A MAJOR STEP FORWARD FOR ON-LINE COAL ANALYSIS

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ABSTRACT
Since the mid-1980’s coal producers have known that the most accurate on-line coal analyzers were the full elemental type, analyzing sample streams and employing PGNAA technology. In 1993, Thermo Gamma-Metrics introduced a through-belt model of this technology to the cement industry, enabling analysis of a full process stream without sampling. However, this concept was delivered to the coal industry just two years ago. The authors offer a review of this new product concept, with field results, advantages, and limitations.

BACKGROUND
On-line coal analyzers began to be developed in the late 1970’s and early 1980’s in the United States, Australia, and Europe. Most analyzers were one of three types:

- On-line moisture meters employing microwave technology,
- On-line ash gauges using gamma ray attenuation technology (collectively known as either dual-gamma gauges, dual-energy transmission (DUET) or low-energy transmission (LET) gauges), (See Figure 1) and
- Elemental analyzers (See Figure 2) used for ash, and sulfur, and sometimes ash constituent information as well. These analyzers relied on prompt gamma neutron activation analysis (PGNAA) for elemental analysis, and they analyzed sample streams rather than the full process flow. When PGNAA is combined with a moisture meter, as is generally the case, moisture, calorific value and lbs. SO₂ per million BTU can also be determined.

The latter 1980’s and the entire decade of the 1990’s saw evolution, rather than revolution, in these instruments. Many of these changes were driven by the users’ demand for less expensive gauges. Among those improvements were the following:

- PGNAA analyzers with integrated input hopper and sample conveyor and a smaller footprint (See Figure 3)
- Dual-gamma ash meters which dispensed with the swing-arm standardization feature
- Ash gauges based upon natural gamma emitters in the ash (potassium and thorium)
Figure 1
Berthold Ash and Moisture Gauge

Figure 2
1812C Analyzer from Thermo Gamma-Metrics
But with all this incremental improvement in on-line coal analyzers there remained a large gap in price and performance between the PGNAA elemental analyzers and the dual-gamma ash gauges. If the coal producer or utility was interested primarily in ash, moisture, and calorific value, the simple ash gauges coupled with moisture analyzers, both mounted over the existing conveyor, could be purchased and installed for less than $125,000 (US). If instead, they wanted sulfur or more accurate ash (especially when the iron fraction of the ash varied significantly), the next step was in many cases was rather daunting; the price tag, installed, for the PGNAA analyzers was $500,000 or more, depending upon the complexity of the installation. We’ve all heard of the sales tactic of “selling up”, but this put the purchase of a “top tier” analyzer beyond the reach of many potential users. Sometimes, even when the PGNAA gauge offered a better rate of return on the user’s investment, the coal producer would opt for the dual-gamma gauge simply because it was less expensive and would more often fit within the capital budget.

In the meantime coal analyzer producers had developed PGNAA devices for analysis of cement raw materials (See Figure 4) that mounted around existing conveyor belts. These devices were well received by the cement industry, and Thermo Gamma-Metrics sold more than 100 of these units. The obvious question arose several times in the 1990’s: why not build the equivalent unit for coal, as the means to bridge the gap between the inexpensive ash gauge and the top-of-the-line PGNAA analyzer. After all, with no sampling system to feed it, no connecting conveyors, and no need to accommodate significant additional ground area (or construct a new tower or building), the installed cost of such an analyzer was expected to be much less expensive than the PGNAA sample stream analyzer.

The dilemma facing the analyzer suppliers was three-fold. For starters, they knew that these devices would not be as accurate, since they would be analyzing a variable, non-optimal (from a physics point of view) cross-section of coal on the conveyor belt. A second deterrent to developing this product was realizing that any such analyzer—that is, PGNAA across the belt—would have to subtract the contribution of the conveyor belt to the raw analysis data, which, given the not insignificant amount of sulfur in most conveyors, would lead to yet another source of analysis variance. And lastly, it was felt that even the most inexpensive manifestation of PGNAA in a crossbelt configuration would cost around three times that of a dual-gamma ash gauge. Would the coal producer be willing to pay that amount of money just to get sulfur and/or a more accurate ash result than the low-end ash gauge, when it was clear that this instrument would not be the analytical equal of say a Thermo Gamma-Metrics CQM? In the end, the decision to develop a PGNAA coal analyzer in a crossbelt configuration was a calculated risk, mitigated by the prior success of PGNAA instruments in use in cement.

DEVELOPMENT CHALLENGES

To the uninitiated, it might seem simple to reconfigure a cement analyzer into a coal analyzer. Just change some of the parameters on the user interface screens, right? Not quite. The development challenges included the following:

Mass flow determination to weight average one-minute analyses in a CQM was relatively simple, relying on a tachometer input from the sample belt along with a density gauge signal from the coal as it passed through the analysis tunnel. In the case of the crossbelt
Figure 3
Coal Quality Manager (CQM) Analyzer from Thermo Gamma-Metrics

Figure 4
Thermo Gamma-Metrics CrossBelt Analyzer at a cement plant
• PGNAA coal analyzer, the mass flow would be coming from a belt scale, necessitating integration and synchronization.

• The CQM sample stream analyzer had an optimal and constant cross-section for neutrons and gamma rays. The crossbelt PGNAA analyzer would have to accommodate whatever belt loading and cross-sectional profile it received. Moreover, physics modeling work showed that the optimal placement of sources, detectors, and reflectors was significantly different than the placement of these components in a cement raw material analyzer.

• One of the keys to the analytical success of the CQM was the easy ability to take representative samples from the 4-20 tph stream that flowed through it, to use in calibration verification. Not only did these small flow rates facilitate this requirement, but the fact that it was not on the main process flow was also a plus. In the case of the crossbelt PGNAA instrument, if there were no sampling system nearby, the challenge of obtaining a physical sample representative of the coal flowing through the analyzer is formidable indeed.

• Whereas sample stream analyzers were always interrogating a rather homogeneous cross-section profile, because of the mixing occurring in the upstream input hopper, the crossbelt analyzer might often be scanning layered belt profiles of very different composition.

Other hurdles for the analyzer supplier included belt compensation, nuclear device registration, and designing both calibration and reference standards, for use in the plant and in the field, respectively. Furthermore, for some of the reasons already mentioned, there would be an unknown and fairly unpredictable falloff in analytical performance (compared to the sample-stream analyzers), which the early purchasers of these analyzers would have to be willing to tolerate.

ADVANTAGES

The through-belt, or crossbelt, elemental coal analyzer has several obvious advantages compared with the PGNAA sample stream analyzers:

• **No sampling system required to feed the analyzer** - This means not only no sampler, but no connecting conveyors, no need to allow for vertical clearance requirements, and no allocation of additional floor or ground area to accommodate the analyzer. Furthermore, the successful use of the analyzer isn’t dependent upon an ancillary system. However, there is one significant drawback to the lack of a sampling system; that is, that it is more difficult to obtain the physical samples recommended to do an optimal job of in-field calibration.

• **Installed cost** - An installed crossbelt PGNAA analyzer could be less than $300,000, inclusive of a moisture meter. This is in contrast with sample stream PGNAA analyzers, which run $450,000 to $750,000 installed.

• **Time to install** - With no additional supporting structure required and no pipes, electrical lines, ladders, or electrical panels to be moved, and no new samplers and conveyors to be added, installation time is dramatically less.
• **Location flexibility** - It can be located where it is needed, not where there is a place for a sample system. There are no constraints on particle size, whereas the sample-stream PGNAA analyzers are usually limited to 3-4 inch topsize.

• **Ease of relocation** - With their simple design, should the mine conveyors be moved, it is much easier to relocate the analyzer.

• **Ease of maintenance** - Although there are tunnel belt liners in a crossbelt analyzers which occasionally need replacement, there are no level sensors, belt drives, or input hopper wear parts subject to intermittent failure and replacement.

**LIMITATIONS**

At the same time there are some limitations that come with crossbelt PGNAA analyzers.

• **Diminished accuracy performance** - Crossbelt analyzer performance will not be as good as sample-stream analyzer performance owing to the variable and non-optimal physics of the coal on the conveyor, and the need to subtract the varying effects of material in the belt itself.

• **Calibration complications** - Obtaining physical samples to compare to the analyzer will be a challenge in many cases. The use of reference blocks will also be more difficult because of the size of the standards required, particularly in wide belt applications. (See Figure 5)

• **Conveyor belt materials of construction** - The crossbelt analyzer is not recommended for steel cable belts, because of the high and varying iron content in the belt.

![Reference Standard](image-url)
SURVEY OF CROSSBELT PGNAA ANALYZER INSTALLATIONS

To date there have been several crossbelt PGNAA installations in the United States and in Australia, a majority coming from Thermo Gamma-Metrics. A summary of the Thermo Gamma-Metrics installations includes the following:

<table>
<thead>
<tr>
<th>Analyzer Owner</th>
<th>Location</th>
<th>Date of Installation</th>
<th>Belt width</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Millmerran</td>
<td>Queensland, Australia</td>
<td>July 2002</td>
<td>1200 mm</td>
<td>Control of mine out-of-seam dilution</td>
</tr>
<tr>
<td>Coastal Coal</td>
<td>Brooks Run Mine, WV</td>
<td>May 2002</td>
<td>42 “</td>
<td>Prep plant control</td>
</tr>
<tr>
<td>Andalex Coal</td>
<td>East Carbon, UT</td>
<td>June 2002</td>
<td>48”</td>
<td>Monitor coal quality truck-by-truck</td>
</tr>
<tr>
<td>Sempra Energy</td>
<td>Twin Oaks Generating Station, TX</td>
<td>Feb 2003</td>
<td>60”</td>
<td>Control stockpile quality</td>
</tr>
<tr>
<td>Trans-Alta Utilities (2 analyzers)</td>
<td>Centralia, WA generating station</td>
<td>Jan 2003</td>
<td>48”</td>
<td>Monitor and control bunker feed</td>
</tr>
</tbody>
</table>

Figure 6
Table of PGNAA Analyzer Installations
Thermo Gamma-Metrics ECA Installations
PERFORMANCE ASSESSMENT
The performance results thus far of the Thermo Gamma-Metrics crossbelt analyzer, called the ECA (Elemental Coal Analyzer), have been excellent. As predicted, there was some falloff in accuracy compared to the sample-stream analyzers, but it was only on the order of 50% or so. Whereas the Thermo Gamma-Metrics CQM can usually achieve precision performance on sulfur of 0.03-0.04%, the ECA has accomplished 0.05-0.06%. Similarly in ash, where a CQM would produce precisions of 0.3-0.4%, the ECA is realizing precision closer to 0.5-0.7%. Below are found some lab vs. analyzer comparisons from one of these installations. This particular site was used for illustrations in this paper particularly because of a few factors: (1) it had taken more comparative samples; (2) there actually was a sampler near the analyzer, although it was homemade and not within the ASTM guidelines; and (3) this was felt to be a more challenging analytical site than most because of its highly variable belt loading (often dropping below the recommended minimum flow) and with layered coal feed of different size distribution and moisture content. Despite these caveats the analyzer and the lab agreed quite favorably.

Figure 7
ECA Sulfur Performance

Standard Error = 0.050
RECOMMENDATIONS TO THE POTENTIAL BUYER

Given the growing popularity of crossbelt elemental analyzers in the coal industry, it is only fitting that we should offer some advice relative to the choice of analyzer location, analyzer type, and even analyzer vendor.

Analyzer Location

As for the choice of location, two primary factors tend to govern this selection. Ideally the analyzer should be located as close to the point in the process where knowing the coal composition is of greatest value. In the case of sorting, for example, the analyzer should be located close to, but obviously upstream of, the sorting point. If the coal complex consists of numerous coal flow paths, there may be need for more than one analyzer, with the preferred sites often determined by where the coal quality variability is known to be the greatest. And in a blending application, the analyzer is preferred just downstream of the point at which all of the coal streams have come together.

Unfortunately, the ideal process location is often unavailable because of the second key factor, physical or environmental constraints. These include such factors as:

• the lack of a sampling system (to either feed the analyzer or to be able to obtain occasional physical samples for analyzer comparison purposes)
• headroom or horizontal space limitations
• inconvenience of running utilities
• inadequate protection from the elements

As a result, the choice of an analyzer location is often compromised. It is expected that the existence of crossbelt elemental analyzers will reduce the incidence of location compromises.

Analyzer type
The choice of analyzer type centers around dual-gamma ash (and moisture) gauges, crossbelt elemental analyzers, and sample-stream elemental analyzers. Criteria of greatest importance in choosing between dual gamma ash gauges and PGNAA elemental coal analyzers are:

- **Parameters of interest** - If the coal producer does not need to measure sulfur on-line, a dual-gamma ash gauge *may* be adequate for the task.
- **Accuracy requirement** - As the accuracy requirements become more stringent, the preference can shift from dual-gamma ash gauge to crossbelt elemental and ultimately, for the best accuracy possible, a sample-stream elemental analyzer.
- **Coal complexity and coal quality variability** - In multiple seam applications and in cases where the iron fraction in the ash is highly variable (more than 4% swings in Fe₂O₃), a dual gamma ash gauge is unlikely to perform acceptably.

This logic diagram (Figure 9) might be useful to the potential analyzer buyer:

![Figure 9: PGNAA Logic Diagram](image-url)
Selecting Appropriate Analysis Technology

In choosing between a sample-stream PGNAA analyzer, like the Thermo Gamma-metrics CQM, and a crossbelt PGNAA analyzer, like the ECA, the decision criteria include the following:

- **Accuracy requirement** - Once again, the greater the accuracy requirement, the more obvious the choice in favor of the sample stream analyzer.
- **Application** - Although it is related to the quality requirement, sample stream analyzers are more appropriate for loadout situations, where quality is paramount. On the other hand, further upstream, where control decisions can be less exact, a crossbelt analyzer is often appropriate. As a rule of thumb, it’s crossbelt for process control, and sample-stream for quality control.
- **Proximity to/existence of a sampling system** - Since a sample-stream analyzer needs a sampling system, when one is already available, such as in a loadout tower, a sample-stream analyzer can be quite feasible. In other cases where there is no sampler nearby, a crossbelt analyzer becomes relatively more attractive.
- **Relative permanence of the installation** - If the coal producer knows that the initial location of the analyzer may be short-lived (e.g., two years) due to life-of-mine considerations, or planned changes in the coal handling scheme of the mine, the ease of relocation of a crossbelt analyzer might tip the scale in its favor.
- **Budget** - Even though a sample-stream analyzer might be more accurate and afford a quicker payback to the buyer, there may be some occasions in which the amount of budget available is limited, and the crossbelt analyzer might squeak in under the limit, whereas a sample-stream system does not.

Analyzer vendor
The key buying factors will obviously vary from one coal producer to another, and even from one manager to another within the same coal company. Nonetheless, the following factors often come into play in the selection of the right vendor:

- **Performance** - An analyzer which isn’t accurate is of little value to the owner. Look for the vendor which has a track record of excellence in accuracy (Woodward, 1996) as well as one which understands the vital importance of calibration—both in the plant before the analyzer ships and in the mine during and after commissioning.
- **Reliability requirement** - No matter how well an analyzer is built, its components do occasionally fail or at least degrade. And most coal mines come to depend so much on their analyzers, uptime is a key concern. You may want to choose a vendor whose service team is both experienced and deep, so that there is ample backup to respond to your needs, no matter when they arise. And with some service providers there is the possibility of bundling service for other process equipment along with the analyzer service in one package, allowing you to realize some economies of scale in your maintenance expenses.
- **System solutions** - Most coal analyzers are purchased to control the process, whether it’s blending, sorting, or cleaning. Why not look for the vendor which can offer the full solution, inclusive of the process control software? Furthermore, if the analyzer of
choice is a sample-stream unit, look for the vendor which can also include the sampling system as part of its scope.

- **Safety** - Every day we are reminded of the importance of safety in the coal mine. Look for the vendor who has taken that matter seriously, particularly when it comes to radiation safety. What are the radiation levels? Check the device registration.

- **Innovation** - Technologies are always on the move. Analyzers which are brand-new today may seem outdated in five or ten years. Look for the supplier which has a track record of continuous improvement, one which has a history of bringing out new and better models over time. You owe it to your company, which no doubt expects to be competitive for decades to come, to partner with suppliers who have the same long-term vision. These are the suppliers who will be keeping you in mind, with long-term maintenance contracts and upgrade packages, when you need them.

**SUMMARY**

The long-awaited crossbelt elemental analyzers have arrived in the coal industry. They are not the analytical equal of the sample-stream PGNAA analyzers, but they do carry with them many advantages such as little or no sampling requirement, lower cost and quicker installation, and probably greater uptime. Field performance has shown these devices to be of adequate accuracy for many applications. Intelligently used and maintained, they offer the coal producer and the utility a cost-effective solution to many process challenges.

**REFERENCE**