Is Your Coal Plant Capable?

Brian Boon, Senior Consultant, Cement Performance International Ltd., UK, discusses some of the problems faced by coal plant operators when utilising cheaper coals.

Introduction

The continual drive for improved competiveness within the global cement industry has meant that the vast majority of plant operators continue to pursue the reduction of fuel costs, whether by reducing specific fuel consumption or specific fuel cost. The move towards reduced specific fuel cost has resulted in the development and use of an extensive range of waste derived fuels; however, for some operators the technical, social, political, and/or geographical considerations can prevent them from being able to utilise these types of fuel. Often the only available approach for solid fuel users is to seek a cheaper alternative source of coal.

However, cheaper coals are generally cheaper for a reason: they are more difficult to utilise. This difficulty may affect product quality (for example, variable ash content), plant operation (elevated sulphur content), production levels (low fuel grindability), plant reliability (poor fuel handling characteristics), or operational safety (high volatile matter content). Over recent months, a number of CPI clients have requested assistance in achieving improved (and safer) coal plant operation, resulting from their desire to use cheaper (higher volatile) coals with their existing plants, which have indirect firing systems with cooler exhaust air as the source of heat for drying.

These types of plant clearly present a greater challenge when using higher volatile coals due to their use of hot drying air and fine coal storage. Most plants using a higher volatile matter coal would normally operate with a 'reduced oxygen' atmosphere, utilising a portion of the kiln exhaust gases to provide the required heat for drying. The use of cooler air therefore requires careful thought.

It is well known that the three conditions required for a fire to occur are the presence of fuel, oxygen, and heat. In addition, an explosion may result if the fuel is present in the form of a suspension and this suspension, the oxygen, and heat are confined within a restricted space. The removal of any of these conditions will eliminate the possibility of an explosion occurring.

As a fuel suspension, heat and confinement are prerequisites of a coal drying and grinding system, the initial consideration should ask whether the plant can be converted to 'reduced oxygen' operation. If this route is impractical, then minimising the possibility of an explosion must concentrate upon the details of system design, process operation, and plant maintenance. Other measures, such as explosion relief, containment, and suppression, while important, are merely methods of minimising the damage (to plant and personnel) once an explosion has been initiated.

Specifically, the following should be reviewed and assessed:

- Coal characteristics.
- Coal sampling and testing frequencies.
- Raw coal receipt and storage procedures.
- Coal milling system:
  - Design philosophy.
  - Construction details.
  - Operating and housekeeping procedures.
  - Maintenance procedures.
- Management procedures.
- System operation.

Coal characteristics

For the initial plant design, the fuel properties should have been assessed for a range of characteristics, primarily to assist with sizing the explosion relief venting area. This will prompt the following questions:

- Has the coal been changed since the plant was initially commissioned?
- Have the coal characteristics been determined?

- Is the basis of the initial design known?

These questions must be answered and, if appropriate, tests should be repeated for each of the current fuels (and any future coals), to confirm that the existing provisions are adequate.

The tests used will depend upon the basis of the original plant design and detailed advice will be required for each particular installation. However, of primary interest will be an assessment of the explosion severity, as defined by the measurement of the peak explosion pressure (*P*max), the peak rate of pressure rise (d*P*/d*t*max). These allow the derivation of dust explosion severity constant (Kst) and the dust explosion severity class (St 1, 2 or 3). Other tests may include: the determination of minimum ignition temperature (MIT); minimum ignition energy (MIE); behaviour of coal dust layers at high temperature (LIT); and safe storage temperature.

Although some typical data for coal dusts may be available, it is important to note that a dust's critical properties vary between sources of coal and can change significantly with moisture content and particle size distribution. It is, therefore, important that the test sample is representative of the fuel being processed.

Coal sampling and testing

Frequency

It is important that coal deliveries are sampled frequently for moisture and ash for commercial reasons, supported by regular (depending upon variability) sampling for testing of the proximate and ultimate analyses. However, for safety purposes, a daily sample of the coal fed to the kiln system should be tested for volatile matter and free moisture content. Total moisture (and therefore inherent moisture, as the difference between total and free moisture) should be tested on a weekly basis. The results for moisture will enable a realistic mill outlet temperature to be targeted, while the volatile matter will provide a ready indicator to the variability in coal reactivity.

Raw coal receipt and storage procedures

The management of raw coal storage is crucial to the safe operation of a coal plant and the following guidelines should be followed:

- Always store different types of coal separately.
- Manage the coal supplier to minimise coal stock levels held at the cement plant, otherwise hold a long term strategic stock onsite. The contents of this long term stock should be used each year to minimise the risk of combustion within the stockpile.
- The long-term stock should be compacted (layers of a maximum 600 mm thickness) with sloping sides (15°, if possible) and regularly monitored for signs of combustion or self-heating by using thermocouples, infra-red thermography and regular visual inspection. A temperature below 50 °C would normally be considered safe but rates of reaction can double for every 10 °C increase above this level. Raw coals with high fines content (because of their higher surface area) will suffer from increased rates of oxidation.
- Ensure that any burning coal is separated from the main stock and carefully doused with high volumes of water.
- The size of the short-term (working) stock will depend upon the delivery pattern for the fuel but ideally should be no greater than one week's usage.

Coal milling system

Design philosophy

The key is to understand the basis of the plant design and the safety philosophy employed. Questions include:

- How did the original designers expect the plant to react in the event of an explosion?
- Should the explosion be contained, vented, or suppressed?
- Which design standards were used?
- Are these standards still relevant to the current operation?
- Have the standards been updated?
- Has the operation changed significantly since the initial design?

Europe

The equipment supplied is subject to Directive 94/9/EC (ATEX 95), while Directive 1999/92/EC (ATEX 137) addresses the use of equipment, with the intention of establishing minimum requirements for the protection of workers at risk from explosive atmospheres. ATEX 137 requires that employers demonstrate that they have controlled explosion risk, using both organisational and technical measures.

Organisational measures will include:

- Permit to work systems.
- Operator training with regard to explosion protection.
- Written instructions for operators in hazardous areas.
- Emergency evacuation procedures.

Technical measures will include:

- Explosion relief systems to include bursting panels and isolation devices.
- Control of static electricity.
- Suitable dust extraction and collection.
- Proper selection of electrical and non-electrical equipment.

USA

The following standard, published by The National Fire Protection Association is applicable: *NFPA 654: Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids.*

NFPA 654 provides standards for system design and process equipment, including pneumatic conveying and dust control systems. It also covers other related topics, such as building construction, explosion venting, ignition sources, fugitive dust control and housekeeping, fire protection, training, inspection, and maintenance.

Construction Details

Having checked the design philosophy and the design drawings, now check the details of the plant's construction! To minimise the possibility of an explosion, everything must be geared to smooth, consistent, and controlled plant operation. Interruptions to operation and variability of coal flow, gas flow, and gas temperature must be avoided. For example, checks are needed to confirm that:

- The coal silo operates as a mass-flow silo.
- Duct orientation and gas velocities do not allow coal settlement.
- Thermocouples and CO detectors are correctly positioned
- Internal ledges and sharp corners have been eliminated.
- Explosion vents are safely positioned.

The ability to operate the coal mill at a rate matching the kiln requirement will minimise mill shutdowns. If there is a current mismatch, investigate possible mill modifications.

Operating and housekeeping procedures

Review all of current procedures. Time can pass deceptively quickly and without a formal system for managing change, some jobs are deferred until time is available. One of those jobs is likely to be writing procedures and, unfortunately, that is often too late. Ensuring that plant is consistently operated in a safe and efficient manner is a major part of successful plant management. The availability of procedures that are comprehensive and frequently reviewed is an integral part of achieving that aim.

However, having good written procedures is pointless unless the content is properly communicated to the operators. Are all current (and future) operators fully conversant with the procedures? Were they involved in their preparation to ensure that they are practical and relevant? A repeat HAZOP Study (which would normally have been conducted pre-commissioning) can be useful for updating operating procedures and also as a training aid as it can involve a range of personnel.

All staff should be aware of the importance of housekeeping, whether as part of a written rota (plant operators) or following a specific job (maintenance staff). Coal that has been cleared away cannot catch fire and NFPA 654 considers housekeeping of such importance that specific guidance is provided.

Maintenance procedures

Shutdowns and start-ups are the most dangerous period for any coal milling plant. It is therefore critical that the reliability of the coal plant is maximised. The use of techniques, such as Failure Mode and Effect Analysis (FMEA) and Root Cause Analysis (RCA), can be invaluable in understanding the real source of plant problems.

How effective are maintenance procedures; which parameters are measured; what targets are set?

National standards and legislation may now require formal inspection, testing, maintenance, and recording procedures. For example, NFPA 654 requires a programme to ensure that the fire and explosion protection systems, related process controls, and equipment perform as designed. This will include:

- Regular planned and recorded inspections of explosion suppression systems and mechanical explosion systems.
- Confirmation that pneumatic conveying and dust control equipment is operating as designed.
- Safe housekeeping methods to remove combustible dust from surfaces within the plant. Dust layers of 1 mm thickness require immediate cleaning.
- Testing of all plant earthing systems.
- Checking of electrical, process and mechanical equipment, including process interlocks.
- System reviews following process changes; for example, a change in coal source or product size.
- Lubrication procedures.

Management procedures

How will the plant management team ensure that the relevant legislation, directives, standards, codes, procedures, systems of work, and instructions are in place, communicated and put into practice? For example, housekeeping may seem unglamorous, but it is a vital contribution to producing a safe working environment. Management must make sure that the correct resources are available and that housekeeping is seen to be a priority function. If housekeeping within the coal plant is made a visible priority, then plant operators will respond.

System operation: new coal

When changing to a new coal, there are certain operational parameters that should be reviewed, primarily the required residual moisture content and dry coal fineness.

Residual moisture content

The milling system is required to produce a fine coal with a moisture content that results in an easy to handle material. This can be achieved with a maximum moisture content of 1% above the inherent moisture content, thus allowing a target mill outlet temperature to be set. Ensure the mill outlet temperature alarm reflects any alteration in the target and record the changes within 'The Management of Change System'.

Coal fineness

The basic 'rule of thumb' for use in the rotary kiln is that a fuel should be ground to give a residue on a 90 µm sieve equivalent to half of the fuel's volatile matter level. However, this is a level intended to avoid combustion problems, even with an inefficient firing system. Many sites can run with 90 µm residues equivalent to 75% of the VM level and a number operate without problem with the residue equal to the VM level.

When using higher volatile coals, the residue can be slowly relaxed while monitoring for the onset of localised reducing conditions within the kiln by monitoring the clinker or, for preheater kilns, by monitoring the SO_3 level both in the clinker and in the material flowing from the lowest cyclone into the kiln.

The coarser the dry fuel, the 'safer' it will be, but at a practical level the occurrence of coal mill system safety incidents are generally related to abnormal operating conditions, primarily shutdowns and start-ups. It is therefore advantageous from a safety perspective to minimise the number of mill shutdowns. Flexibility with the coal fineness may provide some assistance.

Temperature control

The mill outlet temperature is the primary temperature control, but a secondary control loop limiting the mill inlet temperature should be considered for vertical spindle mills. This will limit contact between hot inlet air and coal collected in the rejects zone below the mill table, which may ignite and result in semi-combusted particles being carried into the mill.

Airflow control

Monitor the airflow into the mill, as well as at the filter exit so that any increase in false air is identified immediately, as in-leaking air at any point in the process after the mill inlet would reduce the airflow through the mill. This is likely to result in more coal falling into the rejection zone where gas temperatures are higher and the potential for a smouldering fire increases.

Control loops

Optimise the control loops around the process to give closer control of the process and avoid temperature control dampers operating at either extreme position (fully open or shut) to improve mill temperature stability.

Conclusion

Changing to a cheaper coal is not a simple matter. There are potential implications for a number of operational factors, not least safety. Coals with increased volatile matter content are, by their nature, more likely to ignite and potentially result in an explosion. However, careful management of the key issues will result in a thorough assessment of the risks involved and the steps that can be taken to minimise those risks.