High-Speed, Automated Petrographic Analysis of Coke Battery Charges

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ABSTRACT

A prototype high-resolution, high-speed, automated petrographic system has been developed to measure quantitatively the reflectance of coal macerals, during traverses of a scanning stage. The system discriminates coal macerals from binder, and collects reflectance measurements at up to 2 million readings per minute, enabling very large amounts of reflectance data to be collected quickly.

This system was used to monitor coal blend consistency of battery charges sampled twice daily during each turn (shift), from August 20, 1991, to November 21, 1991, at Inland Steel's Indiana Harbor works. The study involves 324 samples of coal charged to the Plant 2 Coke Batteries, and #11 Coke Battery.

Reflectance data were analysed by linear least squares analysis and cumulative probability statistics; techniques that enable the proportions of constituents in a blend to be determined, regardless of whether the constituents themselves are blends or single coals.

Plant data from the three month period are compared with the petrographic data to evalt,,te the use of the system in statistical quality control (SQC).

INTRODUCTION

In 1977, Nippon Steel Corporation, of Tokyo, Japan, was granted a US Patent for a "method and apparatus for automatically measuring distribution of reflectance of coals" [1]. The photometer-microscope and equipment they describe captures reflectance readings at about 850 per minute, including binder, grain edges, and valid data, since the patented system is not able to distinguish one from the other. Moreover, to obtain the 150,000 reflectance values needed to adequately characterize populations of blended coking coals using whole coal reflectance, such a system would have to run for 3 hours per sample, with the attendance of an operator. For routine analyses such a sytem is too slow.

SYSTEM DESIGN

A solid-state, CCD (Charge Coupled Device) imager, shuttered by a liquid crystal light valve, has been fitted to a Zeiss Universal research microscope together with a scanning-stage and an autofocus device. In the prototype, a CCD with 57,000 individually addressable pixels captures reflectance data, and these are processed and displayed in 1.5 seconds. As with more familiar petrography, the reflectance data are corrected for dark field current. Digital images are displayed on the computer screen, where they confirm both the operation of the autofocus device, and also the parameters used to discriminate low-reflecting liptinite macerals from binder, the latter being discarded [2].

The temporal resolution of the apparatus used in the experiment described here is 2000 times that of the Nippon Steel equipment, at a spatial resolution 400 times greater (Figures 1 & 2).

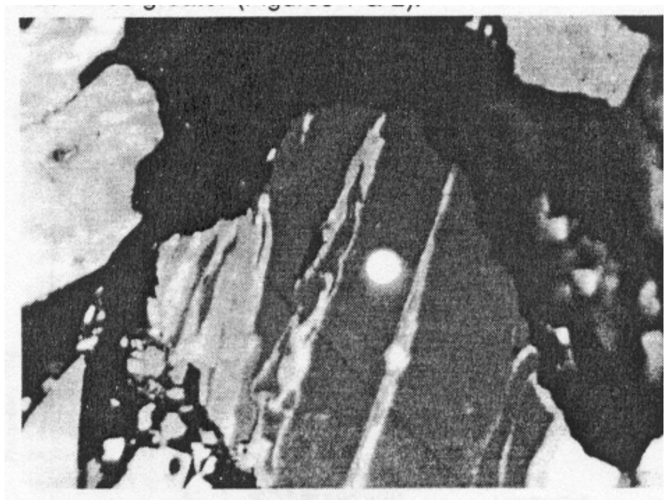

Figure 1.
Photomicrograph of a coal grain. In a typical petrographic system, only the area of the IO μm dot is measured by the photometer.

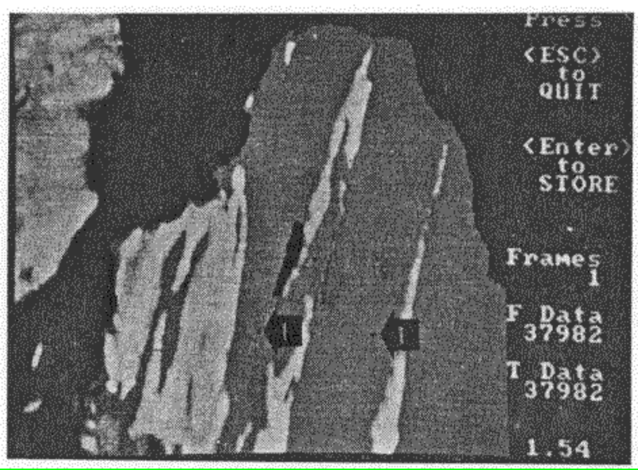

Figure 2.
Photo of the computer screen displaying a digital image of the same coal grain shown in Figure 1. The image is composed of 57000 pixels, two of which appear as arrowed black dots, giving an indication of the resolution of the system.

Figure 1. is a photomicrograph of a grain of coal showing alternating bands of liptinits (dark), and vitrinite (grey). The white circle superimposed on the middle band of liptinite outlines the area over which a photometer would measure reflectance in a typical petrographic system. The diameter of the circle is 10 μmm.

Figure 2. is a photo of the computer screen displaying a digital image of the same coal grain shown in Figure 1. The same three liptinite bands can be located, as can the black hole in the centre of the grain. The arrows in the figure point at black areas, or pixels, each measuring 0.4 x 0.49 µm. These pixels, and the serrated outline of the black hole, give an indication of the resolution of the system. Areas of binder are shown as black, and these reflectance data are discarded by the system. The grey areas of liptinite confirm that the system distinguishes liptinite from binder.

Each image is comprised of 57,000 pixels, but binder and edge-readings are discarded, so that in Figure 2. for example, only 37982 values are of valid coal reflectance. At the lower right hand corner of the screen, the time required to obtain these corrected reflectance data is shown as 1.54 seconds.

MONITORING STUDY

Three hundred and twenty four samples of blended coking coal, form the basis of this study. They are oven-charge samples, taken twice daily at each turn (shift), at the Plant 2 Coke Batteries, and #11 Coke Battery, from August 20, 1991, to November 21, 1991. During that time, minor modifications were made to the blend, so that five blends were used at #11 Battery, and six at Plant 2. Not less than thirty million reflectance readings were measured on each of these samples.

Each component coal in the blend was individually characterized, and the normalized reflectance scans were then mixed in the proportions of the blend receipe, and compared to the battery sample in probability plots, a technique described by Pearson & Wozek [3]. By iterative computer modelling, the proportions of the components in the battery sample can be determined. Figure 3, shows an example of a probability plot of Blend IV/11 from the #11 Battery. The diagram plots the cumulative probabilities for each reflectance category of the individual components, and the modelled blend designed from them.

The proportions of components in the blends were also determined by linear least squares analysis. In this method, the contribution to a blend by each of the components is evaluated for each reflectance class, and a least squares fit for the whole blend is calculated. For example, Figure 4 is a reflectance histogram of the same components and blend used in Figure 3. In each of the 0.01% reflectance classes of the blend, the contribution of each component is precisely as designed. However, if this proportion were to vary, a least squares fit would provide the best estimate of the actual proportions in the blend.

Cokeoven process-variables were assembled for the three-month study period, and these are correlated with the petrographic data obtained from the system.

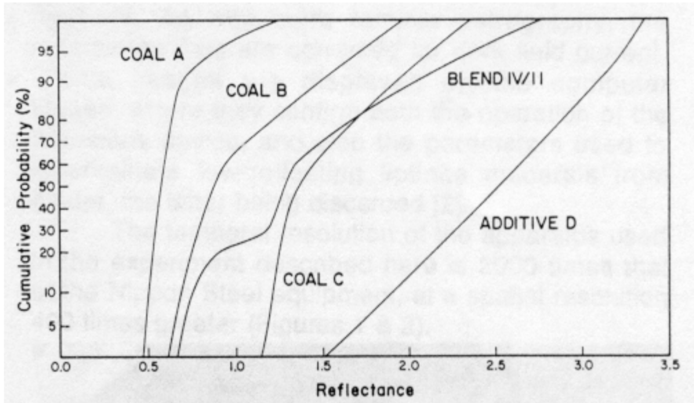

Figure 3.
Probability plot of three coals and an additive. Blend IV/1 1 is the designed target blend of A, B, C & D in the proportions 13:20:60:7.

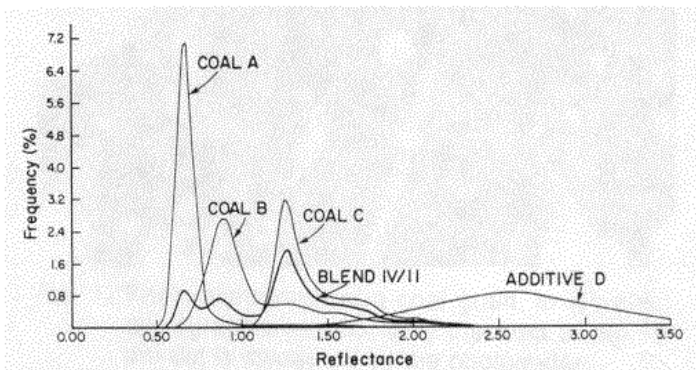

Figure 4.
Whole coal reflectance histograms of three coals and an additive. Blend IV/1 1 is the designed target blend of A, B, C & D in the proportions 13:20:60:7.

REFERENCES

1. K. Kojima, Y. Sakurai, T. Sugai & M. Motegai, *Method and apparatus for automatically measuring distribution of reflectance of coals*, U.S. Pat. No. 4030837.
2. D.E. Pearson, B.T.E. Campbell & R. Kelly, *Method and Apparatus for High-Speed Automated Reflectance Analysis of Coals*. U.S. Patent Application.
3. D.E. Pearson & J.S. Wozek, *Probability Statistics in the Monitoring of Coal Blends* 50th Ironmaking Conference, Washington DC, 1991.