

Efficiency of PrepMaster Analytics Rawmix Control with PGNAA Cross-Belt Analysis

Abstract

Consistent kiln-feed chemistry is essential for stable burning conditions and uniform clinker quality. This Application Note presents a case in which PrepMaster Analytics (PMA) Rawmix leverages cross-belt PGNAA measurements to optimize feeder setpoints and adapt material oxide vectors in real time. Compared to manual control, the PMA-driven system reduced Lime Saturation Factor (LSF) setpoint deviation by up to 80% and lowered variability (RSD) from ~9.5% to ~1.5%. Silica Ratio (SR) dispersion also declined. These gains are consistent with best-practice reports for online-analyzer-assisted raw-mix control. The note outlines the architecture, method, and results, and provides guidance for deployment and expected benefits.

Key words

• Rawmix control • PGNAA • Cross-belt analyzer • LSF • Kiln feed • Kalman filtering

Background & Problem Statement

Raw material variability—arising from quarry heterogeneity, alternative fuels and feeds, or corrective additives—directly impacts kiln-feed chemistry. When control relies on infrequent lab results and manual setpoint changes, the system tends to oscillate or run off target, leading to higher fuel consumption, cement quality swings, or increased corrective dosing. A PGNAA cross-belt analyzer provides continuous online chemistry before the raw mill silo, but realizing the full benefit requires a controller that can translate measurements to actionable feeder setpoints while honoring plant constraints.

Solution Overview (PMA Rawmix & PGNAA)

PMA Rawmix is a supervisory, model-based controller integrated with a cross-belt PGNAA analyzer. Every analyzer update triggers a feed-forward optimization of the upstream feeders to hit operator-defined targets (e.g., LSF, SR) within move limits and capacity bounds.

Adaptive Material Tracking (AMT) refines each material's oxide vector using the measured pre-CBA blend and known feeder rates. This adaptation reduces prediction error when quarry or slag chemistry drifts, minimizing controller hunting and improving stability.

System Architecture & Control Concept

In the representative system, feeders F1–F4 combine upstream of the PGNAA analyzer; feeder F5 is added downstream (Figure 1). The analyzer’s 10-minute rolling average is time-aligned with a ~1-minute process delay. Because F5 is post-CBA, its chemistry is not seen by the analyzer; PMA explicitly accounts

for this via mass balance to achieve the final kiln-feed indices.

Mass-balance for the final kiln-feed chemistry:

$$c_{final} = \frac{\dot{M}_{pre} c_{pre} + \dot{m}_5 c_5}{\dot{M}_{pre} + \dot{m}_5}$$

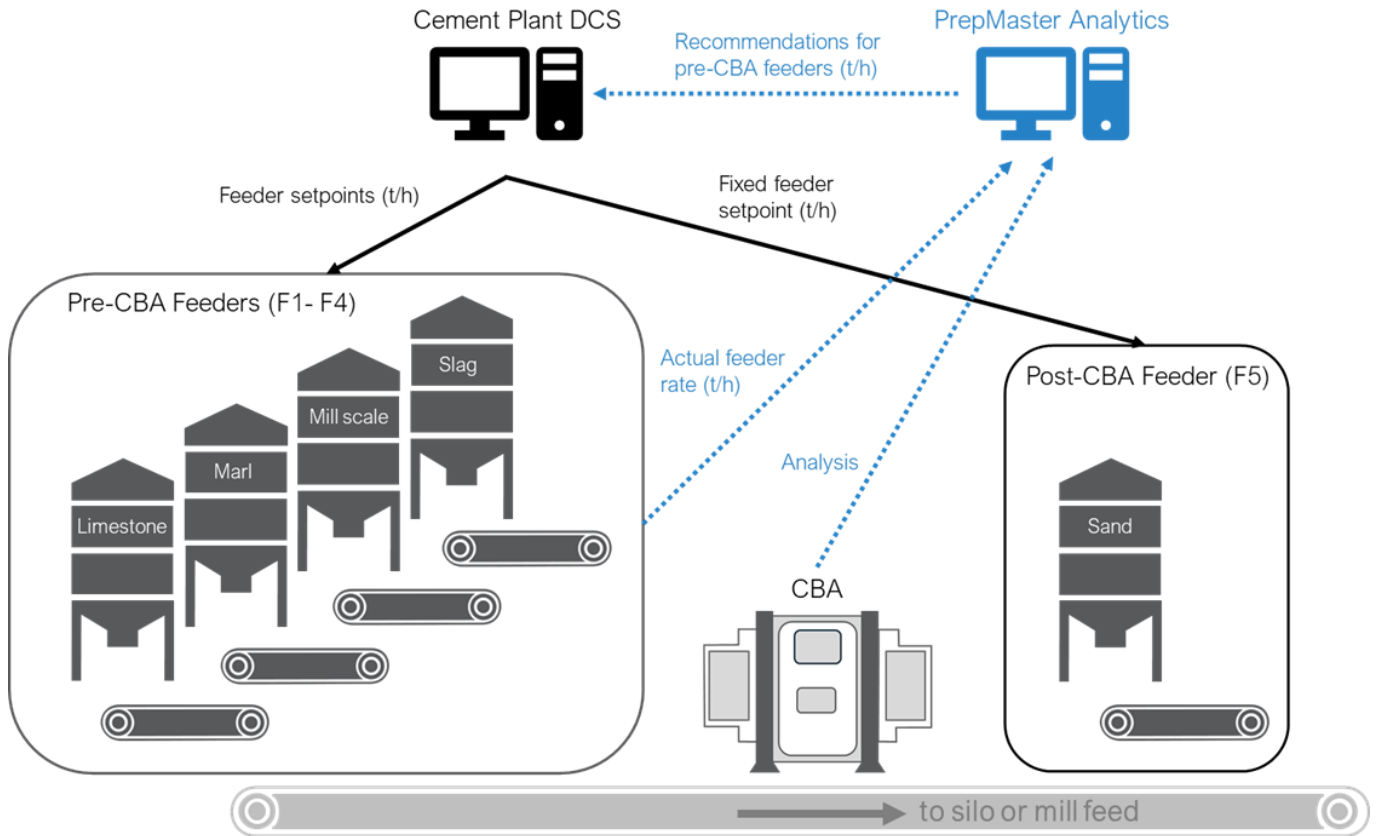


Figure 1: System architecture. PMA Rawmix Module optimizes F1–F4 from CBA chemistry and compensates the post-CBA feeder F5 via mass balance; signals via OPC UA to/from the DCS.

Signals are exchanged with the plant DCS via OPC UA, i.e. feeder rates (Figure 2), status, interlocks; setpoint outputs. Constraints include feeder min/max capacities and rate-of-change limits; the optimizer respects both.

Methods & Evaluation Protocol

We compared automated PMA control to manual operation using analyzer-derived LSF and SR time series. Metrics included setpoint deviation and variability (relative standard deviation, RSD). To assess AMT trend quality, we compared predicted oxides to PGNAA measurements and separated instrument noise from process movement using variance estimates and noise-corrected RMSE/R².

Finally, we evaluated the influence of measurement noise on LSF and SR using a simple Kalman estimator over ~40 hours.

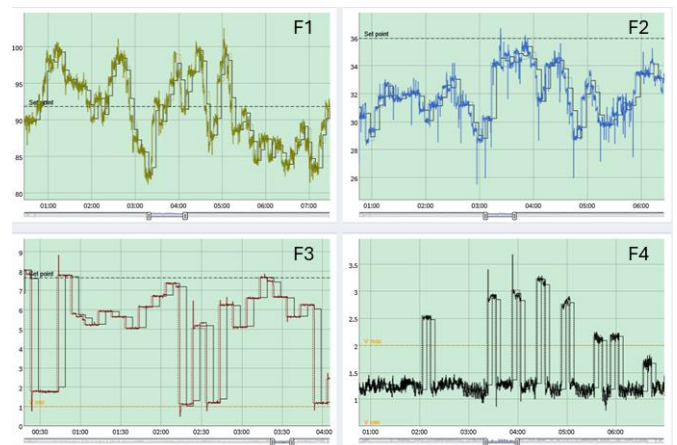


Figure 2: Feeder-rate traces (F1–F4) following PMA Rawmix recommendations

Results for LSF and SR Control

Under automated control, average LSF deviation fell to as low as ~1.5 points from ~8.5 points in manual mode; SR deviation decreased

from ~0.23 to ~0.17 points (Figure 3 A and B). Variability declined from ~9.5% to ~1.5% for LSF and from ~10.0% to ~6.5% for SR.

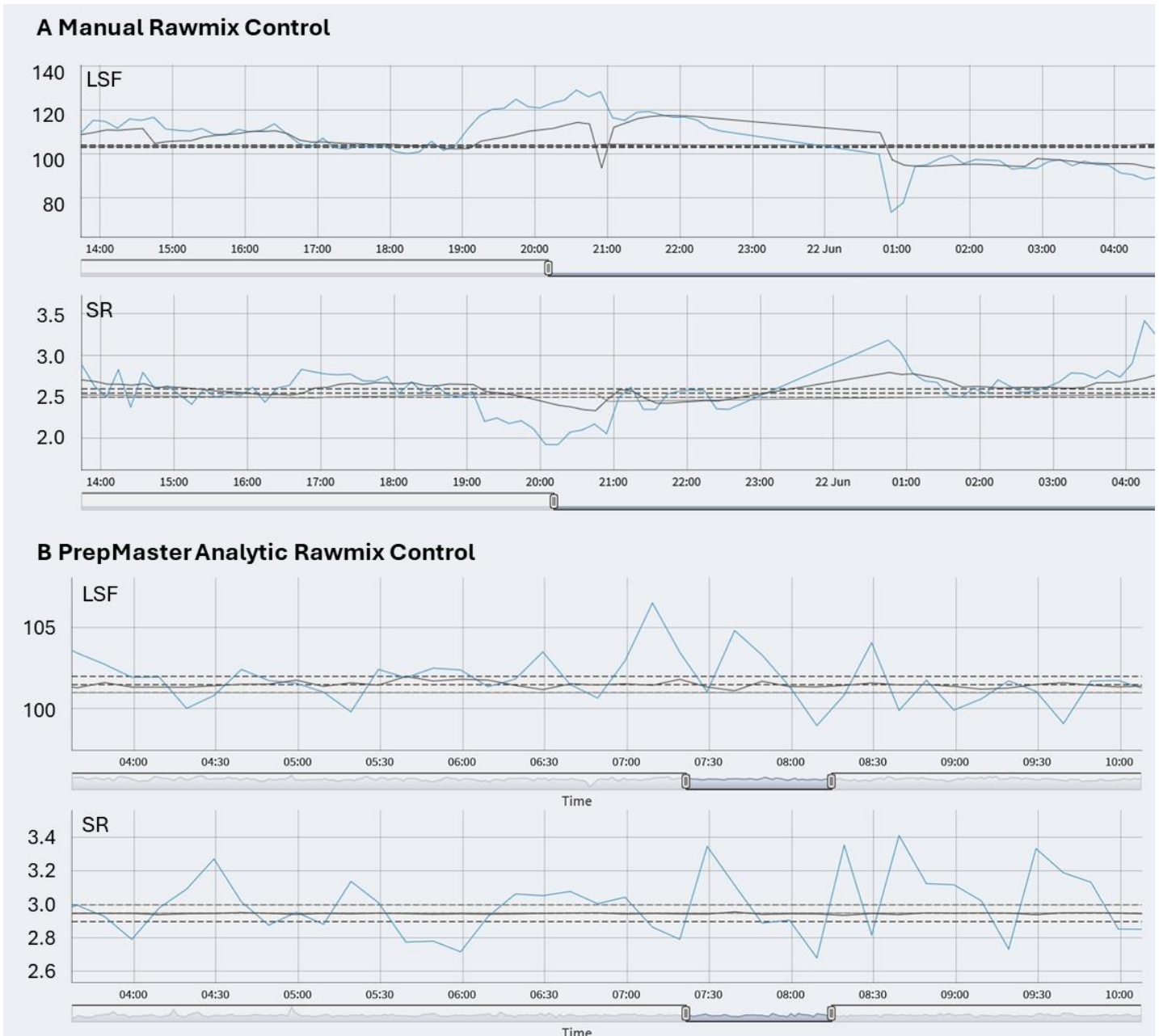


Figure 3: Typical examples of the course of LSF and SR values using (A) Manual control of the raw material feeder rates or (B) Automatic control using the PrepMaster Analytics Rawmix Module.

Abbreviations, Equations & Definitions

AMT	Adaptive Material Tracking
CBA	Cross-Belt Analyzer
PGNAA	Prompt Gamma Neutron Activation Analysis
PMA	PrepMaster Analytics
RSD	Relative Standard Deviation

$$LSF = \frac{CaO \cdot 100}{2.8 \cdot SiO_2 + 1.18 \cdot Al_2O_3 + 0.65 \cdot Fe_2O_3}$$

$$SR = \frac{SiO_2}{(Al_2O_3 + Fe_2O_3)}$$

Kalman estimate: Best current guess of a system's state, blending a model prediction with a noisy measurement by their uncertainties.

Results for Adaptive Material Tracking

Predicted oxide values followed the measured values (Figure 4). Across the major oxides, the noise-corrected R^2 was high, and the noise-corrected RMSE was at or close to the PGNAA

noise floor. After removing the instrument noise, little unexplained variance remained—i.e., the red AMT curve captured the low-frequency process trend in the grey PGNAA trace.

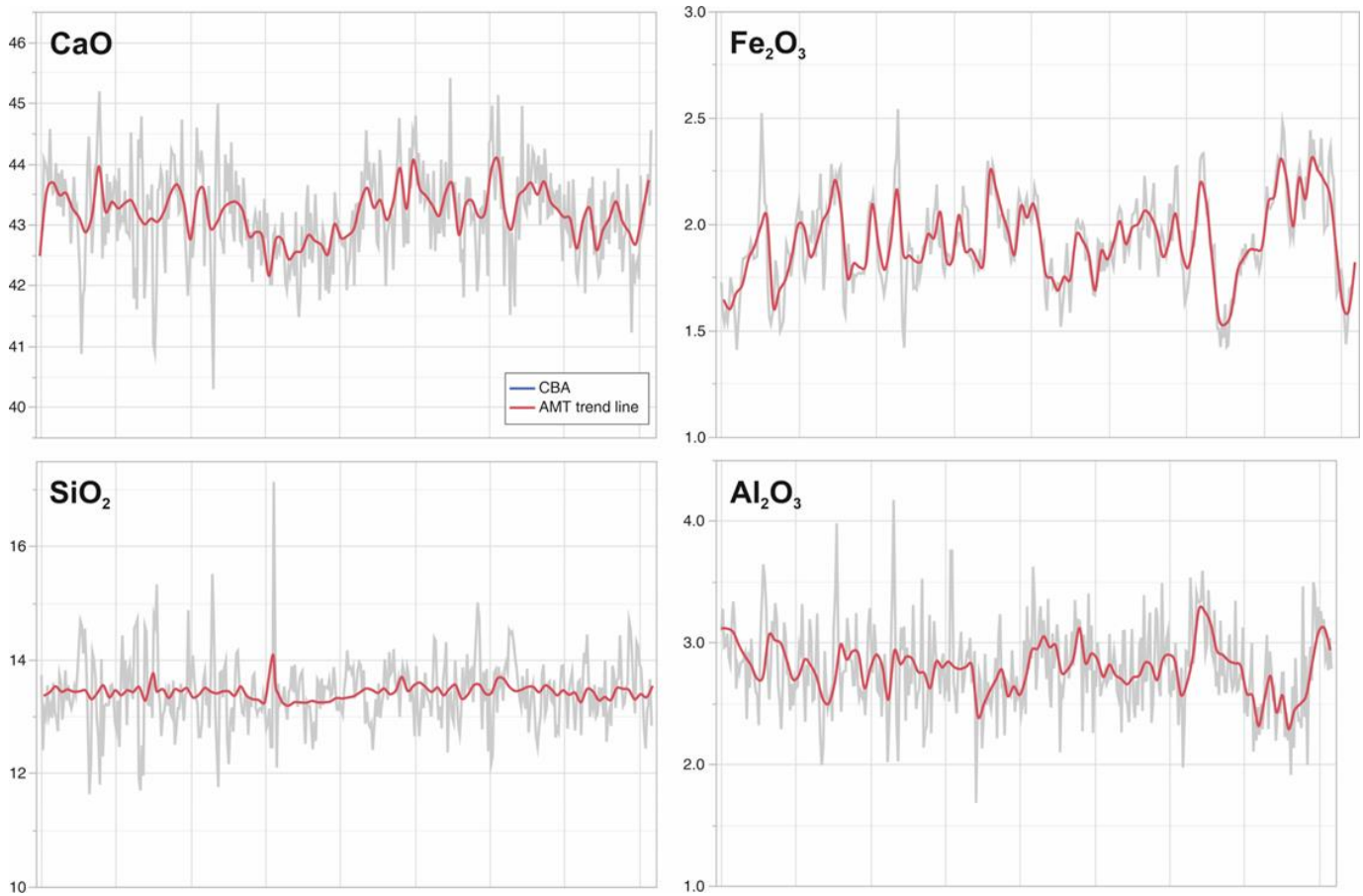


Figure 4: Graph of AMT trendline vs PGNAA values: AMT trendline (red) closely follows measured PGNAA values (grey); after noise correction, R^2 is high and RMSE near the analyzer noise floor.

Results for Adaptive Material Tracking

Kalman estimates suggest LSF variance was mostly process-driven (~70% process vs. ~30% measurement), while SR dispersion was more measurement-limited (Figure 5), consistent with Al_2O_3 's low absolute fraction and higher relative noise contribution.

Discussion

The PMA Rawmix controller achieved a good-to-very-good effect on kiln-feed stability. In our case, the average LSF deviation was reduced by up to 80%, and variability dropped to an RSD of ~1.5%. These outcomes align with -and in parts exceed- published reports on modern rawmix control with online PGNAA, which frequently cite ~50–60% reductions in LSF variability. Reaching ~1.5% LSF dispersion is consistent with “clean-belt” benchmarks and indicates that the upstream blend presented to the silo is already well conditioned.

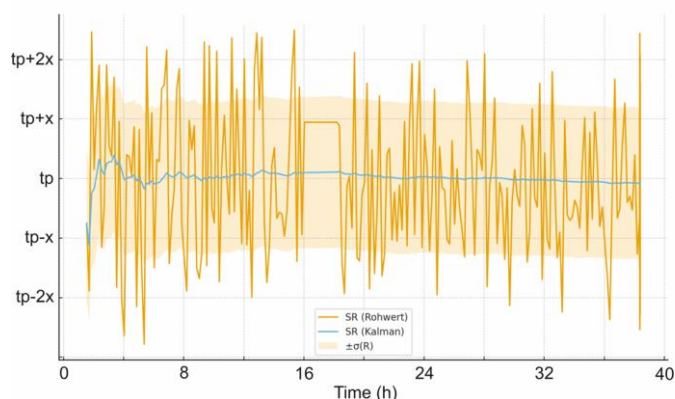


Figure 5: Kalman variance split showing that SR is measurement-limited.

A central enabler is Adaptive Material Tracking (AMT). By continuously updating each source's oxide vector from the measured pre-CBA blend and the actual feeder rates, AMT compensates gradual chemistry drift in quarry or slag streams. This reduces prediction error and prevents

hunting, allowing the optimizer to propose smaller, more accurate moves within plant constraints and move limits.

SR also tightened (RSD ~10.0% → ~6.4%) while the set point deviation was reduced by ~30 %. SR remains more measurement-limited: the denominator ($Al_2O_3 + Fe_2O_3$) is small, and Al_2O_3 -typically ~2–3%- contributes a disproportionate share of analyzer noise. Few studies quantify SR noise explicitly; most focus on LSF. Our finding helps explain residual SR spread under otherwise stable control and points to possible practical mitigations (e.g., mild averaging/Kalman filtering, SR deadbands, periodic bias checks against XRF). However, these are very specific and must be customized for each plant.

In conclusion, PMA Rawmix combines robust optimization with AMT to stabilize kiln-feed chemistry, cut interventions, and support lower fuel use and tighter quality. It integrates with existing DCS/CBA infrastructure, respects plant limits, and offers a low-friction path to measurable gains- making it a compelling upgrade for plants seeking fast, defensible ROI.

References

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PMA Rawmix Performance — Stabilized Chemistry, Lower Variability

Metric	Manual Control	PMA Rawmix Control	Improvement
LSF- Deviation (points)	~8.5	~1.5	~80%
LSF- Variability (RSD)	~9.5%	~1.5	~85%
SR- Deviation (points)	~0.23	~0.17	~25%
SR- Variability (RSD)	~10.0%	~6.5	~35%

- PMA Rawmix turns CBA data into stable raw-mix control
- PMA Rawmix allows seamless DCS/OPC UA integration
- PMA Rawmix leads to fewer manual interventions, steadier burning, and more consistent clinker quality.

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