Introduction

In 1984 a revolutionary new way of process control was introduced to the cement industry from a little known yet innovative company based in San Diego California. That same company, originally known as Gamma-Metrics, is today part of Thermo Electron and has continued its technology driven legacy by introducing countless improvements to its original concept. Thermo Electron’s latest offering in online Prompt Gamma Neutron Activation Analysis (PGNAA) for the cement industry combines leading-edge analytics with unprecedented installation flexibility in a package that has significantly lowered the installed cost.

Historical perspective

PGNAA online analysis debuted as the first system in the cement industry able to analyse 100% of the raw material and it did so online each minute, facilitating process control. While these analysers were an exciting new tool for the industry, several opportunities remained for innovation. Early equipment was designed such that material was introduced to a hopper above the unit where it then traversed through a vertical ‘chute’ for analysis (Figure 1). This equipment was effective for its function and several electrical and component innovations were implemented over the years to enhance performance. Installation costs for these ‘chute’ style systems, however, remained high. Hoppers had to be created; material had to be elevated above the sensor; a material extraction system had to be fitted and chute liners required periodic and cumbersome replacement. A more efficient method was needed.

Online analysis took a leap forward when the first CrossBelt Analyzer (CBA) was introduced by Thermo in 1993. These unique systems no longer required the costly installation of the ‘chute’ style equipment and could be mounted on an existing conveyor belt with relatively few modifications (Figure 2). The CBA was what the industry was looking for and the new analyser quickly became a success. With three sizes to choose from (CBA 800, CBA 1000 and CBA 1200), its user could employ the systems for quarry monitoring and control, as well as raw mix proportioning. The model numbers roughly represented the conveyor width in mm that the unit could accommodate. These early systems had the detectors mounted above the conveyor belt at a slightly slanted position.

Another major advance in CrossBelt Analyzer technology was made with the company’s introduction of the CrossBelt CB-GN system (Figure 3). This family of online analysers added three more sizes to make a total of six available models (CB-GN - 600, 800, 900, 1000, 1200 and 1400) and incorporated:
- Digital signal processing.
- Replacement of a room size electronics module with a small wall mountable unit.
- Reorientation of the detector position to horizontal.

The latest model

The company’s latest CrossBelt analyzer builds on prior generation advancements while offering unprecedented installation flexibility and the latest in signal processing technology. The new Thermo Gamma-Metrics CrossBelt Xpert (Gamma-Metrics - CBX) (Figure 4) is matched to the existing conveyor configuration exactly, which along with an external frame and modular shielding significantly reduces installation costs. The CBX makes use of several innovations to pro-
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demonstrate unique installation flexibility. These new concepts include, but are not limited to, the following:

- Enhanced modularity.
- External support frame.
- Source and detector cartridge.
- New shield materials.
- Unique modular reference standards.

Unique modular assembly

When the concept of a new online analyser was initially conceived by Thermo Electron, industry leading cement producers were consulted to understand better what features would most be desired in such a system. At the top of the list were ruggedness and reliability, low installed cost and minimal impact to the existing installation/operation. With these priorities in hand, the design team began work dedicated to meeting these criteria. What evolved was a radically different concept. The new online analyser uses a combination of nearly identically shaped shielding modules with source and detector ‘cartridges’ that could be assembled in a multitude of ways creating different analyser systems. The system consists of three groups of modules:

- Main shield modules.
- Side shield modules.
- Detector and source cartridge modules.

The new main shield modules adopted a standardised ‘U’ shape with ‘attachment’ points. Two widths are used to provide flexibility (Figure 5). When assembled, the main shield modules are placed alongside each other with their longest dimension parallel to the conveyor line. The aligned ‘U’-shaped cut-outs form a cavity into which either the detector or source cartridge fit. In this manner, the standardised main shield modules are interchangeable for either the upper or lower portion of the analyser system. Various combinations of the two widths form the appropriate amount of shielding to accommodate virtually any conveyor configuration. In essence, the bigger the conveyor line, the more standardised main shield modules are placed alongside each other. The main shield modules are attached to an external support frame that is also adjustable and can be directly integrated into a conveyor line.

This methodology of configuring and assembling the analyser system keeps the overall width of the equipment proportional to the width of the conveyor line and associated access walkways (catwalks). Keeping the width of the system similar to the dimension of the conveyor line reduces installation costs. Early generation CrossBelt Analyzer systems used a single standard width shielding system that had to be large enough to accommodate the largest conveyor line. For example, a 24 in. (600 mm) conveyor would pass through the same size shielding as a 55 in. (1400 mm) conveyor. In retrospect, this method was somewhat inefficient and added unnecessarily to installation costs. The CBX system does not suffer this inefficiency.

With the appropriate overall system width formed by the main shield modules, the side shield modules (Figure 6) are then used to define the dimensions of the ‘tunnel’ through which the conveyor will pass. Side shield modules are tailored to:

- The existing troughing angle of either 35° or 45°.
- The width of the centre and side conveyor idlers.
- The desired height of the tunnel opening.

The side shield modules are simply adjusted by sliding them in or out equally about the centreline of the conveyor and are secured to the external frame.

Finally, the detector and source cartridge (Figure 7) are standardised modules that contain either the neutron source or the detectors. As noted above, each cartridge fits into the space created by the main shield modules. Similar to the main shield modules and side shield modules, both the detector cartridge and source

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cartridge provide a high level of adjustability.

Figure 8 shows how the different modules are assembled to form the analyser system.

**External frame**

An external frame was designed to independently support the modular shields. This concept eliminates most of the mechanical interconnections between modules and therefore permits modules to be configured to match the conveyor design and plant operational conditions as opposed to the analyser mechanical constraints. For example, the side blocks do not carry any load from the shielding above and therefore can be positioned to best match the conveyor profile, instead of their being positioned to match the load bearing points of the shielding above and below. As a consequence of this new freedom of configuration, Thermo now bases the module selection and analyser configuration for each project on idler specifications instead of belt width.

With this change in emphasis, the selection of analyser slider bed is based on the conveyor or idler lengths and not on a predefined analyser dimension. This new process ensures the elimination of localised points of high slider wear resulting from the transition of the belt from rollers to slider bed. The spacing of the side shield assemblies is adjusted to match the slider bed using slotted brackets attached to the external frame (refer to Figure 9.)

The CBX revolutionises the method for supporting the analyser while minimising requirements for rerouting the existing conveyor analysers. The old concept presented the analyser as a monolith that was placed on a support platform erected in an opening cut into the conveyor line. The conveyor return strand was diverted below the platform by a series of high tension bend pulleys. In contrast, the CBX is a set of modules that are mounted on a frame that is integrated into the conveyor line. The elimination of the analyser support platform significantly reduces construction cost and sometimes eliminates the re-routing of the conveyor return strand. The CBX requires only a minimal distance between the carry strand and the return strand of the conveyor. If this clearance is not met by the existing conveyor, it can usually be accommodated by stepping down a few of the return carry idlers.

The external frame allows any side shield blocks to be used in conjunction with any arrangement of upper and lower shield blocks (Figure 10). Since the tunnel opening is determined by side shield height, idler angle, and position of the side shield assemblies, the selection of tunnel opening is independent of any other shielding configuration. The side shield assemblies can be independently selected and, as a consequence, the tunnel opening can be based on the maximum production rate, conveyor loading pattern, surcharge angle, and the conveyed material's particle size.

During the 11 years that Thermo has been working with customers of CrossBelt analyzers, repeated situations have been encountered in which the customer wished to relocate or reconfigure the belt line on which the analyser was installed to allow for increased plant capacity. Prior to the advent of the external analyser frame this was always a difficult problem. With the traditional shield design, a change in tunnel opening or conveyor width required the replacement of major shield components that incorporated the neutron sources and gamma-ray detectors. The CBX has decoupled these functions by placing each in its own module. To change the tunnel opening of a CBX, generally only the two side shields need some type of attention. These are either adjusted or replaced. To change just the belt size it may only be necessary to change the slider plates to match the new idlers and adjust the side block spacing. Any modifications to the external frame that might be required for CBX reconfiguration or relocation can be easily made onsite by the local steel fabricator.

The external frame that integrates the various shielding modules is either supplied by Thermo or by a steel fabricator of the conveyor line.

**Source and detector cartridges**

The CBX design has removed the source and detector hardware from the shield assemblies and turned them into separate modules. This was done for two reasons. The first is to make the analyser shielding truly flexible by separating individual functions into modules, thus
permitting the shielding to be configured to match the conveyor design. Secondly, additional configurability was desired for the detector assembly to match the application requirements.

If the conveyor has a walkway on one side only, the analyser should be able to be assembled and serviced with one-sided access. The CBX detector module and source module have been designed to meet this requirement.

On occasion, customers wish to place CrossBelt analysers near magnetic tramp-metal-removing equipment. PGNAA equipment uses photomultiplier tubes in the detectors. These tubes are very sensitive to magnetic fields and the historic practice has been to avoid location of this equipment or any equipment that generates external magnetic fields in proximity of one another. By locating the detector assemblies in their own module, it is now practical to provide options for magnetic shielding.

Some applications require a ‘trade-off’ between

Figure 10a. Example configurations using combinations of modules.

Figure 10b. Further example configurations using combinations of modules.
maximum cross sectional uniformity of measurement and maximum repeatability of analysis. These two goals are achieved with different detector and source placements and cannot be achieved simultaneously. Some applications require one or the other and some applications require a compromise between the two. The source and detector modules permit this flexibility.

**New shield material and fabrication techniques**

From the first CrossBelt analyzers built by Gamma-Metrics to the new CBX by Thermo Electron, this series of analysers has been constructed with a rugged exterior composite skin that is suited for any outdoor environment including continuous direct sunlight. The CBX has complimented this tough exterior with an advanced neutron shielding material that can also tolerate elevated temperatures. The result is an analyser that can be placed on a conveyor line at any location without protection from the elements. Figure 11 shows such an installation.

The two obvious benefits of this advancement are that the cost of installation can be significantly reduced and some of the constraints on analyser location are removed. Coupled with an electronics enclosure that requires no air conditioning, the CBX is truly a rugged, versatile process control instrument.

**Modular reference standards**

Most analytical equipment utilises a series of reference samples or standards as a base line for performance, operation and troubleshooting. Generally a reference point would consist of materials a system would typically face. The same is true with CrossBelt online analysers. Due to the size of the system, however, the amount of material needed is quite large in comparison to a laboratory analyser. Reference material on the order of 220 lbs (100 Kg) per reference point is needed. Historically, the reference system for a CrossBelt analyser consisted of a set of relatively large shells shaped to fit on a conveyor that were filled with materials mimicking raw materials normally measured. Due to their weight, these ‘reference standards’ would be moved into and out of the system using some form of overhead lift and a winch or pulling mechanism to move the standard into the system. While the process was simple, the equipment and handling requirements for the standards were an annoyance and involved some additional installation costs.

With this in mind, Thermo’s engineering team devised an innovative way to create a completely new reference system for the Gamma-Metrics CBX that was firstly easy to handle by one person without the use of any mechanical devices, and secondly extremely rugged and reliable. The end result was a patent pending modular system that does not require the use or installation of any overhead lift or winch/pulling mechanism. The new reference standards for the Gamma-Metrics CBX consist of a set of rugged ‘tube like’ containers each filled with material (Figure 12). One reference standard consists of multiple tubes, depending on the system size. A user easily moves one tube at a time into the analyser for measurement placing the end of the tube flush with the entrance of the analyser system. Analysers are shipped with multiple reference standards for long term monitoring of the equipment.

The design and application of these new reference standards has several advantages. Their use lowers the installation cost by avoiding a need for an overhead lift or winch; they are extremely rugged, reliable, easy to store and inventory; one person can run the testing and monitoring and the new standards do not require a position measurement to be made because they are inserted into the system flush with the opening.

**Conclusion**

The introduction of the Gamma-Metrics CBX system has provided the industry with a unique option in online analysis. Its ability to accommodate and exactly conform to virtually any process with minimal impact to the existing operation and with minimal installed cost is unparalleled. Should a production line be upgraded or changed, or the system moved at some point, its modular features allow the system to be easily adapted to the new application. Modularity also allows for ease of forward adaptability as technology progresses. Modules can simply be replaced with new modules containing the latest in technology.
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