Development of a Monitoring System for Coal Flow in Bunkers

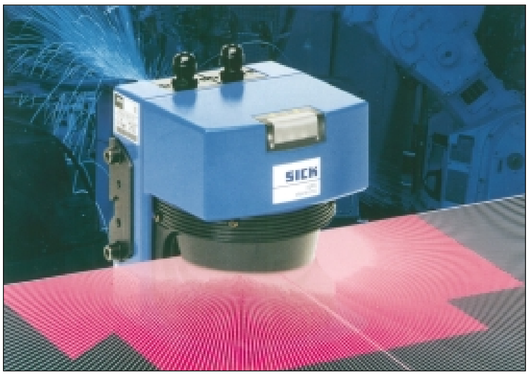

Figure 1. Erwin Sick LMS200 laser monitor scanner (LMS)

OBJECTIVES

- To assess the suitability of scanning-laser monitors in a bunker environment.
- To install a number of monitors in lined and unlined bunkers at a UK power station.
- To develop the software necessary to provide operator information on coal levels, alarms and flows.
- To investigate the durability of the monitors and the required service interval.
- To assess the use of such monitors on moveable conveyors (known as tripper cars) to give 3-dimensional (3-D) profile information and as an aid to identifying other flow problems before they affect coal flows to mills.

SUMMARY

Coal-fired power stations have solids handling systems for both coal and ash products, with operations involving unloading, stockpiling, conveying on belts, storage in bunkers and unloading. Coal is delivered with various levels of moisture and in different sizes. At each stage of the coal-handling process there is the potential to incur problems such as dust blow, difficulty in controlling flow (low or high rates), dust sticking to equipment and coal bridging or rat-holing in bunkers. Much work has been carried out to improve design of equipment to avoid problems but, given the wide range of properties of different power station-grade coals, problems are encountered when fuel quality changes. Monitoring flow, using instrumentation such as belt weighers and level indicators, is a core part of handling processes. At present, ultrasonic level sensors are widely used to give point measurement of bunker levels, but the amount of information produced is limited.

This project was initiated to develop and demonstrate a system for determining coal levels in large utility coal bunkers and the flow characteristics of materials within them. Erwin Sick Ltd has developed a laser-based monitor that has the potential to give not only accurate levels but also an indication of flow characteristics and early detection of problems in bunkers. This instrumentation may also have other solids-handling applications, both in power stations and in process industries, where flow monitoring/level indication is necessary.

Initial testing of a single monitor was conducted in a bunker at Eggborough power station. The results showed that the monitor had the potential to operate reliably in a bunker environment and to measure levels. The profile of the surface showed the potential to give improved level information and early detection of problems such as hang-up, funnel flow and rat-holing. To become more than a research tool, it was necessary to interface with existing control systems.

Erwin Sick developed an interface to process the data from monitors such that they could be viewed and logged on a plant information (PI) system (supplied by Oil Systems Inc) and other systems that could use a MODBUS protocol. The basis of the system was to take the profile comprising up to 360 data points, and condense this to a controlled number of columns giving depth and position information.

Monitors were installed in each of the six bunkers for Unit 3 at Eggborough and were connected to the PI system via the interface systems. The monitors operated from October 1999 to January 2000 and the data collected showed superior information compared with information from existing systems. The bunkers were generally showing even-dropping of levels, referred to as mass-flowing bunkers. The effect of coal type was monitored and results have shown the effect of coal moisture and type.

The scanner was tested on a moveable conveyor to assess the practicality of this for observing rat-holes as the conveyor passes over the bunkers, and as an aid to bunker filling. In both cases the moveable installation would be complementary to the fixed-point monitoring systems as it would clearly be impractical to constantly move the conveyors just for the purpose of level measurement. Monitors were installed on a unit at Didcot power station. Didcot was chosen for this assessment because grate bars were not in place under the conveyors and because rat-holing has been observed in these bunkers. The results showed that these monitors gave some enhanced level detection but do not offer an alternative to fixed-position monitors.

POTENTIAL USERS OF THE TECHNOLOGY

Power stations and companies with significant material-handling requirements, with a need to monitor levels and flow in bunkers.

COST

The total cost of this project was £156,721 with the Department of Trade and Industry (DTI) contributing £55,441, National Power £53,410, Erwin Sick £37,870 and Dr H Wright and Associates £10,000.

Further information on the Cleaner Coal Technology Programme, and copies of publications, can be obtained from:
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MARCH 2000

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Department of Trade and Industry

CLEANER COAL TECHNOLOGY PROGRAMME

Project Summary 247

DURATION

22 months - June 1998 to March 2000

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BACKGROUND

Coal-fired power stations have solids-handling systems for both coal and ash products, with operations involving unloading, stockpiling, conveying on belts, storage in bunkers and unloading. Coal can arrive with various levels of mineral matter and moisture and in different sizes. At each stage of the coal-handling process there is the potential to incur problems such as dust blow, difficulty in controlling flow (low or high rates), dust sticking to equipment and coal bridging or rat-holing in bunkers. Much work has been carried out to improve design of equipment to avoid problems but, given the wide range of properties of different power station-grade coals, problems are encountered when fuel quality changes. Monitoring flow is a core part of the handling processes involving instrumentation such as belt weighers and level indicators.

UK power station-grade coal is typically:

(i) top size <50mm with 10-20% <1mm

(ii) total moisture in the range 7-12%

(iii) ash content in the range 8-20%.

Each of the above factors affects the handling properties of a coal, and the nature and distribution of the ash components is critical. In addition, the coal is also affected by storage, eg long-term stock tends to be much more difficult to handle than newly-mined coal. A contributing factor may be breakdown of shales to form finely divided clays and some studies have found good correlation of ash in very fine particles with handleability. It is difficult to determine the handling characteristics of fuel from standard analyses. The most reliable means is to measure handleability using, for instance, shear cells etc.

A further complication is that handleability must be considered in the light of the equipment design. A coal may not flow in one power station bunker, but will give no problems in another bunker even at the same station. Factors such as bunker lining and outlet dimensions are critical. Generally, power stations have bunkers that have been designed or modified to give good flow for most of the normal coals taken. However, relatively small changes to coal blends can bring problems, even where the new coal appears similar to the normal digest of coals. Minor problems are common, the stations tend therefore to ‘manage’ handleability issues, and only where there is loss of plant availability is handleability considered to be a serious issue and cost factor.

The minimum level in power station bunkers is usually set to give a margin of time to refill the bunker before blowback occurs. The effect of a rat-hole or funnel flow is that the minimum level is reached more quickly, effectively giving reduced coal storage and the need to re-fill the bunker frequently. The maximum level is set to avoid overfilling which could overload the structure of the bunker. The normal frequency for bunker filling depends on a number of factors, eg unit load and coal delivery times, and whether there are handling problems.

The devices currently used for level meaurement in bunkers include acoustic, capacitance, diaphragm, load cells, rotating paddle, photoelectric, resistance, tilting-switch Nucleonic and ultrasonic devices. Most offer only spot measurement at a point in the bunker and therefore best performance from these is when installed in mass-flow bunkers where there is a strong correlation between volume stored and storage level. However, with core flow, none of the above is capable of giving a representative level. In such circumstances it is necessary to use a number of monitors. Therefore the aim for this project was to use a novel device, namely the Erwin Sick laser monitor scanner (LMS), for improved level measurement with added facility of diagnosis of flow characteristics.

The LMS comprises a unit containing a low-power laser. The pulsed laser beam is emitted as a ‘measuring feeler’. If it encounters an object, such as the surface of a bulk material, the beam is reflected and the reflection is registered in the scanner’s receiver. The time between transmission and reception of the impulse is directly proportional to the distance between the scanner and the object (time-of-flight). An internal rotating mirror deflects the pulsed laser beam so that a fan-shaped scan is made of the surrounding area (laser radar). The contours of the target objects are determined from the sequences of impulses received. The scanner’s 2-D contour data are transferred to a computer incorporating Bulkscan software via an RS 422 data interface. A 180° contour of the surface profile being monitored is built up from 360 measurements, ie one point every half-degree.

INITIAL TESTING

Initial testing of the monitor was on a single bunker at Eggborough power station in Yorkshire. The monitor was installed above the ‘C’ bunker of Unit 2 at the start of the project in June 1998. The scanner was located 1.2m below the walkway floor at the bunker top level to avoid interference of the laser scanning by the structural support cross-beams. A 300mm-square hole was cut in the floor at the central position both along and across unit bunker 2C. The scanner was located in position via a suitable vertical steel support rod fixing it to the safely removable floor section. The plane of scanning was along the centreline of the 2.44m-long slotted outlet. Figure 2 shows the Erwin Sick LMS after four months of being installed in a bunker.

Figure 2. Erwin Sick LMS after four months’ operation

In the six months of installation on 2C bunker, there were two reported failures of the system. Both were minor failures caused by disconnection of power and a blown fuse in the main control system panel. The LMS 220 was not maintained in any way during the six-month period and no cleaning or re-calibration was necessary.

The bunker levels were evaluated using the standard ‘Bulkscan’ software which was found to determine bunker levels reliably to as low as 14m below the scanner. The profile of the bunker surface, while interesting, was in too great detail for use in conventional monitoring of levels and would also lead to large amounts of data being stored. However, given the reliability and precision demonstrated, it was decided that the bunker application should be developed further with testing as a working system on all bunkers for a unit.

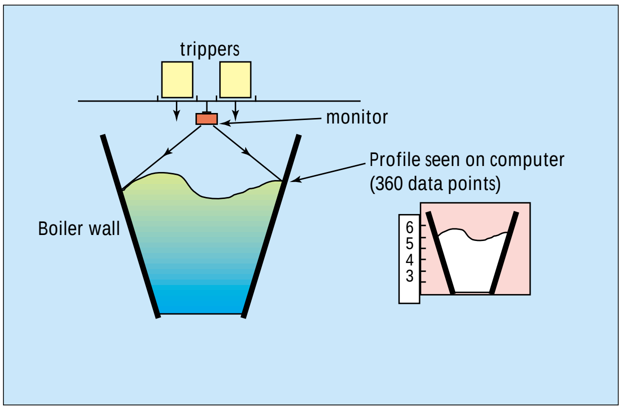

Figure 3. Schematic of bunker level display

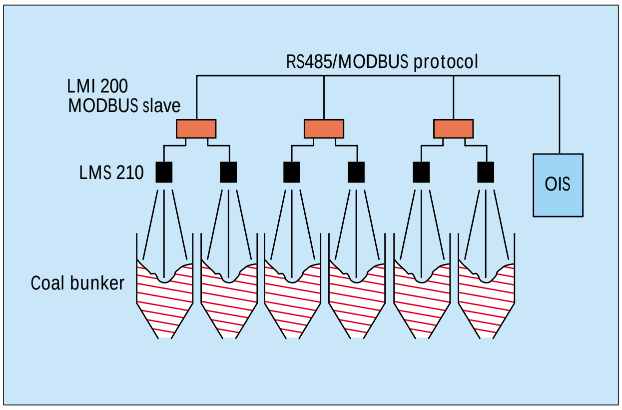

Figure 4. Monitors on U3 bunkers at Eggborough power station

FULL BUNKER INSTALLATION AT EGGBOROUGH POWER STATION

Given the success of the single monitor installation, it was decided to progress to a full unit demonstration at Eggborough power station on the Unit 3 bunkers. The aims of this work were: to install monitors in each of the six bunkers along the feeder line (as determined for the single monitor); to develop a suitable interface to the operation and information system (OIS, supplied by Oil Systems Inc); to build graphic displays to allow visualisation of levels; and to allow storage of manageable amounts of data. Having developed a working system, the aim was then to evaluate the output from the monitors for the range of coal types and qualities supplied to Unit 3.

To resolve the interface issues for relating data from the monitors to the OIS PI system, meetings were held between control and instrumentation engineers from National Power and from Erwin Sick. The principal issues addressed were:

- Converting the 360 data points from each monitor into a manageable number of inputs to be viewed and logged on the OIS.
- Designing an interface with OIS such that the PI system would 'poll' the monitors to collect data, and then for the monitors to send data back to the PI system.
- Hard-wiring the system to the OIS.
- Representing the data in an easy to assimilate form for the coal plant operators.

Erwin Sick designed the interface, including software for the monitors, while Eggborough power station staff planned and carried out the installation of the interfaces and all connections, and other National Power personnel built the graphics and trending for representing the data.

The interface (by Erwin Sick) was designed to operate in an industrial environment to transfer data from the scanners to control/data storage systems. It was agreed that a MODBUS protocol was the most appropriate for the interface (providing the best solution for Eggborough, (though not necessarily for all applications). This would have one interface for every two scanners and then send the data to the OIS via a single twisted pair of wires, as shown in Figure 4.

The procedure used to reduce 360 data points (each with position and depth information) was to convert the bunker profile into a number of columns. By making the exact number and dimensions of these user-defined, it gave scope to make the monitoring as simple or detailed as required.

Installation of the interfaces and monitors was completed in September 1999, following a summer outage on Unit 3. Data collection on bunker levels began in October 1999. There were a number of issues to be addressed in assessing the monitors as a working bunker level system:

- The nature of graphic display that would be useful to the coal plant and for more detailed evaluation of performance.
- Did the monitors give reliable and stable level indication at various heights of coal in the bunkers?
- How did the monitors respond during bunker filling, when dust clouds may be present and the filling could obscure measurements?
- How did levels fall in the bunkers? Did they give mass flow or a tendency for levels to drop more in the centre of the bunker?
- How did coal quality affect the scanner outputs? For instance, did known poor-handling or wet coals give different performance in the bunkers? Coals such as stock coal give different bunker behaviour.
- Could the scanners be used to estimate the coal flow from bunkers?

The simple graphic display developed and used to view bunker levels is shown in Figure 5.

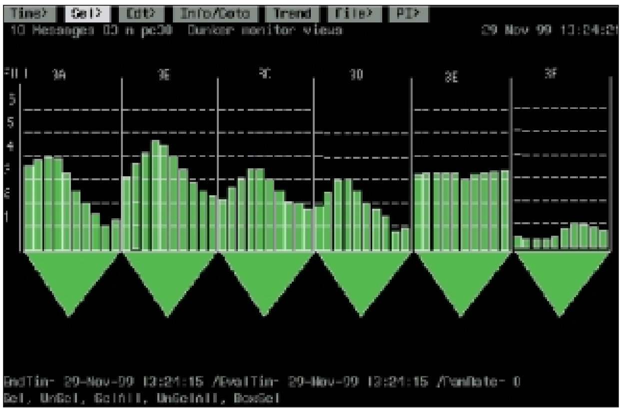

Figure 5. Graphic display on OIS

This display was updated every 10s per bunker and provided a live display not only of bunker levels but also of the surface profile of the coal directly above the feeder slot. This also aided bunker filling from the two moveable conveyors. The limitation on use of these was that the monitors needed to be at least 2m above the highest bunker level to avoid shielding of the surface by raised coal.

By storing the data from the monitors on the Eggborough server, it was also possible to interrogate the data using spreadsheets. The value of the spreadsheet approach was that the data could be manipulated to give diagnostic information on the nature of coal flow in each of the bunkers for a range of fuels.

The monitors have operated continuously since installation with no need for maintenance and therefore there is a wealth on information on the nature of flow.

Unit 3 bunkers, unlike Units 2 and 4 bunkers at Eggborough which are lined with a low-friction lining, are not lined but give good flow characteristics with few problems of rat-holing or arching. The information from the monitors confirmed the 'near-mass flow' behaviour of the bunkers but differences were found for various coals and the initial filling.

Figure 6 shows the nature of flow for a range of coals on D bunker. For some coals and initial fill levels the bunker gave highest flow in the centre but the range of velocities was narrow.

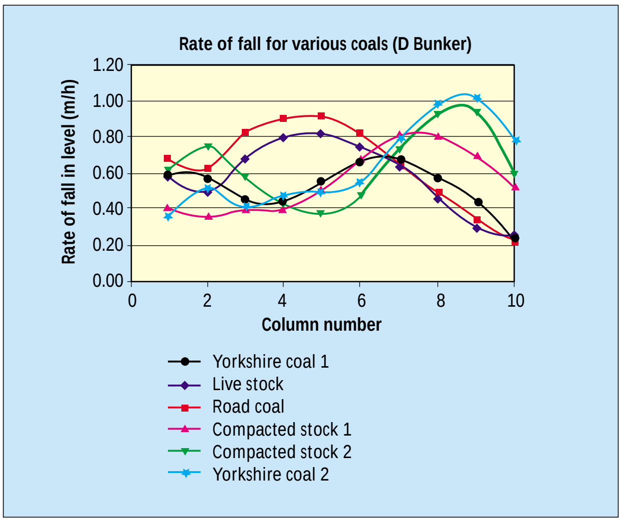

Figure 6. Bunker flow indications for various coals

However, there was a variation and in some cases the flow was much higher on one side of the bunker. Some of this was due to the coal having been filled on that level, and the peak gradually flattening as the bunker level dropped. Care is therefore needed in the interpretation of 'level' information to derive flow characteristics. However, the ability to give detailed information with a manageable amount of data was clearly demonstrated.

TESTING ON THE MOVEABLE CONVEYOR

Testing of a single monitor on a moveable conveyor was carried out at Didcot power station. The conveyors pass over the bunkers during filling and therefore give scope to detect rat-holing or low levels across the whole bunker. In principle this could be used to build a three-dimensional profile. The monitor was assessed for bunker filling and for detection of levels when both stationary and moving.

Operated in this way, the monitors give some scope for enhanced level detection and identification of problems but do not offer an alternative to fixed-position monitors.

CONCLUSIONS

- A novel laser scanner was used to monitor coal levels in power station bunkers, giving accurate level indication and demonstrating excellent reliability.
- There was no need for cleaning or maintenance in the five months of operation.
- The superior diagnostic detail of the output from these monitors was demonstrated by a full-scale unit installation of these.
- The monitors provided an on-line diagnostic tool with the potential to track the coal through the bunker. At the same time, the data were presented to the coal plant control room in a form easily used by the operators.
- The monitors can be used with standard software and a computer as a diagnostic tool.
- The monitors have been demonstrated as a working system on a power station boiler.
- Tracking coal flow through the bunkers from the flow diagnostics can be achieved. It was not conceivable that existing devices could provide this level of detail unless many were used.
- The flow characteristics in different bunkers were assessed for a range of fuels. The type of bunker, coal quality and the fill level were all important for the diagnostics.
- The data from the monitors were transformed into a format easily accessible by conventional data storage systems. The MODBUS protocol used should allow use of the monitors with most digital control systems.

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DTI/Pub URN 00/748