ADVANCED TECHNOLOGY AND APPLICATION OF LARGE-SCALE CDQ

Masayuki Watanabe[1], Naruo Hamasaki[1]

Contact data

[1]JP Steel Plantech Co., 3-1-11F, Kinko-cho, Kanagawa-ku, Yokohama 221-0056, Japan
Tel:+81 45 440 5945, email: hamasakin@steelplantech.co.jp

Summary

JP Steel Plantech Co. constructed 200 t/h and 185t/h large-scale CDQs, through technological improvements and scaling up of the CDQ facility, which was introduced from the former Soviet Union in 1972. Up to now, these CDQs have kept up a yearly operating ratio of 95% even after operation for 25 years, and 18 years respectively. In order to achieve these high operating ratios, I introduce the facilities technology which makes these factors realizable and which need to be taken into consideration.

Key Words

coke; coke dry quenching; CDQ; gas cooling; large scale furnace; enagy saving technology

Introduction

Through the oil crisis of the 1970s and international price competition, the Japanese steel industry has been developing and commercializing various energy-saving technologies. Coke dry quenching systems (CDQs) are typical energy-saving facilities applying some of the technologies.
The CDQs recover the heat energy corresponding to a temperature of approximately 1000°C generated in a coke making process to produce electricity or use steam for energy saving. In the above circumstances, they have increased in size as a blast furnace increases in size.

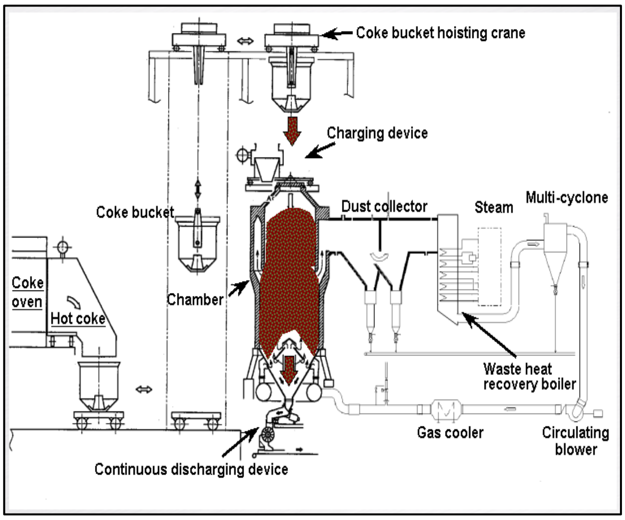


Figure 1: General flow of CDQ

1. Heat exchange in the CDQ furnace and factors to be considered

1.1 Cooling gas volume

The CDQ chamber is a shaft-type heat exchanger as shown in Figure 1. Figure 2 shows the principle of CDQ heat exchange. To improve its cooling performance, the cooling gas volume needs to be increased. As the cooling gas volume is increased to exceed a certain flow rate (flow velocity), coke particles start to be fluidized in the flues on the sidewall. If the gas volume is further increased, the coke particles are carried over through the flues to cause pipe abrasion in the boiler, and as a consequence, the cooling gas cannot be blown into the furnace over the fluidization limit.

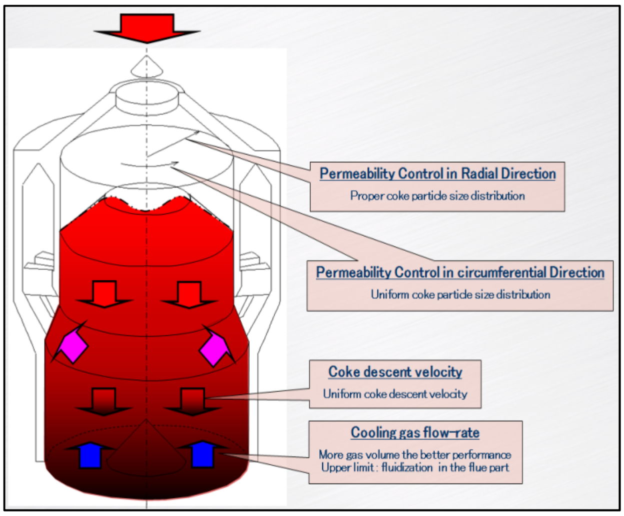


Figure 2: Principle of heat exchange

Figure 3 shows the gas temperature variation at the cooling chamber outlet in the case that the retention time in the cooling chamber is 1.5 hours and the cooling gas volume is changed from 1100 to 1400m3N/ton-coke. The calculation was made under the condition that the inlet coke temperature was 1000°C and the blowing gas temperature was 160°C.

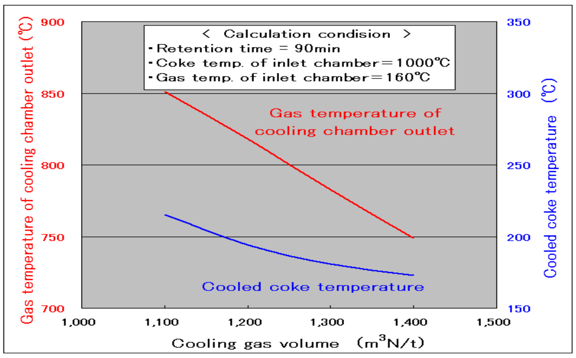


Figure 3: Effect of cooling gas volume

1.2 Control of gas permeability

Coke particle diameters range from those of fine dust to a maximum size of 150 mm of maximum lumps. To cool coke particles as uniformly as possible in the shaft furnace, they should be charged into the furnace with a proper particle size distribution in both circumferential and radial directions.

A rotating coke bucket that rotates and collects the coke particles discharged from the coke oven is adopted to make uniform the particle size distribution in the circumferential direction (Figure 4).

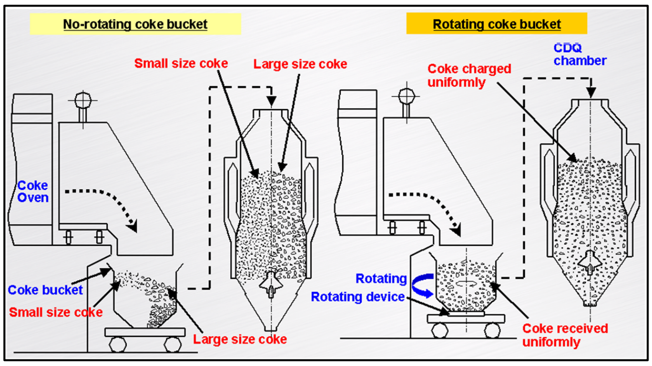


Figure 4: Effect of rotating coke bucket

A special charging bell, which is used as the charging apparatus of blast furnaces, is also adopted to obtain an appropriate particle size distribution in the radial direction. This apparatus distributes large coke particle lumps in the circumferential part and the central part of the furnace, as well as to even out the gas velocity in the radial direction to some extent (Figure 5).

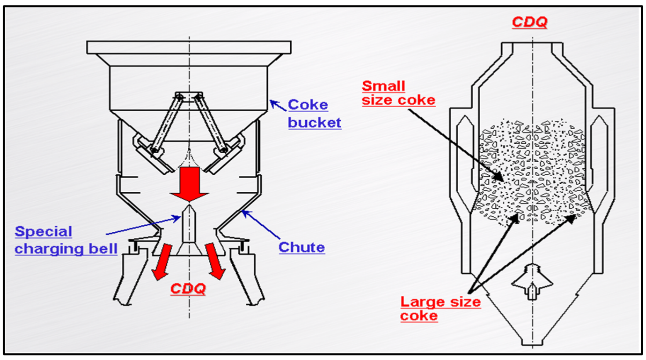


Figure 5: Effect of special charging bell

1.3 Descending velocity control of coke

The apparatus for blowing the cooling gas from underneath is supported by a single directional beam. This support beam obstructs the descent of the coke particles. The shape of the gas distributor is experimentally determined to enable to make uniform the descending velocities of coke particles in the circumferential direction (Figure 6).

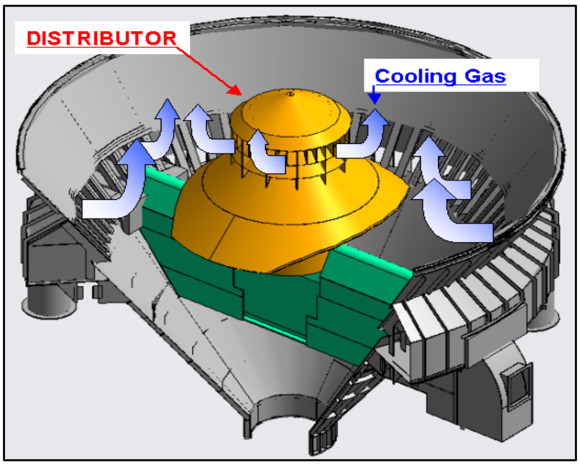


Figure 6: Outline drawing of funnel & distributor

1.4 Application of CDQ Furnace Control Technology

In the above Items 1.1 – 1.3, the factors to be considered for the heat exchange in the CDQ furnace (cooling gas volume, particle size distribution control, etc.) are described. Figure 7 shows the amount of heat exchanged volume between the red-hot coke and the cooling gas in the enhanced efficiency CDQ furnace mentioned above and the amount of heat generated by burning the blowing air in the dust catcher. The amount of power generated is also shown in the figure.

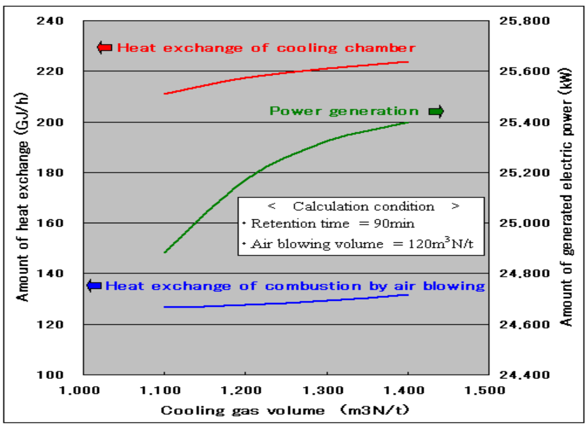


Figure 7: Amount of heat exchanged and electric power generated

2. System factors for maintaining high operation rate

In the CDQ process, the parts that need maintenance and replacement are the lined refractories in the furnace and the boiler's abrasion-proof protectors. A CDQ system manufactured by another company and installed in China, for example, needs about 45-day maintenance work after 2 years of operation.

2.1 Durability of refractories

The cooling gas passes through the coke layer in the cooling chamber. The cooling gas's superficial velocity is about 2m/s. The actual gas velocity passing through the furnace wall surfaces is therefore estimated to be about 10m/s. Coke dust naturally accompanies the gas, causing serious abrasion damage to the furnace wall surfaces. Our recommended cooling zone refractories have a life duration of longer than 10 years, and hence they have excellent abrasion resistance. In addition to the refractories, the joints between the refractories should also be taken into account (Figure 8).

Figure 8.1: Photograph of cooling chamber refractory after 1 year operation (Using conventional refractory)

Figure 8.2: Photograph of cooling chamber refractory after 8 years operation (Using high durability refractory)

2.2 Measures to prevent coke particles from scattering from flues

It is also important to reduce the abrasion by coke particles in the boiler, as well as the multi-cyclone as the secondary dust collector, and the circulation blower. The normal single flue structure has several tens of large openings on the side, which collect the cooling gas to the circular flow passages in the upper part of the CDQ furnace body, and lead the gas to the dust catcher. The areas of the openings are designed to be as large as possible to reduce the gas flow velocity. The increase in height, however, significantly increases the amount of coke particles carried-over, for this reason, the width is increased to a maximum extent. The partition wall thickness between the flues is therefore as thin as about 150 mm, causing concern about the decrease in the strength of the brick structure (Figure 9). Figure 10 shows the form of accumulated coke particles in the flues.

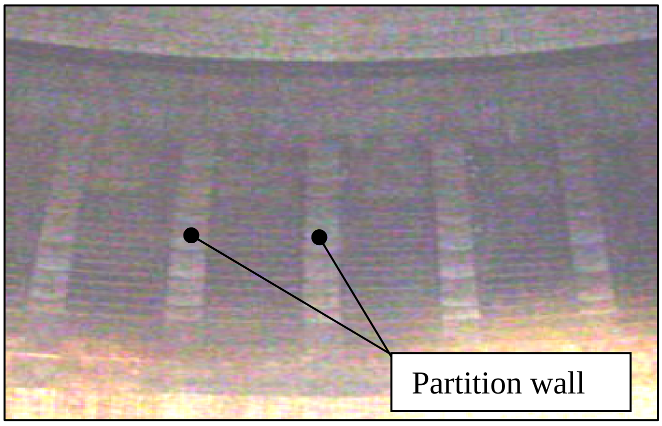


Figure 9: Structure of single flue brick

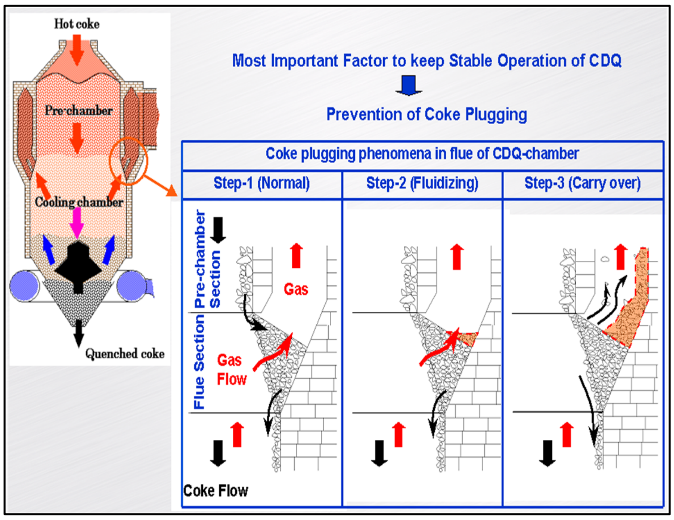


Figure 10: Coke Condition in Flue of CDQ-chamber

Since the gas flow resistance in the upper parts of the flues differs greatly from that in the lower parts, the gas flow velocity passing through the upper parts is much larger than that passing through the lower parts. As a result, when the cooling gas volume is increased to 1200m3N/ton-coke or more, coke lumps start to be fluidized in the flues, and a large amount of coke particles are carried over to the dust catcher or downstream (Figure 11).

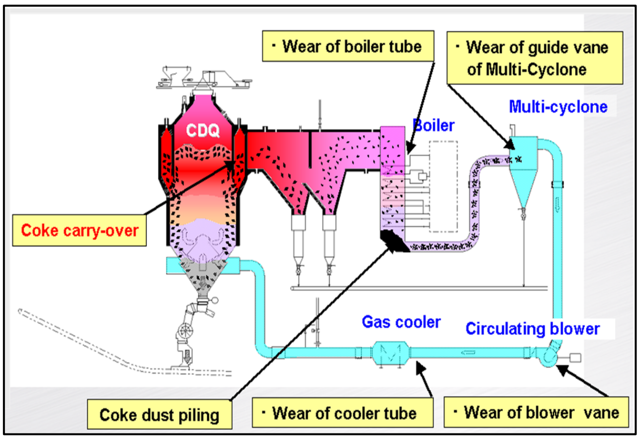


Figure 11: Adverse effect of high gas velocity at flue

To prevent this phenomenon, a two-tier flue structure is employed to extend the flue area as well as to reduce the difference of the gas flow between the upper part and the lower part. This structure is called the “double flue” structure (Figure 12).

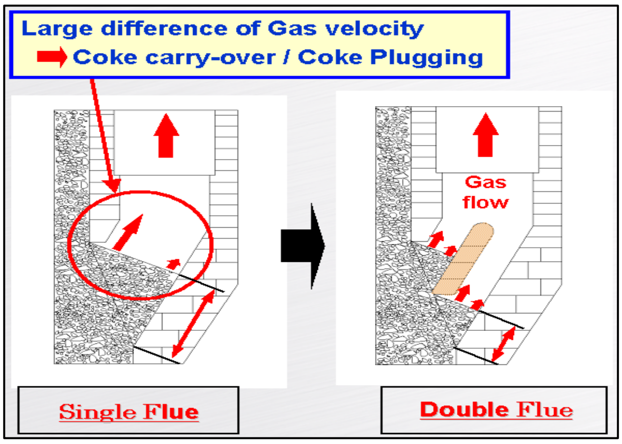


Figure 12: Gas velocity distribution in double & single flue

This technology can reduce the amount of coke particles carried-over to approximately the same as 1,000m3N/ton-coke in the case of the single flue structure, even when the cooling gas volume is increased to 1400m3N/ton-coke.
The cooling capability at the cooling zone can thus be improved through this flue structure. Due to the uniform gas flow velocity, the abrasion loss to refractories at the flue sections can be mitigated. The abrasion loss to the boiler at the flue sections can also be improved since the amount of coke particles is reduced. Using this technology, the life of its mini cyclone comprising the multi-cyclone was successfully extended to about 10 years. The employment of highly durable refractories also extended their lives. Figure 13 shows the abrasion loss of a highly durable refractory after about 6 years of operation. As is clear from Figure 13, the effect is tremendous.

Figure 13: Photograph of refractory of Double flue after 5 years and 8 months operation (Using high durability refractory)

2.3 Structure of dust catcher

Figures 14 and 15 show the flow line charts comparing the cases with and without a collision wall in the dust catcher. Although the dust collection efficiency of the dust catcher is about 25% and not very high, the addition of a collision wall enables the catching of coke particles, in particular, with a large diameter (Figure 16). Large size coke particles contained in the circulating gas obviously increase the degree of abrasion to the boiler and the multi-cyclone.

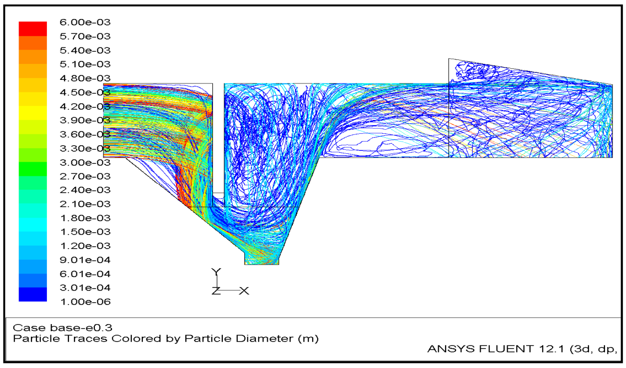


Figure 14: The flow line charts with collision wall

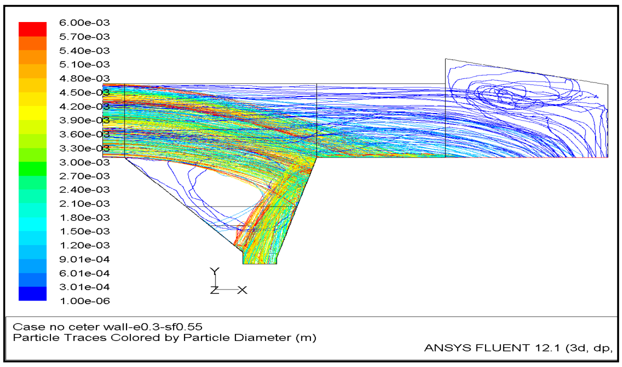


Figure 15: The flow line charts without collision wall

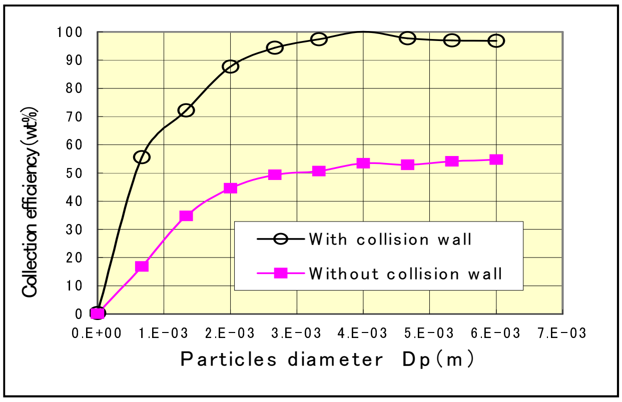
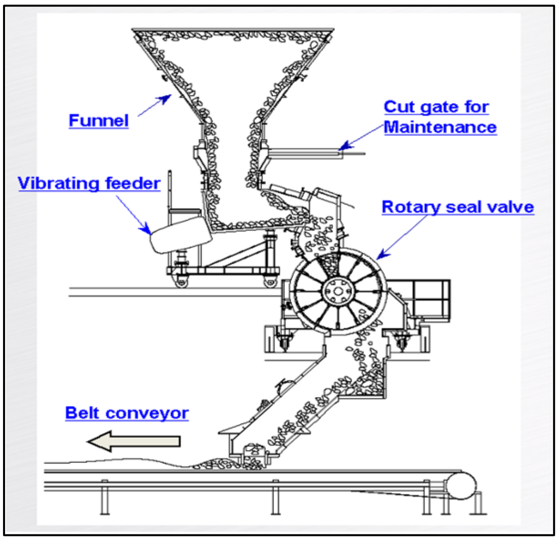


Figure 16: The dust collection efficiency

2.4 Continuous coke discharging device

A double damper system is conventionally used to discharge the coke particles. In the conventional system, the impact pressure caused by the opening and closing of the damper fluctuates the gas velocity passing through the flue sections. In a conventional-type single flue structure with a double damper system, sometimes the dust catcher becomes filled with coke particles due to gas velocity variation has been experienced. It is quite effective to adopt a continuous discharging device consisting of a combination of a rotary seal valve and a large size electromagnetic feeder to prevent such an event (Figure 17). A ceramic lining layer is set inside the valve body of the rotary seal valve to extend its life.



Figrue 17: Coke discharging device

2.5 High reliability of triple pipe type dust cooler

The temperature of the coke particles collected by the dust catcher reaches 1000°C or more. To discharge them from the furnace, they need to be cooled to a temperature around 100°C. Although the dust cooler is not a major device in the CDQ system, it is directly attached to the circulation system, and if problems occur, they will directly cause a reduction in operation rate. Our multiple pipe type dust cooler has a structure to compensate for thermal expansion, and hence no problem has occurred, enabling operation of 25 years or more.

2.6 Forced circulation-type boile

The boiler employs a forced circulation system and enables easy start and stop of operation of the CDQ system. Some measures against scattering coke particles are taken, and the selection of an appropriate superficial velocity is one of them. The circulating gas carries the fine coke particles that cannot be caught by the dust catcher to the boiler section. The particles descend along the wall opposite to the CDQ furnace body, causing the abrasion to the boiler tube. To prevent this, the protector is attached to the upper part of the tube along the membrane wall opposite to the CDQ furnace body. The protector is also attached to the gas passage section of the hanger tube. In addition to the above, abrasion-resistant thermal spraying is partly conducted on the upper part of the steam superheater. Full measures are thus taken (Figure 18).

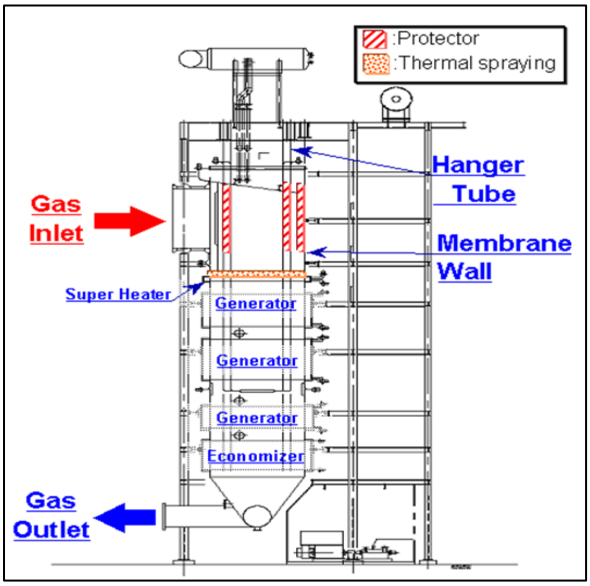


Figure 18: Waste-heat recovery boiler

2.7 Maintainability improvement using a rope trolley type hoisting crane

Overhead traveling cranes are employed in conventional bucket hoisting devices. The conventional systems, however, need winch maintenance work high at the maintenance space at the furnace top. So, a rope trolley type hoisting crane was developed to solve these problems (Figure 19). This system places the winch on the ground to facilitate maintenance work, eliminates the maintenance space on the furnace top, and reduces the weight moving from the furnace top by about 100 tons, resulting in a reduction in frame weight.

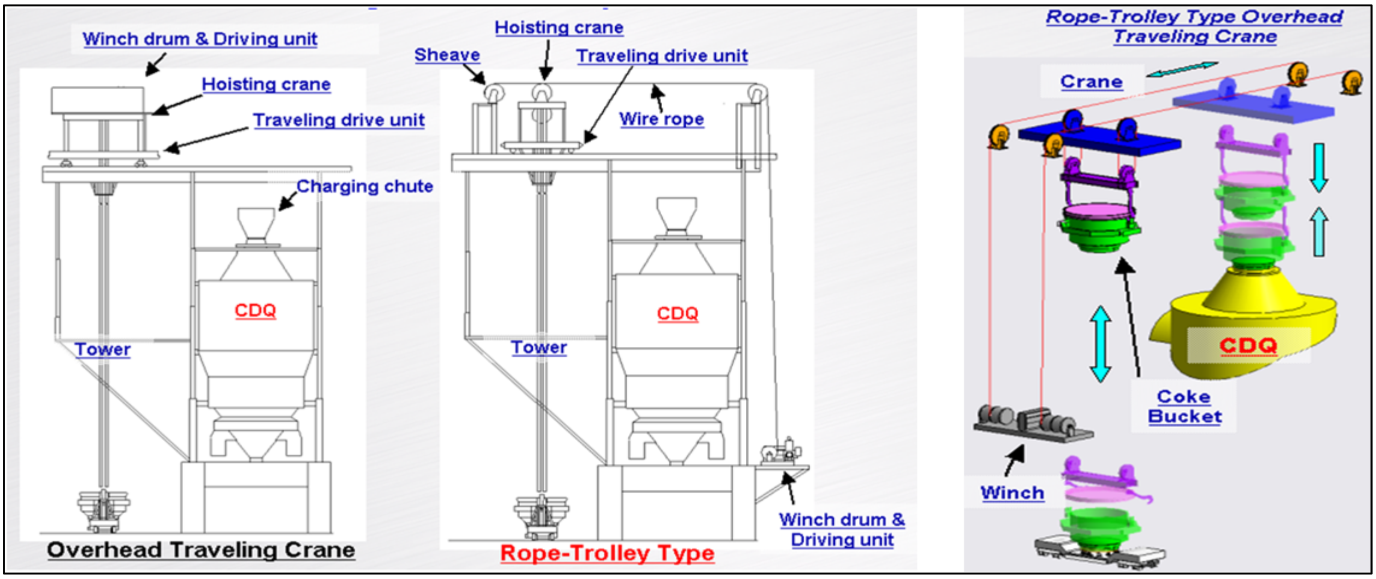


Figure 19: Coke bucket hoisting crane - rope trolley type

3. Conclusion

The above summarizes the process evolution and plant technology that have been studied to realize a high-performance, high operation rate large size CDQ system. Lacking any factor or device which can lead to difficulty in maintaining a high operation rate and a high utilization rate of the CDQ system. The factors leading to the realization of such a CDQ system have been developed in Japanese steel companies together with their customers. We would like to make effort to spread these technologies to maximize energy saving and minimize CO2 emissions, contributing to the global environmental preservation.