COALTECH

MAYA On-Line Analyzer Evaluation

G J de Korte

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Executive Summary

A new type of elemental on-line analyzer was developed by Laser Detect Systems (LDS) of Israel. The new analyzer, called 'MAYA', uses Laser Induced Breakdown Spectroscopy (LIBS) to determine the quality of coal on a moving conveyor belt. LDS and Coaltech agreed to cooperate in testing the unit at Optimum Colliery. The results of the test were favorable.

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1. Introduction

Laser Detect Systems (LDS), based in Israel, developed a new on-line elemental analyzer called 'Maya'. The analyzer differs from other elemental on-line analyzers presently in use in that it utilizes *Laser Induced Breakdown Spectroscopy* (LIBS) to measure the quality of coal on a conveyor belt instead of *Prompt Gamma Neutron Activation Analysis* (PGNAA) used by the other analyzers. The analyzer is much smaller and lighter than the on-line analyzers currently in use and, most importantly, does not use radioactive sources.

LDS and Coaltech agreed to co-operate to test the analyzer in South Africa in order to evaluate its potential. The local agent for the Maya, World Focus, handled the installation and operation of the unit and Coaltech assisted in the evaluation of the performance of the unit.

It was decided to install the analyzer on the Wemco product conveyor at Optimum Colliery. A Coalscan 9500X PGNAA analyzer is in operation on the same conveyor. The conveyor is also equipped with an automatic sampler and two-hourly composite samples are procured and analyzed by the Optimum laboratory routinely. The data from the Coalscan and the laboratory analyses were used to provide a comparison with the readings obtained from the Maya.

The Maya analyzer was installed at Optimum on 22 March 2007. It is worth commenting that the installation was carried out in less than a day. A communication link was provided which allowed the data to be downloaded in Israel and also to facilitate adjustments to the calibration to be made from Israel. The unit was commissioned on 26 March and has been in operation since. Figure 1 shows the Maya analyzer at Optimum.

Figure 1: Maya on-line analyzer

The analyzer has now been in operation for 4 months and the calibration is now fully established. It was therefore decided to evaluate the performance of the Maya as of 1 August 2007. The data from the Coalscan and the Optimum laboratory were compared to the data from the Maya. A special test, during which time sample increments were taken at 5 minute intervals, was also carried out to compare the performance of the Maya over a shorter time period. The results obtained are given in this report.

2. LIBS

The following explanation of the principle used by LIBS to derive the basic elemental composition of materials is taken from the website of Applied Photonics Ltd., based in the United Kingdom. (http://www.appliedphotonics.co.uk/index.htm)

Laser-Induced Breakdown Spectroscopy (LIBS) is a form of atomic emission spectroscopy in which a pulsed laser is used as the excitation source. The basic principle is illustrated in Figure 2 below. The output of a pulsed laser, such as a Q-switched Nd:YAG, is focused onto the surface of the material to be analyzed. For the duration of the laser pulse, which is typically 10 nanoseconds, the power density at the surface of the material can exceed 1 Gigawatt per cm^2 using only a compact laser device and simple focusing lenses.

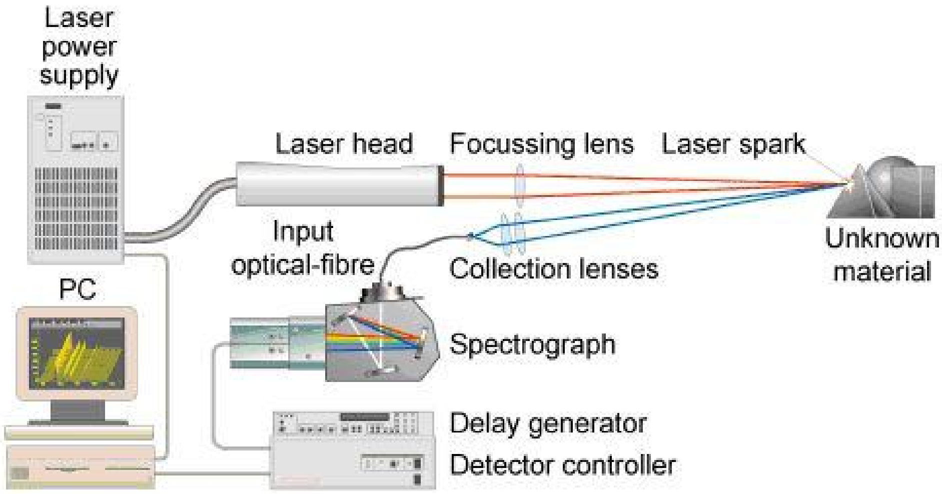

Figure 2: LIBS principle

At these very high power densities, a fraction of a microgram of material is ejected from the surface by a process known as laser ablation and a short lived but highly luminous plasma with instantaneous temperatures reaching 10,000°C is formed at the surface of the material. Within this hot plasma, the ejected material is dissociated into excited ionic and atomic species. At the end of the laser pulse, the plasma quickly cools as it expands outwards at supersonic speeds. During this time the excited ions and atoms emit characteristic optical radiation as they revert to lower energy states. Detection and spectral analysis of this optical radiation using a sensitive spectrograph can be used to yield information on the elemental composition of the material.

3. Maya

The Maya analyzer uses a laser pulse to produce the luminous plasma on the surface of the coal particles on the conveyor which is then analyzed to obtain the basic elemental composition of the coal. Since the height of the coal layer on the conveyor changes continuously, it is necessary to vary the focal point of the laser beam to ensure that it is correctly focused at the precise moment that the laser fires. To achieve this, a height adjustment mechanism, controlled by an ultrasonic sensor, is used to control the distance between the coal and the lens of the laser. The frequency of the laser pulse can be set at up to 20 pulses per second – at Optimum 5 pulses per second was found to be optimal. The spectrum obtained from every single pulse can be analyzed and it is usual to accumulate the average of a large number, typically more than 500, readings to improve the statistics. The analyzer can be adjusted to report the analysis every minute or at longer intervals as required.

4. Calibration

Although some preliminary calibration of the analyzer was carried out in Israel before the unit was shipped, it was required to re-establish the calibration after installation. The calibration took a relatively long time to perfect but this is not unusual, especially considering that this is the first application of the Maya on coal. Initially the Maya data showed a large degree of scatter. The calibration algorithm was, however, further developed and adjusted and as from 1 August, very good agreement with both the laboratory and Coalscan data was obtained. There was, unfortunately, a period of almost two days when the Maya data were unavailable due to a problem with a compressor. Figure 2 shows the comparative data between the Maya and the 2-hourly laboratory results for the period 1 to 15 August. The average Maya results for the 2 week period was 13,2% ash which compares favorably with 13,4% for the laboratory results and 13,3% for the Coalscan. Figure 3 shows the Maya / Coalscan comparison.

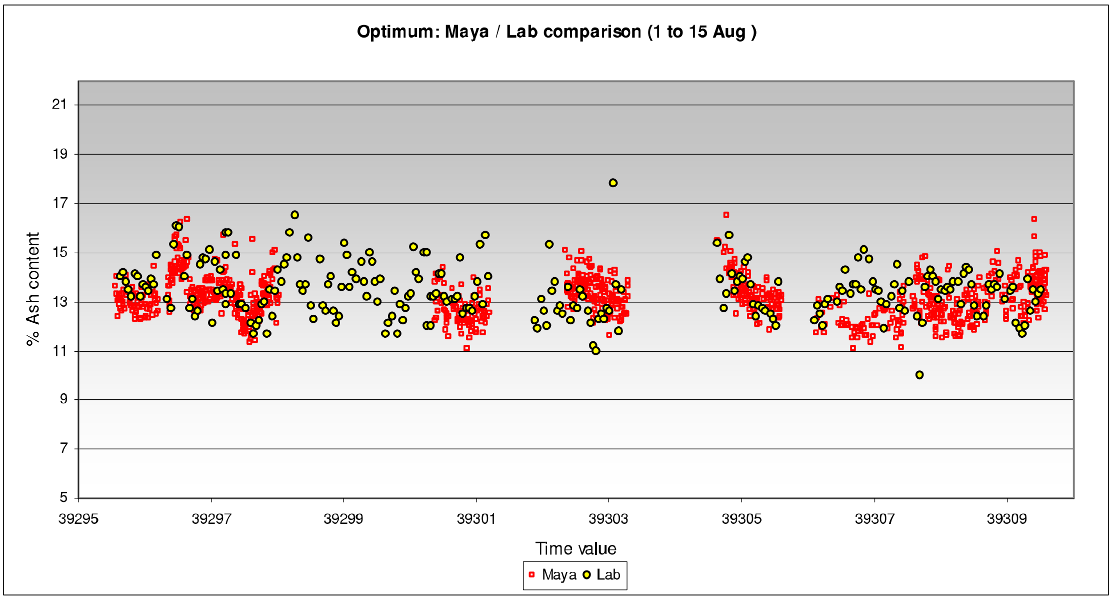

Figure 2: Maya and laboratory results compared

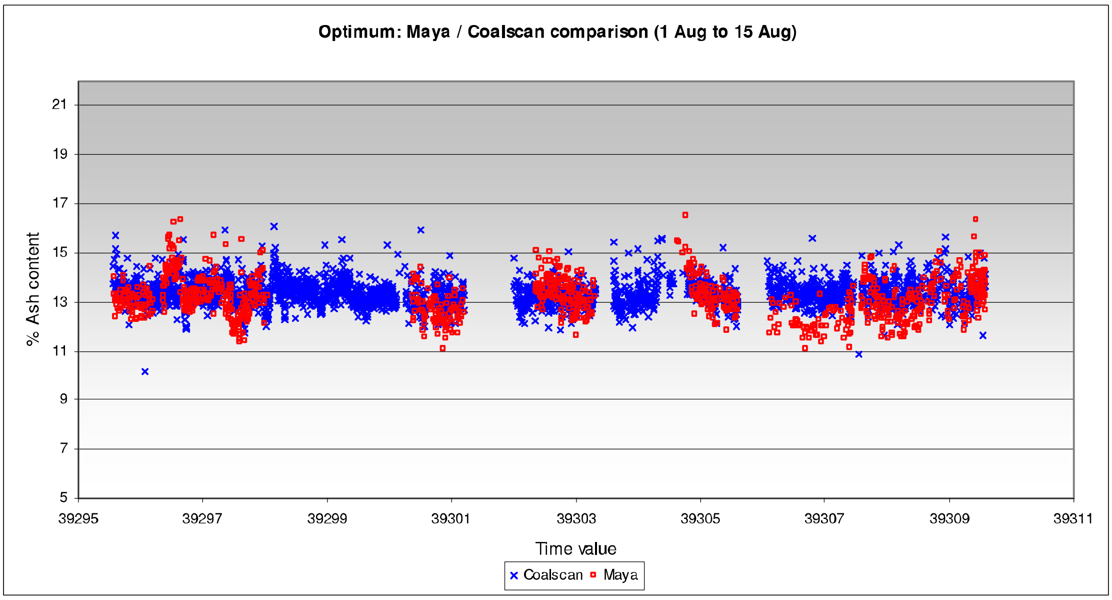

Figure 3: Maya and Coalscan results compared

Table 1 and Figure 4 shows the comparative normal distribution curves for the Coalscan, the laboratory and the Maya results for the period 1 to 15 August.

Table 1: Comparison of ash values

	Coalscan	Laboratory	Maya
Number of observations	2866	250	1015
Mean	13.35	13.43	13.17
Max	30.00	17.80	16.50
Min	10.14	10.00	11.10
Std Dev	0.672	1.064	0.827

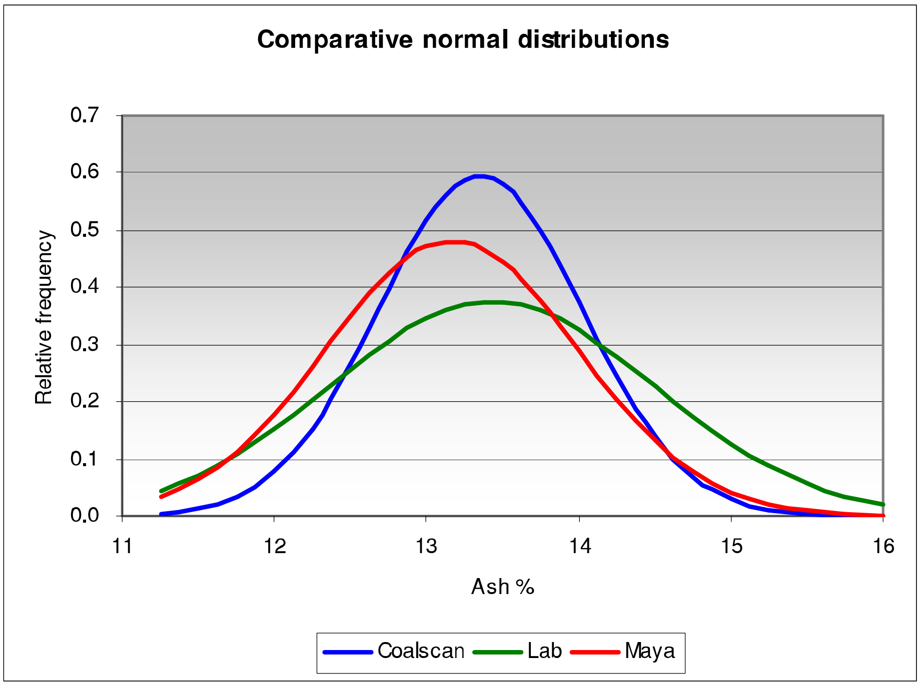

Figure 4: Normal distribution curves

It can be seen from the data presented in Table 1 and also from Figure 4 that the mean of the Maya readings is slightly lower than that of the Coalscan and the laboratory. The standard deviation for the Coalscan is the lowest of the three determinations. This is due to the higher number of values reported by the Coalscan and the fact that the unit derives its values from the bulk of the material on the conveyor. The laboratory values exhibit the highest standard deviation and that of the Maya is intermediate to the other two.

5. Test on 15 August

A special test was conducted on 15 August to compare the performance of the unit over a shorter time interval. The test comprised taking 30 samples from the conveyor, using the automatic sampler, at 5 minute intervals. To do this, the complete primary sample was re-directed to the by-pass chute in the sampling circuit where it could be collected in a plastic bag. The sample was split, using a riffle chute, into two equal portions. One portion was prepared and analyzed at the Optimum laboratory and the second portion by Yanka laboratory. The results obtained from the laboratory analyses and the corresponding data from the two on-line analyzers are summarized in Table 2. The detailed results are appended in Appendix A.

Table 2: Summary of test results

	Yanka laboratory	Optimum laboratory	Average of laboratories	Coalscan	Maya
n	30	30	30	31	35
Mean	13.6	14.0	13.8	13.8	13.7
Std Dev	0.87	0.66	0.54	0.57	0.57

A graphical comparison of the data for the two laboratories and the two analyzers is shown in Figure 5.

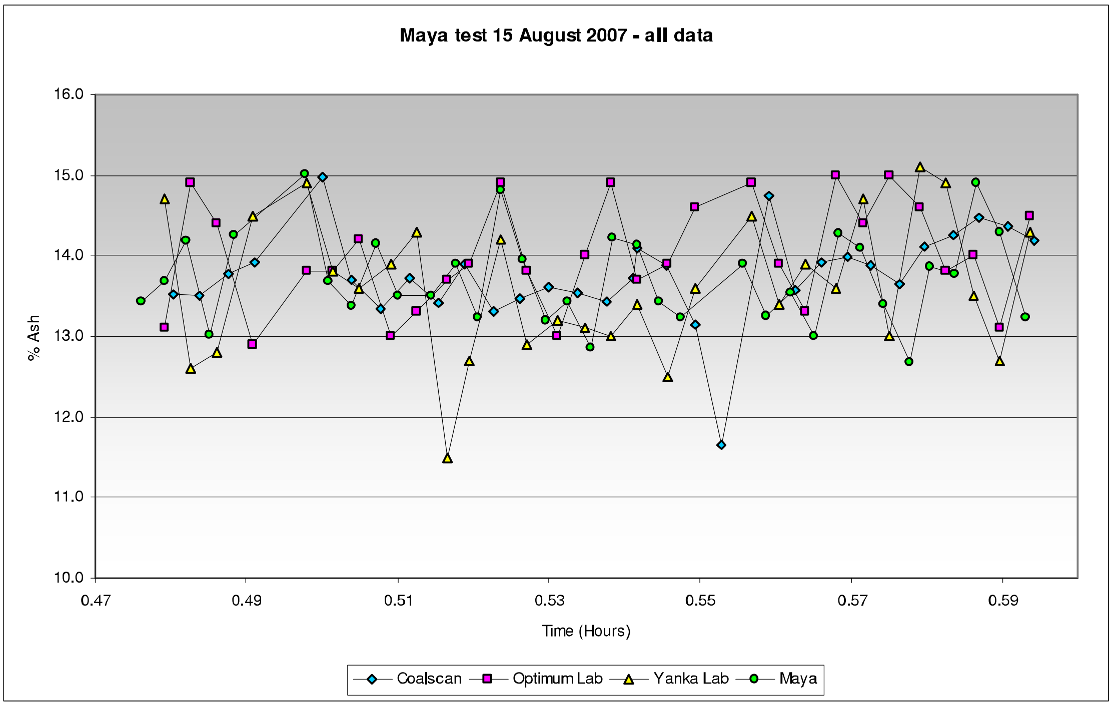

Figure 5: Test data

The Maya results are shown compared to the average values of the laboratory determinations in Figure 6. It can be seen from Figure 6 that there is a relatively good agreement between the data sets.

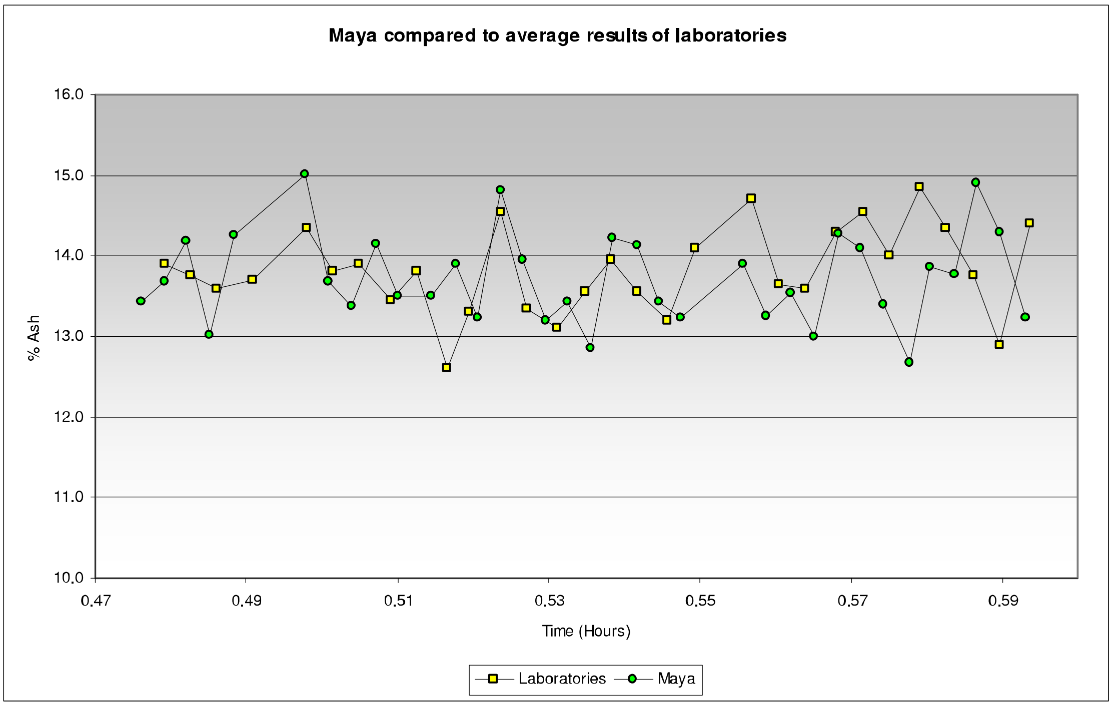

Figure 6: Maya data compared to mean laboratory values

The data presented in Table 2 show that the sample means and standard deviations derived from the laboratory results and the Maya determinations are quite close. Student's t-test was employed to determine whether the means of the distributions are statistically similar. The procedure for the test is given in Appendix B. The outcome of the test was positive and confirms that there is a 95% probability that the two sample distributions were derived from the same population.

6. Conclusion

The Maya analyzer has been proven to be able to accurately determine the quality of coal on a moving conveyor belt in real time. The performance of the unit was evaluated and the results were found to be statistically valid.

7. Comments

A disadvantage of the Maya is the fact that it measures only the surface of the coal particles. On a conveyor transporting a single product, for example Wemco floats as at Optimum, this is not a problem but in cases where cyclone product is placed on the conveyor first and the Wemco product loaded on top, only the Wemco product will be monitored. One possible means of getting around this problem would be to install the Maya after a transfer point so that the mixed coal is presented to the analyzer.

The fact that the Maya analyzes the coal surface, on the other hand, provides a potential advantage. PGNAA (and dual-gamma monitors) require a minimum thickness of coal, typically 100 mm, on the conveyor to be able to effectively analyze the bulk of the material. In many coal preparation plants, especially when low product yields are experienced, the layer of coal on the product conveyor is sometimes only one or two particles thick. Under these conditions, existing on-line analyzers can not provide accurate analyses but the Maya could well. This will, however, require testing in practice to prove.

The Optimum test only evaluated the performance of the Maya when determining the ash content of coal. The unit, being an elemental analyzer, is capable of measuring other parameters of coal as well – calorific value for example. Further work will have to be done by LDS to evaluate this potential.

The Maya calibration for Optimum coal has been established and proven. It is anticipated that the calibration will be easy to adjust when the unit is employed to measure the quality of other South African coals.

8. Appreciation

The author wishes to express a special word of thanks to Claudia Lopes and the staff of the Optimum laboratory as well as the staff of Yanka Laboratories for their assistance in the evaluation of the Maya analyzer.

9. References

1. Applied Photonics Ltd. Website. http://www.appliedphotonics.co.uk/index.htm (accessed on 20 August 2007)

2. Solid mineral fuels – evaluation of the measurement performance of on-line analysers. International Standard ISO 15239

3. Cass, T. Statistical methods in Management. Cassell Ltd. London.