Improve Lime Mud Kiln Operation
By Controlling Mud Moisture Using an Inside-The-Dryer Moisture Sensor

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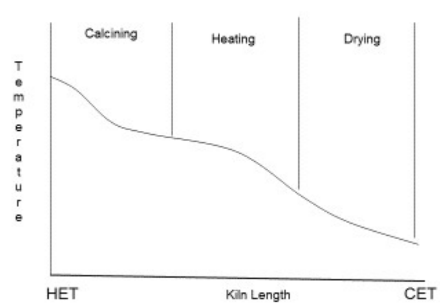
ABSTRACT

A Lime Mud Kiln consists of three sequential unit operations: drying, heating, and calcining. Traditionally, two control loops have been used: A hot end temperature (het) loop maintains the proper calcining temperature, and a cold end temperature (cet) loop is used, perhaps unwittingly, as a non-theoretical mud moisture (mc) sensing and control loop. This cet loop is similar to the flawed, non-theoretical exhaust temperature mc sensing and control loop used for controlling the mc of products being dried using industrial dryers, including counter-current rotary dryers. Fortunately, this flawed mc sensing and control problem has been solved for industrial dryer applications; therefore, it is proposed as a replacement for the old (cet) loop in a new lime mud kiln control system. Based on the analogous relationship between a cet loop and a delta t loop = (het – cet) = delta t loop, if the delta t loop replaces the cet loop on a kiln, the drying zone will be controlled to a constant length with at least 30% less variation in length, and this will in turn control the calcining zone to a constant length with at least 30% less variation in length. Therefore, the delta t loop will control the length (time) component and the het loop will control the temperature component of the time-temperature parameter necessary for producing a superior finished lime

INTRODUCTION

A Lime Mud Kiln may be described simply as a series of three unit operations: drying, heating, and calcining as illustrated by figure (1).

Figure (1) – Three Unit Operation Zones in a Lime Mud Kiln

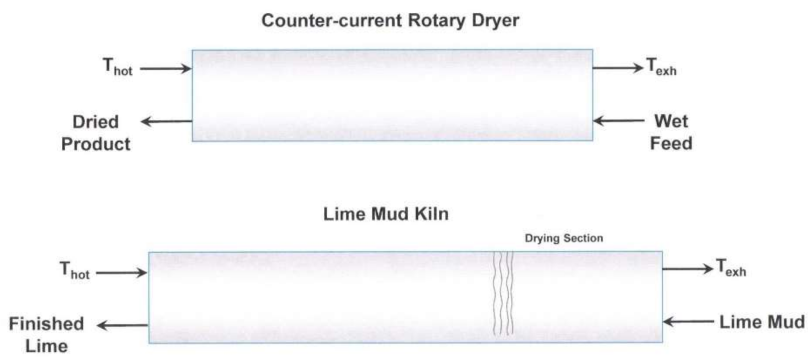


Although simply described by figure (1), there are numerous problems involved in successfully operating a kiln. Since drying is the first of this series of unit operations, it is reasonable to conclude that if the moisture (mc) of the mud leaving the drying zone is not properly controlled, the drying zone length will vary for each change in the evaporative load. Such variations will be transmitted as a change in length of the heating zone as well as a similar change in the calcining zone length. Changes in the calcining zone length cause carbonate content variations in the finished lime that are not detected until the finished lime is later sampled. In addition, it is reasonable to assume that these uncontrolled evaporative load swings contribute to the formation of water-related rings and dusting occurrences.

ANALOGOUS OPERATION OF ROTARY DRYERS AND KILNS

The cold end temperature (cet) loop of a kiln is used to control the mc of the mud exiting the drying zone of a kiln; likewise, the exhaust temperature from a counter-current rotary dryer has traditionally been used to control the mc of products exiting rotary dryers. Figure (2) illustrates this analogy:

Figure (2) - Drying Similarity of a Counter-Current Rotary Dryer and Drying Zone of a Lime Mud Kiln



Although these two non-theoretical methods control in the right direction, as soon as an evaporative load enters the dryer or kiln, the old exhaust temperature or cet setpoint is no longer valid for the new operating conditions, and a precise, mathematical method has not been available for re-calculating a new setpoint. Consequently, both industrial drying and lime mud kilns use the same ineffective mc sensing and control method.

TRADITIONAL DRYER CONTROL PROBLEMS

There are three main problems that prevent traditional mc sensing and control from being effective: (1) lack of timely and reliable mc data upon which to base a control decision; (2) lack of a method for precisely re-calculating the process variable setpoint in order to maintain the target mc; and (3) lack of a simple, non-problematic, and relatively inexpensive evaporative load sensor.

Fortunately, these problems were solved[1,2] by the derivation of the general, moisture control model:

$$\mathbf{MC = K_1(\Delta T)^p - K_2/S^q}$$

This model enables prediction and control of the mc of a product exiting a rotary dryer by relating it to the temperature drop (ΔT) of hot air after contact with a wet product, and the evaporative load, production rate, or dryer speed (S). The model provides the following solutions for the three problems with traditional mc sensing and control: (1) An inside-the-dryer mc soft sensor, consisting of two ordinary temperature sensors, that is rugged, reliable, does not drift, and does not require re-calibration; (2) The capability for re-calculating the process variable (ΔT) setpoint needed to maintain the target mc following evaporative load changes entering the dryer; and (3) A simple, inexpensive, non-problematic, evaporative load soft sensor.

When these three solutions are incorporated into a mc sensing and control system, the target mc is maintained with at least 30% less mc variation than that achieved using traditional mc sensing & control methods. The model applies to such direct dryer-types as rotary, flash, spray, belt, fluid-bed, batch, and to some indirect dryers and batch dryers.

TRADITIONAL LIME MUD KILN CONTROL SYSTEM

Traditionally, two Proportional – Integral – Derivative (PID) loops have been used for controlling a kiln: The hot end temperature (het) loop maintains the proper calcining temperature at the front end (exit) of the kiln and the cold end temperature (cet) loop is used to control the mud mc using the cet setpoint as a non-theoretical surrogate for mc.

As previously stated, the cet loop is analogous to the exhaust temperature control method for industrial dryers; therefore, it suffers from the same three problems listed above for rotary dryer mc control. Consequently, use of this ineffective, non-theoretical cet loop control method for controlling mud mc exiting the drying zone allows the drying zone length to vary, and also the calcining zone to vary in length, thus causing over and under-calcined lime variations. In addition, the kiln temperature profile is distorted for each evaporative load disturbance. Its effect on the finished lime will be discussed later.

TECHNOLOGY TRANSFER

If the drying zone of a kiln is analogous to a counter-current rotary dryer, and the three control solutions are working exceedingly well on industrial rotary dryers, it appears logical to assume that this improved mc control system would be effective in sensing and controlling mud mc exiting the drying zone of a kiln, thus controlling the drying zone length as well. Since this improved method has consistently reduced mc variation at least 30% during control of rotary dryers, it has the potential for reducing variations in a kiln drying zone length (time) by 30%. It is also reasonable to assume that variations in the drying zone will be transmitted through the kiln to produce similar variations in the calcining zone length. Consequently, by properly controlling the mud mc exiting the drying zone, the time component of the time-temperature parameter is determined, and when coupled with the het loop, that controls the temperature component of the time-temperature parameter, a more effective lime mud kiln control system is made available. It is not unreasonable to expect that the carbonate content would be reduced by 30%. For example, if the present carbonate content were 3.5%, it would be reduced to 2.5%. In addition, a 30% reduction in mc variation should reduce or eliminate water-related ring formations, dusting occurrences, and perhaps reduce re-carbonation and sodium vaporization by reducing het excursions.

APPLICATION OF THE DELTA T CONTROL TO A LIME MUD KILN

Transformation of the existing two-loop control system is easily accomplished, usually without hardware addition by changing the cet loop to a delta t loop simply by subtracting the cet from the het (het – cet) = ΔT loop. The het loop remains unchanged. An additional benefit of subtracting the cet and the het is that it eliminates (subtracts) het fluctuations that are normally transmitted to the cet loop and possibly eliminates the interaction present in the traditional two-loop kiln control system. Figure (3) illustrates the possible effect of error reduction by subtracting the two loops (het + noise) – (cet + noise) = (het – cet):

Figure (3) – Shows Reduction in Noise by Subtracting Loops

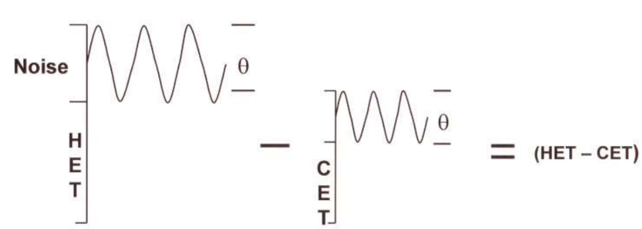


Figure (4) subtracts the cet from the het to give the improved delta t loop.

Figure (4) – The Improved Delta T Loop

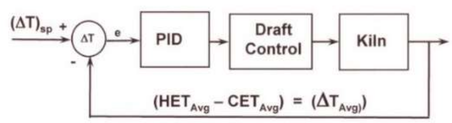
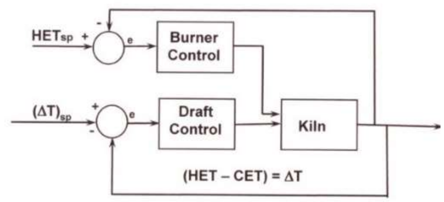


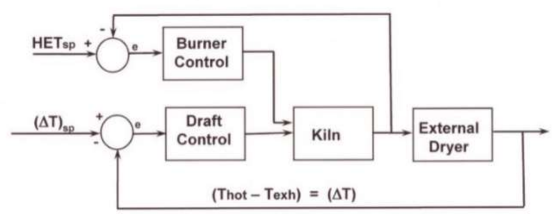
Figure (5) depicts the new kiln control system that combines the het loop with the delta t loop for internal drying:

Figure (5) – Combined Two-Loop Delta T Moisture Control System for Internal Mud Drying



This new kiln control system should operate much better on an external dryer as illustrated by Figure (6).

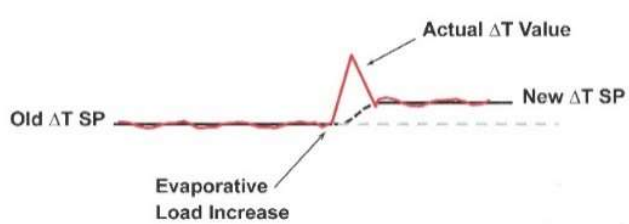
Figure (6) Two-Loop Delta T Moisture Control System for External Mud Dryer



NEW LIME KILN CONTROL OPERATION

Assuming the kiln is operating at steady-state, an evaporative load increase entering the kiln causes the delta t value (het – cet) to increase. The Delta T loop control compares the actual delta t value to the delta t setpoint that produces the target mc at the current operating conditions. The difference (error) is used to pull more air from the front end to bring the delta t back to the old setpoint value. However, since the evaporative load and the air flow through the kiln have increased, the old operating condition setpoint will not produce the target mc. It must be re-calculated using proprietary means as illustrated by figure (7); otherwise, the mud will not be dried properly.

Figure (7) – Re-calculating a New Delta T Setpoint



NEW KILN CONTROL OPERATING EXPERIENCE

A USDOE energy grant financed a trial installation of the patented, award-winning Delta T on No. 3 kiln at Temple-Inland's paper mill at Evadale, TX. It ran for approximately two months during November of 1995 – December 1995. The kiln was a 1950's era kiln and was scheduled to be replaced shortly after the trial. The purpose of the trial was to evaluate combining the two loops. The scope of the trial did not include evaluating its effectiveness in reducing carbonate content; however, it did show a 4% reduction in unit energy consumption. Energy savings would have been higher if secondary air had been available at high production rates to keep the oxygen level high enough to maintain TRS within limits. TRS was controlled by reducing the fuel rate at the expense of higher carbonate content in the finished lime. Overall, the operation was quite smooth over the approximately two months run.

RESULTS & CONCLUSIONS

This new and improved lime mud kiln control system treats the lime kiln as a series of unit operations with the final operation a calcining reactor that is best controlled using the het loop to maintain the calcining temperature, and the new delta t loop to control the time component of the time-temperature parameter. Thus, both components of the time-temperature parameter are available for gaining better control of the kiln. Since mc variations are reduced 30% by an analogous counter-current, industrial rotary dryer application, a 30% reduction in calcining time variation should be realized. In addition, improved control of mud mc should reduce or eliminate occurrences of water-related rings, dusting, and possibly reduce the tendency for re-carbonation of calcium oxide, or sodium vaporization as a result of fewer high temperature excursions. This new and improved kiln control system, normally a software-only solution, does not require kiln downtime, and should be much simpler to operate.

LITERATURE CITED

1. Robinson, J.W., "A New Drying Model," Proc. North American Drying Symposium, Mississippi Forest Products Utilization Lab., MS., State, MS, pp. 78 – 84, (Nov. 27 – 28, 1984).

2. Robinson, J.W., Improve Dryer Control, CEP, Vol. 88, No. 12, pp. 28-33, (Dec. 1992).

APPENDIX

Awards

National Forest Products Association/American Paper Institute Environmental and Energy Innovation Award for 1986.
US Department of Energy – Energy Innovation Award for 1985.
The State of Texas – Energy Innovation Award for 1985.
The Texas Forestry Association – Award of Merit in 1984.
Inventions and Innovation grant from Office of Industrial Technologies, USDOE, to extend DELTA T technology to four industries 1992.

Patents

US Patent No. 4.701,857, Oct. 20, 1987, Method and Apparatus for Controlling Dryers for Wood Products, Fabrics, Paper and Pulp.
US Patent No. 4,777, 604, Oct. 11, 1988, Method and Apparatus for Controlling Batch Dryers.