Upgrading a Lime Kiln Chain Section to Reduce Dust Loading and Improve Thermal Efficiency

By O. Websdale, B. Downing, and H. Tran

Abstract: Due to a 50% increase in pulp production at DMI PRPD, purchased quick lime was used to supplement the mill’s lime requirements. Excessive dust recycle in the kiln hindered kiln production and was the main cause for poor kiln thermal efficiency. The inefficient, high maintenance kiln chain system was replaced by a high efficiency kiln chain system. This greatly decreased kiln natural gas consumption and allowed sustainable kiln production at high rates, thus reducing quick lime purchases.

Due to a 50% increase in pulp production at DMI PRPD, purchased quick lime was used to supplement the mill’s lime requirements. Excessive dust recycle in the kiln hindered kiln production and was the main cause for poor kiln thermal efficiency. The inefficient, high maintenance kiln chain system was replaced by a high efficiency kiln chain system. This greatly decreased kiln natural gas consumption and allowed sustainable kiln production at high rates, thus reducing quick lime purchases.
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 load 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 capacities are not entirely 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 has been burned in the power boiler, but SOG is 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 lime production rate of 337 mt/d, 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 lowered a portion of the normal kiln load and thus resulted in variable kiln load (solids bed depth) along the kiln length. 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 (Fig. 1). Ring formation accelerated local gas velocities and allowed more solids to accumulate behind the ring, as schematically shown in Fig. 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.

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 (Fig. 3). Hangers began to fail and entire lengths of chain appeared in the product lump crusher. The resulting decrease in heat transfer surface area in the chain section increased natural gas consumption and caused feed end gas temperatures to exceed 300°C. High exit gas temperatures, in turn, thermally damaged the baghouse.
socks of the dust handling systems, thereby exacerbating the dust handling issues.

In order to reduce the feed end gas 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 reduced the thermal efficiency and increased the natural gas consumption of the kiln.

**LIME KILN UPGRADES**

**Vacuum Dust Handling System Upgrade**

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

First, although the system was rated for 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.

Second, 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 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 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 (Fig. 4) was installed on the outlet of the baghouse; this valve effectively prevented tramp air from entering the baghouse and evened out the flow of dust into the lime mud feed screw.

**Chain Section Upgrade**

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

- Frequent burn-out and thinning of the 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.
- Inherent in the design of round-link chain was the formation of small “dust scoops” by link connections (Fig. 5). The mud col-
the chain system upgrade was 124 kg/mt lime.

**Installation of Additional Heat Exchange Chain**

Two years of subsequent operation showed that the chain system upgrade would not result in excessively low exit gas temperatures. 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**

**Effect on Dust Loading**

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 successfully reduced the frequency of dust purging, as can be seen by the decrease in the amount of lime dust landfilled in Fig. 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.

The chain section upgrade reduced the kiln dust loading by about 50% of that before the chain system upgrade. This estimate is based on the fact that it is now possible to operate with the pressure dust handling system, which has a maximum capacity of 144 mt/d, alone for up to 4 hours without plugging it. 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 modifications and chain system upgrade on kiln production was evaluated using load duration curves. A load 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 90th percentile of the lime production duration curve as the maximum sustainable rate (MSR) of the kiln is followed.

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 lime. It is also worth noting that the 90th 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 provide the 380 mt/d of lime required to support the current mill production.

The pre-chain system upgrade curve shows a significant reduction in feed end gas temperature as a result of upgrading the chain system. The pre-chain system upgrade curve represents 2,300 mt/yr lime. The difference between the pre-dust handling system upgrade curve and the pre-chain system upgrade curve is complicated by two factors. First, 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 thus, had to be replaced. The impact of this change of equipment on natural gas usage is not well defined.

Second, 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 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, the concurrent reduction in the lime mud solids and the addition of water to the lime mud feed to control the feed end gas temperature reduced the kiln thermal efficiencies. These conflicting conditions can be seen in the erratic nature of the pre-chain system upgrade duration curve.

The 50th percentile of a duration curve represents a median parameter value (e.g., natural gas consumption) in that 50% of the time, whereas after the chain system upgrade, kiln natural gas consumption was less than 7 GJ/mt lime 52% of the time. This improvement 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 feed end gas temperature exceeded 300°C 34% of the time before the dust handling system was upgraded and only 4% of the time after the new chain system was installed. It is important to remember that between November 2003 and May 2004 (concurrent with the dust handling system upgrade), the kiln feed end gas temperature was controlled by decreasing lime mud solids to 70-72% and adding water to the lime mud feed. This measure resulted in low feed end gas temperatures for this period of time. Both of these measures were discontinued after the chain system was upgraded.

Figure 11 presents four duration curves for the feed end gas temperature. The curves show a significant reduction in feed end gas temperature reduced the kiln thermal efficiencies. These conflicts can be seen in the erratic nature of the pre-chain system upgrade duration curve.

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

Comparison of the natural gas consumption before and after the chain system upgrade is complicated by two factors.

First, 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 thus, had to be replaced. The impact of this change of equipment on natural gas usage is not well defined.

Second, 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 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, the concurrent reduction in the lime mud solids and the addition of water to the lime mud feed to control the feed end gas temperature reduced the kiln thermal efficiencies. These conflicting conditions can be seen in the erratic nature of the pre-chain system upgrade duration curve.

The 50th percentile of a duration curve represents a median parameter value (e.g., natural gas consumption) in that 50% of the time. The feed end gas temperature exceeded 300°C 34% of the time before the dust handling system was upgraded and only 4% of the time after the new chain system was installed. It is important to remember that between November 2003 and May 2004 (concurrent with the dust handling system upgrade), the kiln feed end gas temperature was controlled by decreasing lime mud solids to 70-72% and adding water to the lime mud feed. This measure resulted in low feed end gas temperatures for this period of time. Both of these measures were discontinued after the chain system was upgraded.

Comparison of the natural gas consumption before and after the chain system upgrade is complicated by two factors.

First, 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 thus, had to be replaced. The impact of this change of equipment on natural gas usage is not well defined.

Second, 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 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, the concurrent reduction in the lime mud solids and the addition of water to the lime mud feed to control the feed end gas temperature reduced the kiln thermal efficiencies. These conflicting conditions can be seen in the erratic nature of the pre-chain system upgrade duration curve.

The 50th percentile of a duration curve represents a median parameter value (e.g., natural gas consumption) in that 50% of the time. The feed end gas temperature exceeded 300°C 34% of the time before the dust handling system was upgraded and only 4% of the time after the new chain system was installed. It is important to remember that between November 2003 and May 2004 (concurrent with the dust handling system upgrade), the kiln feed end gas temperature was controlled by decreasing lime mud solids to 70-72% and adding water to the lime mud feed. This measure resulted in low feed end gas temperatures for this period of time. Both of these measures were discontinued after the chain system was upgraded.
CONCLUSION

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 the feed end gas temperature and the natural gas consumption.

The chain system upgrade significantly reduced dust loading and permitted sustained kiln operation at higher production rates. It also reduced the kiln feed end temperature and natural gas consumption, despite the removal of insulating brick in the burning zone. Subsequent addition of more chain further reduced the kiln feed end gas temperature and the natural gas consumption. The formation of mid-kiln rings also has occurred less frequently since the upgrade.

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 is less frequent. The rings seem to be softer and Powershot operation is not required, compared to before the upgrade.

In the chain section, mud rings form occasionally (Fig. 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 quick lime has been used to maintain the mill production rate.

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 hanger caps have failed to date. The high efficiency chain system has required no maintenance since its installation in June 2004.