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DRAGON STEEL'S No.1 BLAST FURNACE – DESIGN AND INITIAL OPERATION[1]

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Abstract

In 2006, Dragon Steel Corporation, a subsidiary of the China Steel Corporation Group, commenced construction of an integrated steel mill to supplement their existing electric arc furnace facilities. The first phase of the expansion project included the hot strip mill, continuous caster, steelmaking facilities, coke plant, sinter plant and blast furnace. A contract was awarded to Siemens VAI Metals Technologies in May 2006 to design and supply the new 12 m hearth diameter blast furnace and additional facilities. On startup of the furnace Dragon Steel's annual hot metal capacity of 1 million tonnes from the existing electric arc furnace was increased by a further 2.5 million tonnes. The project included the supply of equipment required for a modern free-standing blast furnace including a copper stave cooling system, casthouse equipment integrated into a flat floor arrangement, bell-less top charging facilities, 3 external combustion chamber hot stoves and gas cleaning plant with top gas recovery turbine arrangement. Also supplied were 2 electric axial blowers, a 100,000 m^3 gasholder and pulverised coal grinding and injection facilities. The blast furnace blow-in occurred on the 27th February 2010 and continues to supply in excess of the designed 7,143 tons of hot metal per day. This paper will discuss the project scope and highlight some of the design features such as the integration of the blower operation, stove crossover improvements and coal injection facilities. Some of the challenges faced through the various phases of the project (design, supply, construction, commissioning and operation) will also be reviewed.

Key words: Blast furnace operation design.

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1 INTRODUCTION

Dragon Steel Corporation, a subsidiary of the China Steel Corporation Group operating in Taiwan, has an iron and steel works which is located on the west coast of central Taiwan in the Taichung Harbour District 30 km from the city of Taichung. The company was founded in 1993 and since 2008 operates as a subsidiary of the China Steel Corporation. The scope of work was to install a blast furnace capable of 2,500,000 tonnes of hot metal per year to add to Dragon Steel's existing steel capacity of 1 million tonnes produced by the electric arc furnace route

2 BLAST FURNACE DESIGN

2.1 General

The blast furnace conforms to all aspects of modern design, with a bell-less top charging system fed by belt conveyor from an in-line stockhouse with 50% overcharge capacity, cast house facilities with a fixed type main iron trough, two electrical axial blowers and hot blast stoves capable of operating with hot blast temperatures of 1,250ºC. There are also gas cleaning facilities along with a top gas energy recovery turbine, a blast furnace gas holder, raw material transportation facilities and pulverised coal preparation/ injection facilities. The key design parameters for the furnace are listed in table 1.

Table 1. Key Blast Furnace Design Parameters

Production Rate	7143 t/d
Type	Free Standing
Inner Volume	3274 m^3
Working Volume	2799 m^3
Hearth Diameter	12 m
Number of Tuyeres	32
Number of Tapholes	3
Maximum Blast Pressure	4.8 kg/cm^2 g
Maximum Top Pressure	2.5 kg/cm^2 g

The furnace stack is of a modern free standing design, using copper and cast iron staves to cool the shell. Closed circuit cooling is provided to the staves utilising softened water, enabling fast and efficient leak detection. The underhearth cooling is also provided from the closed circuit with booster pumps provide cooling water to the tuyeres. The hearth is shower cooled and constructed of supermicroporous carbon and standard carbon bricks.

The furnace has three tapholes, each with independent taphole drill, mud gun and splash cover manipulator. The cast houses are equipped with a dual dedusting system, one for the runner system and one for the roofing system, in order to ensure a clean working environment on the casting floor.

The furnace has 3 external combustion chamber stoves with potential for an additional stove to be added at a later date. These are supplied by 2 blowers which are interlinked for control to ensure that the furnace is supplied with stable blast flow and pressure.

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The furnace was supplied with two pulverised coal injection (PCI) streams to reduce the volume of coke required. The furnace has been designed so that it can operate with and without the coal injection operating.
Note that the second phase of the project involves the construction of a second furnace with the addition of a third blower and third PCI stream.

2.2 Blower System

The blower system provides cold blast air through the stoves where it is heated to become the hot blast air supplied to the blast furnace. A standby blower is available to ensure that if a problem occurs with a blower, furnace production will continue.

2.2.1 Blower design

Blast generation is executed by one multi-stage axial blower which is be driven by an electric motor. Ambient air is drawn via an inlet filter and an air inlet silencer into the initial stages of the blower. The air is compressed in 14 stages to the required outlet pressure and is thus pre-heated by the compression process. There is also a silencer arranged in the cold blast discharge pipeline. To prevent damage to the blower as a result of pressure surges, a blow-off valve is installed in combination with an electronic anti-surge control. A second blower designed to provide 100% of the capacity is available in case of a fault with the initial blower. The key design parameters for the blower are shown in table 2.

Table 2. Key Blower Design Parameters

Item	2 (1 duty, 1 standby)
Blower Discharge Flow Rate (Maximum)	6000 Nm³/min
Blower Discharge Flow Rate (Normal)	4500 to 5500 Nm³/min
Blower Discharge Pressure (Maximum)	4.6 kg/cm²/g
Blower Discharge Pressure (Normal)	4.2 to 4.4 kg/cm²g
Blower Discharge Temperature (Maximum)	250ºC

2.2.2 Blower control system

In general the flow demand from the furnace is met by the automatic adjustment of the blower vanes, with the cold blast flow measured in the cold blast main upstream of the snort valve, and in the event of the furnace demand falling outside of the operating range of the blower then the blower protects itself using either the anti-surge blow-off valves or the anti-choke valve.
During stove pressurisation the blower control system is required to ensure delivery of a constant air flow rate to the blast furnace whilst subject to a rapid increase in the flow required. During this period the blower vanes control the blast pressure rather than the cold blast flow. The switch over to pressure control is managed by the main control system indicating a stove change over is imminent. The set point is then set at the current line pressure, and then will change back to flow control when stove pressurisation is completed. The operator has the option to set the stove to pressure only control or flow only control if the process requires it.

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2.3 Stoves

2.3.1 Stove Design

The stoves used at Dragon Steel No.1 Furnace are large steel enclosures lined with a refractory material with an external steel lined combustion chamber with a ceramic burner linked through a crossover. The crossover was designed to cope with both axial and vertical expansion differences between the two chambers.

2.3.2 Stove crossover improvements

In the past two approaches have been taken in the design of a crossover. The first is to have a fixed structure which is unable to cope with the expansion during stove warm up. The second is to have a bellows incorporated in the crossover which can lead to hot spots due to the movement of the refractory under pressure and temperature cycles and the buoyancy effect of the hot gas against the cooler gas.
The approach adopted at Dragon Steel No.1 was to use bellows. This decision was made so that any future modifications to the stove could be made allowing the stove to cool down without risking major damage.
To avoid the creation of hotspots, a “bolster” comprised of refractory material was inserted into the gap between the bellows and the shell. This was injected after construction and was flexible when moist and compressible when dry. This served to prevent the gas tracking and buoyancy effects.
Position monitoring was attached to the chambers to monitor the relative movement of the stove chambers as discussed below.

2.4 Coal Injection Facilities

The coal grinding plants and injection facilities are designed to provide product coal to the furnace at 54 t/h. The facility was also designed to allow for future expansion of the steel plant and therefore an increased capacity.
The pulverised coal is produced by two 35 t/h (maximum of 55t/h) grinding mills and subsequently transferred to a single product silo prior to injection at the tuyeres.

2.4.1 Coal Injection Design

The injection system is located below the ground coal storage silo and comprises two lock vessels and two dispensing vessels. This arrangement of each lock vessel / dispensing vessel pair feeding an independent injector assembly allows for two separate coal feeds to the Blast Furnace.
Each injector functions as follows:
The coal from the coal storage silo rotary valve fills the injector lock vessel. The fill is controlled by a level probe in the lock vessel. When the vessel is full, the inlet valve closes and seals. The pressure within is then raised from atmosphere to balance with the dispensing vessel. (The dispensing vessel is always maintained at constant pressure).
When the pressures balances, the dispensing vessel inlet valve opens and coal falls, with the aid of fluidisation, into the dispensing vessel. After a time limited discharge period, the valve closes and seals and the lock vessel vents down to atmospheric conditions. The vessel vents into the void above the stored coal in the coal storage silo, and the vented nitrogen discharges cleanly through the silo vent filter.
The dispensing vessel refill cycle as described above is automatically actuated from a level probe in the dispensing vessel. This probe is located such that a head of

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material is maintained over the Rotofeed (volumetric feeder) below, ensuring a constant flow of coal to the splitter. The injector assembly is mounted on load cells, which are used to monitor vessel weight / rate discharge. Weight difference over time is used in the PLC to calculate the discharge rate in kg per minute. This rate is used to generate a calibration factor, i.e. kg/minute/revolution. This calibration factor is then used to set the Rotofeed speed to achieve the selected feed rate to within ± 2 % by weight.

Each injector assembly provides a controlled coal flow to the furnace, using a volumetric feeder, where a splitter device separates the flow equally to the desired Blast Furnace tuyeres. Each tuyere has two injection lances connected so that a different splitter supplies each lance. Thus the two independent 32-way splitter devices feed alternate lances.

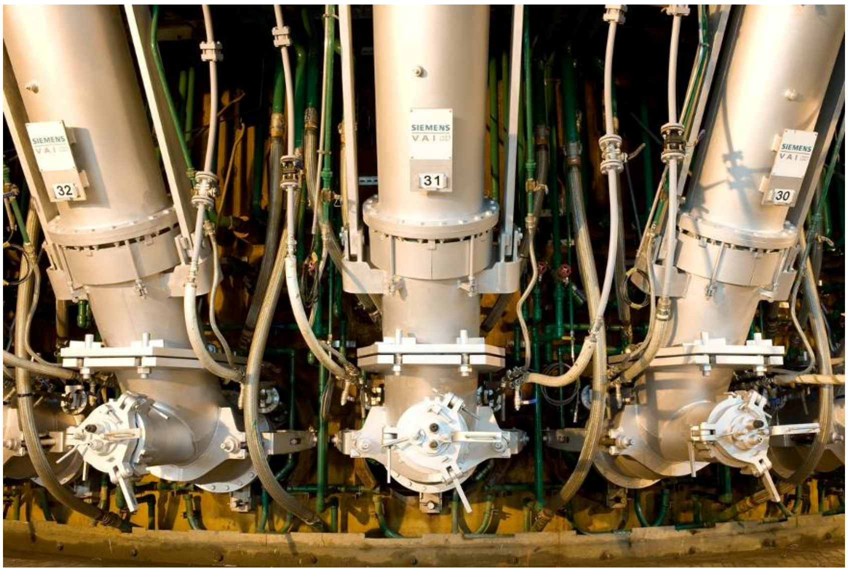

Figure 1. Tuyeres with two injection lances

2.4.2 Coal Grinding Loop Design

From the raw coal delivery system, coal is fed into the mill where the coal is crushed and simultaneously dried in a stream of carrier gas drawn through the system by the process exhaust fan. The dried and crushed coal is then conveyed in the carrier gas stream from the mill to a pulse jet bag filter unit which removes the coal from the waste gas stream and discharges it to the coal screens. The finished product is then discharged by gravity into the coal product silo.

The coal is dried by the hot carrier gas passing through the mill and to avoid ignition or explosion of the milled dry coal, it is necessary to minimise the oxygen content of the drying gas. The drying (carrier) gas comes from a Blast Furnace gas fired heater utilising a natural gas pilot burner. A proportion of the carrier gas leaving the bag filter is recycled to keep the total oxygen content of the gas in contact with the coal below 12 %, whilst maintaining the necessary circuit volume flow and a mill outlet temperature of 85 °C.

2.4.3 Coal Injection Protective Systems

The coal injection plant relies on the principle of preventing oxygen concentrations building up to prevent explosions or fires occurring. To prevent an explosion in the event of a build up of oxygen, nitrogen is used to displace the gas present in the system. Four nitrogen boosters are available to provide high pressure nitrogen to the

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system and to the two emergency storage vessels of 210 m³ each which can be used to purge the system in addition the normal nitrogen supply and in the event of the failure of the main supply of nitrogen. Other methods of protecting against explosions or fires include the monitoring of temperature and carbon monoxide, to indicate any potential fires, and the removal of tramp metals and materials from the raw coal which could provide the initiating spark for an explosion or fire.

2.5 Hearth

2.5.1 Hearth Cooling

The hearth is spray cooled utilising indirect water, with the return water collected in a furnace sump and pumped back to the Customer's water treatment area.

2.5.2 Hearth Lining

The aim was to install a lining concept that is able to resist 15-20 years of continuous contact with molten iron. The principle features of the design are:-

- Under hearth cooling pipes below the furnace seal plate.
- Deep, water-cooled carbon pad.
- The top layer of carbon made from wear resistant supermicropore and micropore carbon blocks and constructed as a flat arch to resist flotation.
- A ceramic layer to protect the pad with a circle brick design.
- Lower walls are constructed from supermicropore carbon, which is a material with excellent resistance to metal penetration and wear as well as a high thermal conductivity to maximise the cooling effect from the walls to encourage the formation of protective skulls.
- Tapholes are constructed from large blocks of micropore carbon, minimising the number of joints to reduce the possibility of gas tracking.
- The upper walls incorporate a vertical expansion joint.

Hearth isotherms are shown below for the new and worn (equilibrium) condition. The position of the 1150°C isotherm (iron freeze line) in the worn condition indicates there is minimal wear expected in the hearth walls and that a stable scab is expected in the critical lower wall area with a remaining carbon thickness at pad top level of 2000mm. This is the ideal situation for a long campaign indicating the Siemens VAI hearth design is capable of operating for the full campaign with minimal wear.

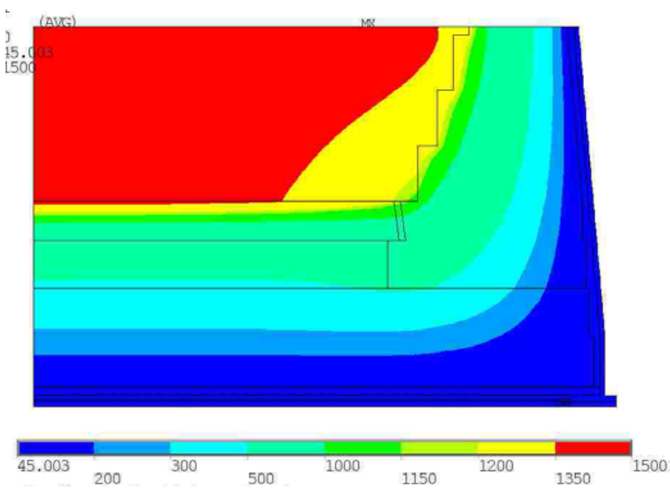

Figure 2. Temperature profile (as new)

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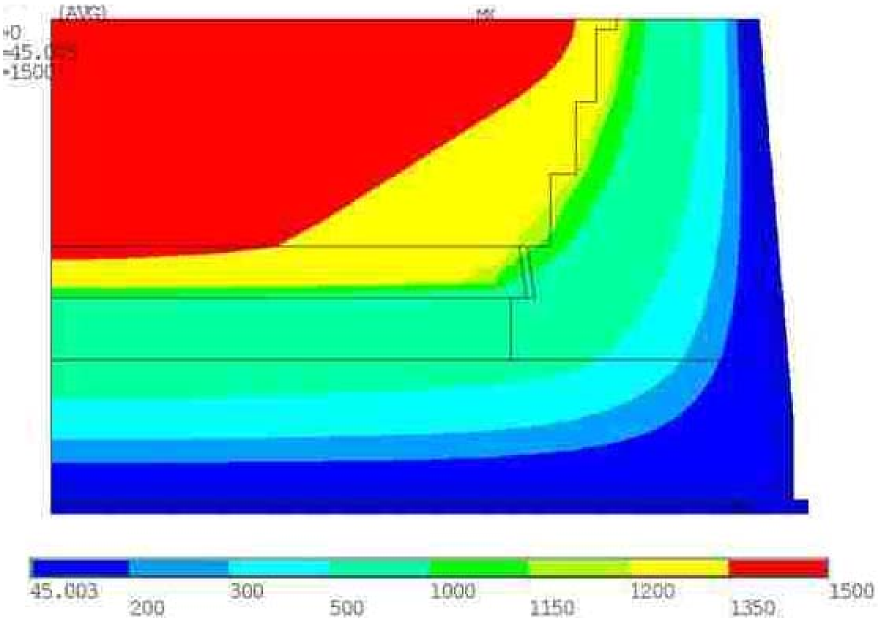

Figure 3. Temperature profile (worn)

3 CONSTRUCTION

3.1 Construction Phase

Construction of the furnace started in August 2007. Dragon Steel carried out the construction work under the guidance of a small group of Siemens specialists (mechanical, electrical, refractory engineers).
Construction and commissioning were occurring in parallel up to the furnace blow in date, with commissioning beginning once key structures and equipment had been installed. The construction and commissioning were completed in February 2010.


Figure 4. Photograph of the furnace after the end of the construction phase

3.2 Commissioning Phase

Commissioning of the furnace started in February of 2009. In a similar manner to the construction phase, the commissioning activities were carried out by Dragon Steel

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under the guidance of a group of Siemens specialists. This team consisted of electrical, instrument, software, piping and process engineers. Communications between the Siemens and Dragon Steel teams were maintained through a combination of a daily meetings and weekly notifications. Since some areas of commissioning began whilst major construction was still on-going, the weekly notifications and daily meetings were important for control of site safety and as a result of the close co-operation between the teams commissioning progressed smoothly through blow in.

4 FURNACE OPERATION

4.1 Blow-in

The blow in occurred on the 27th February 2010, with the first tap occurring on the 28th February 2010. After a few initial installation issues were overcome, the furnace operation stabilised and the initial production ramp up rate became limited by issues occurring with the steel plant.

4.2 Furnace Production over First year

A conservative start up system was adopted. Furnace production was initially ramped up to 5000 t/d before slowly increasing to the designed production rate over 2 months due to limits set by the steel plant. The furnace then operated beyond the expected capacity reaching a peak of 8229 t/d with an average production well above the 7143t/d designed, as can be seen in figure 5.

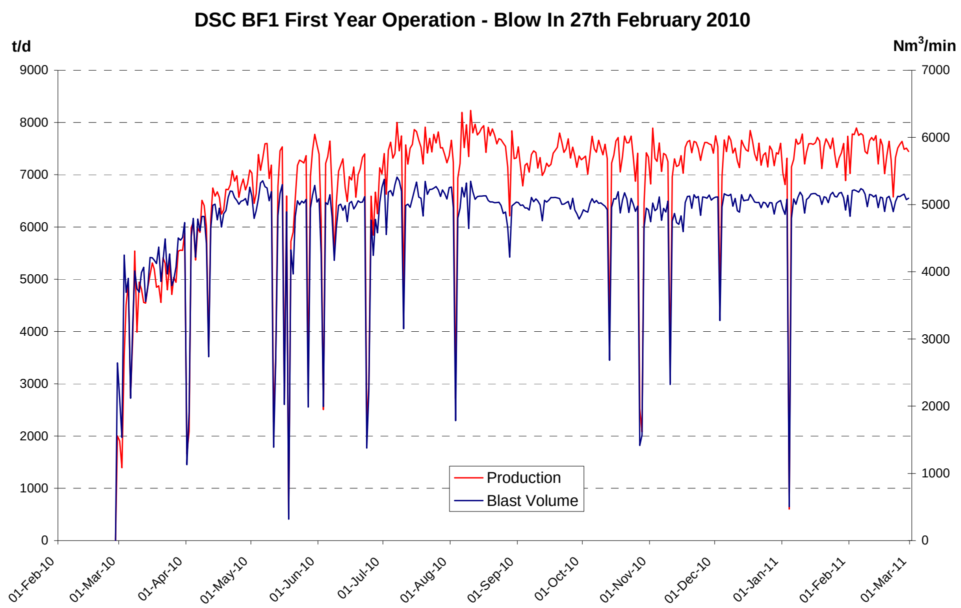

Figure 5. Annual production

4.3 Blower

As can be seen in figure 3, the blowers operated constantly over the first year at approximately 5000 Nm³/min. The dips in blast volume and production are in the majority indications of planned shutdowns for maintenance etc. Figure 6 shows the

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operating data from a blower whilst stove changeover is occurring. The red line indicates the flow, whilst the dark blue line indicates the pressure.

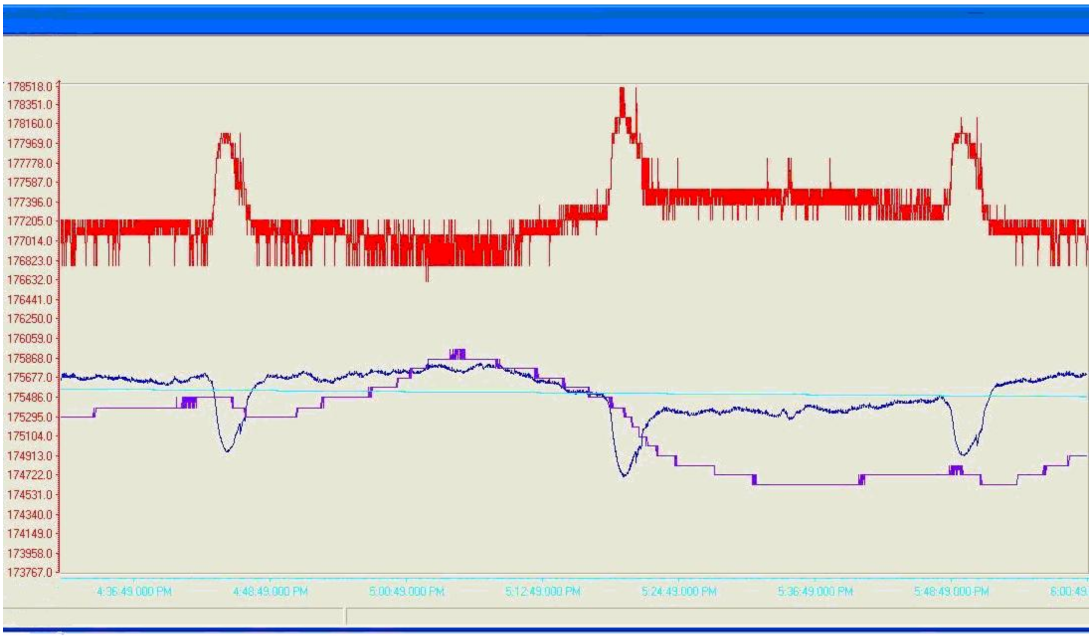

Figure 6. Blower operating data (~2 hours)

It can be seen from figure 6 that pressure drops whilst stove change over occurs due to increase in demand on flow. This shows that the operating system is working as planned maintaining a constant flow to the furnace whilst stoves change before restoring pressure control when stove change over has finished.

4.4 Stove Crossover

To date, Dragon Steel have not reported any issues with hot spots in the bellows or stove tops. Despite some stove movement, the bolster has proved effective in reducing the gas tracking and buoyancy effects, thus overcoming previously reported expansion issues when using external stoves. This design has being replicated for the second phase of development for the stoves for furnace number 2 at Dragon Steel.

4.5 PCI

The PCI plants began operating with a blend of a low volatile containing coal and a high volatile containing coal. In June 2011, the operation of the PCI plant was such that the average injection rate was 148 kg/tonne hot metal corresponding to 1457 kg/h with a maximum injection rate of 160 kg/tonne hot metal. The data for one of the weeks is shown in figure 7.

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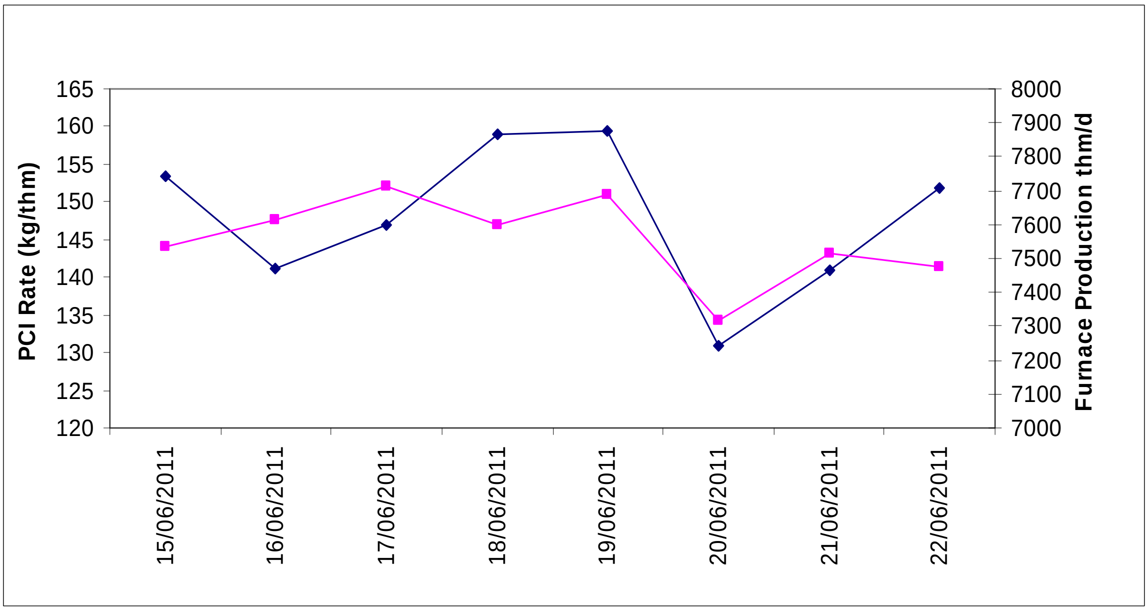

Figure 7. PCI Injection rate compared to furnace production over a week in June 2011

It can be seen in figure 7 that the PCI injection rate has a good degree of flexibility, allowing the injection rate to be controlled in line with the furnace production to achieve optimal injection rates for varying production levels.

5 SUMMARY

This paper has described the key design parameters of the new Dragon Steel Corporation blast furnace in the Taichung Harbour District in Taiwan. The furnace is currently operating successfully with production levels exceeding expected performance values and is a credit to the staff from DSC and the design team from Siemens involved in its construction and commissioning. The second phase of the project is currently in progress with commissioning commencing on the second furnace and including the additional capacity for the common blower and PCI systems.