APPLICATION OF SOLBAS™ TECHNOLOGY IN THE OPTIMIZATION OF MINERAL PROCESS[1]

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Abstract
With the pressures on the producer to conserve valuable high-grade materials or to maximize output while improving the quality the need for analytical real-time chemical characterization reaches critical stages in terms of materials management and process control. Only an analytical on-line system can deliver immediate and dynamic results to allow for this and to proceed with sufficient confidence. However, there are other pressures, including the need to protect workers, avoid use of potentially dangerous excitation materials, such as radioisotopes, neutron sources of any kind, and any external materials that could be considered sufficiently hazardous to require special handling and licensing. The SpectraFlow powered by SOLBAS™ - Safe On-Line Bulk Analysis System - addresses these issues while providing unparalleled advantages in terms of accuracies, reliability, and low costs of ownership and maintenance. ABB is proud to introduce the SpectraFlow Model CM100 that is the first in a series of such safe systems. The basic technology, applied for the first time for bulk materials is a special version of vibrational spectroscopy known as NIRS, or Near Infrared Spectroscopy.
Key words: CPM solutions; On-line analyzers; SOLBAS™'s NIRS technology.

APPLICAÇÃO DA TECNOLOGIA SOLBAS™ NA OTIMIZAÇÃO DE PROCESSOS MINERAIS

Resumo
Fontes de produção têm pressionado para a obtenção da conservação do valor de materiais de alta qualidade ou pela maximização da produção em conjunto com a melhoria da qualidade. Em função desta pressão, a necessidade de uma caracterização química analítica em tempo real atingiu um estagio crítico em termos de gerenciamento de materiais e controle de processos. Somente um sistema de análise on-line pode prover resultados imediatos e dinâmicos para atender a esta necessidade com a confiabilidade requerida. Além disso, existem outras pressões, incluindo a necessidade de proteção para os trabalhadores, evitar a utilização de materiais de excitação potencialmente perigosos, tais como, isótopos radiativos, fontes de neutros de quaisquer tipos e quaisquer materiais que possam ser considerados suficientemente perigosos e requeiram licença e manuseio especial. O Spectraflow baseado na tecnologia SOLBAS™ busca atender a estes requisitos em conjunto com vantagens adicionais em termos de precisão, confiabilidade e baixo custo de manutenção do equipamento. A ABB está orgulhosa por introduzir o SpectraFlow Modelo CM100 que é o primeiro em uma série de tais sistemas seguros. A tecnologia básica, aplicada pela primeira vez com materiais de insumos é uma versão especial daespectroscopia vibracional conhecida como NIRs, ou, Near Infrared Spectroscopy.
Palavras-chave: Soluções CPM; Analizadores On-line; SOLBAS™'s technologia NIRS.

[1] *Technical contribution to the 12th Process Automation Seminar,, October 1st to 3rd 2008, Vitória, ES, Brazil*
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1 INTRODUCTION

ABB SpectraFlow CM100 Raw Material Analyzers powered by SOLBAS™ technology do not require sampling or sample preparation. The system may be used on any conveyor belt, regardless of width or belt composition, or gravity fed slurry transportation systems. The resultant data are available with consistent accuracy. This means that segregation, particle size, mineralogical variations, or mass all have low impact on the analyzer's ability to characterize the material being analyzed. The reason lies in the technology used: SOLBAS™'s NIRS is a molecular analytical technique. Since all matter in the universe is comprised of molecules, regardless of physical state (gas, liquid, or solid), the task of characterization is dependent solely on the system's ability to capture the molecular vibrational energies as expressed by the unique wave length reflectance, absorption, and emissive responses of each molecular group. Key to the quantitative and qualitative reliability of the measurements lie in the consistency of the light source (a simple off-the-shelf high-powered lamp bulb is used), it's constant high illumination, collection of the complex of spectra, and decoding of detector reports. The modeling techniques employed represent, among other means of achieving the aforementioned, the key factor for this technology works as well as it does. Whether elements, oxides, mineralogical species, or polymorphs are required for such characterization, the SpectraFlow CM100 can provide these parameters in real-time.
The system can provide these real time data, measured on line, in a standard TCP/IP format, which can be directly used in ABB's high end Automation Systems.

2 TECHNOLOGY

SOLBAS™ technology utilizes the full wide range of infrared spectra which are provided by a stabilized powerful white light source (lamp). This light illuminates the target material to be analyzed as it passes by the system on an existing conveyor belt or open gravity fed slurry feed. The infrared radiation excites vibrational oscillations of the molecular bonds in the monitored material, which results in reflection and absorption spectra that are characteristic for the analyzed materials. The Figure 1 shows a real installation of the SpectraFlow CM100.

Figure 1: SpectraFlow CM100 shown in operating mode

Different molecular bonds respond to NIR radiation at different ranges in the spectral range, both reflecting and absorbing. For each molecule, this region can be referred to as the “fingerprint region”, which is the unique area for every molecule and its bonding family. This is true for all IR regions; for the limestone materials interrogated by the SpectraFlow CM100 analyzer system, only the NIR ranges are used. When the bonds absorb the NIR radiation, they begin to vibrate. There are 3N-6 vibrations (N = the number of atoms in the molecule) for normal molecules and 3N-5 vibrations for linear molecules. The central atom is stationary, while the bonded (attached) atoms will shift (vibrate) in a mode that either stretches or bends with respect to the central atom. Motions can be symmetrical or asymmetrical. In NIR, there are harmonic motions called overtones, as differentiated from the principal, or fundamental vibration. These overtones can be several times the wave number of the fundamental. It is these overtones that are recognized in the NIR region and are of importance for measurement purposes. Previously, these overtonal regions were known as “garbage can spectroscopic regions”, because they were weaker than fundamentals and were difficult to capture. The application of the proper multivariate statistical analyses and judicious application of computer power now enables these information-packed overtones to reveal both identity and quantity of the molecular materials that produce them. The peaks of these spectral responses are broad and overlap. This was a condition that, until the application of derivative analysis, defied the ability of the system to provide reliable and reproducible results. It is the versatility of the basic nature of these harmonic overtonal groups that makes NIR practical and has led to the widespread usage of the technique in many areas. It has now been applied in an innovative manner to bulk material analysis in the SpectraFlow CM100 for the first time. As the CM100 analyses on-line in real time it avoids the need of sample preparation thus removing the possibility of error in preparation variance, as well as eliminating all errors in sample collection. Depending on the materials being analyzed, NIR can be a combination of reflectance and, if the materials are fine, there is also the capture of transmission vibrations that can be measured, increasing the information from the analyte. This combination is known as trans-reflectance, and can be useful for liquids and liquid/solid mixtures, should this be encountered in the conveyance systems. Any combination of these responses may be occurring at any time in a mass of bulk materials encountered and monitored by the SpectraFlow CM100 system, although most of the signals will be from the reflectance response. The Figure 2 shows the three different possible reflectance response:

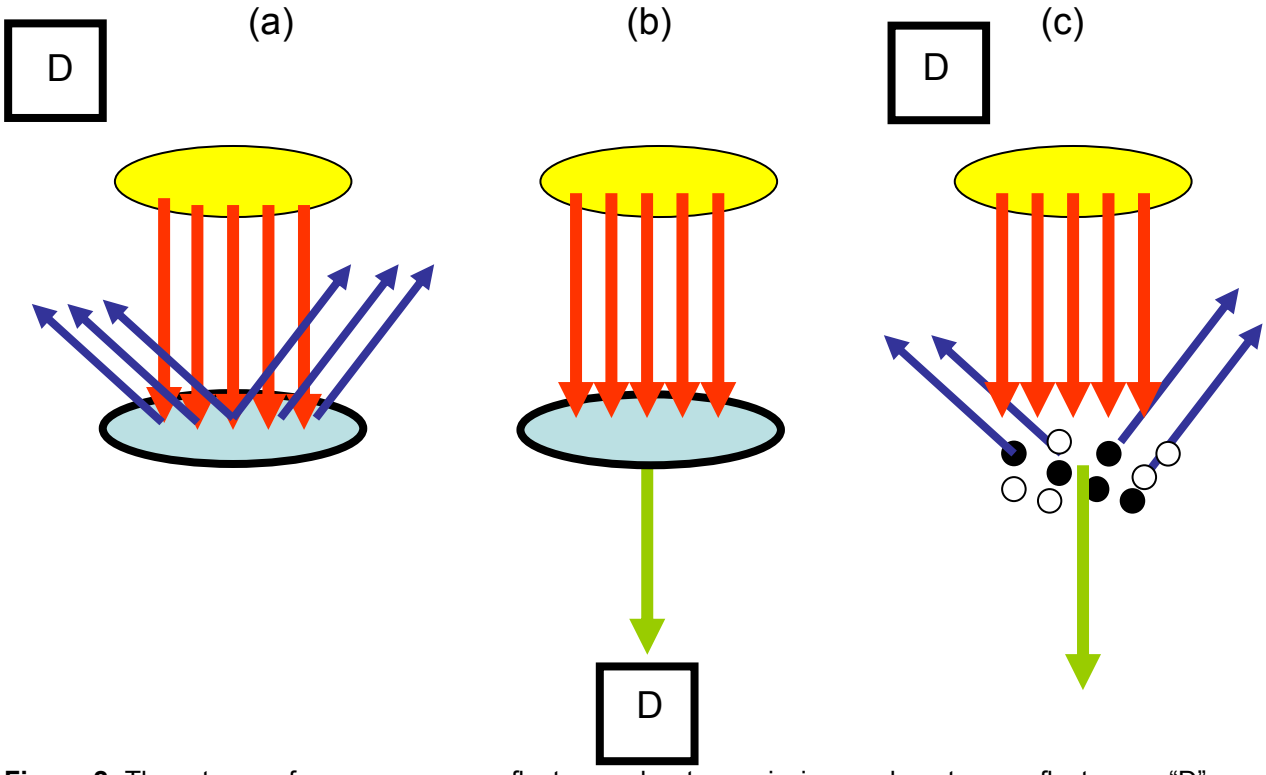

Figure 2: Three types of responses: a = reflectance, b = transmission, and c = trans-reflectance. "D" indicates possible detector position

Since there are expected differences in particle sizes in raw materials as seen in as-is condition, there will be differences in the "family" of spectra from molecules collected by SpectraFlow CM100. However, these spectral bands are still unique to the oxide (= molecule) producing them, no matter how many bands there are. The modeling technique employed in SpectraFlow CM100 is then subjected to a proper chemometric resolution, which then applies the principal of SEP (Standard Error of Prediction) to each and every such spectral band. The lowest SEP number from each of the several bands responding is the selected choice, and the remaining spectral bands will not be used and are rejected, insuring the statistical confidence to apply to each principal component (PC, as oxide, mineral, parameter, or contributing rock type). The modeling and chemometrics employed in SpectraFlow CM100 also remove isolated wave lengths from consideration as "noise", and the prevalent wave lengths consistent with the surviving regional fingerprint.

In NIR, this procedure is commonplace and is known as the "pre-processing" stage, which is a requirement for rigorous analytical results. The prediction uncertainty is computed via the well-known "root mean square error of prediction", or RMSEP. This can be refined as the "root mean square error of cross validation", or RMSECV, which is used when only a small dataset is available. Either system works, as has been shown in the testing phases of SpectraFlow CM100 with the complexity of raw materials encountered during and following the development of the analyzers.

Once the pre-processing stage has passed, the system is ready for accepting the model and comparisons with reference standards. This reduces the SEP or RMSECV to an acceptable accuracy for each principal component of interest, and the system is ready to be mounted and put into service. Interestingly, once the model has been installed, there is no need for periodic recalibrations. If new PC's are required, due to the use of different raw material constituents, the existing model can be updated and additions included in the base model. No degradation of the

model takes place, reducing the need for revisiting an existing dataset. It is this robustness of the physics of the technique that is a hallmark of the uniqueness of NIR as used in SpectraFlow CM100, making it significantly less maintenance-intensive.

3 MOUNTING

The device is mounted over an existing conveyor belt or slurry tank, without the need for any cutting, disturbances, or civil works required as there are no changes made to the conveying system. The Figure 3 shows the head of the SpectraFlow CM100 where is located the lamp, source of the infrared.

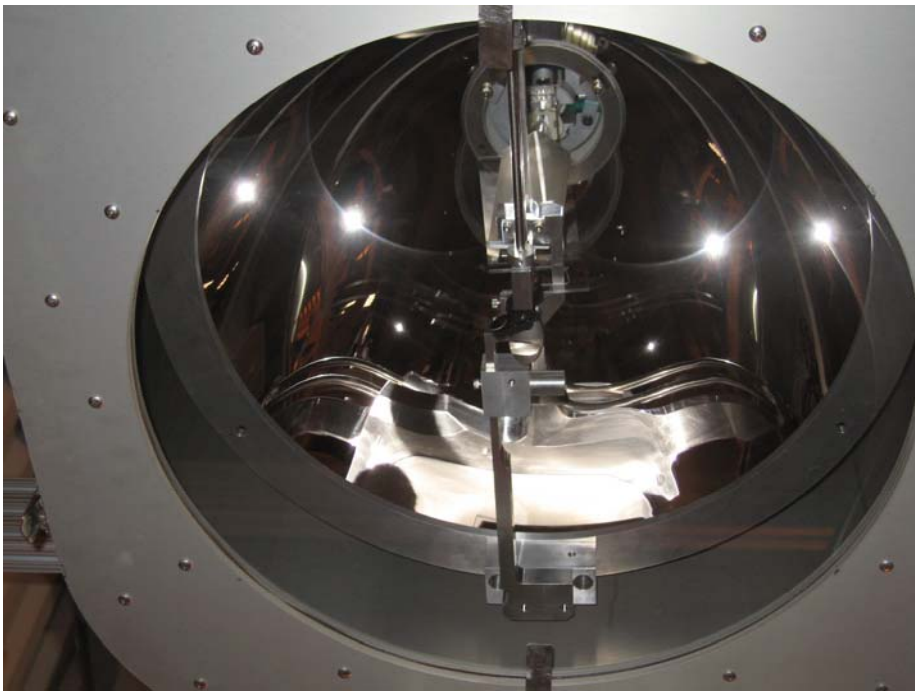

Figure 3: Illumination head of SpectraFlow CM100

The SpectraFlow CM100 device is robust and can operate successfully under all common mineral plant. For this reason, even iron-containing compositional or complete steel conveyors do not in any way inhibit the use or efficacy of the analyzing system.

The illuminating head is comprised of a light source that is designed to provide a consistent high intensity light directed on the material. Resultant reflected energies are captured by the detector collector coaxial configuration. This arrangement, along with site modeling, permits a confocal totally homogeneous zone of spectral acquisition for the material adequate for full characterization. Identification and quantification of Principal Quality Components is accomplished via the analytical model based on a representative set of training samples.

The reflective and absorptive characteristics of the materials are pre-processed in the included spectrometer package. The final material characterization is done in its controlling computer.

ABB SpectraFlow Analyzer powered by SOLBAS^{TM} technology communicates directly with the control room or office monitors via sturdy and reliable fiber optics.

The system is also equipped with remote diagnostics to minimize any servicing requirements.

4 CONFIGURATION

The Figure 4 shows a typical configuration of the control system correlated to the SpectraFlow application:

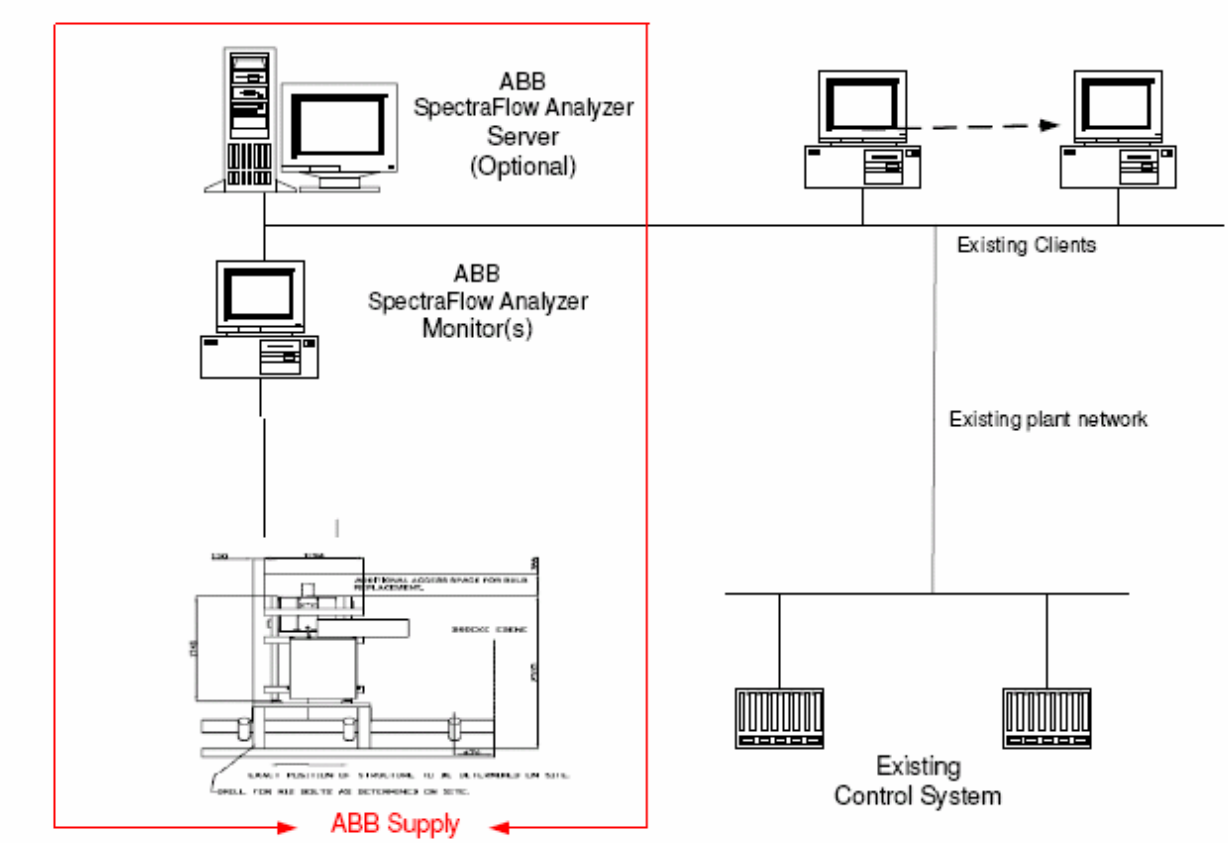

Figure 4: Typical configuration of SpectraFlow CM100

The initial configuration (stand alone system) may or may not require an independent server shown in the drawing above. The server is needed when additional analyzers are put in operation, or in combination with RMP, LIMS, or Expert Optimizer systems.

5 PERFORMANCE

Obviously, it is an interesting exercise to examine how well the SpectraFlow powered by SOLBAS™ technology CM100 compares to other on-line real-time analyzers. We installed a SpectraFlow CM100 in line with a standard operational PGNAA system and compared the synchronized results for several PQC's. The result show better or equivalent results for the standard oxides, such as CaO, shown in Figure 5. However, in Figures 6 (MgO), and 7 (Na_2O), where control for low Mg content (dolomite lenses) and control for low alkali cements were important, NIRS in SOBLAS™ technology are clearly and dramatically superior.
The Figures 5 and 6 shows a compare of the performance of SpectraFlow CM100 with the system PGNAA:

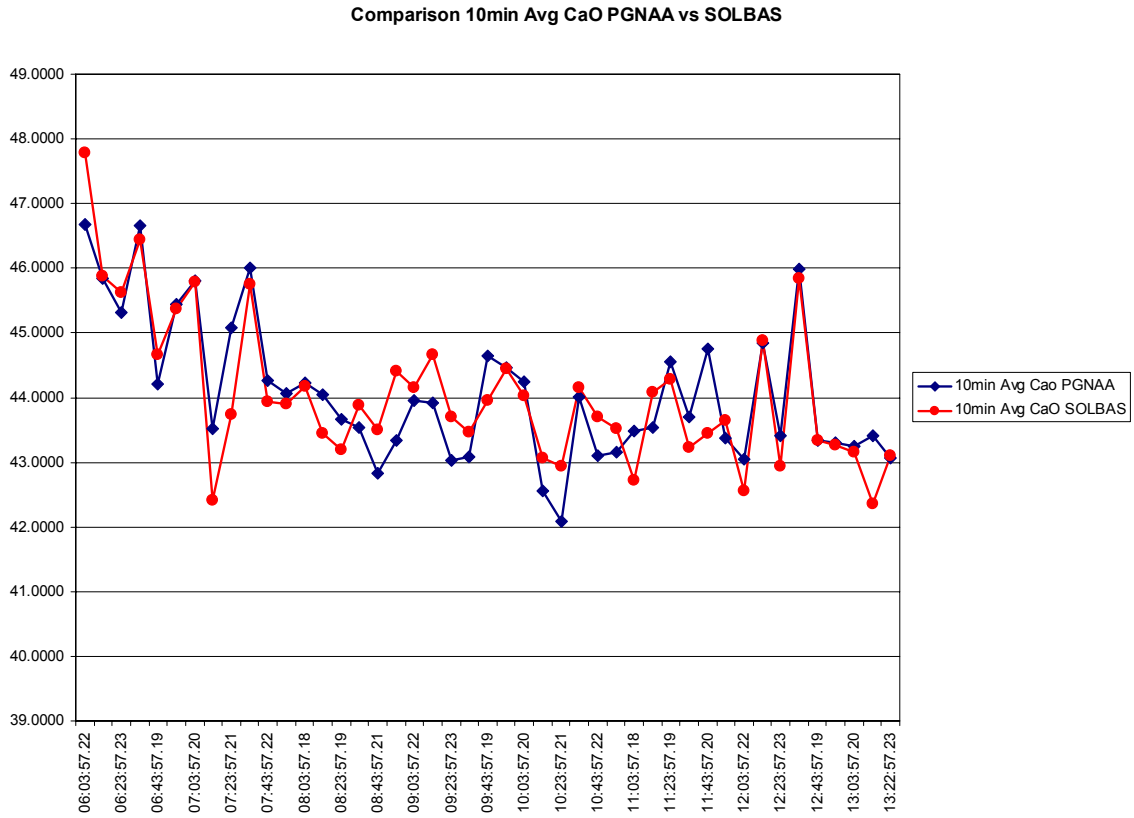

Figure 5: Comparison of Synchronized CaO content in bulk materials for PGNAA and SpectraFlow CM100 analyzer systems

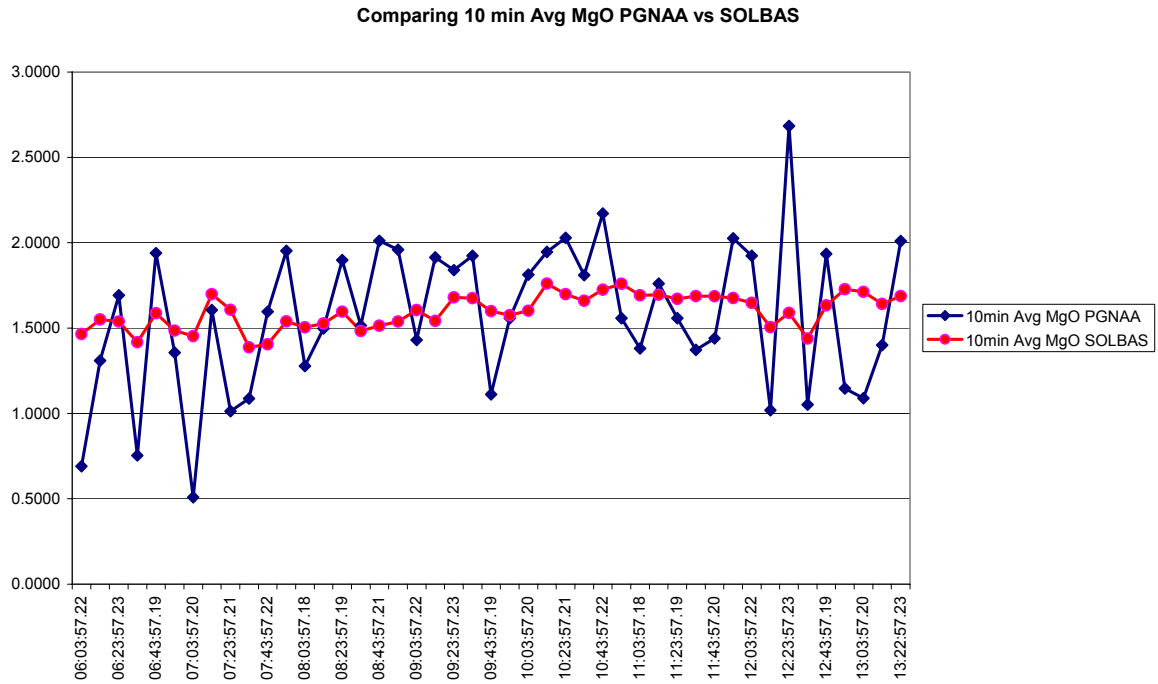

Figure 6: Comparison of Synchronized MgO content in bulk materials in PGNAA and SpectraFlow CM100 systems

6 CONCLUSIONS

The application of NIRS in SOLBAS^{TM} along with the sophistication of inclusion of a high-intensity bright white light source and careful modeling and chemometrics has resulted in the successful evolution of a working fully safe, reliable and robust analytical system. Eliminating the need for potentially hazardous excitation sources, ease of operation, mobility and portability of the resultant family of analyzers means freedom of permitting and regulatory requirements while providing reliable and accurate analyses of materials for the industry's present and future needs for process characterization and control.