UPGRADING A LIME KILN CHAIN SECTION TO REDUCE DUST LOADING AND IMPROVE THERMAL EFFICIENCY

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ABSTRACT

Due to a 50% increase in pulp production, by early 2003 the lime kiln at DMI PRPD proved unable to produce sufficient lime to satisfy the mill's needs. Commercial quicklime was purchased on an ongoing basis to supplement lime requirements. Excessive dust recycle in the kiln was identified as the primary obstacle to increasing kiln production and as the root cause for poor kiln thermal efficiency. An inefficient, high maintenance kiln chain system was replaced by a high efficiency kiln chain system in June 2004. The chain section upgrade greatly increased heat transfer efficiency, thus reducing kiln natural gas consumption, and resulted in sustainable lime kiln production at high rates, thus reducing commercial quicklime purchases.

INTRODUCTION

Daishowa Marubeni International (DMI) Peace River Pulp Division (PRPD) in Peace River, Alberta, Canada is a single-line kraft mill designed to produce 1100 air dried metric ton/day (ADMt/d) bleached hardwood (aspen) pulp. Pulp production has increased steadily over the years since the mill startup in mid 1990, and reached 1510 ADMt/d by mid 2002. In late 2002, the digester was converted into a downflow low solids unit, allowing a significant further increase in mill production. The mill is currently producing 1650 ADMt/d, a 50% increase over the design production capacity.

PRPD's lime kiln was designed to produce 270 Mt/d lime. By the time the downflow low solids project was streamlined in late 2003, the kiln production rate required to support the mill maximum sustainable rate (MSR) had increased to 358 Mt/d lime. The kiln proved unable to support such high mill production rates, and its production had to be supplemented with purchased quicklime, representing a significant operating cost to the mill. In order to support the current mill MSR of 1650 ADMt/d, the kiln must produce 384 Mt/d lime, 42% above its design capacity.

The limiting factor on kiln production was identified as excessive dust recycle in the kiln. In late 2003, the dust loading on the lime kiln was measured at greater than 50% of the total lime mud feed rate to the kiln. This prohibitively high dust loading frequently overwhelmed the dust handling systems, necessitating purging of dust from the system. Dust purging introduced an undesirable kiln operational "swing" that severely limited throughput on the kiln, negatively impacted lime quality, incurred landfill costs, and represented a health and housekeeping hazard.

A further problem with the lime kiln in 2003 was poor heat transfer efficiency within the kiln. Poor heat transfer efficiency resulted in excessive natural gas consumption and high kiln feed end temperatures, which had to be controlled via the addition of water to prevent thermal damage to the dust handling systems.

Investigation into both of these issues concluded that the primary obstacle to reducing dust loading and to improving kiln thermal efficiency was a poorly designed kiln chain system. A new, high efficiency chain system was therefore installed in June 2004 to replace the old, inefficient, high maintenance chain system. The upgrade has greatly reduced dust loading and increased kiln thermal efficiency. This paper describes lime production at PRPD, the problems encountered with the old chain system, the installation of the new chain system to overcome the problems, and improvements in kiln operation as a result of the chain section upgrade.

LIME PRODUCTION AT PRPD

<u>Lime Kiln</u>

The lime kiln at PRPD is a 1990 F.L. Schmidt unit, 3.5 m ID x 101.5 m in length, designed to produce 270 Mt/d lime. The kiln was originally equipped with nine product coolers, two product dams (one in the product discharge zone and one in the burning zone), four continuous rows of product lifters in the intermediate zone, 3.5 m of feed spirals, and a Fuller round-link curtain type chain system which covered a 14 m section of the kiln on the feed end. The product dam in the burning zone and all of the lifters were removed in September 1997.

Due to the recurrent formation of rings in the kiln, two rows of Powershot nozzles were installed over a 54 m section along the kiln axis in the middle of the kiln in June 2003. Powershot nozzles allow pressurized carbon dioxide charges to be inserted through the kiln shell into a ring; the carbon dioxide charges are then detonated remotely to remove the ring.

Kiln Feed

Lime mud slurry from the causticizing plant is fed into a lime mud precoat filter where the lime mud is washed and dewatered to 75 to 80% solids before it enters the lime kiln. Purchased lime rock is also used as make-up for process losses and on occasions when maintenance work is required on the lime mud precoat filter and/or associated equipment.

Kiln Dust Handling

An electrostatic precipitator is used to remove entrained fine dust particles from the gas stream exiting the kiln, and a vacuum dust handling system recycles the dust collected by the precipitator to the feed end of the kiln. A second dust handling system, which is pressurized, is sometimes used when maintenance work is required on the primary dust handling system. The vacuum dust handling system is designed to move a maximum dust loading of 288 Mt/d, while the back-up pressurized dust handling system has a maximum capacity of 144 Mt/d. Both systems can be operated simultaneously, although when so operated their respective capacities are not cumulative.

Kiln Fuel

Natural gas is the primary fuel for the kiln and is burned via an Andritz burner. Concentrated non-condensable gases (CNCG) from the digester and stripper off-gasses (SOG) have historically been burned in the kiln. Since 2005, CNCG have been burned in the power boiler, but SOG are still burned in the kiln.

Product Lime

The residual carbonate content of the product lime is targeted at 3 wt%. The inert content is typically around 7 wt%, giving the product lime a customary availability of 90%.

KILN ISSUES

Dust Loading

In late 2002, operational difficulties with the kiln dust recycle system became paramount. At a production rate 337 Mt/d lime, the dust recycle loading on the kiln was measured in excess of 328 Mt/d. This exceptionally high dust recycle in the kiln equated to roughly 55% of the total lime mud feed to the kiln and caused frequent plugging of both dust handling systems. To prevent kiln downtime resulting from plugged dust handling systems, it was necessary to purge dust from the dust recycle system. This was accomplished by temporarily shutting down the dust handling system(s) and diverting the dust collected by the precipitator to a dust bunker.

Recycled dust is an integral part of normal kiln load. Dust purging thus removed a portion of the normal kiln load and resulted in variable kiln load (product bed depth) along the length of the kiln. This made it difficult to judge how much heat was required at any one time to adequately calcine the lime mud feed, and resulted in undesirable kiln thermal cycles. Kiln thermal cycles exacerbated ring buildup downstream of the chain section (Figure 1). Ring formation accelerated local gas velocities and allowed more solids to accumulate behind the ring, as schematically shown in Figure 2. Some of the accumulated solids were then entrained in the high velocity gas stream as dust. Thus a cycle of dust purging - thermal cycle - ring formation - accelerated gas velocities - entrained dust - dust purging - continued to perpetuate itself.

Figure 1. *Ring formation in the PRPD lime kiln*

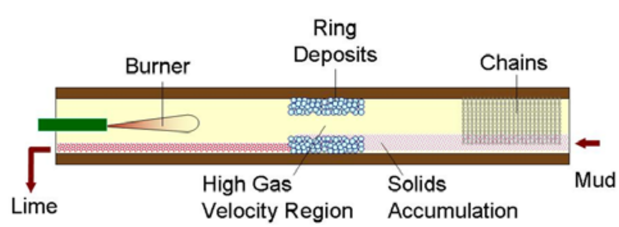

Figure 2. *High gas velocity and solids accumulation at the ringing location*

Heat Transfer Efficiency

Increased lime production necessitated burning additional natural gas. The original round-link chain was unable to withstand the extra heat and began to thin and burn-out more rapidly (Figure 3). Hangars began to fail, and entire lengths of chain appeared in the product lump crusher. The resulting lack of heat transfer surface area in the chain section increased natural gas consumption and caused feed end gas temperatures in excess of 300^{o}C. High exit gas temperatures, in turn, thermally damaged the baghouse socks of the dust handling systems, exacerbating the dust handling issues.

Figure 3. *Thinned and warped round-link chain*

In order to reduce the feed end temperature to an acceptable level, the solids content of the lime mud from the precoat filter was lowered to 70-72%, and a water addition control loop was installed on the mud feed in late 2003. Both actions had a negative impact on thermal efficiency and natural gas consumption.

LIME KILN UPGRADES

Vacuum Dust Handling System Upgrade

Two problems with the vacuum dust handling system were identified in mid 2003:

1. although the system was rated for only 288 Mt/d, investigation of individual equipment capacities revealed that most of the equipment possessed capacity in excess of the rated amount, with the exception of one rotary feeder;

2. tramp air pulled into the baghouse of the vacuum dust handling system fluidized the dust in the baghouse. The dust collected in the baghouse until it eventually collapsed into the mud feed screw in large spurts. Due to lack of mixing time available to moisten the large amounts of dust being periodically dumped into the mud feed screw, the dust was immediately entrained in the gas stream again upon entering the kiln.

To combat the first problem, the rotary feeder limiting the capacity of the vacuum dust handling system was sped up a number of times until a capacity compatible with the remainder of the system was achieved. To address the second problem, a trickle valve (Figure 4) was installed on the outlet of the baghouse; this valve effectively prevented tramp air from entering the baghouse and evened out flow of dust into the lime mud feed screw.

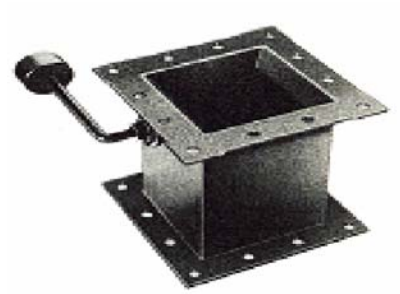

Figure 4. *Trickle valve installed on outlet of baghouse*

Chain Section Upgrade

Prior to June 2004, the chain section consisted of 14 m of round-link curtain chain suspended from tombstone-style hangars. Castable refractory was utilized to prevent heat loss through the kiln shell in the chain section. There were two main concerns with the chain section:

1. an excess of burned-out and thinned chain had reduced the chain density in the kiln to 112 kg/Mt lime, which was significantly lower than the recommended chain density of 150 kg/Mt lime for modern lime kilns;

2. the design of round-link chain was such that small “dust scoops” were formed by link connections (Figure 5). The mud collected by these “dust scoops” was carried out of the solids bed and released into the gas steam as the kiln rotated, negatively impacting dust loading.

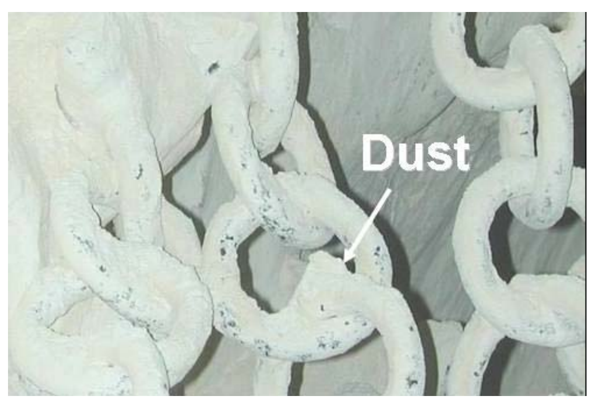

Figure 5. *“Dust Scoops” formed by round-link chain*

In June 2004, the kiln cold end internals were completely removed and an entirely new chain system installed. The new chain system consisted of: a shroud over the lime mud feed screw; 3.5 m of 813 mm tall, angled feed spirals; 5.6 m of carbon-steel round-link chain in the drying zone; 9.2 m of stainless-steel diamond-link heat exchange chain in the preheating zone (Figure 6A); and metal econoliner plates with replaceable link hangar caps and bases (Figure 6B). The complete new chain system was supplied by Jammbco of Barrie, Ontario, Canada.

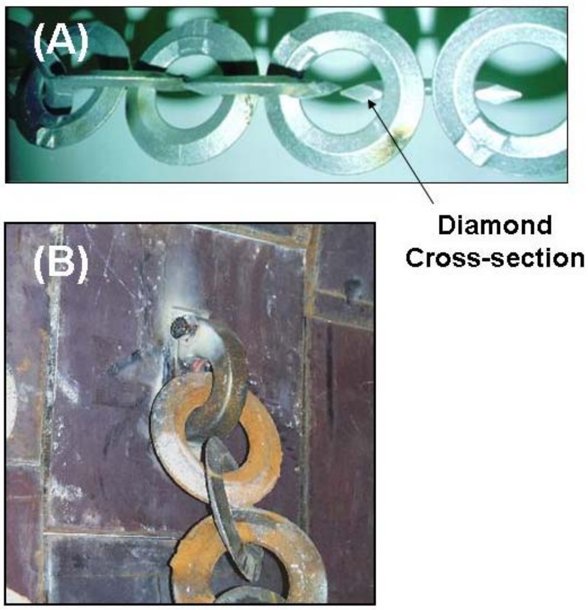

Figure 6. *(A) Jammbco's diamond-link heat exchange chain metal, and (B) Econoliner as insulation medium and attachment point for diamond-link heat exchange chain.*

The new chain system aimed at reducing dust entrainment in the gas stream via the following design specifics:

1. the shroud over the mud feed screw (Figure 7) prevented dust being recycled into the kiln from immediately entraining in the exiting gas;

2. the high angle feed spirals (Figure 7) promoted mixing and turnover of solids in the feed end, preventing the top layer of mud from drying out prematurely and entraining in the gas steam;

3. the relatively sharp edge diamond-link heat exchange chain (Figure 6A) was designed to cut through the product layer rather than scooping it up as it is the case for the round-link chain (Figure 5). Furthermore, the number of link connections was halved as a result of the larger surface area inherent to the diamond-link chain style. The weight and metallurgy of the diamond-link chain also made it more resistant to thinning and burn-out.

4. the metal econoliners (Figure 6B) replaced castable refractory as the insulating medium in the chain section. The econoliners did not reduce the inside diameter of the kiln in the chain section as much as castable refractory, and thus reduced gas velocities and dust entrainment in the chain section.

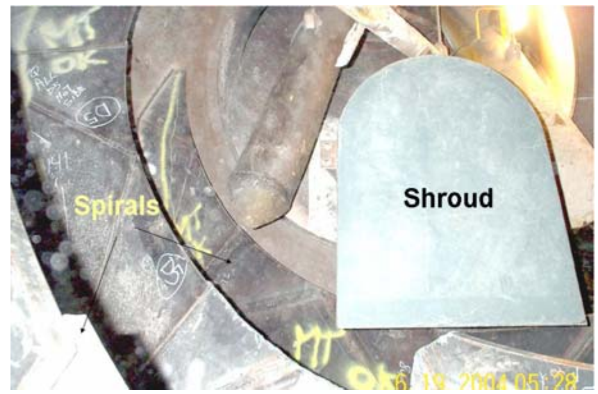

Figure 7. *Mud feed screw shroud (right) and feed spirals (left and bottom)*

The original design for the chain system upgrade recommended a final chain density of 150 kg/Mt lime. However, modeling of the proposed upgrade raised concerns with respect to lowering the feed end temperature too far. Exit gas temperatures lower than 180^{o}C for extended periods of time were a concern because of the potential for corrosion in the precipitator. Therefore, some diamond-link heat exchange chain was not installed and the chain density after the chain system upgrade was 124 kg/Mt lime.

<u>Installation of Additional Heat Exchange Chain</u>

Two years of operation proved that the chain system upgrade would not result in excessively low exit gas temperatures. Therefore, in June 2006, five more rings of diamond-link heat exchange chain were added at the hot end of the chain section. This increased the chain density to 146 kg/Mt lime.

RESULTS OF KILN UPGRADES

<u>Effect on Dust Loading</u>

Effectively, the modifications to the vacuum dust handling system implemented in late 2003 increased its capacity to the point where the extreme amounts of lime dust being generated in the kiln could be managed. These simple solutions proved successful in reducing the frequency of lime dust purging required, as can be seen by the decrease in the amount of lime dust landfilled in Figure 8. However, while the dust handling system upgrade made it possible to reduce the incidences of dust purging, it did little to reduce the actual dust loading in the kiln

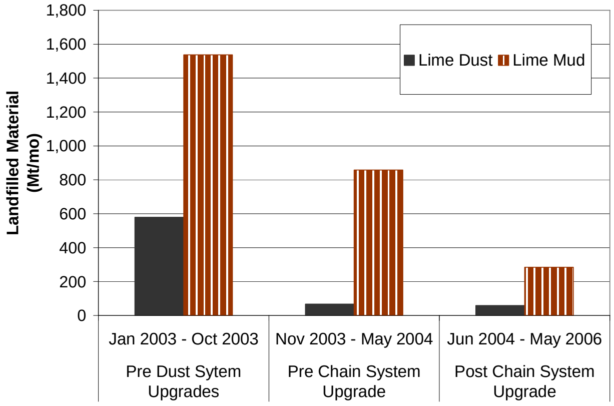

Figure 8. *Amount of lime dust and lime mud landfilled since 2003.*

A significant reduction in kiln dust loading resulted from the chain section upgrade. Following the chain system upgrade, dust loading is estimated to be about 50% of that before the chain system upgrade. This estimate is based on the fact that it is now possible to run the pressure dust handling system, which has a maximum capacity of 144 Mt/d, alone for up to 4 hours without plugging it off. This allows maintenance work to be completed on the vacuum dust handling system while continuing to operate the Lime Kiln.

Effect on Kiln Production

The impact of dust handling system and chain system upgrades on kiln production was evaluated using duration curves. A duration curve is a plot of an operating parameter (e.g. lime production rate) as a percentage of time. In this paper, the conventional method of using the 90^{th} percentile of the lime production duration curve as the maximum sustainable rate (MSR) of the kiln is followed.

Figure 9 shows three duration curves for kiln production rate. The kiln production increased substantially as a result of the dust handling system upgrade; the difference between the pre dust handling system upgrade curve and the pre chain system upgrade curve represents 8,720 Mt/yr CaO. It is also worth noting that the 90^{th} percentiles on the pre chain system upgrade curve and the post chain system upgrade curve are both in the neighborhood of 380 Mt/d lime, indicating that the dust handling system upgrade alone improved the kiln MSR sufficiently to achieve the 380 Mt/d required to support the current mill production.

Figure 9 also shows that the pre chain system upgrade curve drops off sharply at around 68^{th} percentile. This indicates that the large dust loading still present in the kiln following the dust handling system upgrade was counterproductive to stable kiln operation, and that high production rates were not sustainable for long periods of time. The amount of lime mud that still had to be landfilled before chain system upgrade is also indicative of unstable kiln operation.

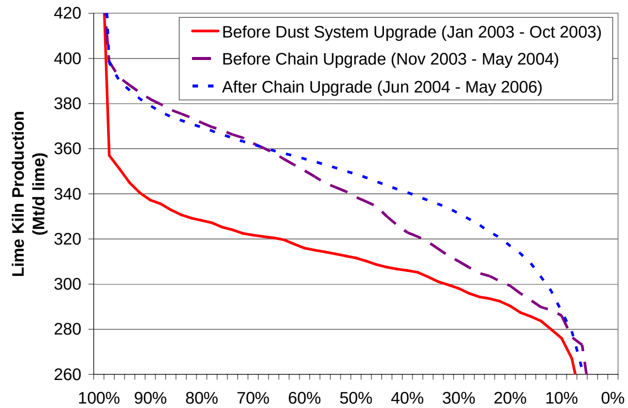

Figure 9. *Kiln production duration curves*

The chain system upgrade resolved the kiln dust loading issue, and the difference between the pre chain system upgrade curve and the post chain system upgrade curve represents 2,300 Mt/yr CaO. Figure 10 shows that the chain system upgrade was responsible for substantially reducing quicklime purchases.

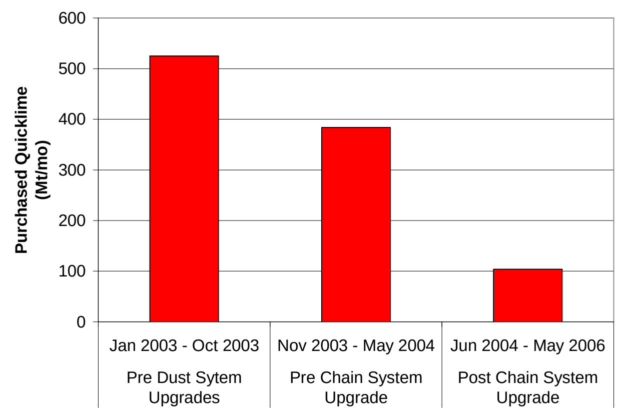

Figure 10. *Amount of purchased quicklime since 2003*

Effect on Kiln Thermal Efficiency

Figure 11 presents four duration curves for feed end temperature, and shows a significant reduction in feed end temperature as a result of upgrading the chain system. The feed end temperature exceeded 300°C 34% of the time before the dust handling system was upgraded and only 4% of the time post chain addition. It is important to remember that between November 2003 and May 2004 (concurrent with the dust handling system upgrade), the kiln feed end temperature was controlled by decreasing lime mud solids to 70-72% and adding water to the lime mud feed: thus the low feed end temperatures for this period of time. Both of these measures were discontinued after the chain system was upgraded.

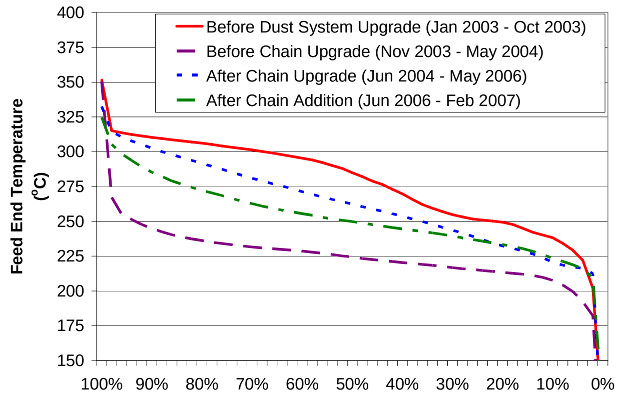

Figure 11. *Kiln feed end temperature duration curves.*

The comparison between natural gas consumption before and after the chain system upgrade is complicated by two factors:

1. The burner tip and primary air damper were both upgraded in June 2004 (concurrent with the chain system upgrade). The existing tip and damper were not sufficient to meet projected fuel requirements, and so had to be replaced. The impact of this change of equipment on natural gas usage is not well defined.

2. In 2003, because of increased natural gas usage to meet increased lime demand, the refractory in the burning zone of the kiln began to degrade rapidly. This refractory was therefore upgraded to a basic type of brick, which had a better chemical and thermal resistance. Unfortunately, the thermal expansion coefficient of the basic brick was considerably higher than that of the underlying insulating refractory. To prevent the basic brick from crushing the insulating brick during a thermal swing on the kiln and causing an unplanned kiln outage, the insulating brick was removed from beneath the basic brick in June 2004 (concurrent with the chain system upgrade). This increased heat losses through the kiln shell in the burning zone, and increased natural gas usage.

Despite these complications, the chain section upgrade proved to be beneficial in reducing natural gas usage. Figure 12 presents four duration curves for kiln natural gas consumption. The reduction in dust purging as a result of the dust handling system upgrade positively impacted natural gas consumption; however, reducing lime mud solids and adding water to the lime mud feed to control feed end temperature resulted in thermal inefficiencies. These conflicting conditions can be seen in the erratic nature of the pre chain system upgrade duration curve.

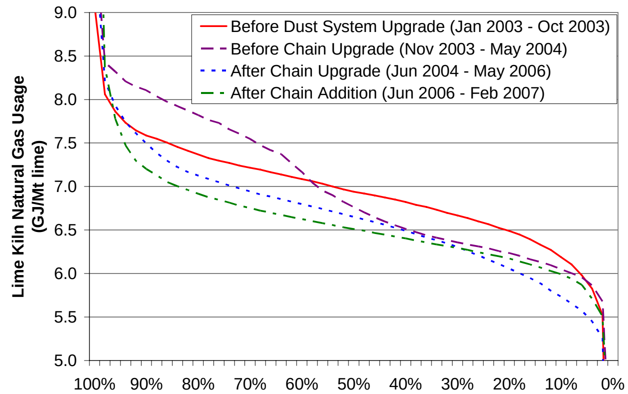

Figure 12. *Kiln natural gas consumption duration curves.*

Figure 13 also shows that before the dust system upgrade, kiln natural gas consumption was less than 7 GJ/Mt lime only 52% of the time, whereas after the chain system upgrade, kiln natural gas consumption was less than 7 GJ/Mt lime 72% of the time. This improvement is impressive given that it includes heat losses introduced by removing the insulating brick in the burning zone. After additional chains were added in June 2006, kiln natural gas consumption was less than 7 GJ/Mt lime 82% of the time.

The 50th percentile of a duration curve represents a median parameter value (e.g. natural gas consumption) in that 50% of the time, the parameter in question exceeds the 50th percentile and 50% of the time the parameter in question falls below the 50th percentile. Using the 50th percentiles of the natural gas consumption duration curves and a required kiln production rate of 380 Mt/d lime, the improvement in heat transfer resulting from the chain section upgrade represents a natural gas savings of 13,100 GJ/yr, while the further improvement in heat transfer efficiency resulting from the chain addition represents a natural gas savings of 16,900 GJ/yr.

Effect on Ring Formation

Prior to the chain system upgrade, ring formation downstream of the chain section near the middle of the kiln was a common occurrence (Figures 1 and 13). The build-up was generally difficult to eradicate, and had to be periodically physically removed using the Powershot nozzles. Since the chain system upgrade, the formation of mid-kiln rings seemed to have occurred less frequently. The rings seem to be softer and Powershot operation is not required as often as before the upgrade.

In the chain section, mud rings are found to form occasionally (Figure 14). They are soft and can usually be removed by introducing a deliberate thermal cycle into the kiln. However, there have been occasions since the chain system upgrade when the build-up in the chain section has limited lime production to the point where purchased quicklime has been required to maintain mill production rate.

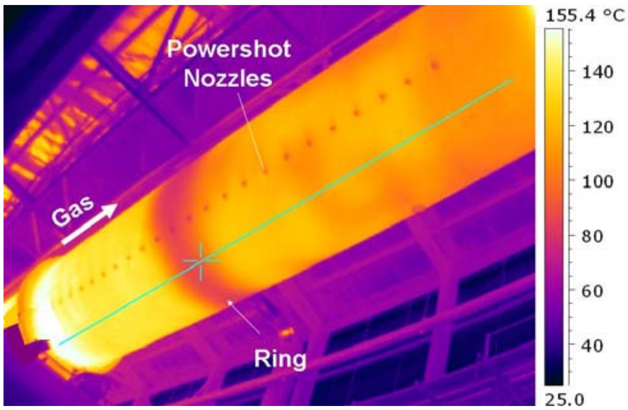

Figure 13. *Thermography scan of kiln hot end shell showing ring formation downstream of chain section and powershot nozzles*

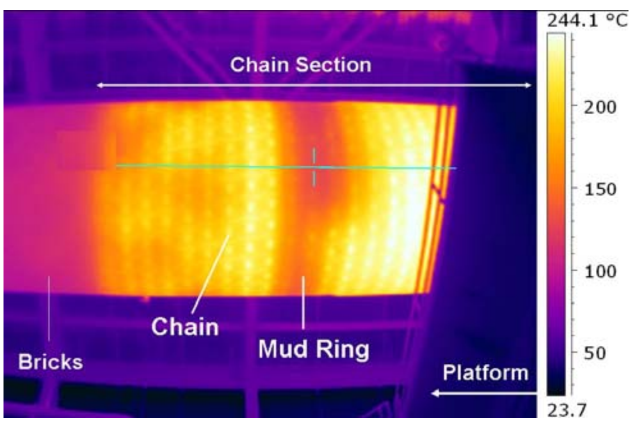

Figure 14. *Thermography scan of kiln chain section shell showing chain section ring*

Effect on Chain Maintenance

The chain section upgrade and the removal of the insulating brick significantly changed the temperature profiles of the gas stream and the solids bed in the kiln. No measurable thinning has occurred on the diamond-link heat exchange chain and no hangar caps have failed to date. The high efficiency chain system has required no maintenance since its installation in June 2004.

CONCLUSIONS

The dust handling system upgrade significantly increased the maximum capacity of the kiln, but failed to address dust loading within the kiln, making high kiln production rates unsustainable. Furthermore, the dust handling system upgrade did little to reduce feed end temperature and resulting natural gas consumption.
The chain system upgrade significantly reduced dust loading and permitted sustained kiln operation at high production rates. It also reduced the kiln feed end temperature and natural gas consumption, despite the removal of insulating brick in the burning zone. Chain addition further reduced the kiln feed end temperature and natural gas consumption. The formation of mid-kiln rings also has occurred less frequently since the upgrade.