

Increasing lime production while decreasing kiln pluggage through installation of the first LimeFlash lime kiln feed system in North America

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ABSTRACT: The Evadale, TX, USA, mill recently engaged in a major lime kiln and recausticizing upgrade. The centerpiece of the project was to upgrade the existing lime kiln feed system to a new LimeFlash feed system, a trademarked technology from Andritz. The feed system in Evadale is the first installation in North America of this technology, and the second installation in the world. The feed system increased the capacity of the lime mud dryer (LMD) fed kiln from 350 tons/day of lime product to 480 tons/day of kiln product, with less than 3% carbonate. The system mixes hot flue gasses with the lime mud before the gas enters the feed end housing, which allows the kiln to operate at a higher feed end temperature without plugging and lime splitting. In startup and low capacity situations, lime mud is fed directly into the kiln rotating part, which eliminates potential plugging problems. Startup and operational experience, along with selected environmental performance, is reviewed.

Application: The use of the new LimeFlash kiln feed system allows a mill to substantially increase the amount of lime production for a given volume of existing lime kiln. The new feed system can potentially support production increases or the elimination of older kilns without the need to purchase an entire new lime kiln and supporting equipment.

In kraft pulp mills, lime kilns are used to convert lime mud (CaCO_3) to lime (CaO) for reuse in the causticizing plant. The process requires a large amount of heat (6-10 GJ/ton CaO production), which is supplied to the kiln mainly by burning fossil fuels such as fuel oil and natural gas. When lime kilns are routinely started and stopped to accommodate variable white liquor production rates, the heat demand on a global basis can change from around 6 to 7 GJ/ton of lime to 11 or 12 GJ/ton of lime produced.

The Evadale, TX, USA, mill has maintained and operated three lime kilns. The two older kilns routinely operated with a combined production rate of 183 tons/day of lime. The No. 7 kiln average production rate was 350 tons/day. The No. 7 kiln was built in 1995 and utilized an early generation lime mud dryer (LMD) feed system. The two older kilns use traditional feed systems with chain sections. Recently, the mill shut down one paper machine and reduced the pulp demand from roughly 1900 tons/day to 1400 tons/day. Lime demand has significantly decreased to the point where the mill needs to run the No. 7 kiln full time and one of the other kilns only part time. As a result of routinely heating up the kiln, the global fuel demand for the part-time kiln operation has become costly and excessive. Additionally, the mill sought to reduce manpower by permanently shutting down the old kiln and associated liquor works.

In an effort to reduce natural gas consumption and improve the overall operation of the mill, a study was under-

taken to increase the production rate of the No. 7 kiln to a level that would allow the mill to shut down both old kilns. In general, a production rate of about 460–475 tons/day of lime would be required. As the No. 7 kiln limit without plugging was roughly 350 tons/day, this required a 36% increase in lime production. Recent literature on upgrading kiln capacity has frequently dealt with less modern kilns [1], so the suggestions and solutions presented were not applicable to the Evadale No. 7 kiln. In an effort to determine the best method of upgrading the No. 7 kiln capacity, the different rate limiting factors for the existing kiln were examined.

RATE LIMITING FACTORS FOR EXISTING KILN

Kiln volume

Typically, lime kiln production is limited by the volume of the kiln inside the refractory. Higher production rates require a larger processing area inside the kiln. Older, inefficient kilns usually were oversized. Newer kilns utilize higher efficiency internal components and product coolers to reduce the kiln volume and improve the energy efficiency of the kiln.

Generalized rules of thumb for kiln sizing suggest that conventional, chain section kilns without product coolers would require roughly 95 to 110 ft^3 /ton of lime produced [2]. Frequently, for new or retrofit kilns, the volumetric loading has been reduced to 70–80 ft^3 /ton of lime [3]. Kilns with modern flash driers may require only 50–60 ft^3 /ton of lime produced. **Table I** shows volumetric production factor con-

LIME KILN

System Type	Production Factor m ³ /MTPD (ft ³ /STPD)	Relative Heat Rate at 75% Feed Solids MM Btu/MT (MM Btu/ST)	Relative Power Consumption at 75% Feed Solids kWh/MT (kWh/ST)
Conventional long kiln	3.09 (100+)	7.7 (7.0)	74 (67+)
Existing long kiln retrofitted with modern internals	2.25 – 2.4 (73 - 78)	6.6 (6.0)	69 (63)
New long kiln with modern internals, product cooler, and electrostatic precipitator (ESP)	2.16 – 2.32 (70 - 75)	6.2* (5.6*)	50 (45)
Kiln with modern internals, product cooler, external suspension drying system, and ESP	1.7-1.85 (55-60)	6.06 (5.5)	55 (50)

* Value corrected from original source with data supplied by Jack Leichter of Andritz.

I. Kiln volumetric production factor [4]. MT = metric tons; ST = short tons; MTPD = MT/day; STPD = ST/day.

siderations for different types of conventional, retrofit, and modern kilns [4].

Process control instrumentation

The use of a multivariable, multipredictive control system has been shown to improve kiln operation in mill scale settings [5]. Typical production rate increases on the order of 5%–6% have been reported with the implementation of a high quality advanced control system. Lime kiln specific fuel consumption has also been reported to decrease as a direct result of advanced lime kiln control.

Unfortunately, the Evadale No. 7 kiln already had an advanced control system installed. A potential problem with the advanced control system in use at the mill was the measurement of residual oxygen in the exiting flue gas. The extremely dusty conditions in the sampling area periodically plugged the sampling probe and required blowing out to unplug the probe. During these times, the oxygen content value was estimated at its last measured value, instead of obtaining an actual measurement. As a result, while it might have been possible to improve the kiln operation, the improvement would be nowhere near the 35%-plus production values required for success of the project.

Chains

Typically, modern LMD type kilns do not use chains to help dry the mud. In the 2010 Lime Kiln Survey, of the 22 LMD type kilns responding, only five of the kilns utilized chains to assist in drying the mud [6].

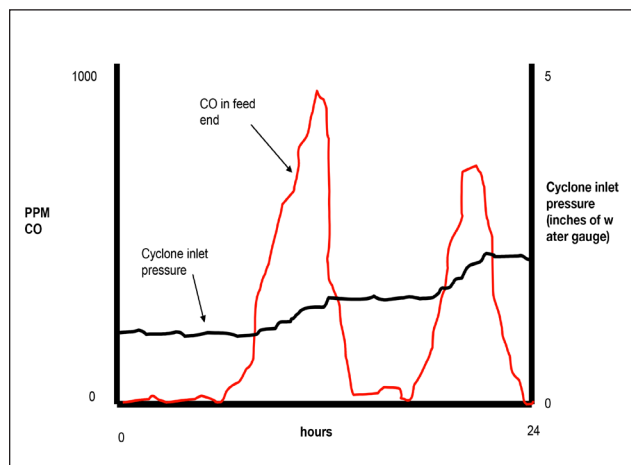
In general, it was decided that chain addition would not be the best idea for the No. 7 kiln, as the use of chains would have the potential to increase the amount of dusting in the kiln and result in a net decrease in production [7].

Feed system pluggage

In addition to the volumetric limitations of the existing kiln,

feed system pluggage associated with increased production rates resulted in a significant limitation to capacity improvement. It was not possible to simply increase the feeding rate of the LMD kiln, as increased throughput resulted in an increasing feed end temperature in the kiln. Typically, when an LMD fed kiln feed end temperature reaches about 700°C (1300°F), the LMD tends to plug, thus limiting production in the kiln.

The Evadale No. 7 kiln also experienced carbon monoxide (CO) burning in the feed ducts. The CO resulted from incomplete combustion of the fuel due to low oxygen levels in the kiln. Air leakage into the LMD feed system resulted in monitored oxygen levels that were higher than the actual level of oxygen in the kiln at the feed end, causing CO combustion in the LMD housing. CO burning in the LMD helped contribute to pluggage problems in the LMD feed system. **Figure 1** shows the impact of CO burning in the kiln. With this feed



1. Impact of carbon monoxide (CO) burning in the lime mud dryer (LMD) feed end of the kiln results in increased feed system pluggage. Left axis is ppm of CO in the feed end of the kiln, and the right axis is the cyclone inlet pressure in inches of water pressure gauge. The x-axis is a 24-h span of operation.

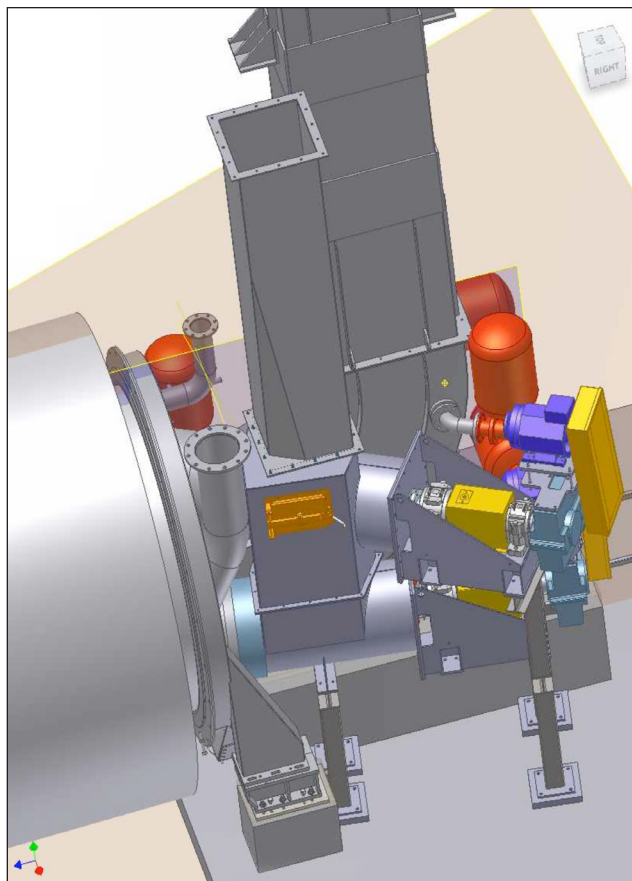
end temperature as a constraint, the kiln was only capable of producing about 350 tons/day of quality product without experiencing plugging problems.

NEW LIME KILN FEED SYSTEM

A potential solution to the feed system pluggage problem was to alter the feeding system of the kiln. The Evadale mill opted to install a new LimeFlash feed system on the No. 7 kiln. The new system, trademarked and supplied by Andritz (Graz, Austria), reduces the volumetric constraint of the kiln to 50–60 ft³/ton of lime produced. The new feed system is the first of its type installed in North America and only the second installed in the world. This system allows much higher feed end temperature, resulting in a significant increase in production. Back end temperature is controlled through the addition of wet lime mud. Wet mud is introduced directly into the gas stream as the gas comes out of the kiln, before the mud enters the ductwork and is flash dried. This forces the sticky fume phase of mud drying to occur inside the kiln shell instead of in the duct; thus, the ductwork does not plug up. The new feed system basically keeps the sticky dust out of the ducts.

The LimeFlash feed system routinely operates at 850°C (1550°F) with no pluggage issues. Under routine operation, lime mud falls down the chute to the LMD feed screw. The mud falls off the end of the screw and is sucked into the LMD riser duct and up to the cyclone. Any feed that does not enter the LMD falls directly to the kiln. Dry kiln feed enters the kiln feed screw from the cyclone and is conveyed to the kiln. Under low temperature and low production rate scenarios, the mud falls down the chute to the LMD feed screw. The mud overflows from the LMD feed screw to the lower kiln feed screw, and the wet mud goes directly to the kiln. **Figure 2** shows details of the new feed system. As a result of installing this system, the kiln production rate has increased to 480 tpd of quality lime, with no operational issues.

The new feed system can still plug and result in decreased production. Typical reasons for pluggage include feeding mud that is too wet to the LMD. When excessively wet mud is fed to the kiln, it can accumulate in the bottom of the duct and bake to a hard buildup, which can impair production. Another method of plugging the new feed system is allowing the gas temperature to exceed 700°C without mud being present. This condition forms a coating on the ductwork and leads to pluggage. Another potential plugging problem results when mud is fed to the LMD without enough gas velocity to convey it to the cyclone. As with the old kiln feed system, CO burning in the LMD ductwork can also lead to plugging problems. The new feed system is constructed much more tightly than the old feed system, thus minimizing air leaks and faulty oxygen readings. Finally, if the blasters are not working, the kiln also has a potential to plug. To date, no pluggage problems have occurred in the upgraded kiln.



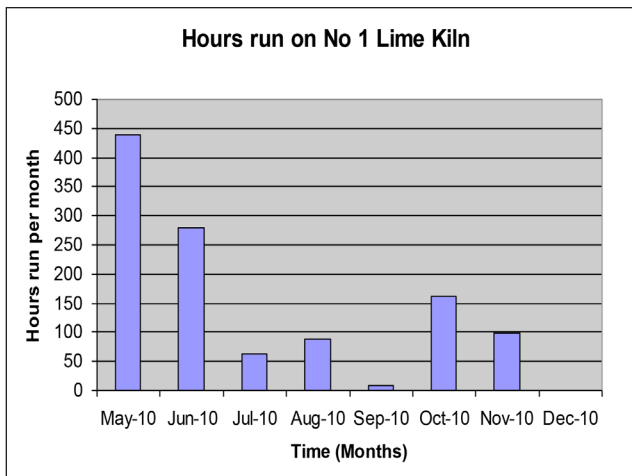
2. The new LimeFlash feed system installed on the No. 7 kiln. Lime mud is fed into top screw and dropped into the kiln at the inlet to the throat of the ductwork. The lime is flash dried as it is sucked up the duct to the cyclone (not shown on top of larger duct), then dropped down to the lower screw to be deposited into the kiln for calcining.

Mechanical design

The mechanical design of the new feed system consists of a rectangular shaped riser duct with a large radius to give extended time for lime mud drying before hitting the duct surface. The larger radius results in less plugging. The feed system utilizes a two screw feeding system and incorporates an adjustable cooling water spray system. It has seven blasters to keep the curve area of the feed duct clean. The riser duct is supported on rails for easy pulling-out, and the elbow contains a removable single-piece wear plate. The kiln feed screw has solid flights at the end to minimize leakage through the screw.

ADDITIONAL PRODUCTION CONSTRAINTS

There are additional variables that impact kiln production. The most critical parameter in addition to kiln volume would be the inside unit diameter, which affects velocities through the unit. With the installation of the new feed system, blowing dust out of the kiln from high air velocity will be the ultimate bottleneck to the kiln production rate. Kiln diameter has a direct impact upon flue gas velocity out of the kiln. The



3. Impact of the No. 7 kiln feed system on the hours of operation for the No. 1 kiln.

kiln has a diameter of 246 ft in length and a shell diameter of 11 ft 10 in.

The amount of brick insulation in the kiln is another factor that inherently impacts internal kiln diameter and also plays a role in production capacity and fuel economy. Excess combustion air and air leaking into the kiln through the feed system ductwork is another source of kiln production limitations. Excess combustion air and leaking air have the potential to increase flue gas velocity and carry excessive amounts of dust into the precipitators.

Finally, fuel type, flame shape, and luminosity also impact kiln performance. For instance, when a kiln burns natural gas instead of fuel oil, the back end temperature of the kiln is typically about 50°F higher [2].

UPGRADED KILN GOALS AND PERFORMANCE

The goal of the project was to be able to permanently shut down the No. 1 lime kiln. The new feed system on the No. 7 kiln was started on May 1, 2010. The upgraded kiln was run through a month long startup curve while several minor operational issues were addressed. Initial problems with short term draft spikes in the elbow were resolved in June 2010 when the temperature control spray nozzle was replaced with a different nozzle design and operating procedures were refined.

The main operational problem that the mill has experienced has been a tendency for the kiln to ring whenever the kiln is run for an extended period of time at a low production rate. Ringing does not appear to be an issue when the kiln is base loaded at full production (99% of the time). Three ringing events have occurred that resulted in downtime. Each time, the kiln had to run with a very low production rate prior to the ringing. The slow production rate was driven by the rest of the mill running a very low pulp production rate and a full white liquor inventory. A minimum production rate has been established for the kiln in an effort to avoid ring formation. When the system has to run below the minimum rate, load is pulled off the kiln.

Figure 3 shows the impact of the No. 7 kiln feed system replacement upon the operational hours of the No. 1 lime kiln. Since startup of the No. 7 kiln feed system, the hours of operation of the No. 1 kiln have substantially decreased to the point where it is not required at design pulp production rates.

The monthly improvement in kiln operation as the operators worked through the startup learning curve is shown in **Table II**. Production rate, availability, and lime quality have all improved since the initial startup of the kiln feed system. The new system has routinely allowed the production of 480 tpd of quality lime, with production spurts up to 520 tpd of lime product. Paper production has continued to increase above the project goal, and the kiln is now the mill production limit. Opportunities to further increase the kiln production rate will need to be pursued or the No. 1 kiln will have to be restarted to meet the higher-than-expected paper production goals.

Environmental impacts

The kiln upgrade was not an environmental project *per se*. However, environmental performance criteria had to be met and maintained with the increased production from the kiln.

One environmental benefit of the project was the installation of a newly designed Andritz burner with primary air on the inside of the flame. Adding the primary air on the inside of the flame results in a better mixing of the staged air. Improved mixing of the air and fuel lowers NOx emissions. The new kiln feed and burner system has contributed to a significant reduction in NOx emissions compared to the old LMD feed system and the old burner.

	Average Production Rate (TPD)	mm Btu/Ton	Average Carbonate in Product (%)	Uptime (%)
Past performance	385	6.0	2.9	97.0
May 2010	409	6.2	4.3	93.7
June 2010	432	6.1	3.8	96.6
July 2010	482	6.1	2.8	99.6

II. No. 7 kiln performance post-startup through July 29, 2010.

STARTUP AND OPERATIONAL ISSUES

One system that did not perform satisfactorily was the continuous emission monitoring system for CO and O₂ for the kiln exit. The system consisted of a unique design (serial no. 1), using a laser gas analyzer system. The issue was pluggage of the side stream sample line in which the analyzer was installed. The sampling point for this monitor has been moved to the outlet of the cyclone. A redesigned temperature control spray nozzle was installed in June 2010 due to the typical flow being below the nozzle's design range for optimal atomization.

During the October 2010 outage, it was discovered that the refractory on the side wall of the LMD elbow was failing. Temporary repairs had to be made before startup. A new elbow with improved plating was installed during the Spring 2011 mill outage and has prevented this problem from reoccurring. **TJ**

ACKNOWLEDGEMENTS

The Andritz team of Kimmo Peltonen, Robbie Diaz, and Jack Leichter and their support team were instrumental in the construction and startup of this project. Their efforts in diagnosing and correcting the elbow refractory problem were also important to the ultimate success of the project. Without their

help and the assistance of the Evadale mill operators, the No. 7 lime kiln upgrade would not have anywhere close to successful as it has been.

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ABOUT THE AUTHORS

The Evadale, TX, mill needed to increase production on a new, larger, energy efficient kiln in order to eliminate the maintenance, operating cost, and manpower associated with operation of two older kilns. The current work was undertaken to improve the cost effectiveness of the mill.

The new LimeFlash kiln feed system, trademarked and supplied by Andritz, builds upon existing lime mud drying technology. The new system effectively extends the calcining section of the kiln by performing all of the mud drying in flight inside the ductwork and cyclone.

The most difficult aspect of this research was identifying the technology. As this lime kiln feed system is the first installation in North America and only the second installation in the world, there was some concern about the viability of the project. There were also some scale-up issues and materials of construction issues associated with this project.

The most surprising thing we discovered from this project was the ability of a modern kiln to operate with a volumetric production rate of less than 55 ft³/ton of lime, which is an astounding achievement. The back end temperatures are over 700°C, and the system operates without plugging.

Current technology suggests that modern lime kilns require 60-75 ft³ of kiln capacity per ton of lime produced. With the new feed system, this number has been successfully reduced to less than 55 ft³/ton of lime. The new feed system will allow other mills to increase production on modern kilns and perhaps improve their energy efficiency. Our next step is to optimize the kiln production and long term operability.

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