POWER GENERATION WITH COKE WASTE HEAT RECOVERY BY CDQ TO REDUCE CO2 EMISSIONS

BY

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SYNOPSIS:

Coke Dry Quenching (hereinafter referred to as the “CDQ”) is a heat recovery system to cool the red-hot cokes produced from Coke Ovens. Thermal energy that is generated during the cooling process is recovered and used to generate steam in the boiler, steam can be then used to generate electricity in the turbine and generator.

Nippon Steel Engineering CO., LTD. (hereinafter referred to as the “NSE”) is highly evaluated as CDQ supplier among steel companies globally with high stem generation rate, stable operation results, development of digital technology, etc. This paper also describes technological development of CDQ by NSE.

CDQ significantly reduces CO2 emissions by replacing with existing Coke Wet Quenching (hereinafter referred to as the “CWQ”).

This paper describes advantages of CDQ replaced with existing CWQ in ASEAN steel industry. CDQ contribute CO2 reduction for steel industries in ASEAN. Estimation of the amount of CO2 which can be reduced by CDQ in ASEAN shall also be introduced in this paper.

Keywords : CDQ, CWQ, heat recovery system, reduction of GHG emissions.

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1. Introduction of CDQ
1-1 CDQ and CWQ

In this chapter, CDQ technology and its implementation effects are described in comparison with CWQ.

In the production of "cokes", which are fed into a blast furnace as fuels to make iron, there is a process where coal is charged in a "coke oven" to make "red-hot cokes" and then is cooled. In this red-hot coke cooling process, two types of equipment (methods) are used: CWQ and CDQ.

CWQ is a large chimney-like structure, and sprays water when cooling red-hot cokes. When water is sprayed, a large amount of heat energy is turned into steam and emitted into the atmosphere through the chimney. (Figure 1-1)

CDQ, on the other hand, has a closed structure as facilities and uses no water but cooling gas to cool red-hot cokes. Thermal energy that is generated during the cooling process is recovered and used to generate steam in the boiler, which can then be used to generate electricity in the turbine and generator (TG). (Figure 1-2)

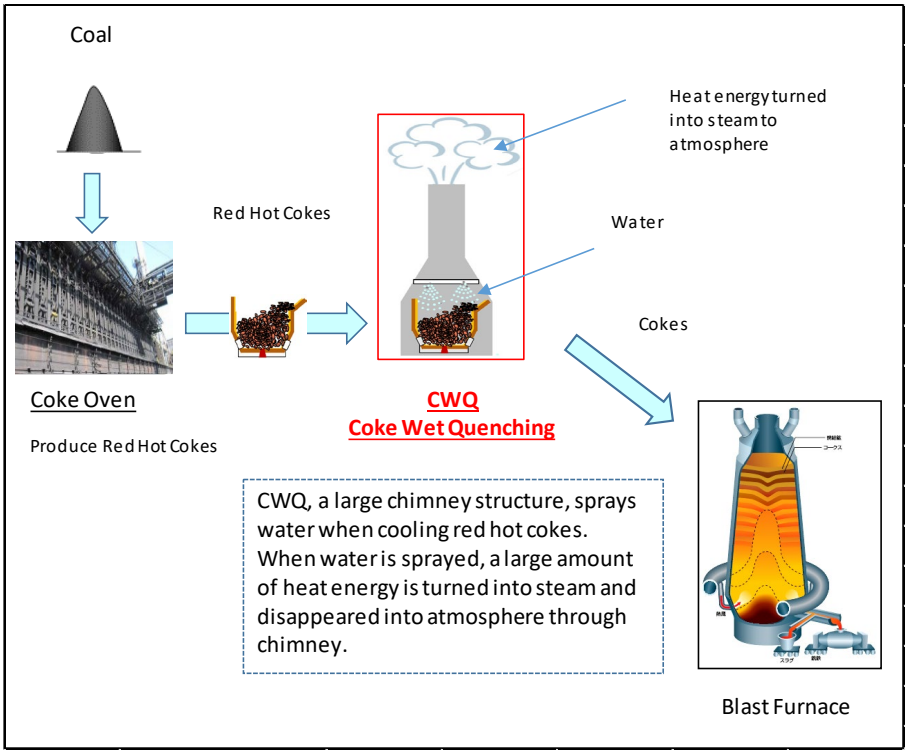

Figure 1-1 Coke Wet Quenching (CWQ)
Source: Compiled by Nippon Steel Engineering

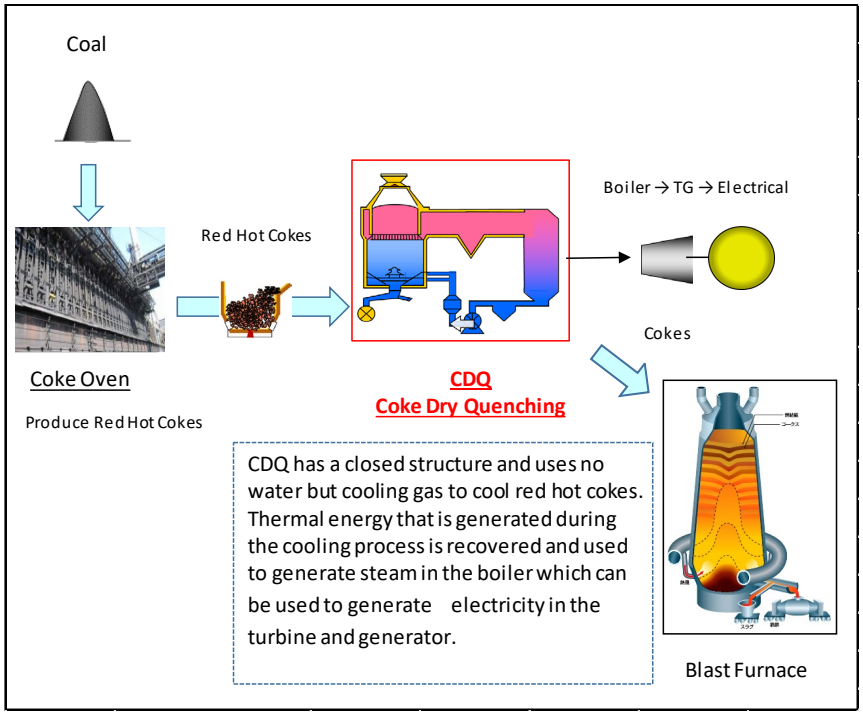

Figure 1-2 Coke Dry Quenching (CDQ)
Source: Compiled by Nippon Steel Engineering

1-2 Feature of CDQ

In this chapter, configuration and feature of CDQ technology and development of technology of CDQ is described. (Figure 1-3)

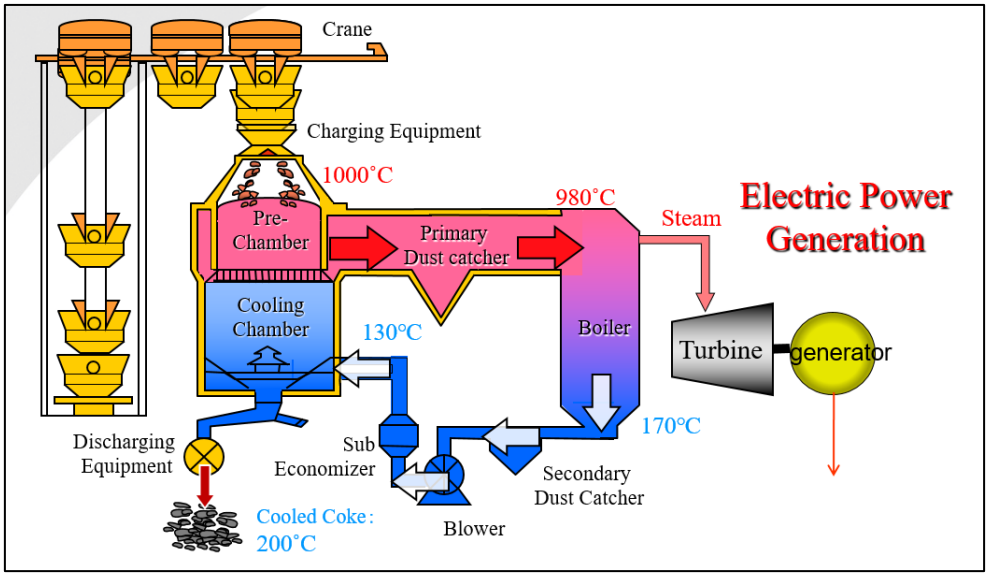

Figure 1-3 CDQ equipment configuration
Source: Compiled by Nippon Steel Engineering

(1) Electricity Generation
Red-hot cokes of high temperature about 1,000°C in the coke oven are cooled to below 200°C in the CDQ chamber. Heat energy recovered from this cooling process is converted into high-temperature, high-pressure steam in the CDQ boiler. Steam produced in the process is pumped into the turbine & generator (TG) and used to generate electricity. Thus, CDQ plays an important role as power generation facilities.

(2) Environment improvement to prevent dust emission
In CWQ, water is applied to red-hot cokes for wet cooling, while in CDQ, no water but inert gas is applied to cool red-hot cokes. The cooling process of CDQ is completely closed, and it does not generate white smoke mixed with dust unlike CWQ, which is quenched with water. CDQ, therefore, contributes to the improvement of the environment around the coke oven. The estimated dust generation is 3g/t-coke for CDQ compared to 300g/t-coke for CWQ, which is a significant improvement of 99% in dust generation reduction.

(3) Cokes Quality Improvement
Cokes play a role of securing pathways for hot metal and reduction gas in a blast furnace with their hardness and particle size maintained, which prevents themselves from being deformed easily in the oven. In this respect, CDQ prevents cokes from becoming porous and internal cracks that occurs in water cooling of CWQ because the cokes are cooled gradually by inert gas. CDQ also improves the reduction efficiency (reaction efficiency) of blast furnaces as friction between cokes during the cooling process causes their fragile parts to peel off, which increases the strength of the cokes. Furthermore, CDQ suppresses required amount of heat in a blast furnace by reducing water contained in cokes to the utmost limit, which helps reduce the amount of cokes used as a heat source.

1-3 Technological Development of CDQ

(1) Size Increase up to 260t/hour
NSE was in need of expanding processing capacity from the original 56 t/hour to cope with growing cokes output, and started technologies development that would make the equipment larger and more reliable. As a result of the technological development, the processing capacity has increased from 100 t/hour to 150 t/hour and finally to 180 t/hour in the 1980s, and reached the world's largest capacity of 260t/hour in 2009, which was embodied in the latest facilities in those days that the company delivered to Jingtang Iron and Steel in China.

The issue of increasing the size of CDQ lies in cooling of cokes uniformly in a chamber. NSE has succeeded in developing a unique technology that enables stable operation without lowering the cooling efficiency even in large-scale facilities through many years of research and development, including simulation analyses and full-scale experiments to ensure uniform flow of coke and cooling gas. (Figure 1-4)

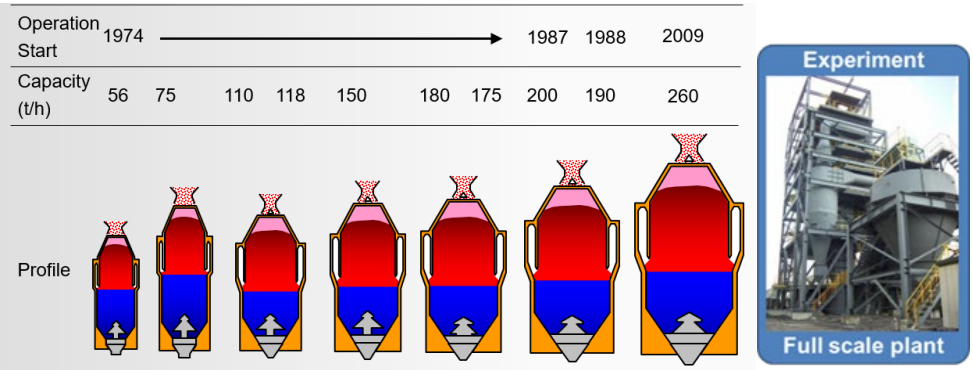

Figure 1-4 Background of the enlargement of CDQ
Source: Compiled by Nippon Steel Engineering

The development of the 260-tons/hour facilities has reduced construction costs by approximately 20-25% compared to the installation of two conventional CDQs with a processing capacity of 130 tons per hour. Furthermore, running costs were lowered by about 20%. The facilities can also reduce the site area required for installation by about 25%. It could improve the problem of securing space (site), which often matters when installing the system. (Figure 1-5)

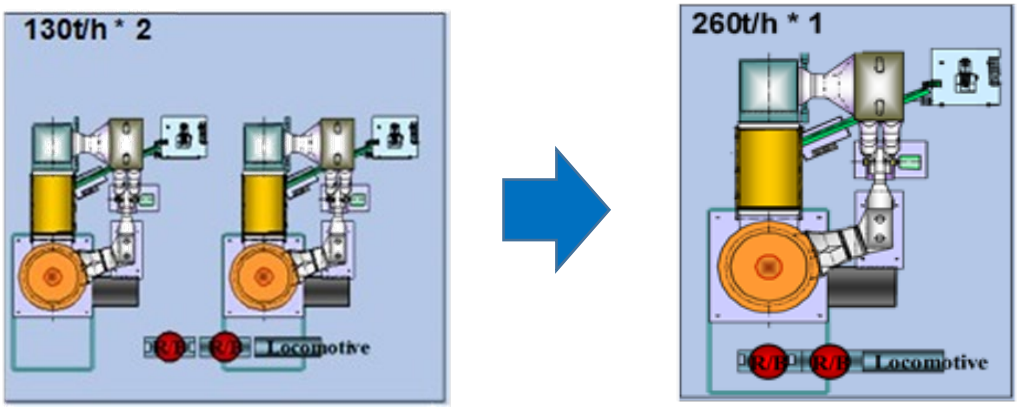

Figure 1-5 260t/h CDQ and 130t/h CDQ
Source: Compiled by Nippon Steel Engineering

(2) Fully Automated CDQ Operation System

CDQ adopts an automatic operation system in order to achieve highly efficient cooling of red-hot cokes in a CDQ chamber and stable steam generation from a CDQ boiler. It means that even if CDQ operation conditions are volatile due to changes in the output in coke ovens, CDQ automatically runs safe and stable operation based on the monitoring data. Automated stable operation reduces damage to refractory materials with controlled temperature changes in the chamber, and also eliminates the need for frequent and complicated manual operations. (Figure 1-6)

Furthermore, NSE have developed the system which automatically calculate volume of discharging coke based on the pushing schedule of coke oven. (Figure 1-7)

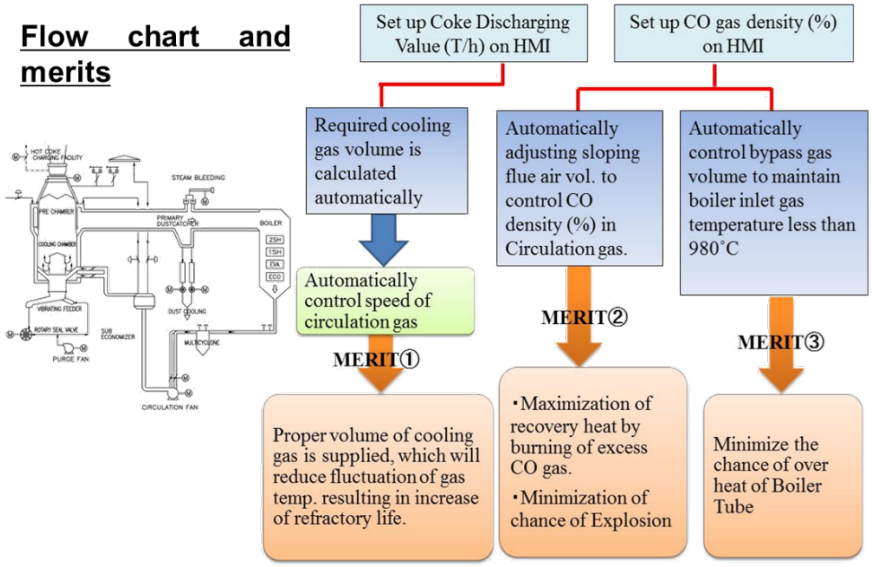

Figure 1-6 Digital Automation Technology
Source: Compiled by Nippon Steel Engineering

Figure 1-7 Optimum discharging coke volume by linkage with coke oven
Source: Compiled by Nippon Steel Engineering

2. Estimated CO2 Reduction

2-1. Growing needs for GHG reductions in ASEAN

ASEAN countries have set the GHG reduction targets as a Nationally Determined Contribution (NDC) under the Paris Agreement. Meanwhile, new blast furnaces and coke ovens are increasingly introduced in the ASEAN region, which makes it an urgent issue to reduce CO2 in the steel industry.

NSE has been supplying CDQ to Japan since 1970s and China since the 1980s. The Chinese government has recognized the effectiveness of CDQ and has been promoting the use of CDQ since around 2005 through environmental regulations, equipment subsidy programs, and other policies. Now, CDQ introduction to coke furnaces has become a requisite in China.

Among ASEAN region, Vietnam introduced CDQ for the first time. There are no environmental regulations in Vietnam that directly refer to the introduction of CDQ except some regulations in relation to part of steelmaking facilities. However, the Vietnamese government has been supplementing and amending the existing environmental regulations; as a result, it has become virtually mandatory to introduce CDQs when newly constructing blast furnaces or coke ovens.

2-2 Estimated potential CO2 reduction of CDQ in ASEAN

CDQ generates electricity from waste heat recovery replaced with CWQ. This means the amount of electricity generated by fossil fuel power plant can be reduced. Therefore, the introduction of CDQ lead to reduction of CO2 emission.

In this chapter, the estimated potential CO2 reduction of CDQ in ASEAN is calculated as below.

In case of 1 million tons coke oven, 115 tons/hour CDQ is applied. Annual power generation of 115 tons/hour CDQ is 132,000 MWh/year, and CO2 reduction amount is 88,000 t-CO2/year.

Based on 115 tons/hour, the amount of CO2 reduction in ASEAN region can be calculated as below. (Figure 2-1)

Country	A	B	C	D
	Coke Oven Capacity (Mt/year)	Number of CDQ (based on 115t/h CDQ)	Annual power generation (MWh/year)	Annual reduction（tCO2/year)
Indonesia	12.1	12	1,583,000	1,061,000
Vietnam	7.9	8	1,033,000	692,000
Malaysia	3.1	3	402,000	269,000
Philippines	5.3	5	689,000	461,000
Cambodia	1.3	1	172,000	115,000
Myanmar	2.6	3	344,000	231,000
Total	32.2	32	4,223,000	2,829,000

Remarks

1) Coke oven capacity (A) = Existing coke oven capacity with CWQ
+ Planned coke oven capacity to be installed in future

2) Number of CDQ (B) = (A)*10^6/365days/24hour/115t/h

3) Annual power generation (C) = CDQ Annual power generation - CDQ Annual power consumption

4) Annual reduction (D) = Annual power generation (C) * CO2 reduction ration (0.67)

5) Assume a CO2 reduction ration of 0.67 t-CO2/MWh

Figure 2-1 Potential CO2 reduction in ASEAN
Source: Compiled by Nippon Steel Engineering

3. Conclusion

In this paper we have verified the effects of energy-saving and GHG emission reductions by the introduction of CDQ under the certain condition on coke ovens in ASEAN.

Regarding the effects of GHG emission reductions by the introduction of CDQ, we verified a significant CO2 Reduction possibility of CDQ for 1 million ton capacity coke oven. CO2 reduction amount of CDQ for 1 million ton capacity coke oven is approx 88,000t-CO2/y. we have also verified potential CO2 reduction amount in ASEAN which is approx 2,800,000t-CO2/y.

NSE continue to contribute to provide environmental and energy saving solution to ASEAN steel industries.