letdown chain upgrade kit



End stripper kit assembly

- Center two-piece end stripper design (replaceable tips)
- Left hand two-piece end stripper design (replaceable tip) with bolted on end plate
- Right hand two-piece end stripper design (replaceable tip) with bolted on end plate

Note: all end strippers consist of the upgraded underside curved design to keep the grate plate closed during transition from head shaft to the letdown chain.

Box beam kit assembly

- Box beam fabrication
- Lot hardware for attachment of end strippers, letdown chains and pulldown rods

Letdown chain kit assembly

- Bracket wear castings – attaches letdown chain to end stripper
- Letdown bar weldments - attaches bracket wear casting to chain link
- Chain link assemblies – attaches to counterweight

Pulldown rod kit assembly

- Pulldown rod assemblies with pneumatic cylinders for tensioning
- Bracket assemblies to attach pulldown rod to structure
- Lot hardware to connect pulldown rods to furnace structure
- Cylinder channel weldment – attaches to furnace structure
- Cylinder stop channel weldment – attaches to furnace structure

End stripper kit details

Legacy design end strippers allowed for the grate plates to open prematurely when transitioning from the head shaft to the letdown chain. This resulted in the grate plates filling up with pellet spillage and caused air flow issues, overheating and pellet quality issues on the machine. The updated design incorporates a curved section under the end stripper to hold the grate plate closed until it transitions fully to the letdown chain. The letdown chain bracket that connects to the underside of the end stripper is also modified to properly transition the grate plate. The two-piece end stripper design with replaceable tips allows the equipment owner to replace a smaller casting when required.

The left hand and right hand end strippers can also be supplied with bolted end plates to help reduce warping of the plate and pellet spillage.

Box beam kit details

The new box beam takes into consideration the new attachment points for the end stripper castings and pulldown rods. The box beam is hollow on the inside for forced air cooling. A new box beam is required to install the new end stripper castings and pulldown rods.

Letdown chain kit details

A loose letdown chain causes the grate plates to open prematurely. With a prematurely open grate plate and a loose letdown chain, jamming, breaking of the plate and excessive wear to the letdown chain will occur.

Along with the new end stripper design, the new letdown chain weldment and bracket wear castings improve the functionality of the grate plate and prevent the plate from opening prematurely.

Pulldown rod kit details

The pulldown rod assembly consists of an air cylinder at the bottom that replaces older spring tension devices. The air cylinder supplies greater pressure equilibrium on the end stripper. Constant pressure has the advantage of peeling off the bed of pellets in a more consistent manner and, if need be, opening the end stripper to allow a jammed/open grate plate to pass. This possesses a clear advantage over the older spring design. Upset conditions like these typically result in a sheared off grate plate and damage to pulldown rods due to the inadequacy of the spring design. The upgraded solution provides the ability for the jam or interference to pass through without the need to shut down the machine to repair. Additionally, the new system provides for the implementation of position sensors on the pneumatic cylinders to indicate when an upset condition has occurred and prevents running the grate for extended periods of time with missing grate plates.

Sideplate seal upgrade kit

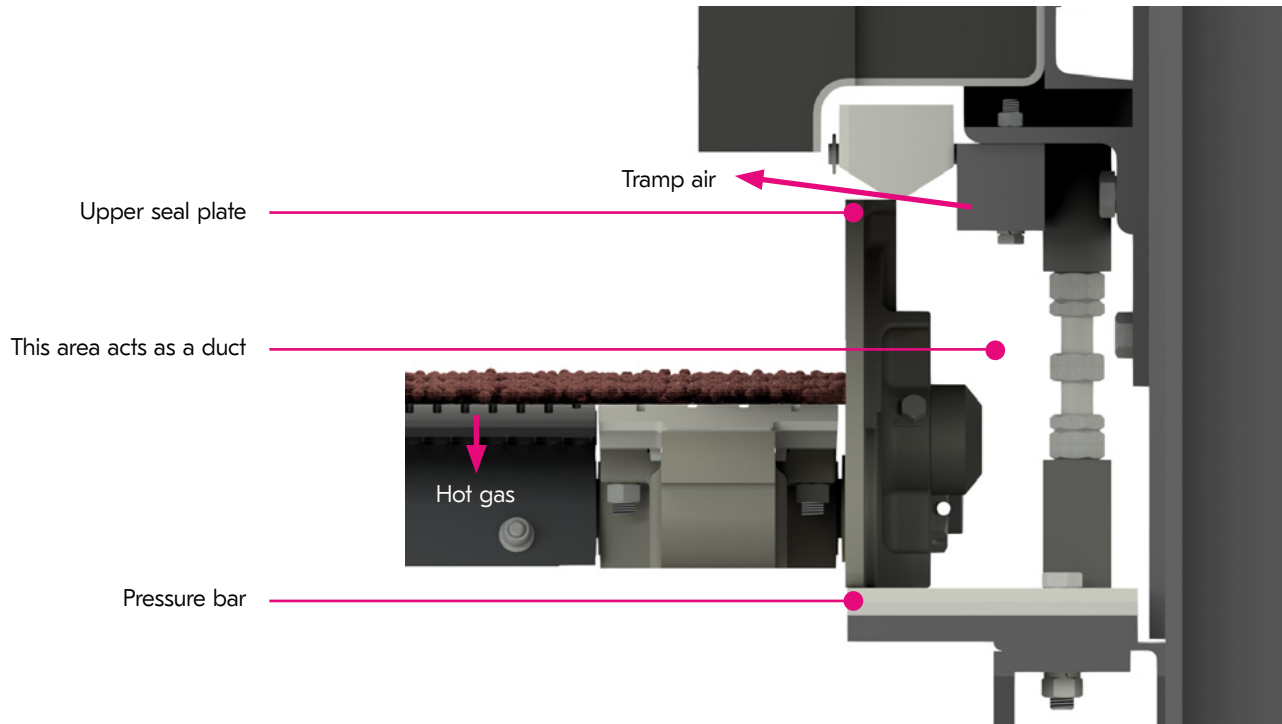


Figure 26: Seals minimize leakage path at initial install and as components wear with use

Sideplate seal kit assembly

- Seal bar casting – left hand side furnace length
- Seal bar casting – right hand side furnace length
- Set of brackets to mount seal bar – left hand side
- Set of brackets to mount seal bar – right hand side
- Set of hardware
- Set of assembly and installation drawings

Sideplate seal kit details

When the 10" pitch chain with the new sideplate design is installed an upgrade option to help seal the upper sideplate to the furnace should be purchased to decrease air losses and wear on the components. The design of the new upper sideplate seal enables continuous sealing as the sideplate wears.

The seal is a curved casting versus the legacy flat design. The curvature of the seal continually contacts the upper sideplate. The floating casting permits it to move up and down freely. With the float, the seal makes excellent contact with the sideplate. Machine efficiency is increased, heat loss, wear and dust egress is reduced and machine function is improved.

Precast refractory curb blocks

Precast refractory curb block kit assembly

- Set of refractory curb blocks for left hand and right hand side
- Set of box beam weldments to hold refractory curb blocks
- Set of hardware
- Set of assembly and installation drawings

Precast refractory curb block kit details

Castable refractory is poured over anchors. When damage to this design occurs, it requires the equipment owner to carry out long repairs or a complete replacement of the castable and anchors. Along with the lengthy and costly repairs, the warmup and curing of the castable takes a considerable amount of time. A new design exists to help reduce duration of the outage through reduced warmup curves and ease of installation.

Precast shapes made from special SIFCA-style refractory are the new standard for the refractory around the upper seal and sideplate. The precast shape is factory-made to a specific design, pre-fired and easy to install.

The design of the refractory curb block is meant to withstand the process conditions of the furnace. The SIFCA-style refractory is excellent for temperature resistance and abrasion/impact. Curb blocks are expected to last anywhere from 3 to 7 years in the furnace, depending on location.

Upper shaft seal upgrade

Upper shaft seal upgrade kit assembly

- Set of brush seals for each upper shaft seal (2 each shaft)
- Set seal stuffing box (2 for each shaft)
- Set of hardware
- Set of assembly and installation drawings

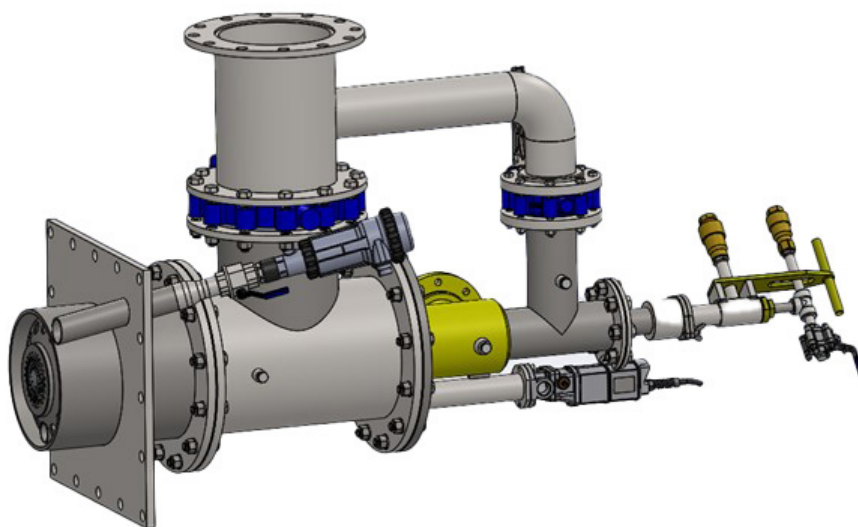
Upper shaft seal upgrade kit details

For some machines the support shaft seal design is essentially a stuffing box with a packing gland. After a short period of time, the seal becomes worn and air easily leaks in or out. When air egresses, dust and hot air escape the furnace causing an environmental issue. When air ingresses, the efficiency of the machine is reduced.

The newly designed seal is a brush design. The brush is made from a high grade stainless steel that can withstand the temperatures of the furnace. The brush is set on a slight angle to continue keeping an effective seal even as the ends of the brush wear. The seal continually provides consistent contact on the shaft. The other advantage of a brush seal is that impregnated dirt and grease provide a better trap for air, whereas a typical packing gland would simply wear out. A brush seal performs well when it is packed with dirt and debris.

After installation equipment owners can expect to experience a more optimized furnace along with a cleaner building. A typical brush seal will last anywhere from 3 to 7 years depending on process conditions and maintenance of the area.





Grate kiln preheat burner

Older system designs lack preheat burners which can limit production and product quality due to outdated burner system thermodynamics. Metso's grate kiln preheat burners are used in pelletizing production with the latest OptiMix™ burner technology or as a standalone retrofit.

Metso's grate kiln preheat burner is designed using the latest computational fluid dynamics (CFD) practices for iron ore pellet preheating ducts.

Able to be used with a range of gaseous or liquid fuels, the grate kiln duct burner is a reliable and robust solution with excellent cold start-up characteristics. The burner is designed to optimize grate kiln pelletizing plant operation together with the latest OptiMix™ kiln burner technology, or as a standalone retrofit.

Metso expertise

Grate kiln pelletizing optimization requires a full understanding of the complete grate kiln process. With an innate knowledge of grate kiln pelletizing technology, Metso can help operators upgrade burner systems to optimize plant productivity, product quality and efficiency by upgrading burner systems with strategically placed preheat burners for optimal heat distribution.

Grate kiln preheat burners are available in 3-, 5- and 9 MW power sizes to cover the required grate kiln plant operating range, with standard mechanical sizing for easy installation.

Tested and proven solution

Metso's grate kiln preheat burner is designed for a range of OptiMix kiln burner applications. Every application is optimized specifically to each project using in-house CFD simulations. Suitable for and successfully proven in both greenfield and brownfield applications, the preheat burner can be supplied with burner management and fuel handling systems to meet the latest standards.

Features

- Simple, robust design
- Designed with the latest CFD modeling techniques to match system operation
- Suitable for existing furnace and vessel retrofits
- Reliable cold start up operation
- High turn down to meet operational requirements
- Integrated flame scanner and igniter to meet customer requirements
- Can be supplied with a burner management system (BMS) and fuel handling system to meet the latest international standards



Hydrogen burners

With the development of new technology, larger production plants and environmentally-driven emission targets, hydrogen is becoming a more viable primary fuel. To minimize risk and optimize efficiency, it's important to ensure that your industrial scale burners account for specific combustion and flame properties, material and equipment selection and system safety generated by hydrogen fuel.

The future of fuel

Hydrogen is an attractive fuel source due to its zero carbon footprint. Historically, hydrogen has been used as a by-product fuel produced through parallel processes and typically at substitution levels not sufficient for use as a primary fuel. This has changed with the development of new plants and increased electricity generation from renewable sources.

Using hydrogen to take advantage of its lower carbon benefits comes with a number of challenges, especially when used in high temperature minerals and metals processing industries.

The Metso solution

Through its dedicated combustion division, Metso has proven practical experience in hydrogen combustion and is developing technology to meet the needs of the minerals and metals processing industries with a suite of burner products and supporting technologies.

Converting processes to use hydrogen requires significant investment, preceded by a full evaluation and rigorous design process. Metso is well-positioned to support hydrogen fuel projects from beginning to end to ensure that your combustion system is designed to meet your process needs.

Industry-leading experience

Our expertise includes computational fluid dynamics (CFD) modeling of your hydrogen combustion process to provide an impact assessment on plant production and emissions, as well as system design and specification, layout, and pricing for equipment and installation.

Our scope can include any or all of the following hydrogen firing project activities

- System surveys and audits
- Process evaluation and CFD modeling
- Project scoping and budgeting
- Basic engineering
- Detailed design
- Equipment supply
- Installation
- Commissioning

Developing our future

Metso is developing a range of burners to meet the future needs of hydrogen fuel-based applications across various processes, using our extensive experience as a leading pyro processing equipment company. Our industry-leading efforts are developed in conjunction with our dedicated burner, process and combustion system experts.

Metso's development program includes upgrades to existing burners and new burner designs targeting high hydrogen substitutions and 100% hydrogen usage. All current and future burner designs are capable of multi-fuel operation.

Metso can design and supply the ancillary equipment needed to support hydrogen burners, such as valve skids and burner management systems (BMS). All supplemental equipment is designed to meet the specific requirements of hydrogen as a fuel, including material and component selection.

Metso burners and combustion systems can be applied to new plants to meet the needs of future industrial and regulatory requirements, as well as upgrade projects to provide extended plant life.

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**.

metso.com