Application of the Thermo Scientific CQM Online Coal Analyzer in Anjialing Coal Preparation Plant’s Rail Loadout

Pingshuo Coal Industry Limited Liability Corporation (PSC) is China Coal Energy Group's key production business. There are six active mines, which include two large surface mines (An Tai Bao Surface Mine and An Jia Ling Surface Mine), four underground mines (No. 1 Underground Mine, No. 2 Underground Mine, No. 3 Underground Mine, and JingDong Underground Mine), five supporting coal preparation plants, and two special railway lines. China coal Pingshuo Coal Co.,Ltd is China's largest and most modern coal business that has both surface and underground mines. Dong surface mine projection is under construction, including three individual projects: a surface mine, a coal preparation plant and a railway line. Dong surface mine has a design annual raw coal production capacity of 20 million tons. PSC raw coal output in 2010 exceeded 100 million metric tons, with outbound commercial coal of 70.63 million metric tons. The quality of the coal products is consistent and reliable, based on heating value and sulfur, and is divided into ten coal products, two of which are exported to Taiwan, Japan, Korea etc., and five of which are sold to electric power companies, including Zhejiang, Guangdong and other large power plants. The products enjoy an excellent reputation in the domestic and overseas markets.

An Jia Ling Surface Mine was built in 2000, following China's largest An Tai Bao surface mine that was built in 1987. It was one of largest scale surface mines combining both mining and coal washing. The mine uses "truck – shovel and semi-fixed crushing - belt conveyor", semi-continuous mining technology. Designed raw coal output was 10 million tpy, and raw coal production reached 23 million tons in 2010. The An Jia Ling Preparation plant, with an annual processing capacity of 15 million metric tons, uses heavy media coal washing, and cyclones. Filter cake was 100% recovered through the press filter department. The preparation plant has three main systems, two waste discharge systems, and uses programmable logic controllers PLC; Products are clean coal, middling coal, coal slurry and refuse dumping products.
After transformation and fine tuning of later stages, the coal preparation plant’s processing capacity reached 23 million tons in 2010. Outbound products are mainly export, domestic Ping2 (calorific value 5500 kcal / kg), Ping7 (calorific value 5200 kcal / kg) and Ping3 (calorific value 5000 kcal / kg). Domestic and international users’ stringent requirements on coal are increasing, and once the coal quality exceeds the allowable limits, they apply pressure for lower prices, making the need for coal blending even more important.

The coal-bearing strata of Pingshuo mine is Carboniferous-Permian. The coal-forming environment is alternative sea and river faces, continental respectively from top to bottom. Therefore, the ash and sulfur of the four major coal products vary widely. So, the raw coal must been mixed, washed and processed in order to meet the coal quality requirements of users. Correct blending not only can increase the variety and quantity of high quality coal, but also make the high-ash coal and coal slime into saleable products, Full utilization of the coal reserves can increase the economic benefits of enterprise significantly.

Surface mines’ coal blending must start from the coal workings, truck blending at the dump, then on to the raw coal stacking tube stockpiles. From there coal flows back to the silos for more blending into the coal preparation plant. After washing treatment, the outputs include clean coal, medium coal, coal slurry and refuse. Products are conveyed into the clean coal slot, and a mixed coal pile, and stacking tube piles while refuse is transported for disposal. Through the loading belt, blending coal for loading the product, the quality requirements of the users’ coal contract specifications are met. Thus, coal blending at the loadout is also an important part, and the final link of the products leaving the Coal Mine Area.

In order to enhance this coal blending, Pingshuo Company decided to introduce an online coal analyzer and chose the Thermo Scientific CQM, which has been in use nearly a year. The following is a description of the application of this analyzer at AnJiaLing coal preparation plant’s rail load out. At the same time will be discussed the purpose and use of two Thermo Scientific ECAs that will be installed to monitor production from the two prep plants serving the two underground mines.

1. The raw coal quality of AnJiaLing Surface Mine
The seam structure of An Jia Ling Surface Mine consists of four mineable coal seams, namely, No.4-1, No.4-2, No.9 and No.11. It has different quality characteristics for each seam. For No.4-1, it is high ash content and low sulfur content, and the washing ability is not good. For No.4-2, it is medium ash content and medium sulfur content, and has a good washing ability. For No.9, it is low ash content and high sulfur content, and also has a good washing ability. However for No.11, it is high ash content and high sulfur content, and the washing ability is very bad. According to the characteristics of each seam, we plan every eight hours to make sure the sulfur contents of clean coals can meet the contract’s specification.

Table 1 The coal seams and qualities of An Jia Ling Surface Mine

<table>
<thead>
<tr>
<th>coal seams</th>
<th>thick (m)</th>
<th>interval (m)</th>
<th>quantity (1000 tons)</th>
<th>ash content (%)</th>
<th>sulfur content (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4-1</td>
<td>8.9</td>
<td>2.0–5.5</td>
<td>8,500</td>
<td>34.7</td>
<td>0.45</td>
</tr>
<tr>
<td>4-2</td>
<td>4.0</td>
<td>20.0–30.0</td>
<td>3,700</td>
<td>31.7</td>
<td>1.01</td>
</tr>
<tr>
<td>8</td>
<td>1.1</td>
<td>2.0–5.0</td>
<td>0</td>
<td>40.7</td>
<td>3.62</td>
</tr>
<tr>
<td>9</td>
<td>14.2</td>
<td>2.8</td>
<td>10,200</td>
<td>28.6</td>
<td>2.38</td>
</tr>
<tr>
<td>11</td>
<td>3.9</td>
<td>2.1–5.4</td>
<td>2,600</td>
<td>35.9</td>
<td>2.97</td>
</tr>
<tr>
<td>total</td>
<td>32.1</td>
<td></td>
<td>25,000</td>
<td>31.9</td>
<td>1.58</td>
</tr>
</tbody>
</table>

Figure 1. The picture of AnJiaLing Surface Mine
2. The raw coal blending system of the coal preparation plant
(Figure 2)

![Diagram of coal quality control system]

Figure 2. Coal quality control systems for mine and preparation plant

(1) Coal Entrance System
There are two coal entrances in AnJiaLing Preparation Plant; each entrance can crush 2500 ton coals per hour. According to the every eight hour coal exploited plan, workers exploit coals in different seams. And each coal entrance has signal lights for three colors: green, yellow and red. Each truck must obey the signal light. When the
light is green, the truck loaded No.4 coal can dump coal into the entrance. And when the light is yellow, the truck loaded No.9 coal can dump coal into the entrance. And when the light is red, the truck loaded No.11 coal can dump coal into the entrance. The signal light sequence is changed each shift according to the eight hour coal exploited plan. For example, when the coal exploited plan is No.4-1 and No.9 is 2:1, the light is green twice and yellow once during each cycle. The raw coal crushes into 150mm topsize through the first crush and second crush, and transits to the raw coal pile, namely A tower, B tower and C tower, which in total can store 250,000 tons. Coal in A tower is for one step washing system (mainly to discharge waste rock), and B and C towers are for two-step washing system (first step to recover clean coal, and second step to discharge waste rock).

(2) Two-step washing system (first step to recover clean coal, and second step to discharge waste rock)

The two step washing system in Anjialing Preparation Plant has three sub systems, namely 1, 2, and 3. Each subsystem can process 800 tons of coal each hour, and can produce clean coal, middling coal and coal slurry. For clean coal, ash content is about 15.5% and heating value is 5700 calories per kilogram; it goes by conveyor to the clean coal slot. The clean coal slot is divided into two parts: one for high sulfur coal and one for low sulfur coal respectively. The high sulfur coal slot contains coal whose sulfur is higher than 1.3%, and the low sulfur coal slot holds coal whose sulfur is lower than 1.3%.

(3) One-step washing system (mainly to discharge waste rock)

The one step washing system in Anjialing Preparation Plant has two sub systems, namely 4 and 5. Each subsystem can deal with 700 tons of coal per hour, the product we call Dumped Waste Rock Coal. In 4 subsystem, the coal that is larger than 1mm is washed. In 5 subsystem, the coal that larger than 13mm is washed. The product from 4 and 5 subsystems is conveyed to the refuse dumping products pile by belt. The ash content for the product that forms 4 subsystem is 22%, and that from 5 subsystem is 26%.

(4) Press Filter System
At present, there are 6 press filters in Anjialing Preparation Plant, and each one can process 80～90 ton per hour. This plant can produce 130 tons coal slurry every hour; the moisture content is 22% and the ash content is 26%.

(5) Product Bin
The clean coal bin is a sealed slot, and can store 9000 tons of coal. The low sulfur clean coal slot has 7 feeders, and the high sulfur clean coal slot has 6 feeders. The Dumped Waste Rock Coal pile can store 80,000 tons of coal, and has 10 feeders. The Coal Slurry Pile can store 100,000 tons of coal.

(6) Train loading system
The train loading system includes two train lines. Each line can load 5000 tons of coal per hour. Each railroad wagon can hold 80 tons of coal, and one train can load about 8160 tons of coal. It takes about two hours to load a train.

3. Blending and Loading System (Figure 2, Figure 3)

In order to meet the requirements of different varieties of coal, the loading process often requires a variety of products for blending coal, such as Ping 2 coal, which needs clean coal, middling coal, refuse dumping products and coal slurry. The coal preparation plant products include Ping 2 coal, Ping 3 coal, Ping 4 coal, Ping 5 coal, Ping 6 coal, Ping 7 coal, Ping 8 coal, and Ping 9 coal. The Coal Quality Target is shown in Table 2. In 2010 the coal preparation plant produced 15 million tons of outbound products, and the weighted average heat content was 5288 kcal / kg.
<table>
<thead>
<tr>
<th>Types</th>
<th>Quality Specification</th>
<th>Particle Size of Product (mm) and Coal Blending</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Net Heating Value as Received basis (calories per kilogram)</td>
<td>Sulfur Content Dry basis (%)</td>
</tr>
<tr>
<td>Ping 2</td>
<td>5500</td>
<td>≤1.30</td>
</tr>
<tr>
<td>Ping 3</td>
<td>5000</td>
<td>≤1.20</td>
</tr>
<tr>
<td>Ping 4</td>
<td>4000</td>
<td>≤1.20</td>
</tr>
<tr>
<td>Ping 5</td>
<td>5000</td>
<td>—</td>
</tr>
<tr>
<td>Ping 6</td>
<td>5200</td>
<td>—</td>
</tr>
<tr>
<td>Ping 7</td>
<td>5200</td>
<td>≤1.20</td>
</tr>
<tr>
<td>Ping 8</td>
<td>5500</td>
<td>—</td>
</tr>
<tr>
<td>Ping 9</td>
<td>4600</td>
<td>≤1.00</td>
</tr>
</tbody>
</table>
4. Application of the Thermo Scientific CQM Online Coal Analyzer in Anjialing coal preparation plant’s loading station

(1) Online coal analyzer CQM Introduction

The CQM online coal analyzer consists of different sensors (elemental analysis, moisture measurement, density measurement) and a belt control unit. This combination enables instant measurement of moisture, ash, sulfur and heat content in the coal. The unit uses californium 252 as a neutron source and employs Prompt Gamma Neutron Activation Analysis, PGNAA, to detect the content of most of the elements of coal, including C, H, N, S, Si, Al, Fe, Ca, Ti, K, Na, Cl, and B. Density measurement uses cesium-137, a weak γ-ray, as the radiation source, and its attenuation in passing through the coal stream is proportional to density. Moisture is measured by a microwave instrument using a propagation delay principle. The four systems work together to show coal quality each minute. These results, which can also be shown on a train cumulative basis, as well as analyzer status information, are found on the Operator Console. Therefore, the loadout operators, who are responsible for blending, can see the quality of the loaded Coal and greatly improve the accuracy of the blending to ensure quality and commercial compliance.
(2) Installation and Application of the Thermo Scientific CQM Online Coal Analyzer in Anjialing coal preparation plant’s loading station

Figure 4 is the primary stage of the sampling system of coal preparation plant loading station. Primary sample increments go onto the primary belt feeder and into the sample crusher.

Figure 4. Primary sampler, belt feeder and crusher in the Anjialing prep plant loadout

Figure 5 shows how the primary sample can be diverted either to the CQM analyzer or directly to the secondary sampler. Normal operation is to flow the sample to the CQM.
Figure 5. Primary Sample Flow Options

Figure 6 and Figure 7 show the coal flow path to the CQM analyzer as well as a view of the analyzer from alongside.

Figure 6. CQM Analyzer Coal Flow System
Figure 7. CQM online Coal Analyzer

Figure 8 shows the CQM Operator Console, on which are found trend displays for ash, sulfur and heating value. The curve shows the results of the Ping2 coal loading.
Figure 8. Operator Console for the CQM analyzer during the loading process

Figure 9 shows the blending person using the on-line Coal Analyzer results to control train quality (there is no automatic blending at the present).

Figure 9. Blending personnel act in accordance with the results of blending analyzer
(3) Accuracy of CQM online coal quality analyzer

Because the traditional coal quality testing process takes a long time, it cannot provide real-time blending guidance. Historically, therefore, the blending process mainly depended on the products’ historic quality and experience. As there is large variability in Commercial coal quality, this often resulted in commercial coal of inferior quality. In the past, the failure rate was over 30%. After blending guidance by the online coal analyzer, the failure rate of outbound commercial coal is below 10%. The following are some of the CQM test results compared with the laboratory results.

1) Formula
   Ping2 coal:
   \[ Q_{\text{net,v,ar}} = 7647.19 - 70 \times M_t - 90 \times A_{\text{ar}} \]
   Ping7 coal:
   \[ Q_{\text{net,v,ar}} = 7646.4 - 70 \times M_t - 90 \times A_{\text{ar}} \]
Ping9 coal:

\[
Q_{\text{net,v,ar}} = 7642.5 - 70 \times M_t - 90 \times A_{\text{ar}}
\]

where: Mt, Aar are online analyzer’s measured data.

2) CQM test results compared with laboratory

CQM put into operation in our company from July 2010, it is stable with satisfactory results. Follow is the comparison chart between CQM test results and laboratory test results of January~March 2011.
It can be seen from the above four Figures, CQM test results and laboratory results are close, but there is still an overall bias, that is mainly caused by a sub-optimal calibration formula used in the process. By using this data to adjust the calibration, the error will be further reduced.
Figure 11. Coal blending guide by online Coal quality Analyzer in Anjialing coal preparation plant. Figure of ash, sulfur control results.

It can be seen from Figure 11, control results of Ping2 and Ping7 coal’s high calorific value are fairly stable.

3) CQM detection accuracy:

Beginning in December 2010, after the CQM commissioning, we tested a lot of data. There are 285 Ping2 coal data, 225 Ping7 coal data. Through the analysis of these data, we obtained the measurement accuracy of CQM.

(4) The effect of Online Coal Analyzer CQM Application

The Application of the online Coal Analyzer in the Coal Loading Station’s blending has improved the coal quality pass-rate greatly, and the mine’s test results are close to the port’s results.
As seen from the table, AnJiaLing coal preparation plant coal quality results are close to the port test results, and the sulfur is not exceeded.

Coal loading and blending guidance by the online coal analyzer facilitates the blending of the refuse dumping coal, the middling coal, the High quality coal maximize(Ping2 coal,Ping7 coal), and60% output Coal Slurry blended in high-quality coal. As of March 2011,Coal Slurry output is 15 million tons, over 90,000 tons blending in high quality coal, with 97% the proportion of high quality coal. In short, the use of the online coal quality analyzer ensures product quality stability, makes low quality coal blending easier, increases the production of high quality coal, and increases the economic efficiency of enterprises greatly.

5. Online Coal quality Analyzer will be installed by Pingshuo

The geological conditions of the Underground Mine working face are complex, and influenced by faults and other geological structures. In the affected periods of faults and other geological structures, while other times gross coal quality is normal, at times coal gross coal fluctuations are large. Limited by the technology of the coal preparation plant (only the wash once process), and the impact of coal gross coal, fluctuations in the products of the coal preparation plant are also large. In order to be able to sort in real time, sub-heap timely, and to sort out high heat coal to increase the amount of high quality coal, but also to match the quality level to meet the quality requirements of users of coal, Pingshuo Coal Industry Co. Ltd. purchased two Thermo Scientific ECA Online Coal Analyzers, one ECA for 1# coal preparation plant and one for 2#coal preparation plant. Currently, the two sets of equipment have been shipped to the mine, and are ready to install.

Figure 12 is ECA installation position of coal preparation plants in 1# underground mine and sorting product coal pile.
Figure 12. Sorting product coal pile of coal preparation plants in #1 underground mine.

Figure 13 is the ECA’s installation position of coal preparation plants in #2 underground mine and sorting product coal pile.

Figure 13. Sorting product coal pile of coal preparation plants in #2 underground mine.
Adhering to the Coal companies’ “market-oriented, customer-centric” business philosophy, in 2011, "Quality Year", the Pingshuo Coal Industry Co. Ltd strengthened quality management of the mine production, washing and processing, and loading outbound aspects. Another goal was to achieve raw coal and production quality standards which include qualified coordinated and efficient operation in production processes, to ensure final product quality meets users’ requirements. In order to enhance the Pingshuo brand and the market competitiveness of its coal, and enhance core competitiveness and management level, our company will walk in the forefront of the industry with respect to new equipment and new technology applications.

Pingshuo Coal Industry Limited Liability Corporation.

2011-4-18