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Energy Saving Analysis of Coal Gas Resource Utilization in Iron and Steel Enterprises

Lu Yan[1], Kai Wang[2*]

(1. MCC Huatian Engineering Technology Co., Ltd.; 2. Hebei Puyang Iron and Steel Co., Ltd.)

Abstract: The article discusses the preparation of a gas balance sheet, as well as the recovery, storage, transportation, and use of gas. An analysis was conducted on the occurrence and consumption quotas of various gas media, and specific energy-saving measures were elaborated for each process. This provides a theoretical reference for saving gas and reducing energy consumption in steel enterprises.
Keywords: steel enterprises; gas; energy conservation

Long process processes in large and medium-sized steel enterprises include sintering, pelletizing, coking, blast furnace ironmaking, steelmaking, and rolling. Among them, coking, blast furnace ironmaking, and steelmaking converter processes can recover coke oven gas, blast furnace gas, and converter gas respectively [1,2]. At the same time, from the sintering process to the steel rolling process, gas is required as fuel gas, and the remaining surplus gas is mostly used for power generation in the steel plant's own power plant. Steel companies usually prepare a comprehensive gas balance sheet for the entire plant, which is used to allocate gas consumption for each process, achieving the goal of energy conservation and consumption reduction.

1 Preparation of gas balance table

1.1 Principles of compilation

The preparation of a gas balance sheet must be based on the actual situation of the enterprise, the design commission materials provided by various specialties, and the relevant gas usage index regulations of the country and region. Firstly, based on the process requirements of gas users, the rationality of the gas supply system, and the balance of by-product gas, the variety, calorific value, and unit consumption of gas for each user should be reasonably determined [3].

In the preparation process, it is necessary to strengthen the research on the interchangeability of energy media, and take measures to utilize low heating value gas as much as possible while meeting the basic requirements of various users for gas heating value, dosage, pressure, etc., in order to enrich high heating value gas. On the premise of fully utilizing the by-product gas, when the by-product gas is insufficient, the variety and quantity of supplementary gas to be introduced should be determined based on the relevant gas usage policies, gas resources and prices, transportation conditions, and user requirements of the country or region, after comprehensive economic comparison [4].

When enterprises construct in stages, they should prepare gas balance in stages to fully utilize by-product gas in each stage, reduce and avoid gas emission. The gas balance table should be compiled with annual balance, hourly balance of operating time, and hourly balance of operating time during partial blast furnace shutdown.

1.2 Occurrence and consumption quota

The production quota of coke oven gas is 440-470m^3/t, and the calorific value is 16720-17560kJ/m^3; The production quota of blast furnace gas is 1600-1800m^3/t, and the calorific value is 3098-3350kJ/m^3; The production quota of converter gas is 90-140m^3/t, and the calorific value range is about 5862-6699kJ/m^3.

The unit heat consumption of a coke oven is 2.96GJ/t, the self consumption of blast furnace gas is calculated at 40% to

* Corresponding authors.
E-mail addresses: 6982532014@qq.com

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45% of the generated amount, while the rest is supplied externally. The unit heat consumption of converter gas for users such as converter steelmaking and baking is 0.18~0.22GJ/t, continuous casting cutting refined coke oven gas unit heat consumption is 0.05~0.1GJ/t. The gas used in the sintering process is mainly for ignition of the sintering machine, which can be ignited using coke oven gas or blast furnace gas. The unit heat consumption for ignition using coke oven gas is 0.084GJ/t, the unit heat consumption using blast furnace gas ignition is 0.167-0.268GJ/t.

Pellet drying uses blast furnace gas, while pellet roasting uses coke oven gas or mixed gas [5]. The unit heat consumption of pellet drying blast furnace gas is 0.171GJ/t, the unit heat consumption of pellet roasting coke oven gas is 0.641~0.869GJ/t. Lime kilns generally use converter gas or mixed gas with equivalent calorific value, and the unit heat consumption of lime kilns is 3.28~4.1359GJ/t. The steel rolling process includes bars, high-speed wire rods, H-beams, hot-rolled strips, etc. The unit heat consumption of bars is 1.138GJ/t, the unit heat consumption of high-speed wire is 1.05~1.125GJ/t, the unit heat consumption of H-shaped steel is 1.23-1.3GJ/t, the unit heat consumption of hot-rolled strip steel is 1.2GJ/t.

1.3 Application example of gas balance table compilation

The gas balance table can intuitively and clearly reflect the utilization status of gas. A 3 million ton steel enterprise has a blast furnace gas calorific value of 3135kJ/m^3, a coke oven gas calorific value of 17556kJ/m^3, and a converter gas calorific value of 7680kJ/m^3.

When the 1350m^3 blast furnace is shut down for a short time, the shortage of blast furnace gas is replenished by the blast furnace gas holder [6]. When the blast furnace is in normal production, there is an excess of 66540m^3/h of blast furnace gas, which can be sent to the power plant as a buffer user. The fuel for the power plant boiler can be adjusted accordingly according to the amount of gas. The basic balance of converter gas and coke oven gas is 22730m^3/h, which can be used as high-quality fuel for enterprises to produce high value-added products.

2 Energy saving measures in gas recovery, storage, transportation, and use

2.1 Energy saving measures for gas recovery

Coke oven gas is a byproduct produced by the high-temperature dry distillation of coal in a coking furnace, while producing coke and tar products. The factors that affect the yield of coke oven gas are the composition of coal, furnace structure, and coking process system. Because the process system and furnace structure of coking generally do not change much, it is mainly controlled from the composition of coal materials [7].

The gas produced during the coking process is called raw gas, which needs to be condensed, cooled, and purified. The entire process should select suitable purification processes and equipment according to the user's requirements for gas quality, and reduce the impact on the environment to reduce operating costs and save construction investment [8].

The process of blast furnace ironmaking requires a large amount of primary energy consumption, mainly coal powder and coke. A significant portion of the energy consumed is transferred to the top of the furnace gas, which is the blast furnace gas, and is purified and recycled. The purification treatment methods are divided into wet purification and dry purification, and wet purification consumes a large amount of water and energy [9]. The bag filter for dry purification, as a mature process equipment, is currently widely used in the gas purification system of medium-sized blast furnaces. When conditions permit, it should also be applied as much as possible in the gas purification system of large blast furnaces.

The production and heating value of blast furnace gas are not only related to the conditions of the raw materials, but also to the thermal operation and process. Therefore, it is necessary to control the selection of primary energy varieties, the proportion of enriched oxygen blowing, the composition of injected materials, and the fuel ratio.

The main energy consumed in the converter steelmaking process is secondary energy, such as electricity, gas, oxygen, etc. The carbon in molten iron forms a mixture of carbon monoxide and a small amount of carbon dioxide by blowing in oxygen at high temperatures, known as converter gas, which is recovered after purification and dust removal [10].

The purification and dust removal methods include OG method and LT method. The OG method has a high dust content (=100mg/m^3) after treatment, and the LT method has a dust content of≤10mg/m^3. It is recommended to use the LT method.

The recovery and utilization of converter gas are mainly affected by two factors: supporting equipment, operation, and operation. The supporting equipment mainly includes flue gas cooling and purification recovery equipment, as well as supporting converter gas cabinets and pressure equipment. Operation and operation include three parts: first, controlling the source of molten iron and arranging the variety of steel; Secondly, during the smelting process, the oxygen blowing amount and time should be reasonably adjusted to reduce

the concentration of CO recovery at the beginning and end; The third is to determine the appropriate capacity of the gas holder, match the maintenance time of the gas holder and steelmaking, and adjust and control the gas delivery volume and delivery time.

2.2 Energy saving measures for gas storage and transportation

A gas holder is a steel container for storing gas. In addition to storing gas, it also plays a role in mixing and stabilizing pressure. If the amount of converter gas produced is uneven and the composition changes during a smelting process, the gas recovered from multiple smelting processes of converter gas is usually fed into a gas storage cabinet, mixed, and then transported to the user.

The energy consumption of the gas holder mainly consists of electricity consumption, including gas compressor, sealing oil circulation pump, and electric internal suspension cage. Choosing energy-saving equipment can effectively save electricity consumption. The energy-saving of gas cabinets mainly lies in avoiding gas emission, taking measures to balance the gas pipeline network, adjusting the gas consumption and time of each user, and trying to avoid gas emission as much as possible. Secondly, the gas holder should be arranged near the source of electricity and located in the center of the entire plant's gas supply. The converter gas holder should be arranged near the primary dust removal fan room, and the pipeline resistance loss should also be calculated to ensure that it meets the pressure requirements for entering the cabinet.

When gas is transported through the pipeline network, attention should be paid to the selection of economic flow rate, calculation of pressure drop, and extension of pipeline operation life. After long-term engineering summary, the economic flow rate for gas pipelines has been basically determined for design reference, as shown in Table 1. During the transportation of gas, there will be a pressure drop. In order to meet the pressure requirements of the user, it is necessary to calculate the pressure drop and take corresponding measures. Table 2 shows the pressure drop in the 100 meter straight section of the DN1000 blast furnace gas pipeline corresponding to different flow rates.

The extension of the service life of gas pipelines mainly considers stress compensation and pipeline corrosion issues. By calculating the temperature and pressure stress, a natural compensation bend or compensator can be reasonably set up. To solve the problem of pipeline corrosion, drainage devices should be installed at regular intervals, and new anti-corrosion materials such as acid resistant steel (Q345NS) can be used to increase the wall thickness of the pipeline.

Table 1 Economic flow rates corresponding to different diameters of gas pipelines

Gas pipe diameter DN / mm	200～400	500～800	900 ～1200	130 ～1500	160～2000	220～3800	4000～4600
Economic flow rate/ $m \cdot s^{-1}$	5 ～10	8 ～11	10 ～15	12 ～17	14 ～18	16～22	18～23

Table 2 Pressure drop in a 100 meter straight section of DN1000 blast furnace gas pipeline corresponding to different flow rates

The speed of gas flow/ $m \cdot s^{-1}$	6	8	10	12	14	16	18	20
Gas flow rate/ $m^3 \cdot h^{-1}$	17230	22970	28710	34460	40200	45940	51680	57430
Pressure drop/9. 8Pa	9. 0	16. 0	25. 0	35. 9	48. 9	63. 9	80. 9	99. 8

2.3 Energy saving measures for gas supply

In steel enterprises, by-product gas is mainly used for processes such as coking, ironmaking, steelmaking, and rolling, while surplus gas is mostly used for power generation. Coke ovens are divided into reheat and single heat types. The reheat coke oven can use coke oven gas or blast furnace gas, while the single heat coke oven can only use coke oven gas. For the reheated coke oven currently using coke oven gas, it is necessary to supply blast furnace gas or enriched blast furnace gas to the owner after communication, in order to extract as much coke oven gas as possible and supply it to users in steel joint enterprises who need high calorific value gas. The energy-saving of coke oven equipment itself can be achieved through the use of efficient heat exchange equipment and the development of new purification processes.

In the ironmaking process of blast furnace, the hot blast furnace and coal injection generally use the by-product blast furnace gas. In recent years, top combustion thermal storage

hot blast furnaces have gradually become the mainstream configuration for blast furnace ironmaking. It uses dual preheating of air and coal to increase the arch temperature of the hot blast furnace, increase the thermal storage capacity of the hot blast furnace, and thus increase the hot blast temperature. One of the methods for energy conservation and consumption reduction in blast furnaces is to optimize the gas flow rate and distribution inside the hot blast furnace. When the flow rate is high, the heat exchange rate will increase, and the heat loss carried away by the gas will also increase; When the flow rate is small, in order to ensure heat exchange capacity, it is necessary to increase the heat exchange area. There is a theoretical optimal value for the gas flow rate. By adopting oxygen enrichment technology in front or behind the machine, the oxygen enrichment rate can be appropriately increased based on equipment performance and the oxygen supply situation of the enterprise, which can also reduce gas consumption.

The iron, steel, intermediate, and steel tanks in the converter steelmaking workshop require the use of converter gas for online rapid baking. The main measure to save gas is to increase the recovery rate of converter gas, as described earlier. The energy-saving measures for baking users mainly focus on improving combustion efficiency, such as renovating burners and air supply pipelines.

Heating furnace is the main energy consuming equipment in steel rolling production. Heating furnace can use single gas as fuel or mixed gas as fuel. When compiling a gas balance sheet, the types of gas used in the steel rolling process can be adjusted according to the total gas balance. Reducing the gas consumption of the heating furnace can be achieved by increasing the temperature of the slab entering the furnace and the hot charging ratio, increasing the hot air temperature at the outlet of the heat exchanger, reducing the heat dissipation loss of the furnace body, and improving the hot air temperature and heat exchange efficiency of the heat exchanger.

The remaining gas in steel enterprises can be used to produce high value-added products or generate electricity, among which traditional gas boilers and emerging combined cycle power generation projects mainly use gas for power generation. Traditional gas power generation projects have lower gas utilization efficiency and higher consumption of circulating cooling water. Therefore, the National Energy Administration has successively identified medium and low calorific value gas-steam combined cycle power generation technology and ultra-high pressure power generation technology as key projects and development goals for energy conservation and emission reduction. The main way to improve the efficiency of gas power generation relies on improving the unit parameters, which are influenced by technical equipment development, metal material characteristics, and cannot be improved without limitations. Some enterprises have attempted to dehydrate the gas medium used for power generation. Before the gas enters the power plant users, a gravity dehydrator is installed. The mechanical water content of the imported gas from the gravity dehydrator is 30-50g/m^3, and the mechanical water content of the exported gas is less than 5g/m^3, resulting in a certain improvement in power generation efficiency.

3 Conclusion

The gas balance table of the entire steel enterprise plays an important guiding role in the rational use of gas in various processes. When compiling the gas balance table, it is important to strive for accurate data. The various processes of recovering by-product gas should adopt corresponding advanced process recovery measures according to the actual situation of the enterprise, and maximize the recovery amount of gas. Each gas energy consumption process should combine theory and practice, and various measures should be taken in production to save energy and reduce consumption, and reduce production costs.

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