Improve Lime Mud Kiln Control

By Accurately Sensing and Controlling Mud Moisture

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John Robinson and Roger Douglas
Drying Technology, Inc

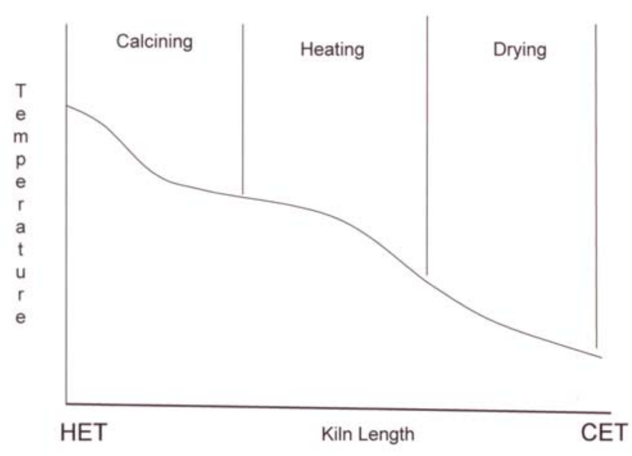
Abstract

A traditional Lime Mud Kiln consists of a series of three unit operations: drying, heating, and calcining Major operating problems such as ring formation and dusting are reportedly moisture related. This paper suggests an additional moisture related problem is caused by evaporative load swings that enter the drying zone and leave uncontrolled, thus causing time-temperature parameter swings in the calcining zone that directly affect finished lime quality. Since most kiln operating problems are moisture related, kiln operation should be significantly improved by including effective mud moisture control in the overall control scheme, whether traditional control or MPC is used. Presently, the (cet) loop, perhaps unknowingly, serves as a surrogate for mud moisture, while primarily being used for temperature profile control. However, during unsteady state operation, the (cet) exhibits a very poor correlation with moisture; and in addition, there is no method for automatically and correctly adjusting the (cet) setpoint for evaporative load disturbances. Fortunately, there exists a highly effective moisture control system, validated by numerous applications on industrial dryers, that solves these two basic problems with the (cet) loop with regard to moisture sensing and control. This technology and a limited trial on an operating kiln are described; also, inclusion of effective moisture control in the overall control scheme is recommended for systems using either external or internal drying.

INTRODUCTION

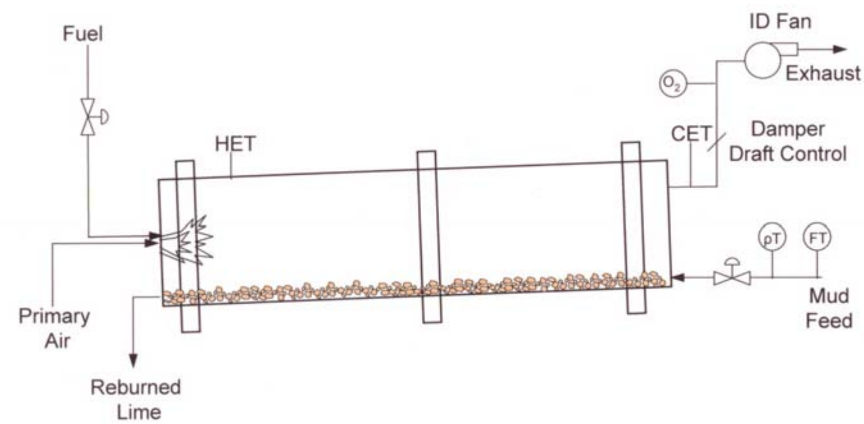
A Lime Mud Kiln operation includes a series of three unit operations (zones): drying, heating, and calcining as depicted by figure (1). The mud drying operation is performed either in the first zone of a kiln, or in an externally located suspension (flash) dryer.

Figure (1) – Lime Mud Kiln Operating Zones



These three unit operations proceed inside the lime kiln as depicted by figure (2)—a large, rotating, cylindrical, vessel of finite length and diameter The control objective is to convert lime mud into high-quality, calcined lime while minimizing ring formation, excessive dusting, and un-oxidized sulfur emissions. Considering the many variables and constraints involved, producing high quality lime presents a significant process control challenge.

Figure (2) – Lime Mud Kiln
(Temple-Inland's No.3 Lime Mud Kiln --1994 – 1995)



TRADITIONAL LIME KILN CONTROL

Traditional lime mud kiln control is based on maintaining a temperature profile along the length of the kiln that produces a good quality lime product. Two control loops are used: (1) the hot end temperature (het) loop (figure 3) insures that the proper temperature is maintained for properly calcining the lime as measured by the carbonate content of the finished lime; and (2) the cold end temperature (cet) loop (figure 4) is used to maintain the proper temperature profile along the kiln length by maintaining a (cet) setpoint for a given production rate. Since the exhaust temperature from industrial dryers under ideal conditions correlates fairly well with the product moisture exiting the dryer, the traditional practice of controlling to a (cet) setpoint may be an attempt to use it as a surrogate for mud moisture content at a given evaporative load. If the evaporative load to the kiln is increased by an increase in mud moisture or production rate, the (cet) will immediately decrease and the control action will pull more heat to the feed end to handle the extra drying load. If the evaporative load decreases, less heat is needed at the feed end so the (cet) increases, and the control action reduces the draft to pull less hot gas to the feed end. Moisture control is in the right direction, but there are serious problems with its ability to accurately control mud moisture. This will be addressed below.

Figure (3) – Traditional Hot End Loop

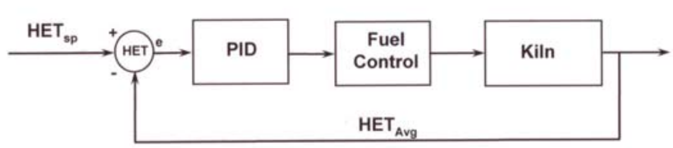
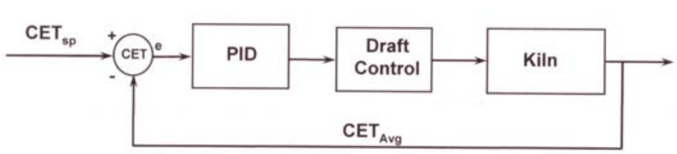


Figure (4) –Traditional Cold End PID Loop



A. PROBLEMS WITH TRADITIONAL CONTROL

Two main problems are present when a (cet) loop is used under unsteady state conditions: (1) the correlation between moisture of the product exiting a dryer and the exhaust temperature (cet) is extremely poor; and (2) when the evaporative load changes enter the kiln, the previous (cet) setpoint is no longer valid and must be properly adjusted to produce the target mud moisture. However, there are no methods available for automatically and precisely making such adjustments. The operator must hunt for the correct setpoint following disturbances to the system. The combined effect of these two inherent weaknesses in the (cet) loop is that moisture control of the mud is ineffective, thus any moisture related problems present in lime mud operation are not effectively addressed.

B. PROPOSED SOLUTION

It has been reported[1] that the two major lime mud kiln operating problems that reduce the quality of re-burned lime—ring formation and dusting—are moisture related. Since mud drying is involved, it is suggested that uncontrolled moisture swings in the mud moisture entering the drying zone ultimately cause swings in the time-temperature parameter of the calcining zone, thus adding an additional moisture related problem. Therefore, it appears that the key to significantly improving lime mud kiln operation is to improve moisture control of the mud inside the kiln or exiting the pre-dryer. Since it has been previously pointed out that the (cet) loop suffers from two inherent and significant weaknesses, it follows that if a moisture control system could be found that solves these two moisture control problems, it would be advantageous to include it in existing lime mud kiln control systems.

Fortunately, patented [2] moisture control technology exists in the industrial drying industry that solves these two problems present in the (cet) loop

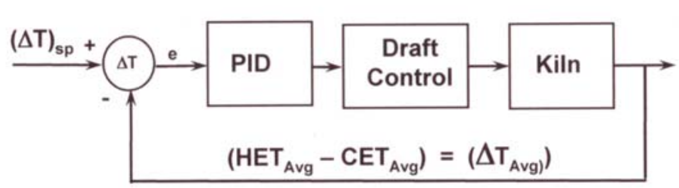
The Delta T Moisture Control System is based on a first-principles-derived mathematical model[3]

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

that relates the product moisture (MC) exiting a dryer to the temperature drop (ΔT) of hot air after contacting the wet product, and the production rate (S).

This control system has been validated by several hundred moisture control applications for various products being dried using a variety of dryer-types.[4, 5] The moisture sensor consists of two temperature sensors and the model; therefore, it can operate inside the harsh environment of a lime kiln or pre-dryers. It is highly accurate and never requires re-calibration. The control algorithm enables automatic adjustment for evaporative load adjustments. Figure (5) depicts the delta t loop that would replace the (cet) loop when drying is conducted inside the kiln rotating shell. For application to an external suspension dryer, the delta T term would be the difference in the hot gas entering the dryer and the temperature of the exhaust temperature leaving the cyclone. It should be noted that raw delta t data must be processed by the model before it gives valid results.

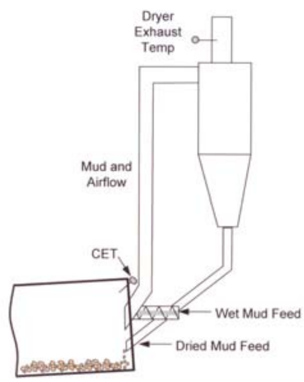
Figure (5) – Delta T PID Loop



CONTROL OF MUD MOISTURE FROM A PRE-DRYER

The (het) loop would be used to properly calcine and reburn the lime. The (cet) loop would be replaced by the delta t loop for the control of the mud moisture leaving the dryer. The delta t process variable is obtained by continuously measuring the difference between the hot gas temperature (T_h) entering the suspension pre-dryer and the temperature of the cooled gas (T_c) exiting the dryer exhaust. This difference, $((T_h - T_c) = \Delta T$ = delta t, is the process variable for the delta t moisture control loop. A proprietary one-time calibration method for a given dryer and product would be used to establish a delta t setpoint for a given production rate. Thereafter, the setpoint would be automatically adjusted (using proprietary means) for changing operating conditions. The control objective would be to reduce the variation in mud moisture exiting the pre-dryer (figure 6) to prevent or significantly reduce variations in the calcining time-temperature parameter such that water related problems—ring formation, dusting, and variable calcining zone length—would be significantly reduced or eliminated.

Figure (6) – Suspension Dryer with Temperature Sensors for Moisture Control



MOISTURE CONTROL TRIAL ON A LIME MUD KILN

A US DOE sponsored trial was conducted on Temple-Inland's No. 3 Lime Mud Kiln at its Evadale, TX Pulp and Paper Mill during 1994 and 1995. This trial replaced the (cet) loop with a delta t loop (het – cet) loop. Trial runs were conducted for several weeks with no apparent operating or quality problems. The kiln was old, with no capability for regulating secondary air, and was slated for replacement soon thereafter. The scope of the trial was limited to determining if replacement of the (cet) loop was viable and did not include checking results on lime quality; however, no complaints were received in this regard, nor were any operating problems attributable to use of the delta t loop. The results were: (1) an apparent reduction of 3 – 4% in gas usage per ton of product was measured; and (2) no difficulties were experienced using the delta t loop.

RESULTS AND CONCLUSIONS

If the main problems experienced in operating a lime mud kiln are moisture related, it would seem wise to improve moisture sensing and control of the lime mud. This is now possible using technology proven by hundreds of applications on industrial dryers. If the lime mud kiln is controlled using the traditional two-loop control system (het/cet), the (cet) loop should be replaced with a (het – cet) loop that enables "inside-the-kiln" moisture sensing, and a control algorithm that automatically and accurately adjusts the setpoint to maintain the same target moisture content. If an external suspension dryer is used, it may also be controlled using the same control system, but the delta t variable will be the temperature drop of the hot gas following contact with the wet product (see figure 6). If more sophisticated multivariable control is used, sensing and control of the mud moisture should improve its operation as well.

Due to the short drying time in a flash pre-dryer, if high mud moisture excursions are causing operating problems, perhaps a portion of the dried mud could be recycled from the cyclone and mixed with the mud feed to reduce the effect of such disturbances. This is widely practiced with great success in industrial drying, especially on suspension dryers that experience periods of high moisture feed to the dryer.

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