Coal and charcoal injection in blast furnaces

The use of coal injection to replace coke in blast furnaces has risen significantly since the 1980s, as coke and environmental costs have continued to rise. Clyde Materials Handling Ltd. has been involved in producing injection and associated equipment for blast furnace operators throughout this period, both for granular coal and pulverised coal injection; providing safe, reliable and controllable systems. More recently charcoal injection systems have been developed and installed in mini blast furnaces.

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Crude steel production broke through the billion tonne barrier in 2004, with production rising currently to about 1.25 billion tonnes. Forecasters are predicting a year-on-year rise of between 1% and 2% over the next five years. This dramatic increase in steel demand and production has been predominately driven by the astronomical boom within the Chinese market. As a result, the cost of steel has nearly doubled in recent years, and is predicted to continue to rise for the foreseeable future.

Furthermore, an integral element of the steel production process, metallurgical coke, has also risen significantly in price, reflecting demand for good quality coking coal and increased transport (shipping) costs.

Typically coke costs about three times that of coal, thus ironmaking costs, coupled with concerns over coking coal availability, and environmental pollution from coke ovens (and the cost to remedy the pollution), have encouraged ironmakers to develop methods to reduce the amount of coke used in the BF. This has been achieved by developing coal injection technologies. Although some trials were done in the 1960s its development really took off in the 1980s, since when, its use has continued to rise as the cost of coke has risen.

INJECTION TECHNOLOGIES

There are two main injection processes, granular coal injection (GCI) and pulverised coal injection (PCI). Granular coal has a size of 5mm max., whereas pulverised coal has a size of 70% less than 75 microns. Both technologies involve crushing coal to the predetermined size range then injecting it via the tuyeres into the furnace. The process route involves raw coal storage, crushing, drying, crushed coal storage, weigh hoppers and pneumatic conveying to the tuyeres, together with associated process control and safety measures to prevent explosions. Additional oxygen is also injected to maintain raceway temperatures as coal initially acts as a coolant and reduces the adiabatic flame temperature.

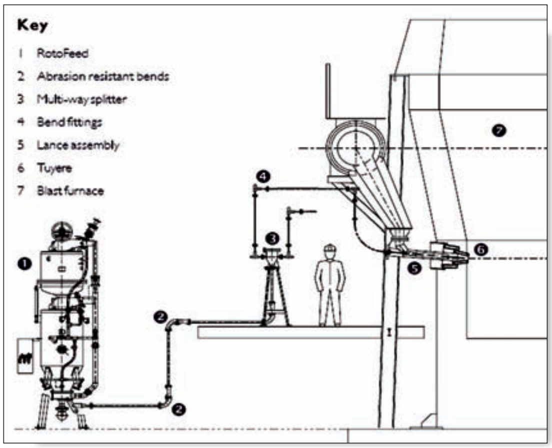

Fig.1 **Schematic of injection system**

Typically there is a 0.95:1 replacement ratio of coke by coal, thus the financial and environmental savings can be considerable. Today the quantity of coal injected per furnace is usually in excess of 100kg/THM, typically about 150kg/THM, and occasionally in excess of 200kg/THM. The reason for the range of results is not the process capability, but reflects individual plant conditions in terms of steelworks energy balance, coke availability, iron demand and so on. Substantial trials with oxy-coal injection have resulted in over 300kg/THM.

DEVELOPMENT OF THE PROCESS

Although Clyde Materials Handling systems have been installed in blast furnaces throughout the world, two plants will be described.

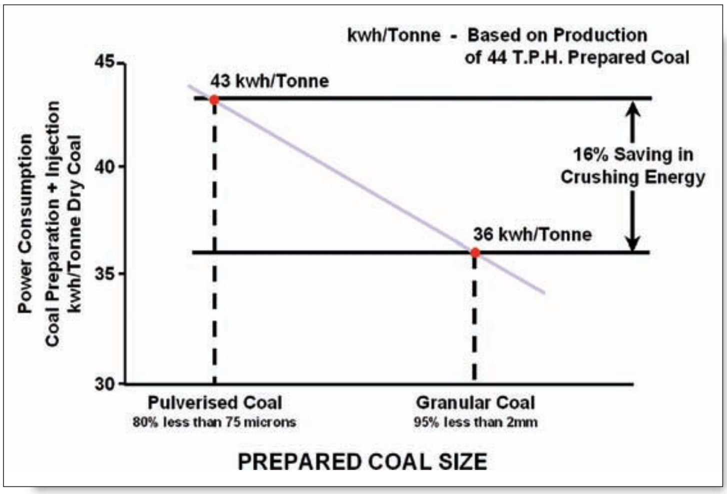

Fig.2 Typical savings in grinding costs

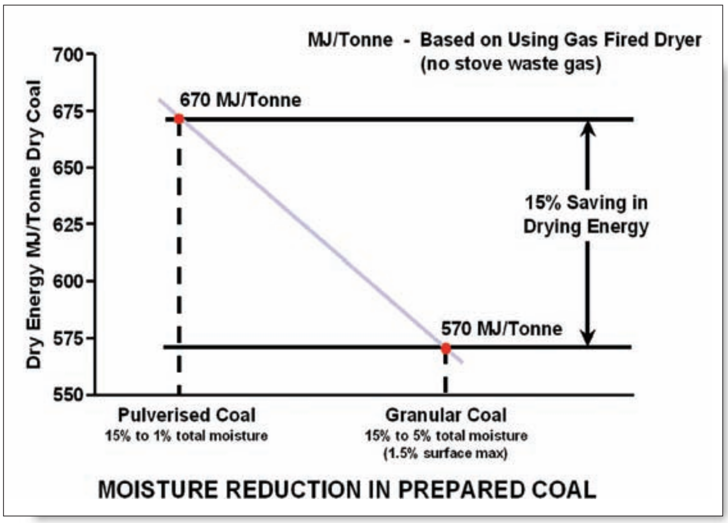

Fig.3 Typical savings in drying costs

Scunthorpe Works, Corus Clyde Materials Handling have been associated with coal injection since the early 1980s when the Scunthorpe Works of the then British Steel were investigating use of coal injection and contacted us (then known as Macawber Engineering) as we had injectors that were suitable for coal injection. We worked closely in partnership with British Steel to develop a total coal injection system. The first trials were via a single tuyere on Queen Mary blast furnace, which was soon followed by a full-scale system.

During the initial trials a comparison was made between granular and pulverised coal injection. Replacement ratio, furnace permeability, hot metal quality and off-gas dust composition were recorded, and it was concluded that as the furnace performance was the same using both sources, and as GC was cheaper and easier to use, then GCI was the preferred route.

Coal injection technology was installed on Queen Victoria, Queen Anne and Queen Bess furnaces in 1985, 1987 and 1989 respectively. The first on-site granular coal preparation plant was constructed in 1985, followed by a second plant in 1987. Since that time, the systems have been upgraded to increase capacity, and oxy-coal was installed on the Queen Victoria furnace in 1992, with injection rates of up to 222kg/THM being achieved.

At the Scunthorpe Works, coal is distributed from the preparation plants to the injection plants by road tankers which are discharged pneumatically into product coal silos. The silos provide 8 hours of buffer storage capacity and are designed for mass flow discharge to prevent hang up of the coal. They are equipped with explosion relief, nitrogen purging and CO/CH_4 and temperature detection.

Granular coal is discharged from the silo via a weigh bin that is used to maintain an inventory of coal throughput and an automatic calibration system ensures weighing accuracy. From the weigh bin the coal is discharged into a multi-outlet distribution hopper that supplies coal to the coal injectors. One coal injector is provided for each tuyere allowing coal feed to each individual tuyere to be accurately controlled. In this way, a total tuyere-to-tuyere input accuracy of better than +/- 1% is achieved. *Figure 1* shows a typical layout.

Over the 25 years that Clyde technology has been used within Corus, system availability has exceeded 99%, with a total of 9 million tonnes of granular coal injected.

Burns Harbor Works, Bethlehem Steel Bethlehem Steel took the decision to utilise Clyde Materials Handling blast furnace coal injection systems after recognising the exemplary benefits delivered to Corus throughout the UK. Bethlehem Steel retrofitted two high-capacity blast furnaces with granular coal injection technology at their Burns Harbor facility in an effort to reduce coke use and become self-sufficient in coke. Each furnace required 2,800t coal/day, with each injection unit comprising a raw coal reclaim area and two 240t enclosed storage bins, a 500-Hp Williams variable speed coal grinding mill and integrated dryer, two 180t product coal silos designed to exclude oxygen, two distribution bins each with 14 conical trouser leg distributors, 28 injectors with lock hoppers and metered screw feeders, and a high-pressure air system transporting the coal 600 feet to injection lances mounted on 28 separate tuyeres.

The system was able to inject either GC or PC. The granular coal used in the injection process performed as well as pulverised coal in the raceway and proved easier to handle than pulverised coal, which tended to plug equipment when using low volatile coals. Direct comparative testing on a specific coal showed that 60% less energy was consumed in producing granular coal than in pulverising coal.

As a result, the coal injection solution generated several environmental, operational and economic benefits to Bethlehem Steel. The granular coal injection technology uses low volatile, low ash coal and displaced up to 0.96lbs of coke for every pound of coal, thereby reducing the air toxic emissions associated with coke production. By adjusting blast furnace slag, no additional sulphur emissions resulted from the coal injection, and sulphur levels in the product remained within the specified range.

From an economic perspective the capital, fixed and variable cost associated with the injection system at Burns Harbor placed against the performance of the furnace generated savings of tens of millions of dollars.

COMPARISON OF GCI AND PCI

Both GCI and PCI are widely used throughout the world, and there are proponents for both systems. We are able to provide injection systems for both, but believe the major advantages of GCI are:

Reduced grinding costs - The energy cost savings are significant when using granular coal *(see Fig. 2)*. For example, 185 kW of energy is required to grind 50t/h in an impact mill compared to 600kW in a roller mill. The savings generated by a 415kW reduction in energy are significant. The US Department of Energy's study into GCI at the Burns Harbor works also concluded that granular coal required 60% less energy than pulverised coal production.

Reduced drying costs - Due to the retention of moisture inherent within granular coal substantial energy cost savings are generated, as the need to use expensive roller mill crushers is negated (this means you do not have to dry the coal as much) energy savings of around 15% over pulverised coal are achievable *(see Fig.3)*.

Reduced capital costs - The cost of an impact dryer mill for GC is approximately one third that of a roller mill, used for pulverised coal

Enhanced Safety - The surface area of granular coal is small, so the risk of producing dust clouds is reduced and thus an explosion risk is minimised

Fig.4 **Rotofeed unit**

INJECTION EQUIPMENT

Although primarily developed for GCI, Clyde Materials Handling equipment has also been used for PCI in a number of furnaces. Indeed the equipment is so flexible that as substances such as charcoal, petroleum coke and plastics can be injected.

The key features are now described (Refer also to figure 1):

Accuracy of material feed One of the major parameters required by manufacturers is that injection rates are as near as possible to those selected. It is vitally important to the performance of a furnace that a consistent and smooth feed of material is accomplished. Clyde's RotoFeed technology helps accomplish this.

The RotoFeed solution comprises a dispensing vessel and a volumetric feeder *(see Fig. 4)*. The dispensing vessel is used to provide a constant supply of material ▷

Fig.5 **Dome valve**

to the volumetric feeder. A locking vessel is used to periodically replenish the dispensing vessel with material, ensuring the injection of coal into the furnace is continuous and that the performance of the furnace does not oscillate.

Individual tuyere control Coal injection requires an accurate, efficient, steady and reliable flow rate control and measurement from tuyere to tuyere as these attributes all help to generate an even distribution of coal around the furnace. We advocate one injector per tuyere as this provides greater accuracy and control of the process and guarantee a total tuyere to tuyere accuracy of better than +/-1% via the RotoFeed solution.

Reliability Many of Clyde' s solutions utilise the Clyde Dome valve*(see Fig. 5)*, widely regarded as the original and best material-handling valve in the world. The Dome valve has the ability to cut through static or moving columns of material through the use of its innovative inflatable seal mechanism, ensuring that a consistent pressure-tight seal is created when the valve is in the closed position, but in the open position it provides an unrestricted full bore opening for the best product flow characteristics possible. The Clyde Dome valve is recognised as a low maintenance, long life solution that can last at least 1 million cycles between maintenance inspections. Such is the outstanding performance, reliability, durability and availability of the Clyde Dome Valve that many of Clyde' s competitors use this for application within the iron and steel industry. The Clyde Dome Valve is used to control material flow, airflow and vessel pressures in both conveying and injection solutions.

Availability Clyde-built solutions have generated availability rates of over 99% for their customers in the iron and steel industry. Supported by 25 years of experience, expertise and process knowledge, Clyde is able to guarantee this exemplary level of availability, coupled with significant savings in energy, maintenance and capital costs.

CHARCOAL INJECTION

Clyde Materials Handling has also made significant in-roads into the development of pulverised charcoal injection into mini-blast furnaces in Brazil. Brazil produces around 6.5Mt of pig iron per year from mini blast furnaces, each with an average annual production of about 100,000t. As well as the difference in size and output, another main difference between the conventional blast furnace and the mini blast furnaces in Brazil is the fuel used. Rather than utilising coke, Brazilian mini blast furnaces operate with charcoal, derived from forests with reforestation programmes.

Charcoal, the most expensive raw material in this process, is currently priced at US$135 -140/t. During the transportation process from the charcoal producers' site to the pig-iron works, fines are generated. Charcoal is screened upon arrival, with a cutting point around 10mm, whereby all particles below this size are normally sold to cement works as a low value-added fuel, for around US$13/t, or a 10th of its price in lump form.

In order not to waste this valuable resource, Clyde Materials Handling, in conjunction with Praxair Metals Technologies, has made great strides into this market by offering a complete charcoal preparation and injection system, whereby the pig iron producers are able to inject the once wasted material via the blast furnace tuyeres, at rates up to 120kg/THM. Five mini blast furnaces are currently operating with Clyde Materials Handling injection systems, which is leading to significant savings and also increased production rates. Now that this technology has been proven, Clyde Materials Handling and Praxair are well positioned to consolidate its position as number one supplier of such systems in Brazil.

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