Improve Lime Mud Kiln Operation

Presented

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<u>Improve Lime Mud Kiln Operation</u>

By Accurately Sensing and Controlling Mud Moisture

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ABSTRACT

A Lime Mud Kiln consists of three sequential operating zones: drying, heating, and calcining. To achieve proper calcination, lime is subjected to the calcining temperature for a certain length (time) of the kiln. Since calcining is the final zone, any deviation from its required length causes variations in finished lime carbonate content. If mud moisture disturbances entering the drying zone are not effectively controlled, they will be transmitted through the kiln to the calcining zone, thus producing under or over-calcined lime. Consequently, the best moisture sensing and control technology should be considered for inclusion in the overall kiln control system. Although the (cet) method controls in the right direction, it carries two major problems that render it ineffective: (1) poor correlation between (cet) and mud moisture; and (2) no precise method is available for automatically adjusting the (cet) for evaporative load disturbances. Fortunately, a highly effective moisture sensing and control system is available that solves these two problems. It has been validated by numerous applications on industrial dryers. This technology is explained, a trial run on a lime kiln is briefly discussed, and a recommendation to include it in all kiln control system is made.

INTRODUCTION

Recognizing that major problems affecting successful operation of a lime mud kiln are sometimes moisture-related, [1] and that lime mud drying is a major unit operation involved in converting lime mud into a quality finished lime, it seemed worthwhile to investigate the feasibility of integrating the latest moisture sensing and control technology into a lime mud kiln control system.

For simplicity of analysis, the traditional, two-loop control system is used to demonstrate the importance of including improved mud moisture sensing and control as a part of the kiln control system. Although traditional mud moisture control is normally used on kilns with internal drying, any control solution developed herein should apply equally as well for kilns using external flash drying. The two-loop control system includes the hot end temperature (het) loop and the cold end temperature (cet) loop, as depicted by figures (1) and (2).

Figure (1) – Traditional HET Control Loop

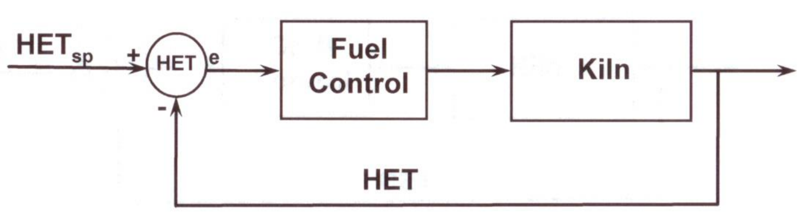
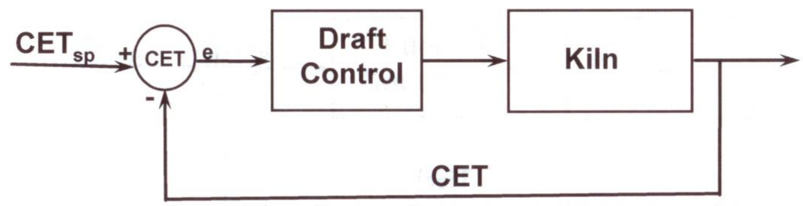
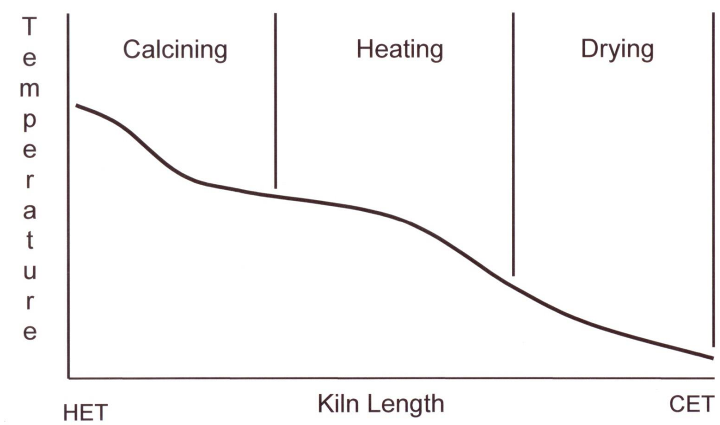


Figure (2) –Traditional CET Control Loop



A traditional lime mud kiln includes a series of three unit operations (zones): drying, heating, and calcining as depicted by figure (3). The mud drying operation is performed either in the first zone of a kiln, or in an externally located suspension (flash) dryer.

Figure (3) – Lime Mud Kiln Operating Zones
(Internal Drying)



These three unit operations proceed inside a lime mud kilnð 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, sulfur emissions, and refractory wear, etc. Considering the many variables and constraints involved, producing high quality lime presents a significant process control challenge.

TRADITIONAL LIME MUD KILN CONTROL

Production of good quality finished lime requires that it to be subjected to the proper calcining temperature for a specific amount of time. The hot end temperature (het) loop, depicted by figure (1), is used for maintaining the proper calcining temperature. The cold end temperature (cet) loop, depicted by figure (2), maintains the kiln temperature profile by controlling to a (cet) setpoint.

Assuming steady-state production of a quality finished lime, all variables, including the lengths of the three operating zones depicted by figure (3), are constant for a given mud feed rate. However, following evaporative load disturbances to the kiln, the internal kiln drying zone length, unlike industrial dryers, has the freedom to expand or contract if the moisture of the mud is not properly controlled. If this happens, the calcining zone length will change. Although the proper calcining temperature is maintained, lack of proper control of the mud moisture will cause variations in the time element of the time-temperature parameter requirement for proper calcining, thus producing a poorer quality finished lime.

MOISTURE CONTROL PROBLEM

Assuming initial steady-state operation with the two-loop, traditional kiln control system, if an evaporative load increase occurs, the (cet) loop control action increases the draft to pull more heat to the cold end of the kiln. In time the (cet) will return to the setpoint value, but this setpoint value no longer produces the same mud moisture as before. Although it controls in the right direction, the mud moisture will be higher, thus demonstrating the failure of the tenuous (cet) vs. moisture correlation. If the (cet) setpoint is not properly corrected, the drying zone length will increase, which ultimately reduces the calcining zone length (time in zone), thus producing under-calcined lime.

SIMILAR CONTROL PROBLEM IN INDUSTRIAL DRYING

A similar control problem exists in the field of industrial drying where the exhaust temperature from a flash, spray, or rotary dryer is used as a surrogate for moisture sensing and control. This is somewhat similar to the use of the (cet) as a surrogate for moisture in an attempt to sense and control lime mud moisture. It has been found by experience and by a simulation study (see Table I) that the Exhaust Temperature Method and the Air Flow Method (cet) for sensing and controlling product moisture are inherently flawed; they exhibits two problems that prevent them from being effective: (1) correlation between the exhaust temperature and moisture exiting the dryer is poor; and (2) there are no published method for precisely adjusting the setpoint for changes in operating conditions.

If the hypothesis is accepted that poorly controlled mud moisture negatively affects finished lime quality, it seems wise to investigate whether including improved moisture sensing and control in the overall kiln control system would significantly improve kiln operation.

PROPOSED SOLUTION TO MOISTURE CONTROL PROBLEM

In addition to some ring formations and possible some dusting, a third major moisture-related kiln control problemð poorly controlled mud moistureð is proposed and in need of a solution. The solution is to find a moisture sensing and control system that solves the two universal moisture sensing and control problems: (1) lack of a reliable, accurate and precise moisture sensor that can be installed inside the harsh environment of a kiln; and (2) lack of a control algorithm that has the capability of automatically and accurately adjusting for evaporative load changes entering with the feed.

Fortunately, use of the patented [2] Delta T Moisture Sensing and Control System (hereafter referred to as the Temperature Drop Method) solves the two previously mentioned problems inherently present when using flawed alternative control methods listed in Table I below. As a result, the Temperature Drop Method has significantly improved moisture sensing and control in the field of industrial drying. This improved moisture sensing and control system is based on the first-principles-derived mathematical model[3]

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

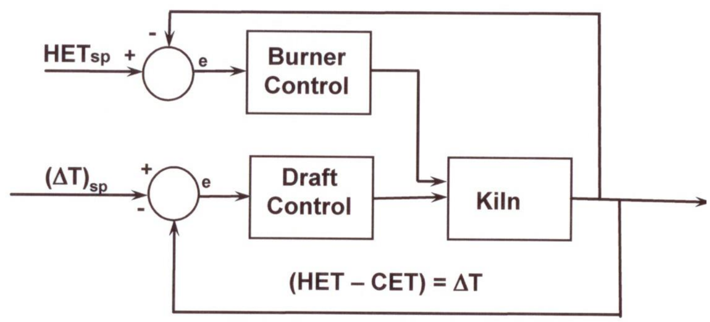
that relates the product moisture (MC) exiting a dryer to the temperature drop (ΔT) of hot air after contacting the wet product, and the production rate (S). The model also applies to indirect dryers and batch dryers.

This model-based control system has been validated by approximately 400 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-dryer. It is highly accurate and precise in sensing and controlling moisture. The control algorithm enables automatic and precise adjustment for evaporative load changes entering with the feed.

CONTROL FOR INTERNAL DRYING

Since the effect of moisture-related problems should be reduced if moisture control is improved, it is recommended that this improved moisture sensing and control technology be included in the kiln control system (with internal drying) by replacing the (cet) loop with a temperature drop loop as shown by figure (4). The (het) loop would remain unchanged.

Figure (4) – Mud Moisture Control Loop for Internal Drying



CONTROL FOR EXTERNAL DRYING

Figure (5) is a sketch of a type of flash pre-dryer for a lime mud kiln. Lime mud is introduced in the most effective way such that its breakup and entrainment by the hot gas flow carries it into the pre-dryer. The partially dried mud is separated from the exhaust gas by a cyclone and fed to the kiln. By performing a large portion of the drying externally, the kilnós production rate is increased, and the thermal energy consumption per ton of product should be significantly reduced.

The temperature drop (ΔT) control parameter for applying the improved moisture control system is obtained by continuously subtracting the temperature of the dryer exhaust temperature (Tcold) from the hot air temperature (Thot = old cet). The temperature drop value after processing by the model infers mud moisture, the drying rate of the mud exiting the flash dryer, and the change in evaporative load to the flash dryer.

Figure (5) – Sketch of a Pre-Dryer for Lime Mud Moisture Control

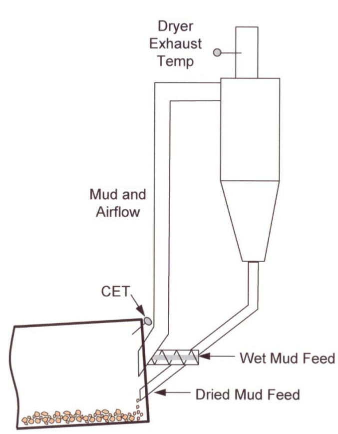
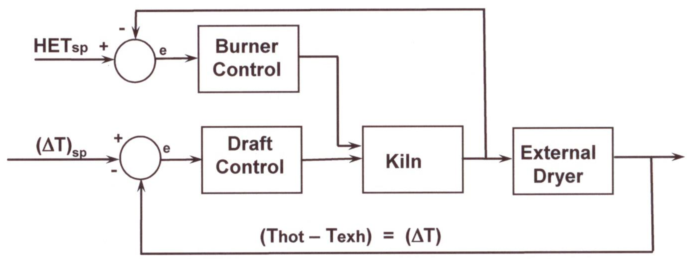


Figure (6) depicts the control loop for controlling mud moisture for a kiln using a pre-dryer.

Figure (6) – Mud Moisture Control System a Kiln using a Pre-dryer



TRIAL OF IMPROVED MOISTURE CONTROL

The United States Department of Energy sponsored a trial of the Temperature Drop Lime Mud Kiln Control System on No. 3 Lime Mud Kiln at its Evadale, TX Paper Mill during 1994 and 1995. The trial replaced the (cet) loop with the Temperature Drop loop similar to figure (4) above. 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. The scope of the trial was limited to determining if replacement of the (cet) loop was viable; it did not include checking results of lime quality; however, no complaints were received in this regard, nor were any operating problems attributable to use of the Temperature Drop Method. The results were: (1) an apparent reduction of 3 ï 4 % in gas usage per ton of product was measured; and (2) no difficulties were experienced during the trial.

EFFECTIVENESS OF IMPROVED MOISTURE CONTROL METHOD:

A comparison of three different moisture sensing and control methods was made using a dryer simulation program that used mass and energy balances to calculate the moisture of a product exiting a dryer using baseline input information. Results of the comparison are given in Table I and show that the Temperature Drop Control Method is far superior to the other two moisture control methods. This is attributed to its theoretical basis; whereas, the other two control methods have no theoretical basis at all. Note that the Air Flow Rate Method that is equivalent to the use of the (cet) loop was the worst of the three methods compared. Details of the simulation results summarized in Table I are given in the Appendix Section.

Table I
Comparison of Three Methods for Controlling Moisture from Dryers

MC Control Method	% MC Entering Dryer	%MC Exiting Dryer	MC Variance
Baseline	50	4.27	-
Exhaust Temperature	45	3.76	-0.51
	55	5.11	0.84
Air Flow Method (cet)	45	3.63	-0.62
	55	5.29	1.01
Temperature Drop	45	4.27	0.00
	55	4.27	0.00

CONCLUSIONS

Variations in the evaporative load in the mud feed to the kiln can cause variations in the calcining zone time-temperature parameter if the mud moisture leaving the drying zone or pre-dryer is poorly controlled.

The Temperature Drop Moisture Sensing and Control Method, proven in the field of industrial drying, is shown to be far superior for sensing and controlling moisture while the product is being dried; therefore, since evaporative load swings occur and need to be effectively controlled, the best available moisture sensing and control technology should be included in all kiln control system, whether they are antiquated or sophisticated.

Since some ring formation, possibly some dusting, and poorly controlled mud moisture are moisture-related, inclusion of an effective moisture sensing and control system specifically aimed at moisture control should significantly reduce the effect of these costly problems.

If excursions of wet mud feed to the kiln are problematic in the operation of a flash pre-dryer, if practicable, use a proven method in industrial drying that recycles a portion of the dried lime from the dryer cyclone for mixing with the wet mud feed.

REFERENCES

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APPENDIX

Dyer simulation method for data shown in Table I:

The dryer simulation data was produced by a dryer simulation program build around a finite element analysis method using heat and energy balances and a set of drying properties of a generic product. A set of baseline values for all variables were created to be used as targets and/or set points for the control methods. The disturbances were created by changing the feed moisture content. The input variables, inlet temperature, dry feed rate, and air flow, were manipulated to reflect the control response of the control methods. The outputs of the simulation were the outlet temperature, temperature drop, and the product moisture content. The comparison table was constructed from the results of running the simulation for each control method for increased and decreased feed moisture content. The exhaust temperature method adjusts the inlet temperature to maintain an exhaust temperature set point. The airflow is constant. The airflow method adjusts the airflow through the dryer to maintain an exhaust temperature set point. The inlet temperature is constant. The temperature drop method adjusts the exhaust temperature set point to maintain the temperature drop set point provided by the control model. The inlet temperature is constant. The airflow will be adjusted by the exhaust temperature loop.