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# BAOSTEEL NO.1 BLAST FURNACE ENERGY CONSERVATION AND CONSUMPTION REDUCTION PRODUCTION PRACTICE[1]

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**Abstract**

Some equipments and BF operation systems for energy conservation and consumption reduction have been applied by Baosteel No.1 Blast Furnace. These equipments, such as dry type bag filter cleaning technology, top pressure recovery turbine equipment(TRT) and hot stove residual heat recovery technology, are the foundation of energy conservation and consumption reduction. BF operation systems, such as high blast temperature and high top pressure, focus on BF long-term stability and smooth running. Solid waste and secondary energy sources are recycled and reused. Energy consumption of Baosteel NO.1 Blast furnace is lower.

**Key words:** Blast furnace; Energy consumption; Energy conservation and consumption reduction.

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## 1.INTRODUCTION

Carbon dioxide of industrial production take share the proportion of total global emissions by more than 20%, And CO2 that is produced by iron and steel industry account for 15-20% of all industries and for 3-4% of global man-made greenhouse gas. CO2 emissions of China's steel industry accounted for about 12% of total China CO2 emissions and for more than 50% of global steel industry emission. The main task of reducing CO2 emission is to lower energy consumption including carbon-based fuels, other energy.

Low-carbon economy is a economic model based on low energy consumption, low pollution, low emission. And is another major step of mankind following agricultural civilization and industrial civilization. For iron and steel industry the nature of low-carbon production is efficient energy use, recycling waste and environment-friendly production. Steel industry is an energy-hungry industry. Total energy consumption of China steel industry account for 16.1% of nation's energy consumption in 2010. Comprehensive energy consumption of Baosteel ironmaking is 394.88kgcet/t-iron, And steelmaking is 595 kgcet/t-steel. Ironmaking energy consumption is about 65% of steelmaking. So reducing energy consumption and low-carbon production of BF ironmaking are very essential for enterprise and society.

## 2.THE PRESENT SITUATION OF BAOSTEEL NO.1 BF'S LOW-CARBON PRODUCTION

Baosteel NO.1 BF(3rd generation) was blow-in on February 15. 2009，Its inner volume is 4966$m^3$. At the beginning of BF design, a series of processes and equipments which can reduce energy consumption and clean production were adopted, and provide equipment guarantee for NO.1 BF's low-carbon production. Under the context of BF raw materials and fuels degradation, Baosteel NO.1 BF still get good grades in the technical and economic indicators with high availability and pulverized coal rate, low fuel rate and process energy consumption.

Process energy consumption is energy sum which were consumed for a unit production in the iron and steel process, and is an important index that can measure the level of the energy consumption. Ironmaking energy consumption of Baosteel BF is composed of fuel consumption, energy medium consumption and energy recycling. The fuel consumption include coke pulverized coal, small size coke and CDQ dust powder. Energy medium consumption include water, electricity, BF gas, steam, nitrogen and blast consumption. Energy recycling include BF gas reuse, hot stove waste gas residual heat recovery and top pressure recovery turbine equipment(TRT). In recent years energy consumption of BF ironmaking process have made great progress. The record of energy consumption has been broken continuously because many measures have been taken. The year of 2002 is a turning point year that the energy consumption of BF is below 400kgcet/t-hot metal for the first time. In 2011, the ironmaking process energy consumption of Baosteel four BFs is 393.75kgcet/t-hot metal; NO.1 BF is 388.65kgcet/t-hot metal and is the best level. Figure 1 is the trend graph of fuel rate of process energy consumption of Baosteel NO.1 BF, As shown in Figure 1, fuel rate of NO.1 BF keeps 480-485kgcet/t-hot metal，only378.19kgcet/t-hot metal in June 2010.

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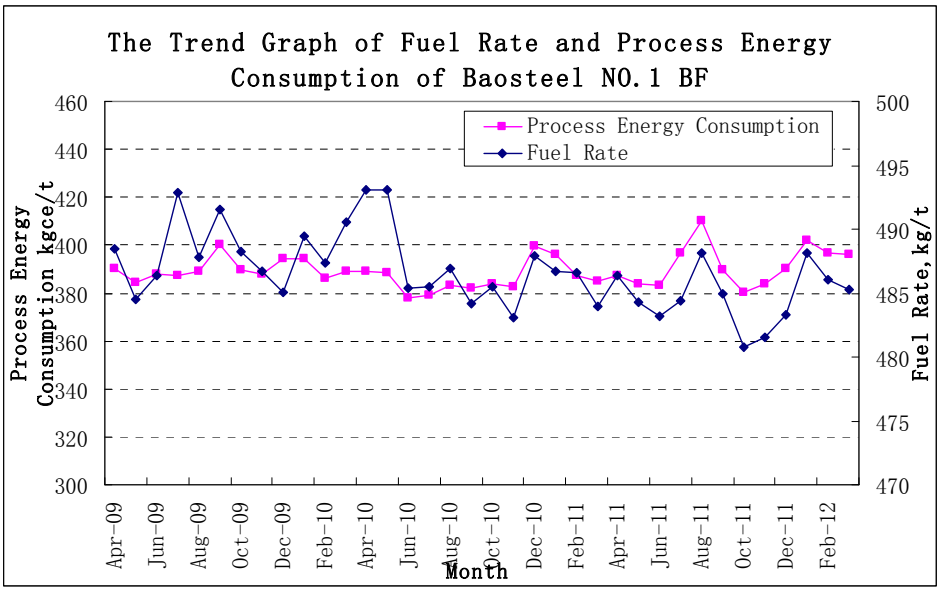


**Figure 1.** The trend graph of fuel rate and process energy consumption of Baosteel NO.1 BF

Figure 2 is the comparison chart of four BFs process energy consumption. From the chart, it can be seen that the energy consumption of NO.1 BF is lower than others.

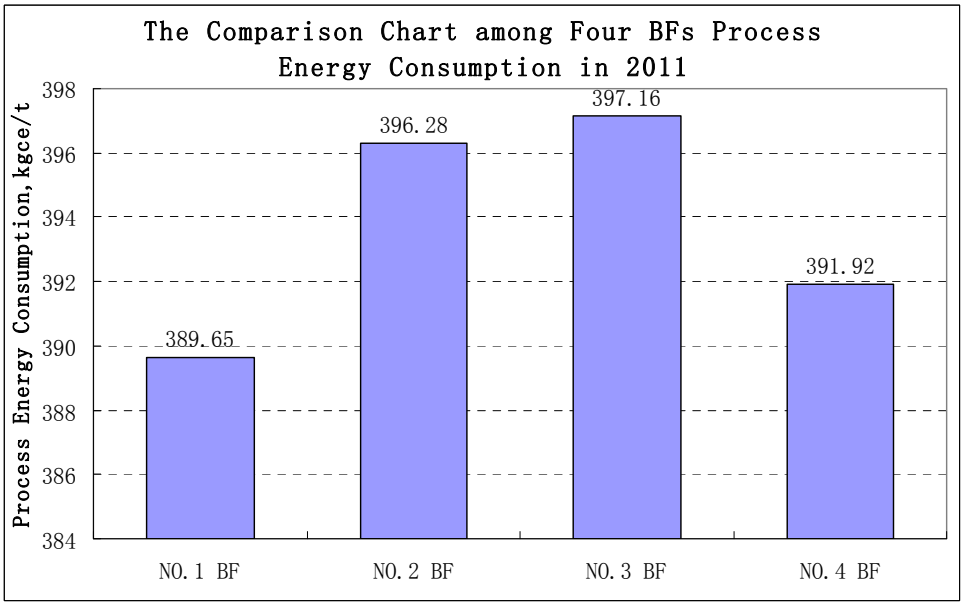


**Figure 2.** The comparison chart among four BFs process energy consumption

In summary, energy consumption of Baosteel NO.1 BF keeps low level, it is inseparable with the low carbon production thought, advanced BF operation technique, a series of energy conservation and consumption reduction technologies.

## 3 REDUCING THE CONSUMPTION OF BF CARBON-BASED FUELS

### 3.1 Ensuring BF long-term stability and smooth running

BF long-term stability and smooth running are best energy conservation, consumption reduction and low-carbon production. With more than twenty years operation experience Baosteel have form sophisticated large-scaled furnace

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operation techniques.

Baosteel NO.1 BF use two parallel hoppers with bell-less top and stave. After BF blowing in, furnace condition is usually abnormal, such as unstable gas distribution, the furnace wall accretion. The main reasons are that two parallel hoppers result in burden distribution segregation and unreasonable cooling system lead to furnace wall accretion. In order to eliminate the adverse effects, with the continuous exploration and practice, a preventive segregation equipment(having applied for a patent) for burden distribution has been used and some control techniques, such as A/B distribution mode with simultaneous burden grade and hoppers switchover and heat load sectioning management. On operating system, NO.1 BF have formed stable and reasonable gas flow distribution and kept long-term stability and smooth running through optimizing blast system and matching upper conditioning(charging system) with lower adjustment(blast system). The chemical energy and heat energy of BF gas can be made full use, and gas utilization rate keep high level. According to Baosteel experience, every improve the gas utilization rate 1%, can decrease coke rate about 5kg/t-hot metal. So it can decrease the fuel rate. Figure 3 is the trend graph of gas utilization of Baosteel NO.1 BF. From the chart, it can been seen that the gas utilization maintain between 51-52% for a long time. The high gas utilization is one of the most important mark of BF stability and smooth running.

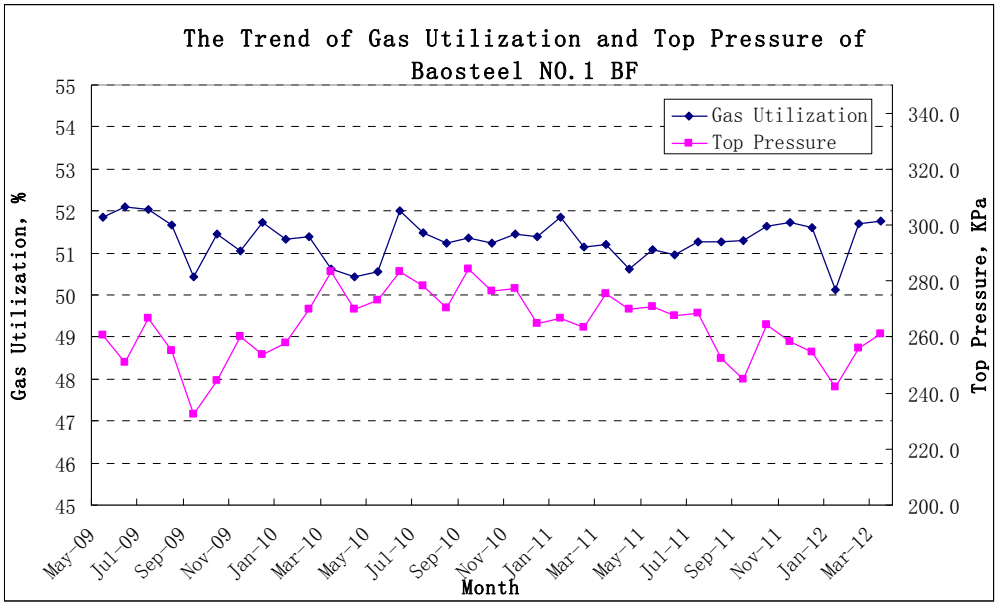


**Figure 3.** The trend of gas utilization and top pressure of Baosteel NO.1 BF

In addition, it is very important to keep BF condition stability and decrease fuel rate. Some strengthened smelting measures such as high top pressure and oxygen enrichment are taken. High top pressure can extend the residence time of gas. It's helpful for improving ore reduction, decreasing gas dust, keeping BF condition stability and reducing coke rate. Figure 3 is the trend graph of top pressure of NO.1 BF. At present, top pressure of NO.1 BF is about 270KPa. The oxygen enrichment percentage is rose from 4% on February 2010 to 5% or so, it will make for improving pulverized coal combustion and alleviating disadvantageous effect of unburned coal powder, decreasing BF gas dust and fuel rate. Figure 4 is the trend graph of gas dust rate and oxygen enrichment percentage.

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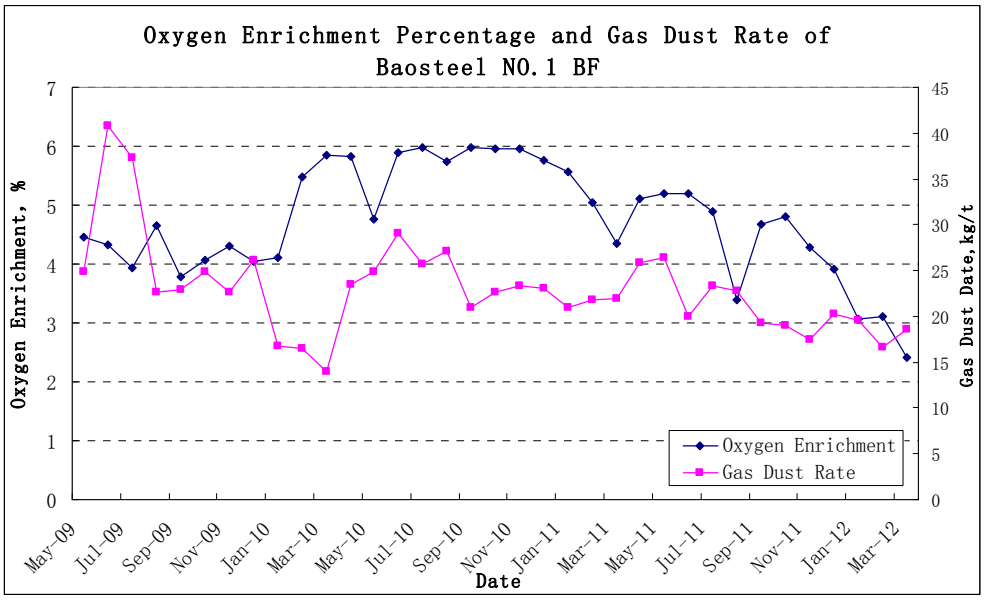


**Figure 4.** Oxygen enrichment percentage and gas dust rate of Baosteel NO.1 BF

### 3.2 High-grade burden guideline and economical pulverized coal rate

Although material quality is degraded continuously, Baosteel BF insist on the high-grade burden guideline all along. High-grade not only pursue good material performances, but also seek for the best comprehensive properties of proportioning. For example, in order to adapt to proportioning change, the basicity of sinter is improved from 1.55 in 1985 to 1.95 at present. The intensity and reducibility of sinter are improved. Material structure was 85% sinter,5% pellet and 10% lump ore in 1985, nowadays, the structure have been changed to 66% sinter, 18% pellet and 16% lump ore. On the material management, all other processes such as BF material, coking and sintering make BF ironmaking process for central task and all kinds of material is based on BF long-term stability and smooth running.

On the background of material price continuous rising, Baosteel NO.1 BF pursuit economical index and low-carbon production from single technical index, especially on the pulverized coal rate, seek for economical pulverized coal rate from high pulverized coal rate gradually. Because of the price gap being close between coke and pulverized coal, under the high pulverized coal rate condition, continuously improving pulverized coal rate will lead to a series of disadvantage effects, such as pulverized coal utilization decreasing, fuel rate and carbon-based fuels consumption increasing, the cost and energy consumption rising. So in order to lowering carbon-based fuel and energy consumption, NO.1 BF pursues for reasonable economic pulverized coal rate.

### 3.3 BF operation with high blast temperature and low blast humidity

The blast temperature of NO.1 BF keep about 1250□ steadily. On the one hand, the physical heat of high blast temperature can decrease the fuel consumption directly, on the other hand, can improve the replacement ratio and the pulverized coal combustion state on tuyere raceway. With Baosteel BF operation experience, every improve blast temperature 10□, the coke rate can decrease about 0.8kg/t-hot metal. That is helpful for decreasing fuel rate.

The blast humidity reacts with carbon on tuyere raceway with a great amount of

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heat absorption. Every decompose 1 gram water, 6.9KJ heat to be absorbed. That is to say, each increase 1g/m$^3$ blast humidity, about 0.8kg/t-hot metal coke rate need to be increased. So NO.1 BF always keep low blast humidity to less fuel consumption. Because of high atmospheric humidity on summer, dehumidified blast is used for controlling the blast humidity under 12g/m$^3$, when atmospheric humidity is lower on winter, the blast humidity is lower. Low blast humidity can less fuel consumption effectively. Figure 5 is the trend graph of blast temperature and humidity of Baosteel NO.1 BF.

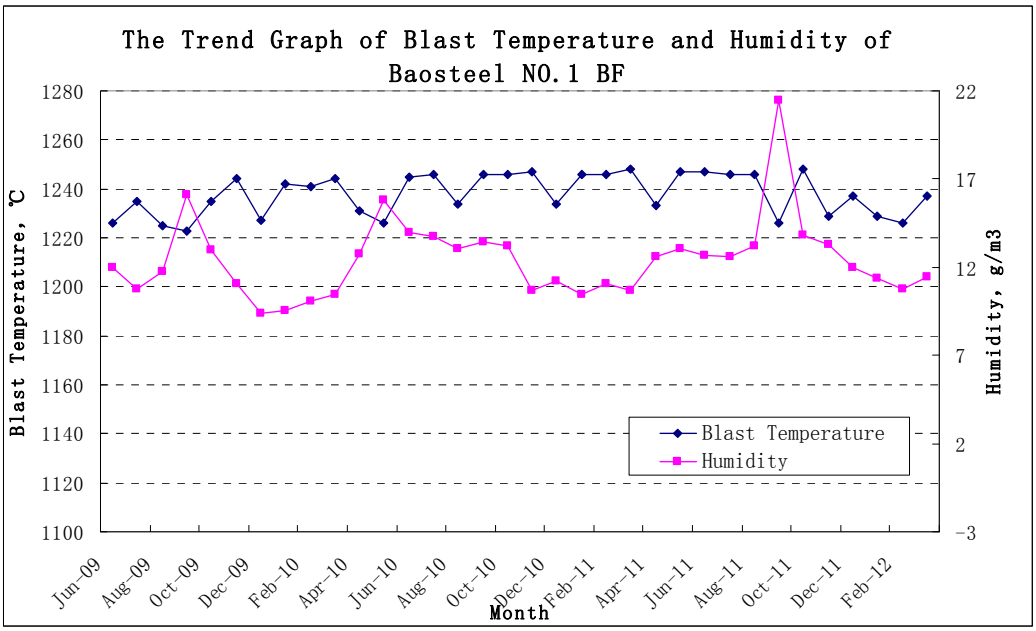


**Figure 5.** The trend graph of blast temperature and humidity of Baosteel NO.1 BF

### 3.4 Maintaining lower BF downtime

Extra fuels must be added to compensate heat when BF blows down and much non-absolute utilization carbon is emitted into the atmosphere and lead to waste and pollution. Through strengthening equipment management, NO.1 BF equipment is stable and some hidden troubles is eliminated in time. So unplanned downtime ratio is reduced. The scheduled downtime cycle is extended from once three months to once four months. The scheduled downtime time is shorten to 20-24 hours. The downtime ratio is reduce to 1.051% in 2011 from 1.662% in 2009.

### 3.5 Research and application of Large-scaled BF intelligence and expert system

Large-scaled BF intelligence and expert system has been researched and developed by Baosteel independently for several years, and it is formally put into use on NO.1 BF on September 2010, the system is aimed at trend management and closed-loop control. There are seven expert models in the system, including furnace temperature adjustment, gas distribution control, slag properties adjustment, the metal tapping and slagging management, BF campaign life management, abnormal BF condition diagnoses and handling and hot stove automatic control. After the system is put into use, the rate of adopting advice which is offered by the system is more than 98%, and the accuracy rating is 100%. The closed-loop control rate of slag basicity is 100%. The accuracy to BF condition control is improved, the human effects

ISSN 2176-3135

to BF condition is eliminated. So fuel rate is lowered and low-carbon production is realized.

## 4 DECREASING BF ENERGY SOURCE MEDIUM CONSUMPTION

BF energy source medium include water, electricity, BF gas, hydronitrogen, oxygen and air. Energy source medium is usually converted to standard coal. Some energy conservation and consumption reduction equipments such as dry type bag filter cleaning and hot stove residual heat recovery decrease energy source medium consumption effectively.

### 4.1 The application of dry type bag filter cleaning

Dry type bag filter cleaning is an important technology to energy conservation, emission reduction and clean production on 21$^{st}$ century. NO.1 BF newly built dry type bag filter cleaning which is independently integrated and manufactured, and is firstly used for Large-scaled BF which volume is above 4000m$^3$. Compared with the traditional wet type cleaning system, the new technology can improve BF gas cleaning degree, gas temperature and heat value, and hardly use water and electricity, and obviously decrease new water and power consumption. Power output of top pressure recovery turbine equipment (TRT) is increased greatly, utilization ratio of secondary energy is improved, and water pollution and sludge treatment are radically solved, and environmental pollution is reduced. The dry type bag filter cleaning is an important technological approach that iron and steel industry realize circular economy and sustainable development, and is development direction of BF ironmaking. The technology highlights environmental, economic and social benefits, and it has played a positive role on accelerating energy conservation and emission reduction paces, and building environmental friendly enterprise.

At the beginning of using dry bag filter cleaning, the dry type bag filter cleaning operating ratio is low. So the dry type and wet type existed simultaneously. With constantly exploration, some problems such as high top temperature and gas pipe erosion have been solved. At present the operating ratio has improved to more than 99%. Figure 6 is the trend graph of dry bag filter cleaning operating ratio, the dry type can effectively decrease the water and electricity consumption, increase top temperature and TRT power output which is raised 20-40% compared with wet cleaning system.

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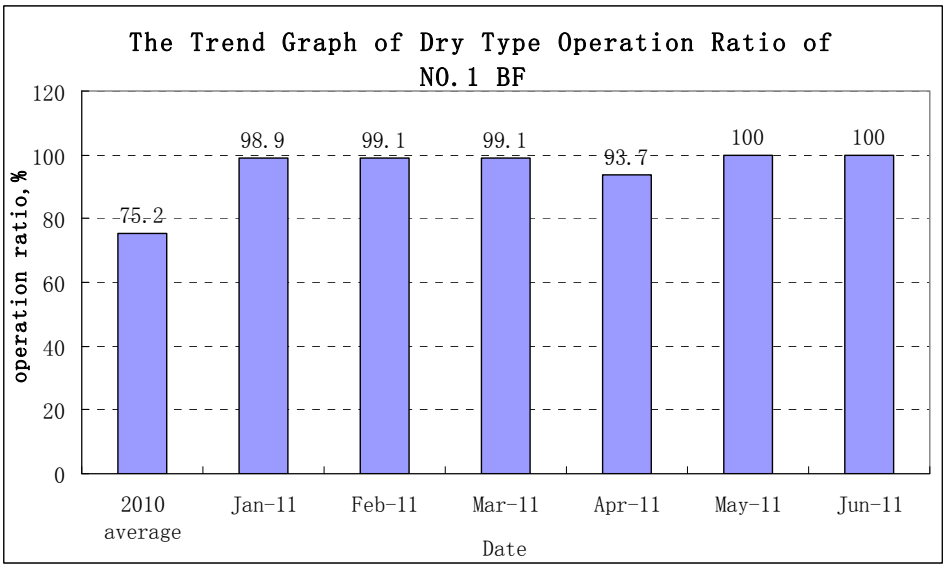


**Figure 6.** The trend graph of dry type operation ratio of NO.1 BF

### 4.2 Hot stove residual heat recovery unit

Hot stove residual heat recovery equipment of NO.1 BF was put into use on December 23 1990. Because of space limitation, water heat transmission recovery unit was adopted. Waste gas sensible heat which is produced by hot stove preheat BF gas and combustion air they are used for burning and heating hot stove. The pure water (used for heat transmission) absorbs waste gas heat, and waste gas temperature is decreased form about 290□ to 170□, then hot water separately enter air heat exchanger and gas heat exchanger, combustion air is heated from normal temperature to about 145□, and BF gas is heated from about 42□ to about 145□. In a word, through heating combustion air and BF gas with waste gas heat, blast temperature is increased and gas consumption is decreased.

### 4.3 BF high-efficient cooling system

Except using a little cooling plate above tuyeres on the bosh NO.1 BF body and hearth use stave. Copper staves are used on some key parts such as tap hole, bosh, belly and lower shaft, its cooling effect is better than other cooling type and the cooling water is saved.

Water consumption is decreased efficiently because of pure water closed circulating system. NO.1 BF pure water has two parts: I system and II system. Pure water I system is composed of BF bottom, hearth, upper and central shaft, the Water flow is 4320$m^3$/h. Pure water of I system firstly cool hearth stave, then flow out from branching pipe and flow in 8 headers, finally, flow to staves of upper and central shaft through branching pipes. Pure water II system cools the stave between bosh and lower shaft. The water flow is 5084$m^3$/h. Besides, pure water cooling system cool BF bottom and hot-blast valve, and the water flow is 1200 $m^3$/h. Water supply of BF bottom water cooling tube is 540$m^3$/h, and evenly supply water to three groups of furnace bottom water cooling tubes. The pure water is back to pumping station through drainage pipe after it has cooled water-cooling pipe and hot-blast valve.

High-efficient staves with pure water closed-loop cooling system greatly reduce water consumption of NO.1 BF. Figure 7 is water consumption comparison chart of Baosteel four BFs. As can been seen from the chart that NO.1 BF unit production

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water consumption can save more than 50%.

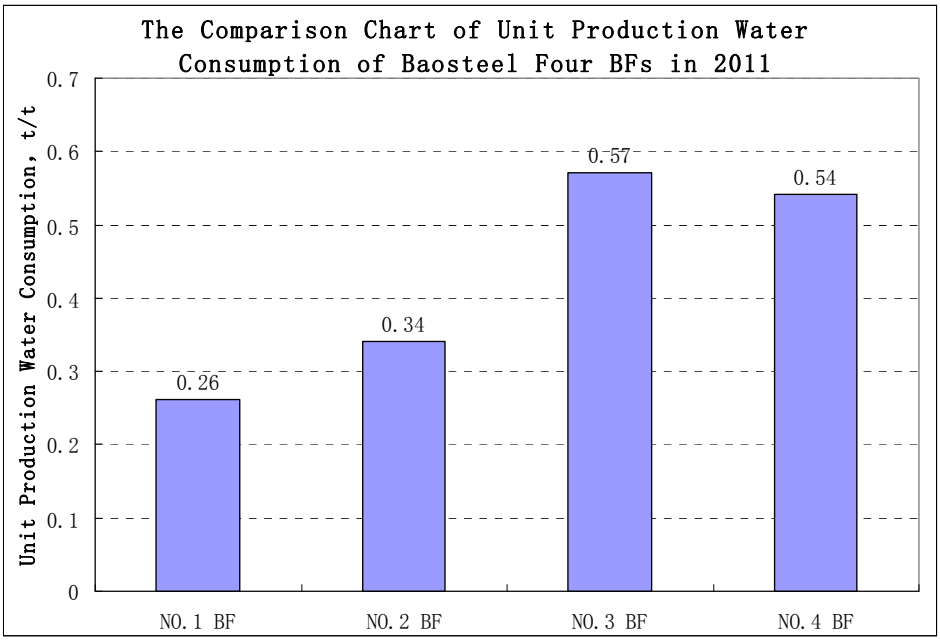


**Figure 7.** The comparison chart of unit production water consumption of Baosteel four BFs in 2011.

### 4.4 Oxygen-enriched combustion technology for hot stove

The hot stove oxygen-enriched combustion, on the one hand, can reduce gas consumption, on the other hand, is helpful to improve theoretical combustion temperature of hot stove. According to calculation, each increased oxygen-enriched rate 1%, the theoretical combustion temperature can improve 20□ or so. At present oxygen-enriched rate of NO.1 BF hot stove is about 2.2 %( 5600$m^3$/h), which can reduce gas consumption and improve blast temperature.

## 5 RECYCLE OF SOLID WASTE AND SECONDARY ENERGY

### 5.1 Recycling small-size coke and coke dry quenching dust powder

Small-size coke is undersize of coke hoppers; the size is less than 25mm generally. Except small-size coke is used for sinter fuel, it is recycled and mixed with iron ore for BF ironmaking instead of coke partly. According to the domestic and international production experience, small-size coke mixed with iron ore not only can replace large-size coke, decreases coke rate and cost, but also can improve permeability of lump ore zone and cohesive zone, BF smooth running and gas utilization. At the same time, it still can promote ore reduction, decrease direct reduction and heat loss, and keep coke strength (preventing degradation because of coke reaction). Small-size coke usage of NO.1 BF is about 20kg/t-hot metal and that has a remarkable effect to strengthen smelting and decrease energy consumption.

All Baosteel coke adopt dry quenching, CDQ powder is dust powder of coke dry quenching. Its colorific value is higher than pulverized coal. Through the adjustment of BF pulverized coal injection process, CDQ powder is mixed into pulverized coal, and then injected into BF. Maximal usage reaches 24.96kg/t-hot metal that can decrease fuel rate and cost.

ISSN 2176-3135

### 5.2 Top pressure recovery turbine equipment (TRT)

TRT is an excellent energy saving equipment that can convert BF top gas pressure to mechanical energy through turbine unit, and then through generator convert mechanical energy to electricity. All Baosteel four BFs install the TRT. Because NO.1 BF adopt the dry type bag filter cleaning, nature, reliable and advanced dry/wet dual-use axial stationary blade turbine was chosen. BF top gas temperature of dry type bag filter cleaning is higher than wet type, the electricity output of dry type that can reach more than 45kwh/t-hot metal is higher than wet type. It can recycle more than 90% of NO.1 BF total electricity consumption. Figure 8 is average TRT electricity output contrast graph of Baosteel four BFs from February to May in 2011.

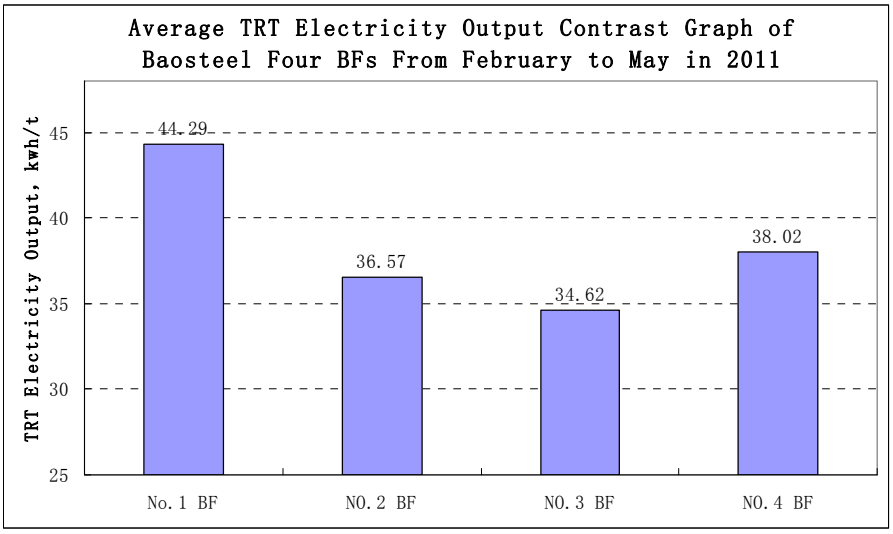


**Figure 8.** Average TRT electricity output contrast graph of Baosteel four BFs from February to May in 2011.

### 5.3 Reusing BF dust

BF dust contains a large number of carbon and ferrous material. All gas dust and other dust are reused by sintering and desiliconization agent; not only cost is saved, but also pollution is reduced.

## 6. CONCLUSIONS

“3R” manufactory principle always is followed by NO.1BF, that is, Reduce, Reuse and Recycle. The BF process energy consumption is decreased obviously. NO.1 BF is setting up the model of the low-carbon production

1) NO.1 BF (3$^{rd}$ generation) adopted many equipments and processes of energy conservation and consumption reduction at design time, such as dry type bag filter cleaning, TRT, hot stove residual waste heat recovery equipment. That provide guarantee for energy conservation and consumption reduction of NO.1 BF production.

2) NO.1 BF always focus on the central task of long-term stability and smooth running, and adopt high-grade burden guideline, strengthen equipment management. On operating system, some technologies such as high top pressure, high oxygen enrichment, low blast humidity are adopted to decrease fuel consumption; large-scaled BF intelligence and expert system provides new support to BF long-termed stability and ensure low-carbon production.

ISSN 2176-3135

3) On energy source medium consumption, the water and gas consumption are reduced through high-efficiency cooling system, hot stove oxygen-enriched combustion and dry type bag filter cleaning technology.

4) Reusing waste such as small-size coke, CDQ powder, BF dust and recycling secondary energy such as top gas pressure and waste gas heat can reduce cost effectively.

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