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Saving of Coke Oven Gas by Reduction of Smoke Pushing of Recovery Type Coke Plant

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Abstract

For stable oven operation and prolongation of the coke oven life, it is important to remove excess carbon formation on the coke oven wall. It is considered that the carbon formation rate is influenced by the gas components generated during carbonation, the gas velocity and oven wall temperature are not uniformly maintained, as a result of smoke pushing. The smoke pushing is not favourable for the good health of the coke oven battery. In this paper, the smoke pushing can be rectified by proper maintenance of the gas path. Energy consumption and economic growth are interwoven, and rising energy levels always represent rising energy consumption. Coke is a reducing agent and a load-handling tool in blast furnaces. By this rectification, the coke oven gas flow was reduced from 17600Nm^3/hrs to 17300Nm^3/hrs without any extra manpower cost. The experimental set-up implementation of this modern proposal in a coke plant will make coke more extra energy efficient with no other extra costs.

Keywords: *Coke, Coke Oven Gas Flow, Coke Plant, Heating Flues, Specific Heat Consumption*

1.0 Introduction

Coke is produced by the proper destructive distillation of coal in a coke plant. Especially feeding coal blends comprising the various types of blended coals of desired coking parameters are heated in an oxygen-free atmosphere (coked) until the most volatile components in the coal are removed. The process is carried out in a battery, which contains twenty or more tall, wide and narrow ovens arranged side by side. After charging, a coke oven is heated for twelve or more hours, during which a variety of volatile compounds evolves from coal. The quality and quantity requirements for current and upcoming blast furnace operations are included in the coke demand analysis [1]. Receiving constant, high-quality coke is necessary for the blast furnace to reduce its coke rate, boost its output, and cut costs. Modelling and testing in a pilot oven can be used to analyze the composition of current coal blends. During plant audits, a study of the current coke-making technologies is conducted, and possibilities to introduce new or modified technologies are noted. Each coke facility's battery design, nameplate capacity, current and historical production, reline dates, service life, number of ovens out of commission and undergoing extended coking cycles, number of ovens requiring end flue or through wall repairs, and delays are all established as part of the coke supply analysis. As the raw coke oven gas is cooled, tar vapour condenses and forms aerosols which are carried along with the gas flow [2]. These tar particles would contaminate and foul downstream processes and would foul gas lines and burner nozzles if allowed to continue in

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the gas stream. The tar precipitators typically use high-voltage electrodes to charge the tar particles and then collect them from the gas by means of electrostatic attraction. The task of the unit is to remove tar droplets entrained in gas after the primary cooler. To remove tar mist entrained in gas, three electric tar precipitators are provided, normally three precipitators in operation, in case of one in maintenance and two in operation, tar content in the gas canal so be reduced to 20mg/Nm^3 is guaranteed experimental value while two electrostatic tar precipitators are in operation. Gas enters into the electric tar precipitator from its bottom, via the gas distribution plate gas is uniformly distributed onto the whole section, then flows through the high voltage electric field of the honeycomb upward to leave the electric tar precipitator and enters into the exhauster unit. When gas passes through the electric tar precipitator, solid and tar mist droplet in gas is deposited on the surface of the honeycomb, the tar flows via the tar outlet at the bottom into the water seal pot, from which it flows into the underground slop tank. Coke oven gas from the exhauster is first it is fed to the final cooling stage at the lower part of the hydrogen sulfide scrubber. The gas is cooled at about 22^{o}C by spraying with the circulating water. After the circulating water out of the hydrogen sulfide scrubber is cooled with the cooler for circulating water, the circulating water is sent back again to the final cooling stage at the lower part of the hydrogen sulfide scrubber for circulating cooling. At the upper part of the hydrogen sulfide scrubber, hydrogen sulfide in gas is absorbed with enriched ammonia water from ammonia scrubbing and lean solution from the de-acidifier and ammonia stripping unit. At the same time as hydrogen sulfide removal in a hydrogen sulfide scrubber, also carbon die oxide, hydrocarbons and ammonia are absorbed. Because the absorption process of hydrogen sulfide, CO2, hydrocarbons and ammonia is the process of an exothermic reaction, therefore both the upper stage and lower stage of hydrogen sulfide scrubber are provided with the coolers for hydrogen sulfide circulating scrubbing solution. The primary purpose of coke ovens is to transform coal into coke, which is utilized in the blast furnace as a fuel and reducing agent [3]. The entire process of creating coke is fraught with safety risks, such as being hit by or tangled in moving machinery, getting burned, starting a fire or explosion, falling and slipping, and being exposed to dust, noise, heat, gas, etc. The majority of health risks associated with coke production are caused by emissions produced during coal charging, coal carbonization, coke pushing, and coke cooling. Polynuclear aromatic hydrocarbons, which cause cancer, are present in coke oven emissions along with other hazardous materials. The authors developed a new model for reducing variation in the burning of coal to coke during the coke-making process to gain good quality and also to properly develop the energy in the coke plant [4]. The total length of the battery is a hundred meters, consisting of rectangular-shaped heating chambers of a length of sixteen meters, a height is seven meters, and a width of 0.41 meters with removal door ends. The recovery-type coke-making process takes a period of eighteen to twenty hours depending on the number of pushes by indirect heating with the coke oven gas or mixed gas. A 7-meter tall battery has sixty-eight heating walls and each type of wall has thirty burning flues [5]. The total average temperature of each flue is about maintained at about 1200 to 1300 **°C**. Maintaining the proper uniform operating conditions is a difficult task due to the dynamic pushing of the operation and achieving the required production target. The pulverized coking coal that has been carbonized at a high temperature produces coke (-3 mm size) [6]. To create lumpy coke, coal is burned to a temperature between 10,000 and 10,000 degrees Celsius in the absence of air. It includes in terms of its impact on the functioning of the blast furnace and the quality of the hot metal, coke is the most significant raw material put into the furnace [7]. Several by-products, some of which may be solid, liquid, gaseous, or plastic in form, are produced during the coke-making process. Many of these by-products are hazardous to the environment and poisonous. They need to be handled with extreme caution and restraint. Each battery used to make coke has a number of slot-type furnaces for carbonizing the coal [8]. To drive out the volatile stuff found in coal, each oven receives a sequential charge of coal from the coal preparation plant and stores it in a coal tower. This process is known as coking. Coke is forced out of the oven, quenched and properly cooled using the wet/dry process, and then supplied to the blast furnace via the coke handling plant once the gas evolution and subsequent coal carbonization are finished. Coke oven gas is saved up to 300-400 Nm^3/hour by using reversal cycle modification in the coke plant. The by-product factory receives evolved gases from the ovens to recover important compounds such as tar, ammonia, naphthalene, benzene, and others [9]. The gas and preheated air are fed to the base of the flues from where they move upwards under the influence of chimney drought [10]. The hot products of combustion cross over to the adjacent flues and pass on to the re-generators where the checker-work absorbs most of the sensible heat contained in the product of combustion [11]. In this paper, the cooled gases from the re-generator move to the waste heat flues and then to the chimney. These two currents of heat flow, i.e. the up-current and down-current are periodically reversed every 20 minutes to maintain uniform and state temperature conditions throughout the whole battery [12]. Due to the growing public awareness of environmental issues in a developed country, the major modern process of large-scale industries is under tremendous pressure to minimize the control of air emissions. In an integrated steel factory where coke and coke oven gas are the main sources of energy, the production of metallic coke in the by-product of recovery-type ovens is one of the important major sources of air pollution. Dust is produced at every step of the coke-making process, including improper receiving, improper unloading, improper handling, abnormal crushing, improper carbonization, and subsequent coke handling. Hot air plumes, dust, and gaseous emissions are produced during the charging, pushing, and coke-quenching processes.

2.0 Methodology of Research

The carbon deposits on coke oven walls may not only interrupt the oven operation but also cause damage to the oven walls, although many studies have been made on the properties of deposited carbons and the mechanism of their formation. There are few on the quantitative emission of carbon formation in an actual coke oven. For the purpose of stable oven operation and prolongation of oven life, it is necessary to remove carbon according to the amount of carbon deposited on coke oven walls.

In this paper, it is introduced that a quantitative emission of carbon formation rate on the wall was developed and a new type of SOP for regular maintenance of gas paths like distribution pipe cleaning, orifice cleaning, cylinder and horse pipe cleaning as a daily routine basis, as results all flues like pusher side and coke side temperature will be gradually increased. This method is also helpful for reducing coke oven gas flow.

There are some difficulties to remove carbon efficiency with conventional methods of carbon removal. Sometimes compressed air is also helpful for full distribution pipe cleaning as well as horse pipe cleaning.

2.1 Seven-Meter Tall Battery Experimental Description

The experimental set-up for a 7-meter tall coke oven battery required some technical processes and operation parameters which are shown in Table 1. There is a sixty-seven heating oven, sixty-eight heating walls and sixty-nine numbers of waste heated boxes for transferring the waste gas tunnel to the chimney. There is three charging hole for feeding the coking coal into the heating oven. Thirty-two tonnes of blended dried coal is charged per oven and output coke is around twenty-five tones produced. There is a total thirty-two number of heating flues out of thirty-two sixteen numbers of heating flues on the pusher side and sixteen numbers on the coke side. The experimental brief description is given below in tabulation form in Table 1.

2.2 CPD of Recovery Type of Coke Plant

2.2 Represents the mathematical formula for the coking period of a coke plant:

$$\text{CPD} = \frac{N_1 \times 24}{N}$$

$$\text{CPD} = \frac{67 \times 24}{91}$$

Table 1. Technical parameters for experimental set-up

No. of oven	No. of heating walls	No. of waste heat boxes	Dry-charged coal in tones	No. of heating flues on the pusher side	No. of heating flues on the coke side	No. of heating flues per wall	Output coke per oven	No. of charging holes per oven	Oven height in meter
67	68	69	32	16	16	32	25	03	7

$$CPD = 17.67\,hrs$$

2.3 Requirement of Coke Oven Gas Flow as per Schedule of Pushing/Charging

2.3 represent the mathematical formula for calculating the required gas flow:

$$V = \frac{W \times Q \times N \times 1000}{T \times CV}$$

First-week average coke oven gas flow required on an hourly basis before rectification

$$V1 = \frac{610 \times 91 \times 32 \times 1000}{4200 \times 24}$$

$$V1 = 17622.22\,Nm^3/hrs$$

second-week average coke oven gas flow required on an hourly basis before rectification

$$V2 = \frac{610 \times 91 \times 32 \times 1000}{4200 \times 24}$$

$$V2 = 17622.22\,Nm^3/hrs$$

third-week average coke oven gas flow required on an hourly basis before rectification

$$V3 = \frac{610 \times 91 \times 32 \times 1000}{4200 \times 24}$$

$$V3 = 17622.22\,Nm^3/hrs$$

fourth-week average coke oven gas flow required on an hourly basis before rectification

$$V4 = \frac{610 \times 91 \times 32 \times 1000}{4200 \times 24}$$

$$V4 = 17622.22\,Nm^3/hrs$$

The average gas flow required the entire first to the fourth week which is given below

$$V = \frac{V1 + V2 + V3 + V4}{4}$$

$$V = 17622.22\,Nm^3/hrs$$

$$V = 17600\,Nm^3/hrs \text{ (approx)}$$

Similarly, after rectification average coke oven gas flow required the entire first week to the fourth week which is given below

$$V = \frac{V1 + V2 + V3 + V4}{4}$$

$$V = 17333.33\,Nm^3/hrs$$

$$V = 17300\,Nm^3/hrs \text{ (approx)}$$

All mathematical calculation value is shown in the tabulation form which is elaborated in Table 2.

3.0 Results with Discussion

3.1 Rectification of Smoke Pushing

In this paper, it is introduced that a quantitative emission of carbon formation rate on the wall was developed and a new type of SOP for regular maintenance of gas paths like distribution pipe cleaning, orifice cleaning, and cylinder and horse pipe cleaning as a daily routine basis, as results all flues like pusher side and coke side temperature will be gradually increased. This method is also helpful for reducing coke oven gas flow. Firstly we have taken the

Table 2. Heating wall No. 26 pusher side flue wise temperature

Flue No.	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16
The temperature in °C before rectification	1080	1090	1110	1160	1180	1170	1190	1200	1200	1210	1190	1210	1200	1210	1190	1200
The temperature in °C after rectification	1110	1120	1150	1180	1200	1210	1220	1230	1220	1230	1210	1220	1230	1220	1210	1220

Table 3. Heating wall No.26 coke side flue wise temperature

Flue No.	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
The temperature in °C before rectification	1200	1190	1210	1200	1220	1210	1200	1200	1190	1170	1160	1140	1110	1090	1070	1060
The temperature in °C after rectification	1220	1220	1230	1240	1250	1250	1230	1210	1200	1190	1180	1170	1150	1140	1130	1120

temperature reading of particular problematic heating wall No.26. The temperature reading is taken on the pusher side sixteen flues and coke side also sixteen flues before and after rectification of smoke pushing which is shown in Tables 2 and 3 then is plotted in a graph which is already shown in Figures 1 and 2.

Tables 2 and 3 comprise the problematic heating wall No. 26. The temperature reading is taken on the pusher side sixteen flues and the coke side also sixteen flues before rectification temperature of all flues is not uniform. The maximum temperature before rectification is 1220°C, then after a new type of SOP is developed for regular maintenance of gas paths like distribution pipe cleaning, orifice cleaning, and cylinder and horse pipe cleaning on a daily routine basis, as a result, all flues like pusher side and coke side temperature will be gradually increased. After rectification, the maximum temperature is 1250°C, as a result, smoke pushing is controlled and the unwanted heat losses are also controlled and the coke oven gas flow is also saved at 300 Nm^3/hrs.

Figure 1 comprises the variation of temperature with respect to the pusher side flue number. There are sixteen heating flues on the pusher side. Firstly temperature reading is taken of each flue by using the digital pyrometer. The temperature reading is given in Table 2 which can be plotted on a graph in Figure 1. The temperature is gradually increasing with respect to the heating flue number. The temperature is starting from 1080°C for heating flue number 01, the 2nd flue increases the temperature to 1090°C and the 3rd flue temperature is around 1110°C. The maximum temperature reaches 1210°C in flue number 10 of the pusher side before rectification. The minimum temperature reaches is around 1080°C and the maximum temperature is 1210°C before rectification of smoke pushing. After the rectification of smoke pushing the temperature is starting from 1110°C of heating flue number 01, the 2nd flue increases the temperature to

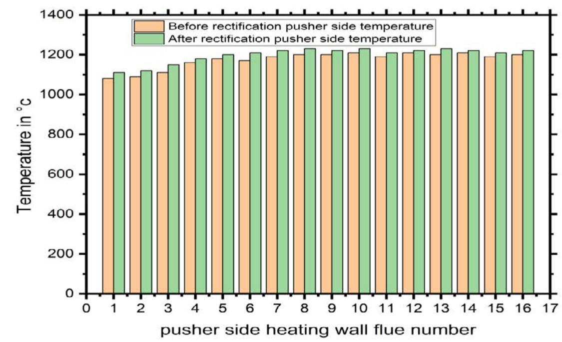

Figure 1. Variation of temperature for pusher side flue number.

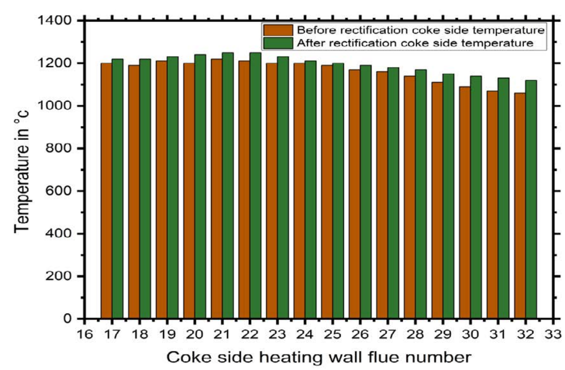

Figure 2. Variation of temperature for coke side flue number.

1120°C and the 3rd flue temperature is around 1150°C. so that after the rectification temperature is increased by 30°C of 1ist flue, 2nd flue temperature increased by 30°C and 3rd flue temperature is increased by 40°C without affecting the quality of coke. So that after rectification. The maximum temperature is increased from 1210°C to 1230°C in pusher side heating flues.

Figure 2 comprises the variation of temperature with respect to the pusher side flue number. There are sixteen heating flues on the coke side. Firstly temperature reading is taken of each flue by using the digital pyrometer. The temperature reading is given in Table 3 which can be plotted on the graph in Figure 2. The temperature is gradually increasing with respect to the heating flue number. The temperature is starting from 1200°C for heating flue number 17th, then18th the flue decreases the temperature to 1190°C and the 19th flue temperature is around 1210°C. The maximum temperature reaches 1220°C in flue number 21st of the coke side before rectification. The minimum temperature reaches is around 1060°C and the maximum temperature is 1220°C before rectification of smoke pushing in the coke side of heating flues. After the rectification of smoke pushing the temperature is starting from 1220°C of heating flue number 17th, the 18th flue increases the temperature to 1220°C and the 19th flue temperature is around 1230°C so that after the rectification temperature is increased by 20°C of 17th flue, 18th flue temperature increased by 30°C and 19th flue temperature is increased by 20°C without affecting the quality of coke after rectification. The maximum temperature is increased from 1220°C to 1250°C on the coke side of the heating flues.

In Figures 1 and 2 excluding before rectification of smoke pushing to each flue of the pusher side, the maximum temperature is achieved as 1220°C. After rectification, the maximum temperature is 1250°C, as a result, smoke pushing is controlled and the unwanted heat losses are also controlled and the coke oven gas flow is reduced from 17600 to 17300 Nm^3/hrs.

Figure 3 comprises the requirement of coke oven gas flow requirement with respect to the number of weeks. There are four weeks taken average reading is taken for the requirement of coke oven gas flow. Firstly before rectification of smoke pushing gas flow requirement is about 17600 Nm^3/hrs which is shown in graphical form Figure 3. After the rectification of smoke pushing gas flow requirement is about 17300 Nm^3/hrs.

By using this methodology coke oven gas flow requirement is reduced from 17600 Nm^3/hrs to 17300 Nm^3/hrs without affecting the quality of coke. The average pushing/charging schedule remains constant before and the after rectification of smoke pushing on the recovery type of coke oven plant.

Figure 4 comprises the experimental value of specific heat consumption with respect to the number of weeks. Specific heat consumption is directly proportional to the gas flow requirement. Firstly requirement of the coke oven

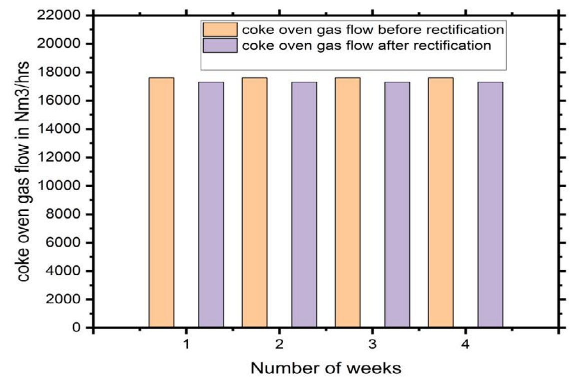

Figure 3. Variation of coke oven gas flow for No. of weeks.

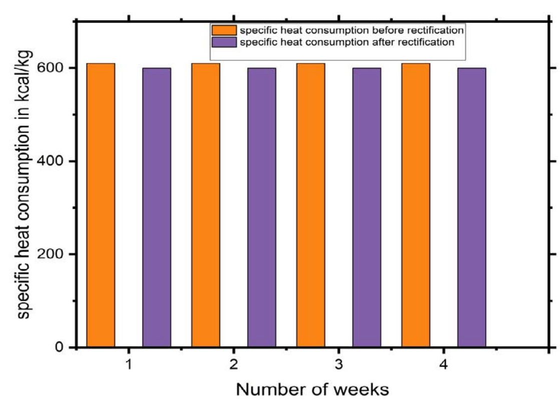

Figure 4. Variation of specific heat consumption for the Number of weeks.

Table 4. Experimental calculation value before and after rectification

No. of weeks average experimental data	Average pushing / charging schedule	Before rectification average gas flow required in Nm^3/hrs	After rectification average gas flow required Nm^3/hrs	Before rectification average specific heat consumption in kcal/kg	After rectification average specific heat consumption kcal/kg	Average COG saving on an hourly basis
04	91	17600	17300	610	600	300

gas flow is about 17600 Nm^3/hrs then after rectification gas flow requirement is about 17300 Nm^3/hrs. This shows that 300 Nm^3/hrs coke oven gas is saving on an hourly basis. After the rectification of smoke pushing specific heat consumption value is reduced from 610 kcal/kg to 600 kcal/kg which is given in Table 4.

Figure 3 represents the coke oven gas flow variation with respect to the number of weeks. The coke oven gas flow requirement before rectification is 17600Nm^3/hrs. After the rectification of smoke pushing the coke oven's gas flow requirement is 17300Nm^3/hrs. Figure 4 represents the specific heat consumption variation with respect to the number of weeks. Before rectification of smoke pushing the specific heat consumption value is 610 kcal/kg. After the rectification of smoke pushing, the temperature of the heating wall of all flues of both sides like the pusher side and the coke side temperature is also uniformly increased and the specific heat consumption value is also reduced from 610 kcal/kg to 600 kcal/kg. The experimental value is elaborated in Table 4.

4.0 Conclusions

By this rectification, the coke oven gas flow was reduced from 17600Nm^3/hrs to 17300Nm^3/hrs without any extra manpower cost. This methodology is also helpful for reducing the manufacturing cost of coke in a recovery type of coke plant and stable oven operation and prolongation of coke oven life. Future advancements in this technique will allow us to minimize the need for money, which will revolutionize the nation's economy.

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