Improving Product Uniformity & Process Efficiency in Rapidly Changing Market Conditions Using PGNAA Technology

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***Abstract* – When the Colorado cement plant was commissioned, its associated quarry and reserves made it suitable and economical to produce an ASTM Type I cement, requiring a low percentage of limestone and a high percentage of shale. As has been the case with many cement plants around the world, changing market conditions and customer demands for ever increasing cement performance forced the plant to move to Type II and Type V production and eventually oil well cements which require a much higher percentage of limestone in the mix. These demands combined with a complex quarry led the plant's management to utilize an online nuclear (PGNA) analyzer. This paper examines how the plant and manufacturer's teams worked together to meet the aforementioned demands while lowering LSF deviation and providing customers with a more uniform product.**

I. Nomenclature

Cf-252 - Californium 252
LSF - Lime Saturation Factor
PGNAA - Prompt Gamma Neutron Activation Analysis
RHEA - Raw Mix Control Software

II. INTRODUCTION

The plant was acquired in 2000 and began operations in December 1969. The entire operation occupies 2,000 acres on a significant limestone and shale outcrop called the Niobrara formation in Boulder County, Colorado. The plant serves a market area that covers the Denver metroplex, Colorado Front Range (including counties in Nebraska, New Mexico, and Kansas), and counties in Wyoming.

The plant's original 600 acre quarry was replaced in 1997 with a new 1,620 acre quarry located in the Dowe Flats Valley two miles from the plant. The old quarry was restored to lakes and rolling hills. The plant has invested significantly in protecting the surrounding environment, particularly in the reclamation of mined land at both the old and new quarries.

The cement plant has a capacity over 500,000 TPA of Portland, Low Alkali, and Masonry Cement. The majority of the cement produced is shipped by truck. The plant has recently installed new pollution control equipment. The labor force varies depending on product demand at any given time and can be as many as 100 workers.

As is the case with many cement production facilities, the Lyons Colorado plant over the years has had to deal with a complex quarry while at the same time continue to ship product to meet shifting market conditions and customer needs. In recent years this has necessitated moving to Type II and Type V product as well as oil well cements which require more limestone in the mix. The difficulty in achieving these conflicting demands with conventional manual control of raw mix led to the consideration of the use of a Prompt Gamma Neutron Activation (PGNA) online nuclear elemental analyzer to achieve its goals. After a thorough review of multiple analyzer vendors, the plant determined that one analyzer met their criteria for a high performance unit that offered ease of installation in tight quarters. Additionally, this unit did not require an external electronics cabinet or need for cabling other than the power connection and Ethernet cable to the unit.

Fig 1. Due to the modular nature of this design it can fit in a tight space

III. Technology

The analyzer is based on Prompt Gamma Nuclear Activation Analysis (PGNAA) and provides a weight percent measurement of elements in the material. The analyzer determines the composition of the material by measuring energies of gamma rays that are emitted when the material absorbs neutrons from a Californium 252 (Cf-252) source within the analyzer. Each element in the material gives off a characteristic gamma ray spectrum from which the total weight percent of the element can be determined.

<u>Prompt Gamma Nuclear Activation Analysis</u>

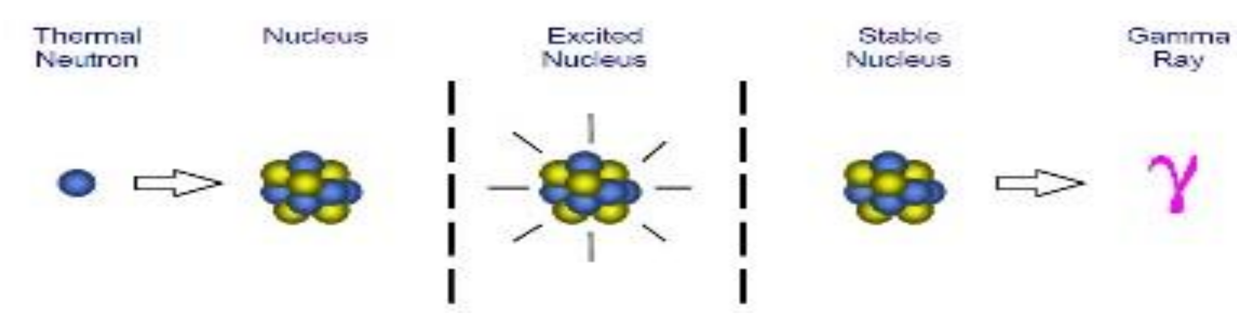

Fig 2. PGNAA Fundamentals

The analyzer can be configured to measure and display specific elements and parameters of interest such as CaO, Fe2O3, SiO2, MgO, S, TiO2, Na, and Cl.   Eighty percent of cement producers using PGNA technology use it in a raw mix sitions stream of the additive feeders.

IV. Application

Quarried and additive material consist of limestone, 2 types of shale, iron, and sand. Weigh feeders dose each material according to percentage set points onto a collection belt. This includes 2 identical feeders for limestone for the raw mill and the 2 types of shale, iron, and sand. The analyzer looks at all of the material on this moving conveyor and delivers a real-time weight percent elemental and cement quality parameter analysis. This collection belt carries the material to the dense phase pump which is used to pneumatically convey the analyzed raw mix to the kiln feed silos.

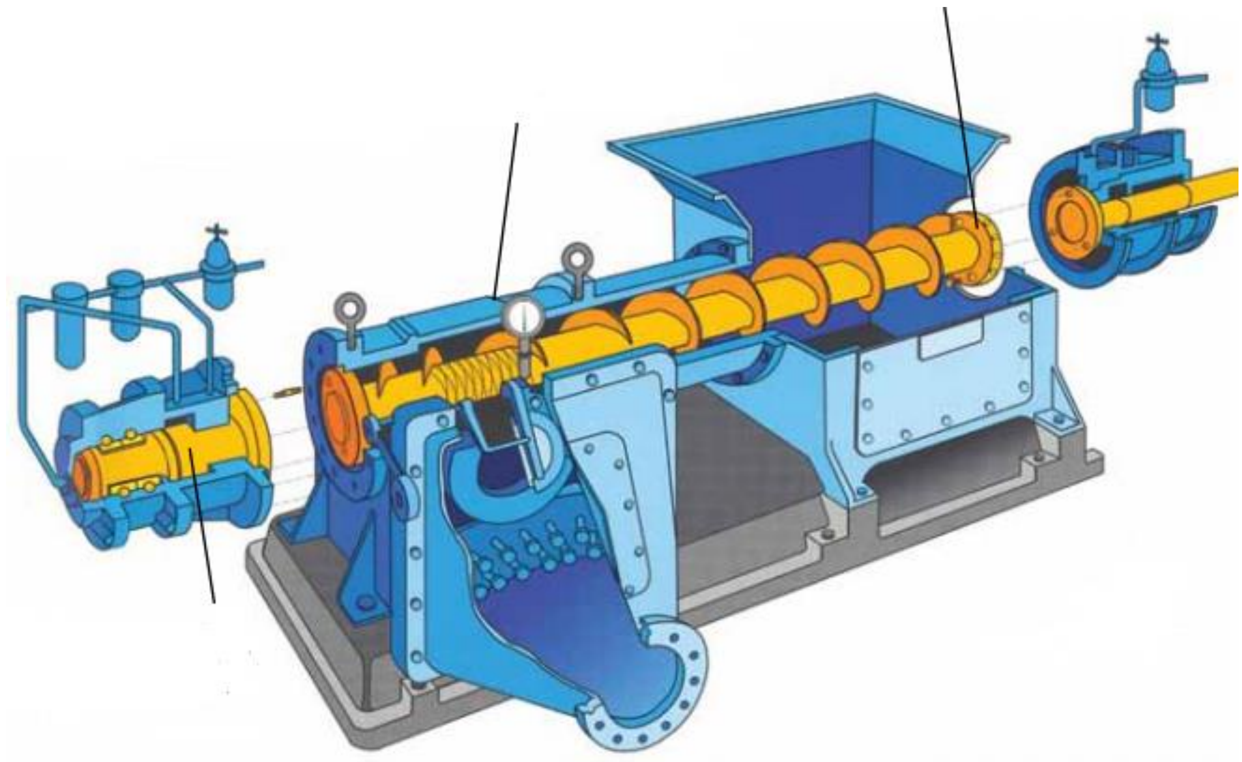

Fig 3. Pump

Historically, in order to manually control the raw mix, an analyst would collect composite samples from a sampler which has a cylinder with a slot that extends into the material stream every 5 minutes and drops into a composite can. The composite sample is analyzed every 2 hours with the use of X-ray fluorescence (XRF) in the lab. Changes would then be made to the feeders based on a set of established guidelines for the analysis results. The analyst would then call the changes to the control room where they would be entered by the control room operator. Typically this sample collection and analysis process would take 3 – 4 hours to complete including the time to do the analysis and implement the changes.

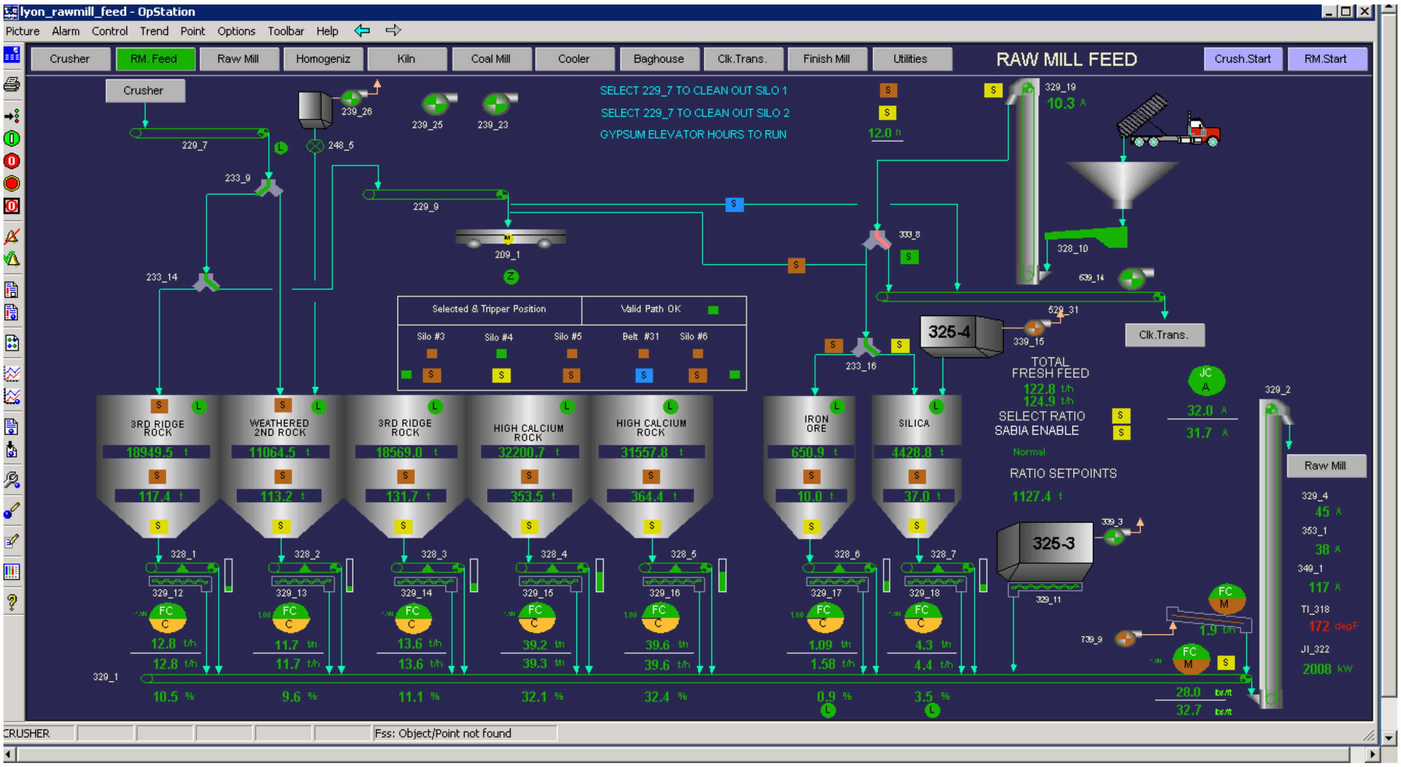

Fig 4. The plant material flow

Since the PGNAA analyzer has been installed, the raw mix control software automatically makes feeder corrections every 10 minutes. In addition to analyzing more frequently, the control software is able to make changes instantaneously, thus eliminating the sample prep time, XRF analysis, and the need to call results to the control room. The use of the analyzer and control software makes the process more responsive to fluctuations in raw material chemistry. By making small changes more frequently, the system is now able to avoid some of the large swings and overcorrections that often occur with manual control. With this real-time visibility of the process utilizing PGNAA, the plant personnel are able, for the first time, to have feed forward control and reduce the variability of their processes.

V. Control Software

The control software works in conjunction with current operating procedures to better stabilize and achieve stable operation at the maximum economic production rate for the fineness and chemical composition required with the short-term fluctuations reduced. The user interface is accessible via a web browser from multiple users each with individual permissions, security, and control access connected to the same local network as the analyzer server. Each user has the ability to customize their dashboard (figure 5) for their unique individual requirement. This has increased productivity and streamlined workflow for each individual user.

Dashboard options implemented include but are not limited to:

- Feed Rates
- Set Points
- Product / Source Profiles

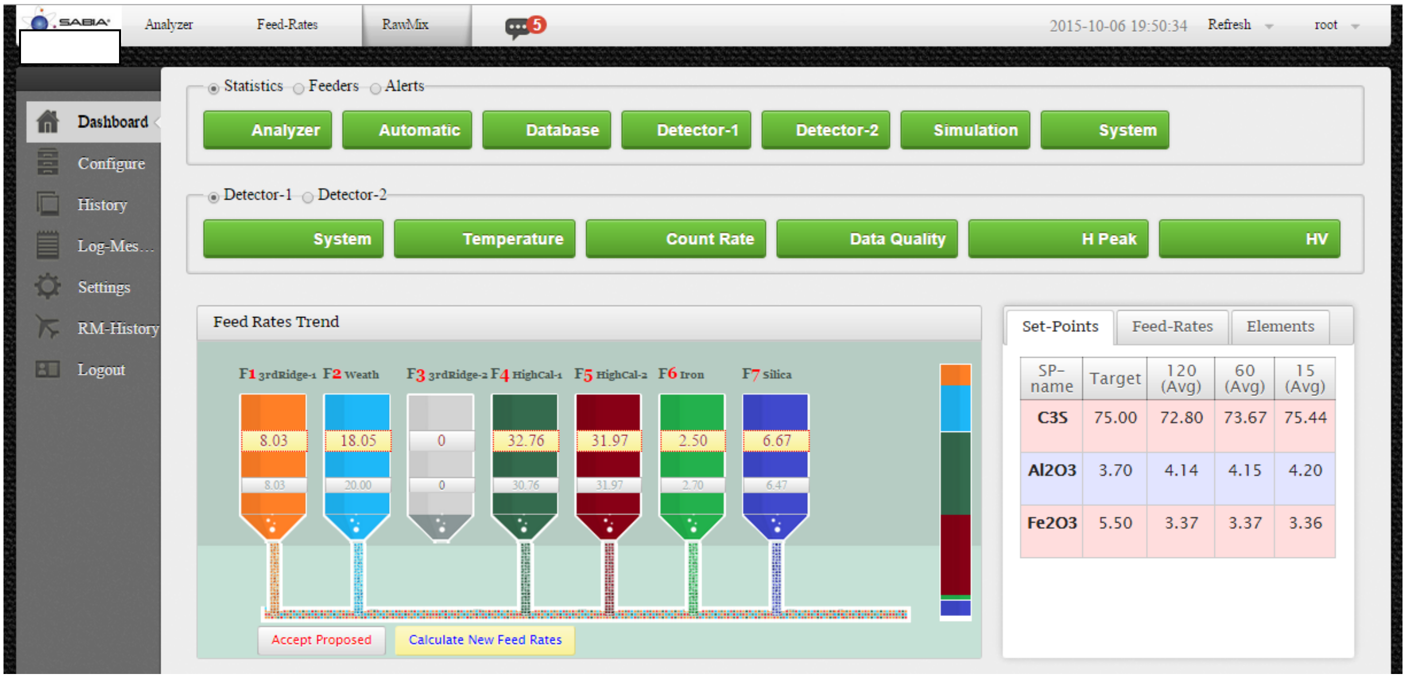

Fig 5. Customizable User Dashboard

The successful implementation of closed loop raw mix control was due in part to the teamwork between the analyzer vendor and plant personnel. During the commissioning process, the “simulation” mode feature was used to test potential adjustments and see what results would be expected for fine tuning the parameters.

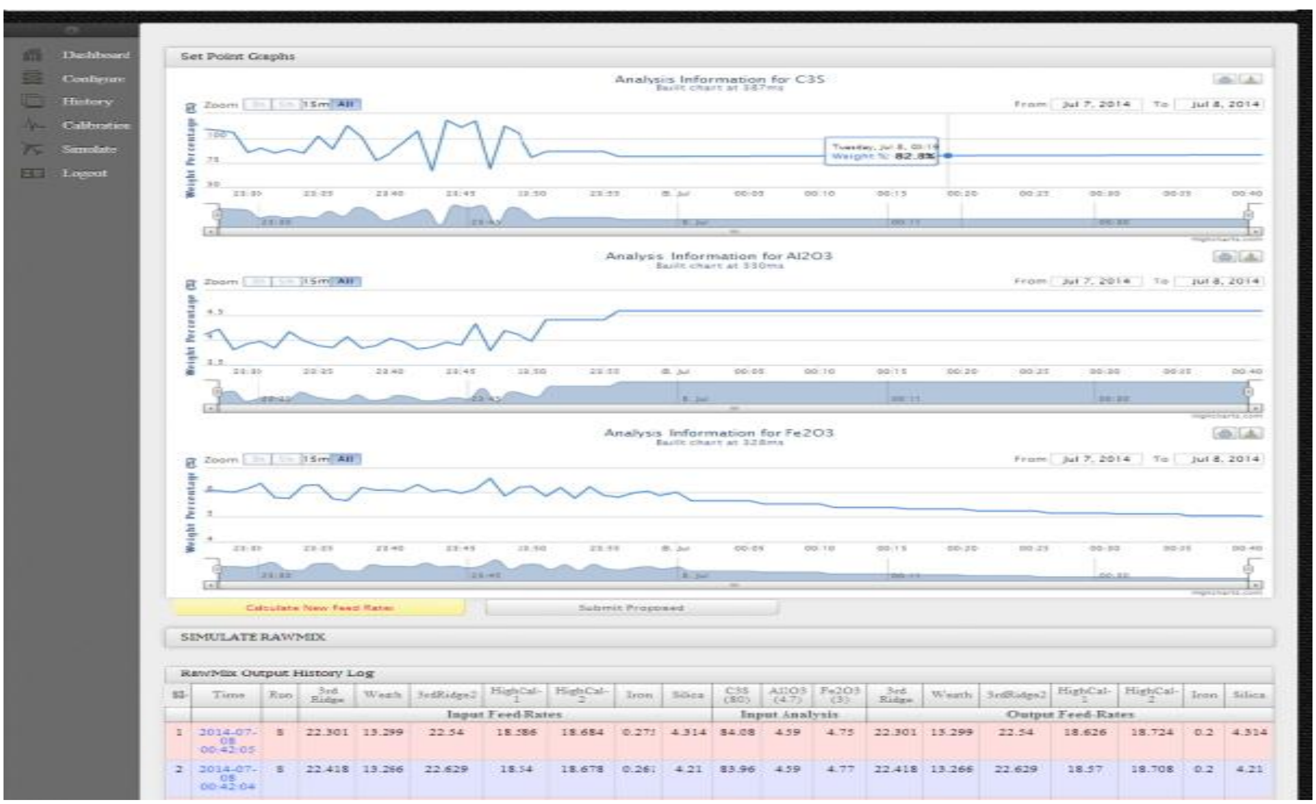

Fig 6. Simulation Mode

For real-time testing, large scale change adjustments, and tweaks before the automatic modes were enabled by the site personnel, the feed rates were inputted in "manual" mode for each feeder as shown below:

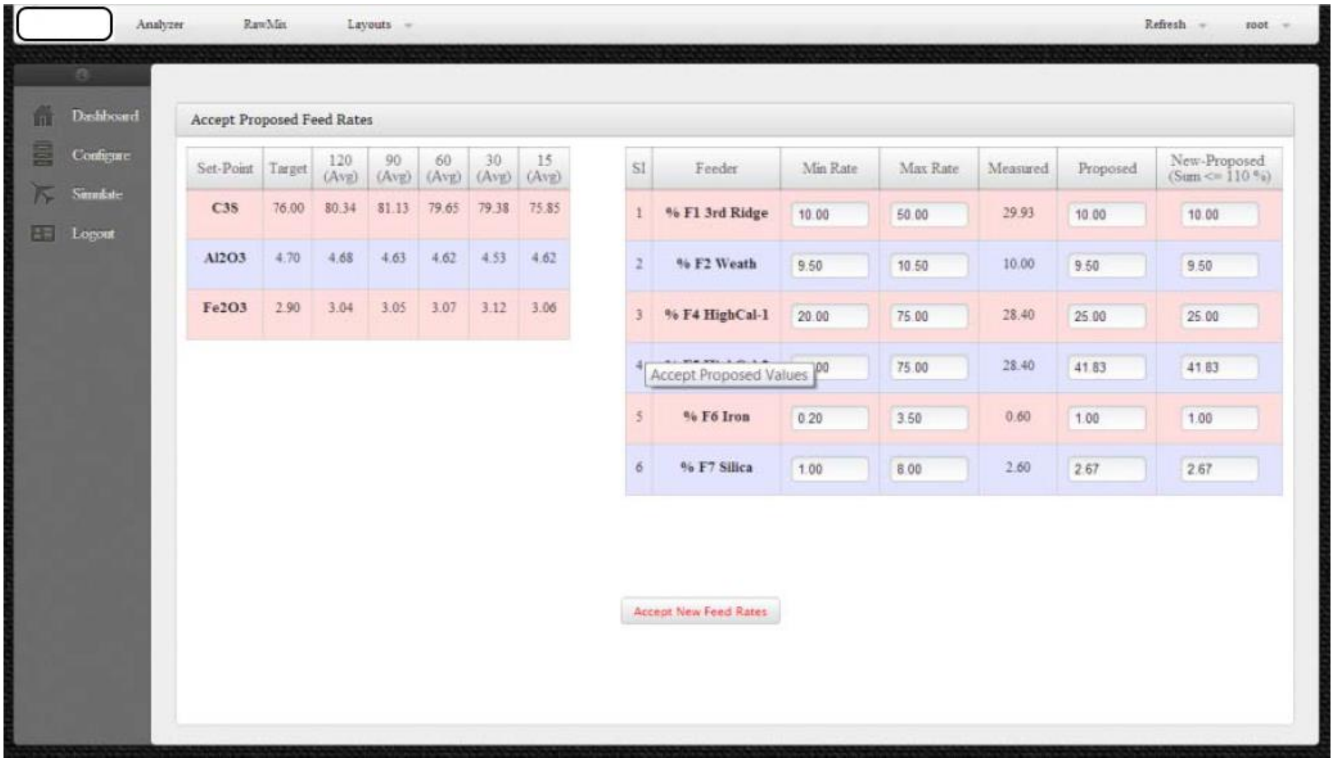

Fig 7. Manual Mode

In ideal circumstances a PGNAA analyzer can be installed for automated closed loop raw mix control without the above step being taken but is safe to assume in most cases the results is not optimal. The Bias Based PID Control Software works based off a self-learning multi-variable predictive algorithm. With these extra steps taken by the users, this has provided stability in their raw mix operations.

The charts (Fig 8 and 9) show the daily LSF deviations and moving averages for Mix A (Type II) and Mix B (Class C oil well mix) sampled at the raw mill. The dotted red line indicates the time when the PGNAA (May 2014) was installed.

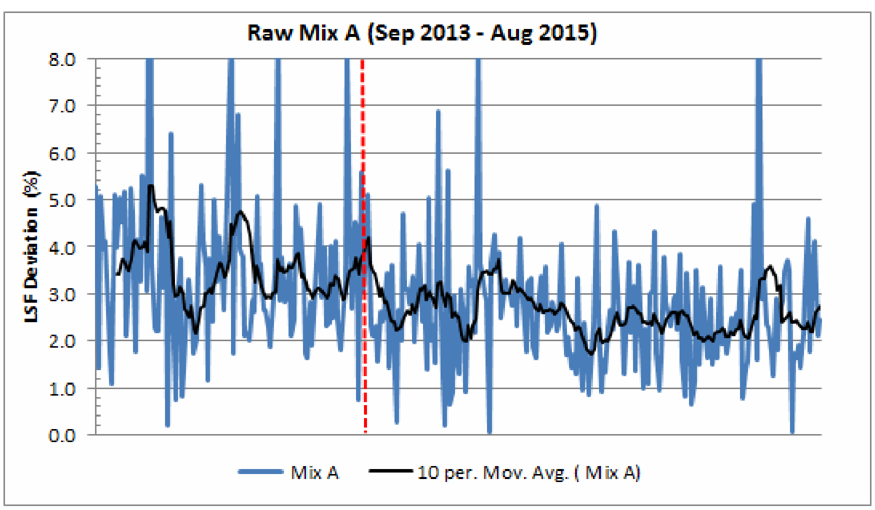

Fig 8. Raw Mix A

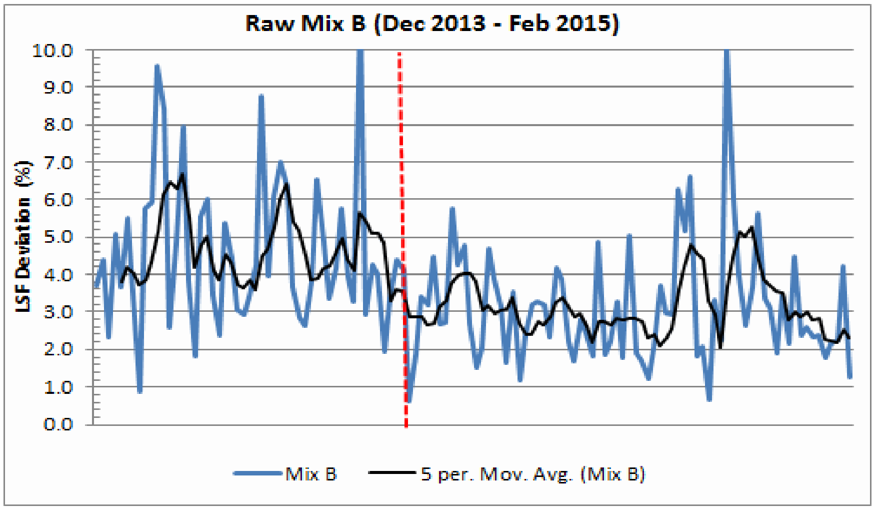

Fig 9. Raw Mix B

The data shown is unfiltered for days and when the raw mill uptime was relatively poor or for events of silo contamination and feeder starvations due to mechanical issues.

Table 1 shows % LSF deviation at two sampling points (raw mill & Kiln feed) before and after the installation of the PGNAA analyzer. It can be inferred that conservatively a minimal 30% reduction in LSF deviation can be achieved with a PGNAA analyzer even in challenging applications.

Table 1: LSF Deviations before and after PGNAA

%LSF Deviation				
	Mix A		Mix B	
Sampling Point	*Raw Mill*	*Kiln Feed*	*Raw Mill*	*Kiln Feed*
Before PGNAA	3.55	2.28	4.58	3.0
After PGNAA	2.60	1.57	3.11	1.96
% Reduction	27%	31%	32%	35%

Conclusions

As shown by the results the plant achieved a significant reduction in C3S variability enabling the plant to deal effectively with changing market conditions, customer demands and positioning them to take on future challenges with confidence. A PGNA analyzer controlling the C3S target on raw mix in a closed PID control loop can achieve dramatic improvement in the control of kiln feed.

Acknowledgment

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