INTRODUCTION OF CURRENT TECHNOLOGIES FOR COKE DRY QUENCHING SYSTEM

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SYNOPSIS:

Nowadays, Coke Dry Quenching (CDQ) plant has been regarded as essential facility as a counter-measure against environmental problems like global warming by CO_2 and air pollution.

CDQ has widely spread especially in Asia. Because one large CDQ (single-chamber CDQ) is more efficient than multiple small CDQ (multi-chamber CDQ) and this fact generates much benefit for the users, currently, almost all users choose single-chamber CDQ. In order to cope with a tendency of recent enlargement of coke ovens, expansion of single-chamber CDQ capacity was necessary.

NIPPON STEEL & SUMIKIN ENGINEERING CO., LTD. (NSENGI) has the best single-chamber CDQ solutions. Since 1976, NSENGI has constructed the first CDQ plant with 56t/h capacity in Yawata Works of NIPPON STEEL & SUMITOMO METAL CORPORATION; NSENGI has not only left a lot of construction achievements but also expanded this technology to other countries, especially in other Asia countries. In addition, through the long-years development of CDQ technologies, we have established numerous original technologies.

Now, NSENGI has developed world's largest 280t/h capacity single-chamber CDQ and is one and only supplier which can supply CDQ with various capacity from 56t/h to 280t/h, which is most suitable for each customer.

In addition, "Stable operation" is very important factor to single-chamber CDQ. As one of the NSENGI's solutions for stable operation, NSENGI provides "Automatic control system" for customers who have little experience in CDQ operation.

Keywords: environment pollution, energy-recovering, CO_2 reduction, large-scale Coke Oven, large-scale CDQ plant (large-scale Coke Dry Quenching plant), single-chamber CDQ, automatic control, the largest treating capacity

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1. Introduction

In recent years, as the environmental problems such as global warming by CO2 and air pollution have become more serious, Coke Dry Quenching (CDQ) plant has gathered a lot of attention from the world by its efficient energy recovery and the characteristic of reducing the environment pollution.

CDQ is a system to cool the hot coke brought out of coke ovens at a temperature of about 1,000 °C with inert gas and generate electric power by steam produced in the waste heat recovery boiler. Since the sensible heat recovered by the heat exchange in the cooling chamber is utilized as the heat resource for the steam generation, electric power generated from the CDQ is environment-friendly and clean energy. In addition, compared with conventional wet quenching system, CDQ brings about advantages such as reduction of dust emission and improvement of coke quality.

Since production capacity of coke ovens is increasing in recent years, CDQ capacity also have been demanded to adapt to this changing trend. NIPPON STEEL & SUMIKIN ENGINEERING CO., LTD. (NSENGI), in order to follow this tendency and satisfy various customer requirements, specially launched the development of large-scale CDQ comprising single chamber (single-chamber CDQ) for quenching a large quantity of coke.

For single-chamber CDQ, availability is very important factor because there are no spare facilities. In order to achieve high availability, stable operation is essential. For inexperienced operator, however, it is difficult to achieve the stable operation by adjusting various parameters. In recent years, we developed a new automation technology for customers unaccustomed to CDQ operation.

This literature is to introduce the general information of CDQ including the advantage such as reduction of the environmental pollution, the NSENGI's development of CDQ technology and “Automatic control system” for customers who have little experience in CDQ operation.

2. Outline of the CDQ plant

The configuration of a CDQ plant is as follows (Figure 1);

(1) Hot coke (at approx. 1,000 to 1,100 °C) brought out of the coke oven is received in the bucket and transferred to CDQ lifting tower by CDQ locomotive.
(2) The hot coke in the bucket [1] is hoisted by the crane [2] and charged into the Pre-chamber [4] by the charging facility [3].
(3) The hot coke, while descending in the chamber, is cooled (less than 200 °C) by the circulation gas blown from the lower zone of the cooling chamber [5] and discharged from the discharging facility [6].
(4) The high-temperature circulation gas (at approx. 900 to 950 °C) after a heat exchange process in the cooling chamber [5] passes through the primary dust catcher [7] and is supplied to the boiler [8].
(5) The circulation gas after a heat exchange process in the boiler is cooled down to approx. 180°C. The steam generated in the boiler is used as general-purpose steam, or converted into electric power through a turbine generator, depending on the energy circumstances in the works.
(6) The circulation gas passes through the secondary dust catcher [9] into the gas circulation blower [10], by which its pressure is booseted, and repeats circulation.
(7) If necessary, the sub-economizer [11] is installed to decrease the temperature of circulation gas to approx. 130°C, improving the cooling efficiency of the cooling chamber.
(8) As an auxiliary, a dedusting facility, a dust treatment facility or others are installed.

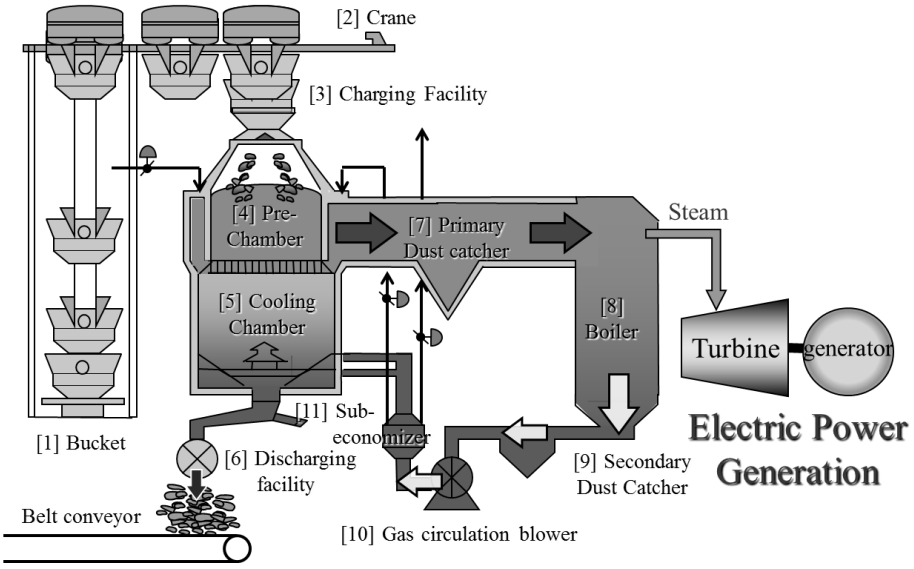


Figure1 CDQ Process flow

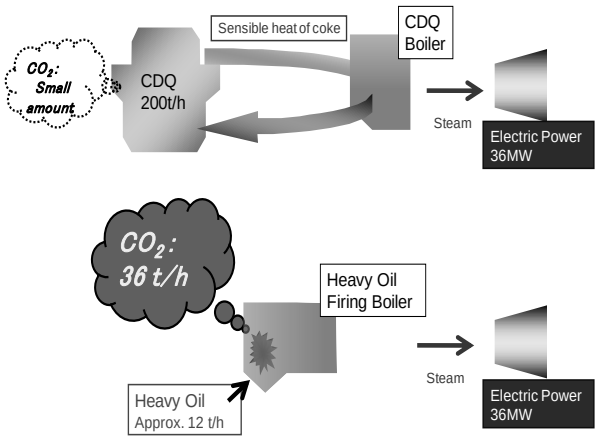


Figure 2 Power generation amount from CDQ

3. Advantages of CDQ

CDQ process has many advantages in comparison with conventional wet quenching process. Main advantages are as follows.

(1) Power generation utilizing sensible heat of hot coke

The electric power can be generated by CDQ without consuming fossil fuels. Therefore, the CO_2 emission can be reduced by installing CDQ plant.
For instance, CDQ with 200t/h capacity can generate approx. 36MW of electric power. To generate the same output with a heavy oil firing boiler, 12t/h heavy oil is required and 36t/h CO_2 is emitted to the atmosphere. In case of a steel work with 8.5 million t/year crude steel productions, approx. 0.5 million t/y CO_2 emission can be reduced if all coke is quenched with CDQ and the electric power is provided from it.
By an installation of CDQ, both the ecological and economic advantages can be enjoyed enormously.

(2) Prevention of dust emission during coke quenching

In general, much amount of coke dust contained in steam (approx. 300-400 g/t-coke) is emitted from the wet quenching tower.
Recently, an improved new wet quenching tower which reduces the dust emission volume and the Coke Stabilization Quenching (CSQ) is gradually spreading, but CDQ is more efficient in prevention of dust emission.
The dust emission volume from CDQ is less than 3 g/t-coke, besides, new type charging equipment, which is covered with the screen. And the inside dust is suctioned to the de-dusting facility. Therefore it achieves further reduction of dust emission from the CDQ.

(3) Improvement of productivity at Blast Furnace

Table 1 shows the benefits on Blast Furnace (BF) which is the actual result in Nippon Steel & Sumitomo Metal Corporation (NSSMC) group. Concerning the coke quality, the coke quenched by CDQ has two excellent features in comparison to the wet quenching method.

1) High mechanical strength of the coke
2) Containing little moisture in the coke (nearly zero)

These features provide the following benefits in BF.

- Reduction of fuel consumption and CO_2 emission
  The fuel consumption in BF is reduced by a few percent because extra heat energy is not required such as for the evaporation of moisture contained in the coke. And it also contributes to the CO_2 reduction at BF, and an improvement of power generation on TRT due to the increasing of the temperature at the top of BF.
- Improvement of iron productivity
  By using the coke quenched with CDQ, the permeability in BF can be improved due to high coke strength. High permeability in BF can raise the efficiency of reductive reaction in BF, and the iron productivity is also improved. Our CDQ users take the advantage of high productivity on BF, and found dry quenched coke is essential for the stable operation of BF, especially for large capacity BF. Therefore, in practice, there also is strong demand from the viewpoint of BF operation to construct CDQ plant.
- Increase of injection limit of pulverized non-coking coal
  As the coking coal strength is increased, interior of BF can maintain the sufficient permeability and thus more much amount of pulverized non-coking coal can be used.

(4) Improvement of coke quality

As mentioned above, the coke quality is improved by means of being quenched with CDQ compared to the wet quenching method. The reason is that the coke is cooled gradually with the cooling gas in CDQ chamber instead of quenching by sprinkling water. And the water-gas reaction is also avoided.
In particular, both 1.5 % improvement in mechanical strength (DI) and 2.5% increase in strength after the reaction (CSR) are expected from our experience. NSENGI's studies of recent years show that the increase rate of coke strength is relatively little, in case that the content percentage of high-grade coking coal in raw materials of coke is high. The coke oven users can get large benefits by increasing the utilization percentage of non-coking coal amount than before at the same time of installation of CDQ.

Table 1 Improvement of productivity at BF (※Actual result in NSSMC group)

Item	Effect
Iron productivity limit	8% UP
Fuel ratio	6 kg/t-pig iron DOWN
Injection limit of pulverized non-coking coal	100 kg/t-pig iron UP

4. The popularization of CDQ

CDQ has widely spread especially in Asia. Figure 3 shows the installation rate of CDQ of each country (Japan, China, Korea, Taiwan and India).

Japan: CDQ is installed for almost all coke ovens in Japan. This high installation rate is due to not only the high electricity expenses in Japan, but also the high demand of dry quenched coke for BF in steel industry.

China: The government fully understands the benefits of CDQ, and expanding installation of CDQ is clearly mentioned in the national goal from 2000. In case of new coke oven construction, the owner of coke oven is required by law to install CDQ.
Although the installation rate of CDQ is approx. 40%, the rate for steel industry is approx. 85% in China.

India: The installation rate of CDQ is not high, approx. 30%, but the installation of CDQ is rapidly expanding. In some prefecture in India, the installation of CDQ is required under the prefectural ordinance in recent years.

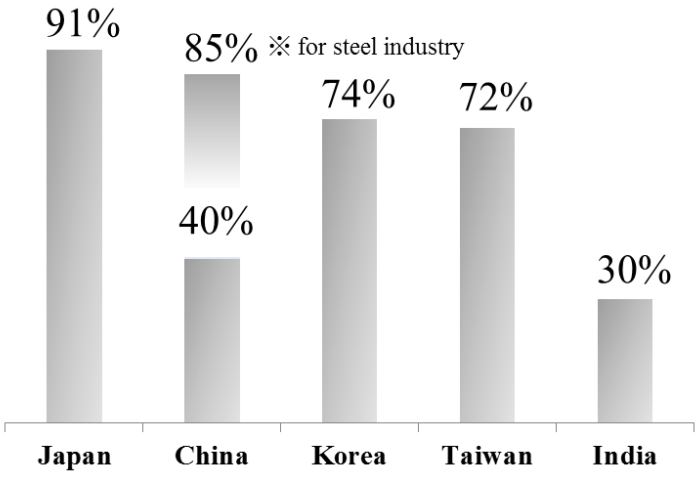


Figure 3 Installation rate of CDQ (Based on internal investigation)

5. NSENGI's development history of large-scale CDQ plant

As large capacity CDQ brings about the following advantages, most customers choose single-chamber CDQ (one large CDQ) instead of multi-chamber CDQ (multiple small CDQ). Following is comparison between the costs of 2units of 140t/h CDQ and 1unit of 280t/h CDQ:

1) Drastic reduction of construction cost
   Because the numbers of facilities decrease from 2 to 1, total weight of equipment is also cut down. This way can achieve approx.20 to 25% construction cost down.
2) Reduction of running cost
   One-CDQ-plant configuration allows a reduction of approx.20% of running cost. It also allows a reduction in electric power consumption by CDQ plant itself, which leads to an improvement of energy conservation effect.
3) Space saving
   Less number of facilities makes a smaller configuration to allow a reduction of about 25% of site area required.

Therefore, enlargement of single-chamber CDQ has been indispensable to cope with a tendency of increasing production capacity of coke ovens.

We constructed a CDQ plant having a treating capacity of 56t/h in Yahata Works, NSSMC in 1976. Thereafter, we have worked on the development of large-scale CDQ. In order to expand CDQ capacity larger than 200t/h, we have challenged the improvement of heat-exchange efficiency in the chamber by new design method of large-scale chamber established by numerical simulation and 1/10-scale chamber model experiment. We also have tried to develop high reliability technologies of discharging system, boiler, secondary dust catcher, and so on. Through step-by-step efforts, we succeeded in the growth in capacity up to 280t/h.

Consequently, NSENGI are now highly esteemed for its engineering capability to provide CDQ plants responding to various coke throughputs and the facility-compacting competency to reduce an investment cost. We have constructed more than 110 CDQ plants all over the world; they have been showing good results (Refer to Table 2 and Figure 4).

In addition, based on our enough experience of not only supplying the plants but also the experiments and achievements, we have been improving the stability and efficiency of the CDQ plant. In the actual operation, NSENGI's single chamber achieves 96% availability.

Table 2 Actual result of scale-up development

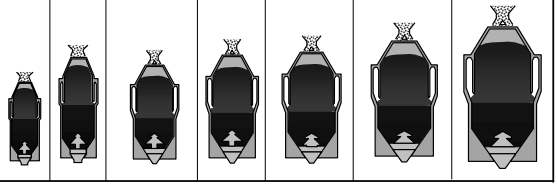
Works	Yawata #2	Shanghai Baoshan Steel #1,2,3,4	Hirohata #3,4	Nagoya #1,2	Kansai Coke and Chemical #1,2	Oita #3,4	Yawata #4,5	Kimitsu #4,5	Oita #1,2	Jimg tang #1,2
Operation Start	1974	→	→	→	→	→	→	→	→	2009
Capacity (ton/h)	56	75	110	118	150	180	175	200	190	260
Profile										

Figure 4 NSENGI's supply record of CDQ (As of Mar. 2016)

6. Automatic control system

For stable operation, which is necessary to operate CDQ plant safely and effectively, NSENGI has pursued technical development continuousuly, ahead of other companies. As an example of our development of hardware for stable operation, we developed "Continuous discharging system" for the first time in the world.
On the other hand, we have developed software in the past few years. Even with the technical development of the hardware mentioned above, stable operation was still difficult for inexperienced operators because it was necessary to adjust various parameters which interact with one another. In view of this problem, we developed "Automatic control system" for customers who have little experience in CDQ operation. In this system, the following control is carried out automatically and brings customers profit as below (Refer to Figure 5).

A Automatically control circulation gas volume to get desired cooling gas volume based on discharging coke volume.
→ That leads to minimization of fluctuation of temperature for inside of chamber which results in longer refractory life.

B Automatically adjust sloping flue air volume to control CO concentration (%) in circulation gas.
→ That leads to maximization of heat recovery volume by burning of excess CO gas and minimization of chance of explosion under normal operation.

C Automatically control by-pass gas volume to maintain boiler inlet gas temperature less than 980°C.
→ That leads to minimization of chance of boiler tube over heating under normal operation.

As every parameter (circulation gas volume, sloping flue air volume, by-pass gas volume) affects each other, experienced skill is necessary to regulate those parameters manually and to operate CDQ stably. By the "automatic control system" mentioned above, those parameters are automatically controlled so that the values of discharging coke temperature, CO concentration and boiler inlet gas temperature are within allowable range.
This technology is introduced for several years and now is installed into 6 CDQ systems (including 1 CDQ system under construction).
We believe that this automation technology is very attractive for customers who examine the introduction of CDQ, from the perspective of stable operation.

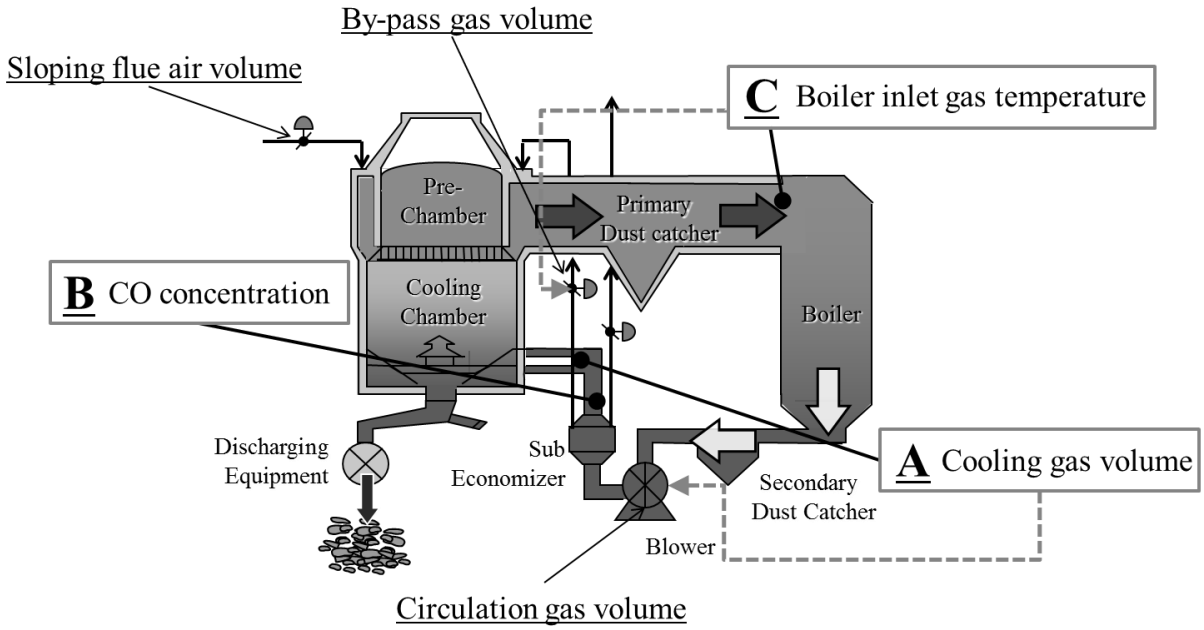


Figure 5 Automatic control system in CDQ

7. Conclusion

Amid growing concerns over global environmental preservation in recent years, CDQ plant has received a lot of attention all over the world as the efficient energy recovery, the environmental protection in the world and prominent benefits on BF and coke quality improvement.

As stated above, the large-scale CDQ plant carries advantages such as drastic reduction of construction cost and running cost, which proves its high contribution to the investment effect of customers.

By the establishment of large-scale CDQ technology, NSENGI has come to be able to provide optimal CDQ plants corresponding to a variety of specifications and capacities of coke ovens. Furthermore, we can provide “Automatic control system” for customers not used to CDQ operation.

We will continuously aspire to spread the CDQ technology over the world and make more outstanding contribution in protecting and improving the environment.