2005 Prize of Director General of Regional Bureau of Economy, Trade and Industry

Aiming to become an Earth-friendly Plant

Nippon Chutetsukan KK, Kuki Shobu Plant,
Energy Conservation Project Team

◎ **Keywords: Waste heat recovery and usage**
High efficiency fuel combustion
Rationalized conversion of heat into motive energy, etc. (Co-generation facility)

◎ Outline of Theme

This plant manufactures ductile casting products, mainly water supply pipes, and has a cupola furnace to handle molten metal of 1500°C or over, a melting furnace such as an electric furnace and an annealing furnace for heat treatment, etc. meaning it consumes a larger amount of energy than other plants in the manufacturing industries. Under such circumstances, we have decided to become an earth-friendly plant and since 2000, with this in mind, have tackled not only cost reduction through energy conservation, but also actively implemented measures to reduce the energy consumed in our plant, focusing on the higher energy-consuming melting and annealing furnaces. In addition, in 2003, we introduced a co-generation facility as part of overall plant energy conservation and succeeded in significantly reducing both energy and CO_2 emissions.

◎ Implementation Period for the Said Example

From July 1998 – May 2005

- Project Planning Period: July 1998 – December 2003 (total of 66 months)
- Measure Implementation Period: August 2000 – August 2004 (total of 49 months)
- Measure effect Verification Period: October 2000 – May 2005 (total of 31 months)

◎ Outline of the Business Establishment

- Production items: Manufacture of ductile cast iron pipes, ductile cast iron lids
- Employee: 340
- Annual energy consumption (actual record of 2004)

Coke:	7,321 tons
City gas:	4,369,000 Nm^3
Electricity:	13,853,000 kWh

◎ Process Flow of Target Facility

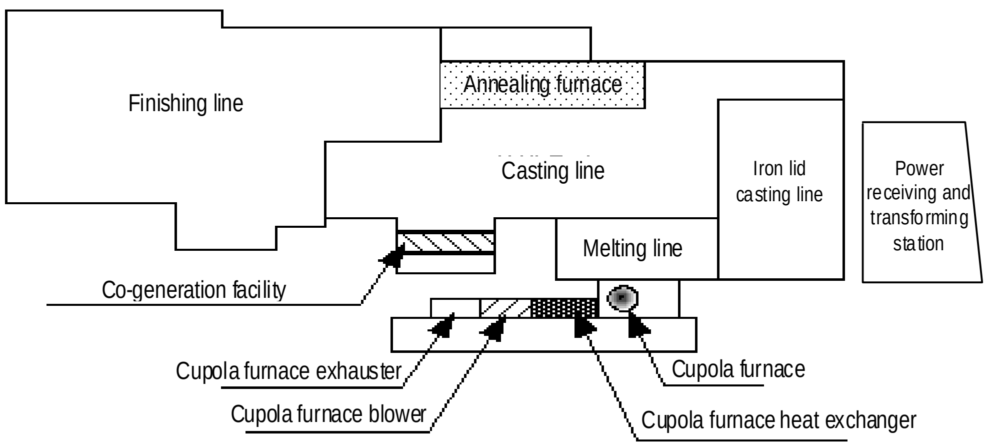


Fig. 1: Arrangement drawing of the target facility

1. Reasons for Theme Selection

This plant has implemented dust prevention measures at various locations, expanded the air conditioning and heat equipment to deal with environmental issues, subdivided the production processes for the introduction of new equipment in order to produce higher performing ductile iron pipes, renewed obsolete equipment and introduced higher performing production processes to improve the capacity of the production facilities - factors which have helped the year-on-year increase of energy consumption. In order to reduce the consumption of unnecessary energy and the amount of CO_2 generated, this plant has decided to implement multiple and overall energy saving measures.

2. Understanding and Analysis of Current Situation

(1) Understanding of Current Situation

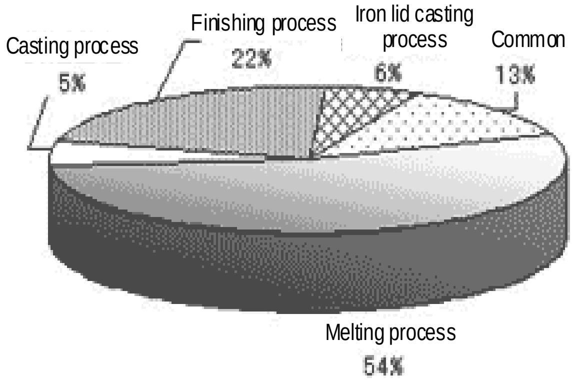


Fig. 2: Energy consumed during plant processes

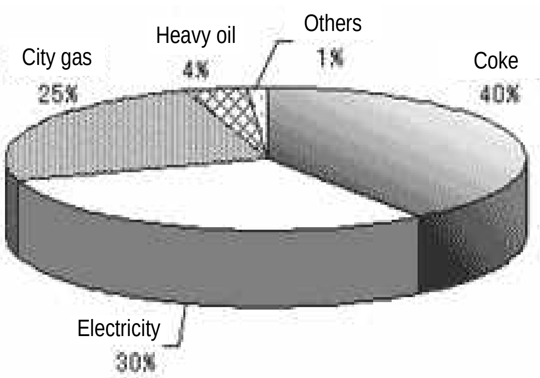


Fig. 3: Type of energies consumed in the plant

Fig. 2 “Energy consumed during plant processes” shows that more than half of the energy is consumed by the melting process that uses the cupola furnace to melt the raw materials and the furnace holding the molten metal. Subsequently, the finishing process using the annealing furnace consumes approx. 22% of the total energy consumed at the plant. Fig. 3 “Type of energies consumed in the plant” shows that the percentage of coke used for melting the scrap is the largest; with electricity ranked second, and the city gas used in the annealing furnace ranked third; these are the three major energies used in the plant.
The key point of the energy conservation campaign is how the consumption of these three major energies can be reduced.

(2) Analysis of Current Situation

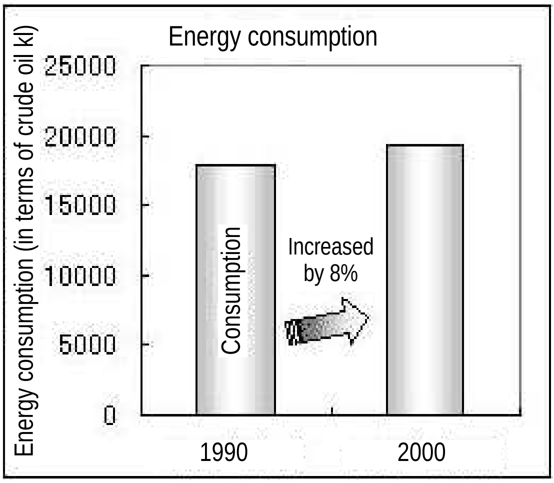


Fig. 4 Change in energy consumption

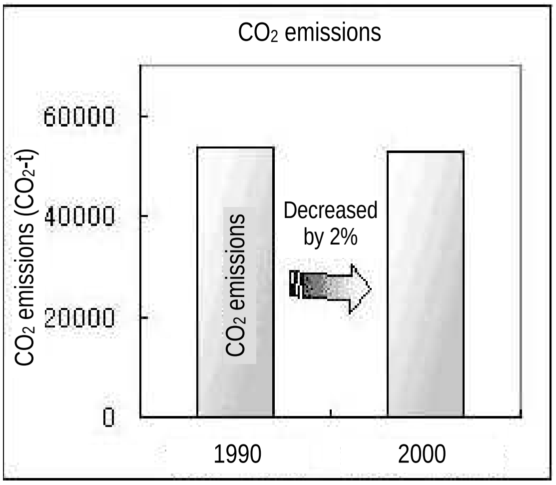


Fig. 5 Change in CO_2 emissions

When the energy consumption at the plant in 1990 is compared with the figure in 2000, we see that the energy consumption increased by approx. 8%, despite the fact the production volume was almost the same. The CO_2 emissions dropped by approx. 2%, partly because this plant switched from LP gas to city gas in 1996.

3. Progress of Activities

(1) Implementation Structure

We decided that it would be difficult to achieve composite energy saving targets set at a high level, simply by promoting the conventional energy conservation activities led by the person in charge of each line. Therefore, we established a promotion system for collective participation in energy conservation efforts, in which the energy conservation committee would play the central role, and in 2000, we organized an energy conservation project team consisting of 10 persons to actively promote the energy saving campaign.

(2) Target Settings

We set the following two goals in 2004, based on the actual records of 2000:

[1] Reduce the energy consumption by 20%.

[2] Reduce CO_2 emissions by 20%.

(3) Problem Points and Their Investigation

In order to subdivide the processes to achieve the goals, we asked the “Advisory program for introduction of energy conservation technologies” of the Energy Conservation Center, Japan to conduct a audit on the energy consumption at our plant.

(4) Determine the Measures to Be Taken

We decided on the actual measures to be taken in the course of the energy conservation campaign, including audit of the energy consumption at our plant.

[1] Establishment of a comprehensive waste heat recovery system, through the introduction of a new type of heat exchanger to the cupola furnace.

[2] Electric power saving and environmental protection measures, through the introduction of an inverter control for the cupola furnace blower and exhauster.

[3] Energy conservation and improvement of the product materials, through the introduction of a regenerative burner to the annealing furnace.

[4] Reduction in CO_2 emissions and environmental protection measures through the introduction of a city gas burner instead of the heavy oil burner.

[5] Energy conservation through the introduction of co-generation and the stable use of natural gas.

4. Details of Measures

(1) Introduction of a New Type of Heat Exchanger to the Cupola Furnace

In the conventional heat exchanger, more than 70% of the energy remaining in the exhaust gas from the cupola furnace was released into the environment. In this new type of heat exchanger, the efficiency of the heat exchanger has improved, and the percentage of waste heat recycled from the cupola furnace has increased. In addition, it is possible to circulate the thermal oil through the collecting pipes, called the “tube bundle”, in order to recover the excess waste heat.

Moreover, it is also possible to operate a waste heat boiler called the “steam generator” using the heat from the thermal oil, so that the operation of the conventional gas firing boiler can be shut down, which helps significantly reduce the city gas consumption.

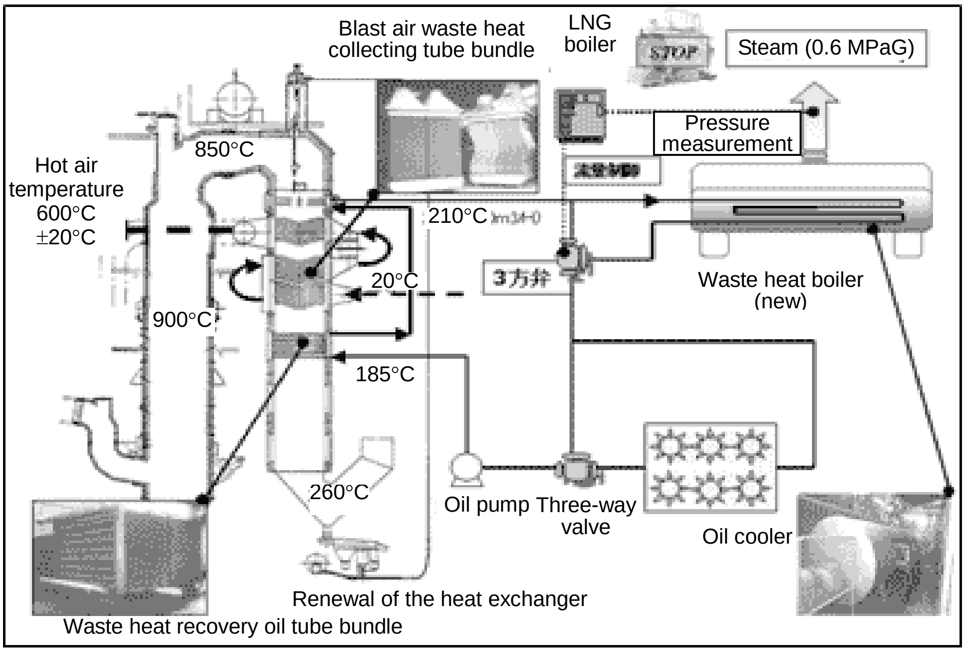


Fig. 11: Diagram of the cupola furnace heat exchanger and waste heat recovery system

Introducing a new type of exchanger, with a totally new design and construction, we succeeded in energy collection (7% from the blast air waste heat and 43% from the waste heat recovery). In addition, while approx. 74% of the exhaust gas energy was released into the environment before the introduction of the new type of heat exchanger, this percentage has dropped to 24%.

Total waste heat recovery rate
26% ⇒ 76% (50%UP)

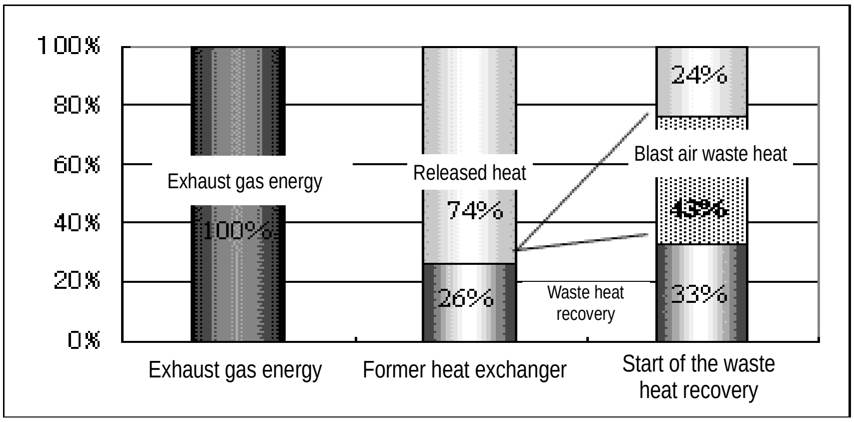


Fig. 7: Exhaust gas energy recovery rate

In August 2000, we introduced a new type of heat exchanger and started the operation of the steam generator in April 2001. Consequently, we were able to shut down the operation of the gas firing boiler and the gas consumption was reduced by 60%, or halved, in terms of unit consumption. (Refer to Fig. 7.)

In addition, following the introduction of a new type of heat exchanger, the hot air temperature (blast air preheated temperature) increased by 130 – 150°C and the increase in the hot air temperature contributed to reducing the unit consumption of coke by 10 kg/ton. (Refer to Fig.8.)

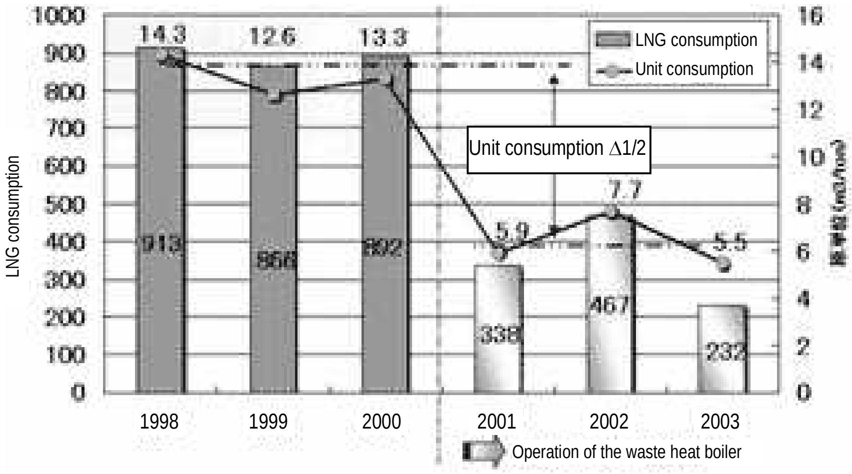


Fig. 8: Change in the consumption of city gas

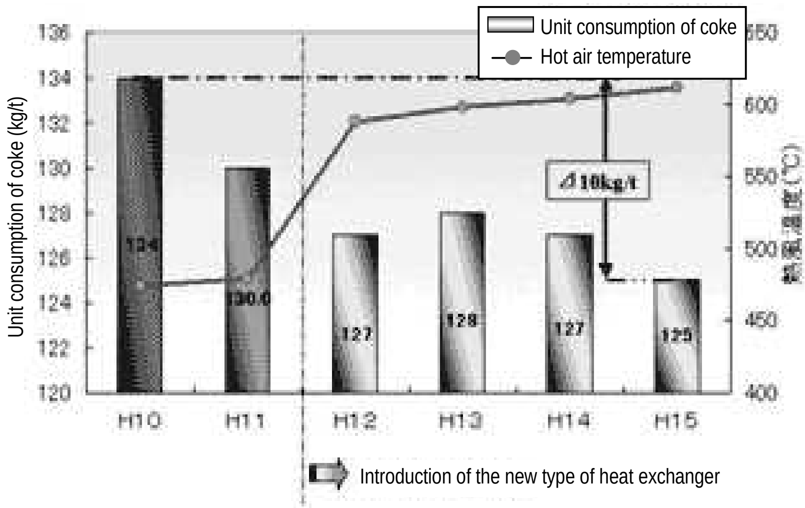


Fig. 9: Unit consumption of coke and the hot air temperature

(2) Introduction of the Inverter to the Cupola Furnace Blower and Exhauster

In 2001, we altered our operating system so as to make the melting capacity of the cupola furnace adjustable. The inverter control has made it possible to precisely adjust the blast volume without reducing the maximum performance of the blower and exhauster, and when a large blast volume is not required, significant power conservation can be achieved.

The rated voltage and power of the cupola furnace blower are 3000V and 300 kW, while those of the exhauster are 3000V and 350 kW respectively. The blast volume of the blower can also be adjusted to between 180 and 350 (Nm^3/minute) depending on the required melting capacity.

The operation of the exhauster is controlled so that the static pressure of the cupola furnace top will be ±0mm H20, and the potential for temperature drop in the combustion chamber, due to excessive suction and environmental contamination caused by leakage of the exhaust gas through insufficient suction, are eliminated.

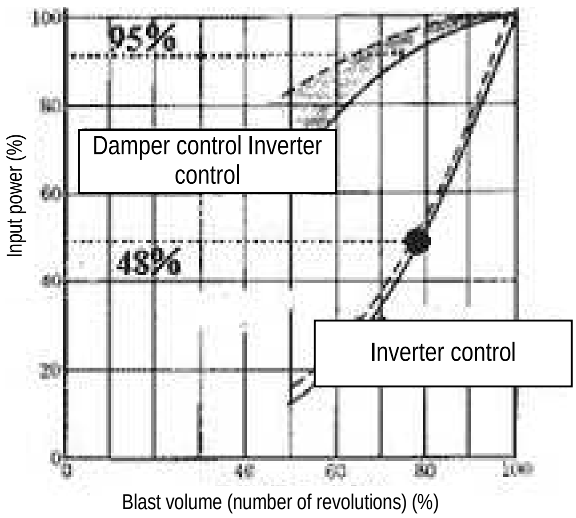


Fig. 10: Effect of the blower inverter

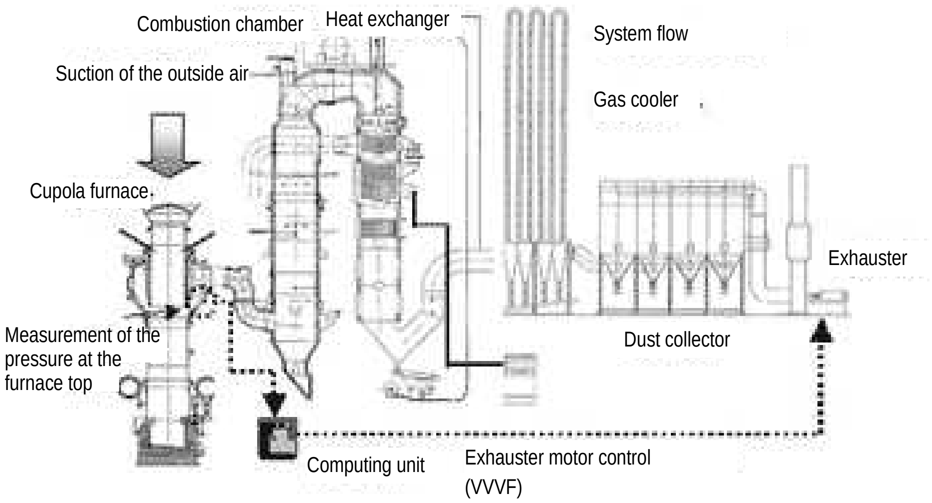


Fig. 11: Inverter controlled cupola furnace exhauster

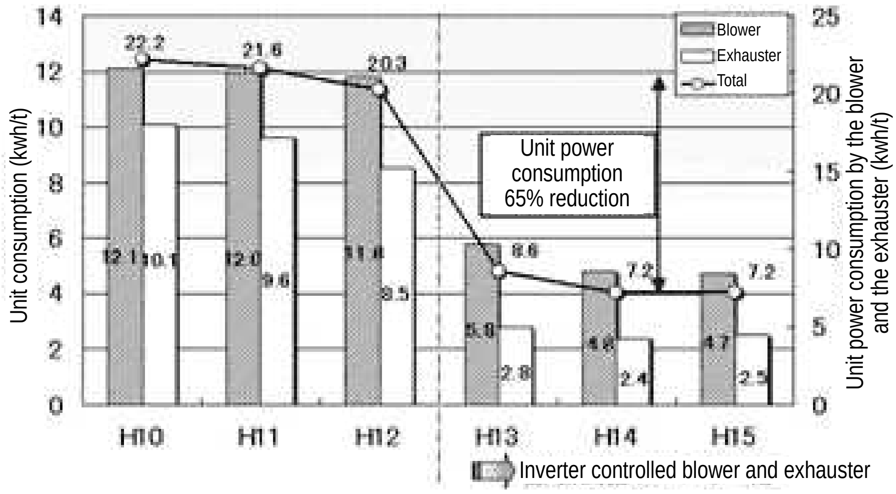


Fig. 12: Effect of the inverter controlled blower and exhauster

As shown in Fig. 12, since the introduction of the inverter control to the cupola furnace blower and exhauster in 2001, the exhauster can be operated with a power consumption of 1/4 and the blower can be operated with power consumption of 1/2 when compared to the conventional damper control. The total unit power consumption of the exhauster and blower was reduced by approx. 65%.

(3) Introduction of the Regenerative Burner to the Annealing Furnace

Our plant uses a rolling type continuous annealing furnace for refining, fuelled by city gas in order to refine the iron pipes after casting the cast iron pipes. In the conventional facility, the heat exchange of the charge air and exhaust air was conducted at the heat exchanger installed outside the furnace. In the newly introduced regenerative burner, the two opposing burners function as a pair and while one burner is in the firing state, the other one burner exhausts the gas, and the exhaust gas passes through a ceramic honeycomb structure, in order to directly store the sensible heat contained in the exhaust gas.

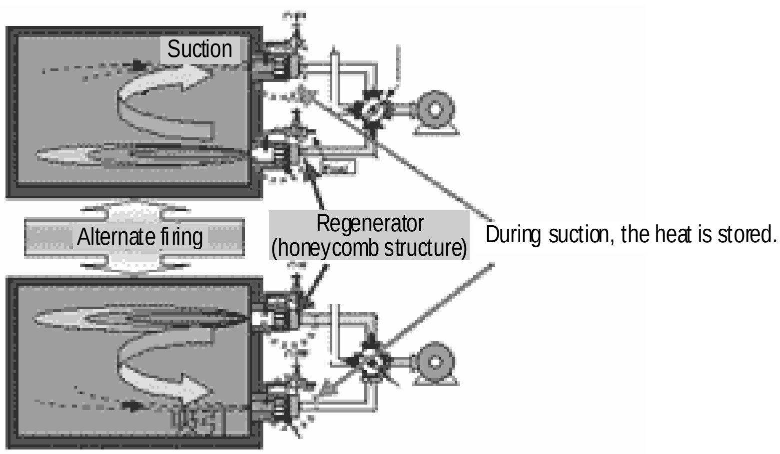


Fig. 13: Sketch drawing of the regenerative burner

27 units of conventional burners in the heating zone (15 units) and the soaking zone (12 units) were removed, and 14 units of regenerative burners were newly installed in the heating zone (6 units = 3 pairs) and in the soaking zone (8 units =4 pairs).
After these new regenerative burners were installed, the temperature of the preheated air temperature, which was about 320ºC before the installation, rose to 950ºC and, as a result, the waste heat recovery rate improved significantly to nearly 90%. (Refer to Fig. 14.)
Moreover, the unit consumption of city gas after the introduction of the regenerative burners was halved when compared to that before the introduction. (Refer to Fig. 15.)

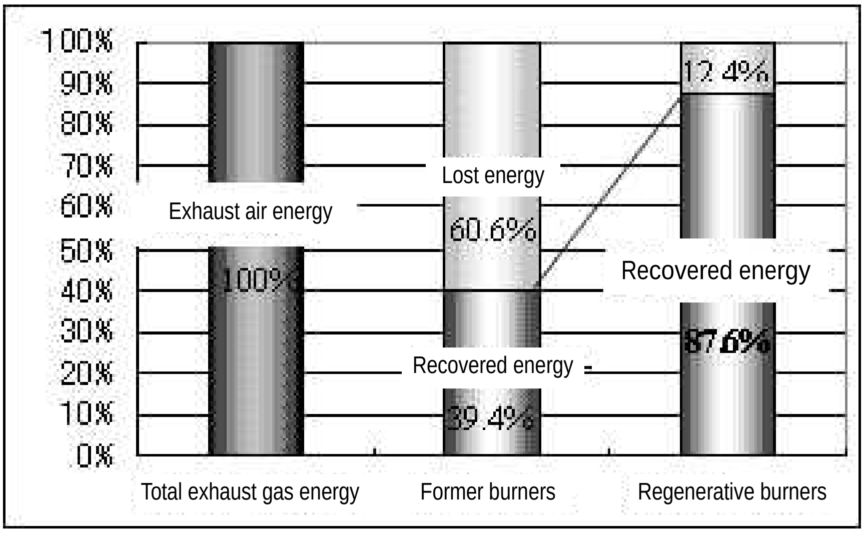


Fig. 14: Energy recovery rate discharged from the annealing furnace

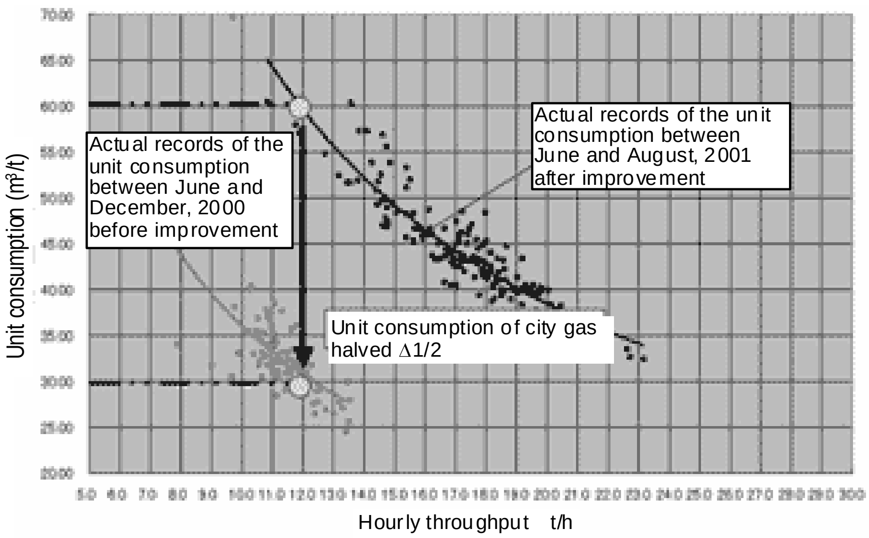
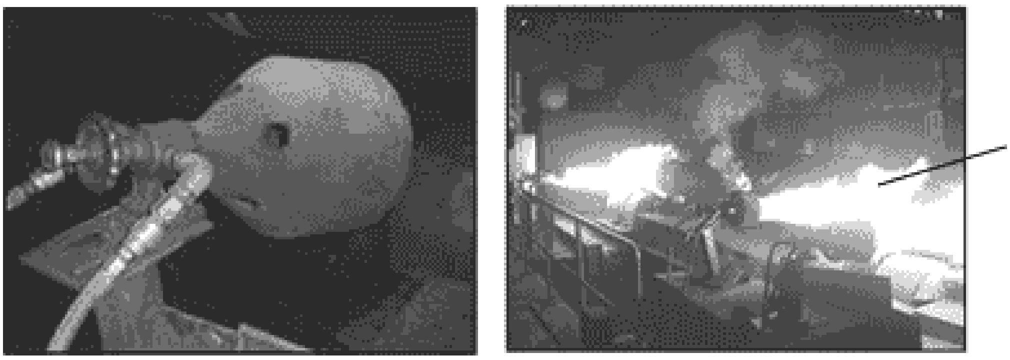


Fig. 15: Unit consumption of the city gas

(4) Introduction of the City Gas Burner instead of the Heavy Oil Burner

Our plant previously used heavy oil burners, consuming heavy oil as fuel, in order to heat the ladle and the casting mold. Because the heavy oil burners generated smoke and soot, they contaminated the environment. Our policy of making our plant "oil free" has been adopted, not only to promote energy conservation but also to improve the plant environment. Our "oil free" policy has been carried out successively since 2001. We applied for and were granted a government subsidy in 2003 and were consequently able to convert all the heavy oil burners in our plant to city gas burners. Thanks to the conversion from heavy oil burners to city gas burners, we succeeded in reducing CO_2 emissions by approx. 30%.



Smoke and soot are generated; and large flames

Fig. 16: Heavy oil burner and their burning state

Fig. 17: City gas burner and their burning state

(5) Introduction of the Co-generation

Because of the improvements mentioned in [1] – [4] above, we succeeded in reducing coke and city gas consumption between 2000 and 2003. However, as we introduced new processes to deal with the environmental issues, the consumption of electric power went on rising. Under such circumstances, we introduced co-generation in 2004 in order to conserve energy and thereby reduce costs and CO_2 emissions.

When introducing co-generation into our plant, we focused on the following points:

1) Significant reduction of the demand (basic rate), taking into account the peak period during the summertime

2) Recovery of investment into existing equipment within a short period of time and the utilization of various subsidies

3) Increased recovery of unrecovered energies released from existing equipment

The gas engine power generator can generate 1050 kW and the exhaust heat is converted at the exhaust gas boiler into steam at the rate of 0.7 tons/hour with pressure of 0.9 MPa. Conventionally, the pressure of the steam was decreased before it was supplied. However, in order to efficiently recover the energy of the steam, a 450 kW steam turbine compressor was introduced in place of the pressure reducing valve. Moreover, in order to increase the steam pressure at the turbine inlet, a tube bundle was newly installed to the cupola furnace heat exchanger. Consequently, the exhaust heat recovery efficiency from the cupola furnace improved, the feed water temperature to the steam generator rose to 120ºC and, therefore, the steam generator can now, at the maximum, generate steam of 7.3 tons per hour at a pressure of 0.88 MPa.

Before introducing steam turbine compressors, of the eight 150 kW screw compressors, three units of the old type were removed and replaced with turbine compressors. Consequently, the operating efficiency significantly improved as well as the heat recovery performance of the steam turbines and the efficiency of the compressors, meaning we could reduce electrical power consumption by approx. 450 kW.

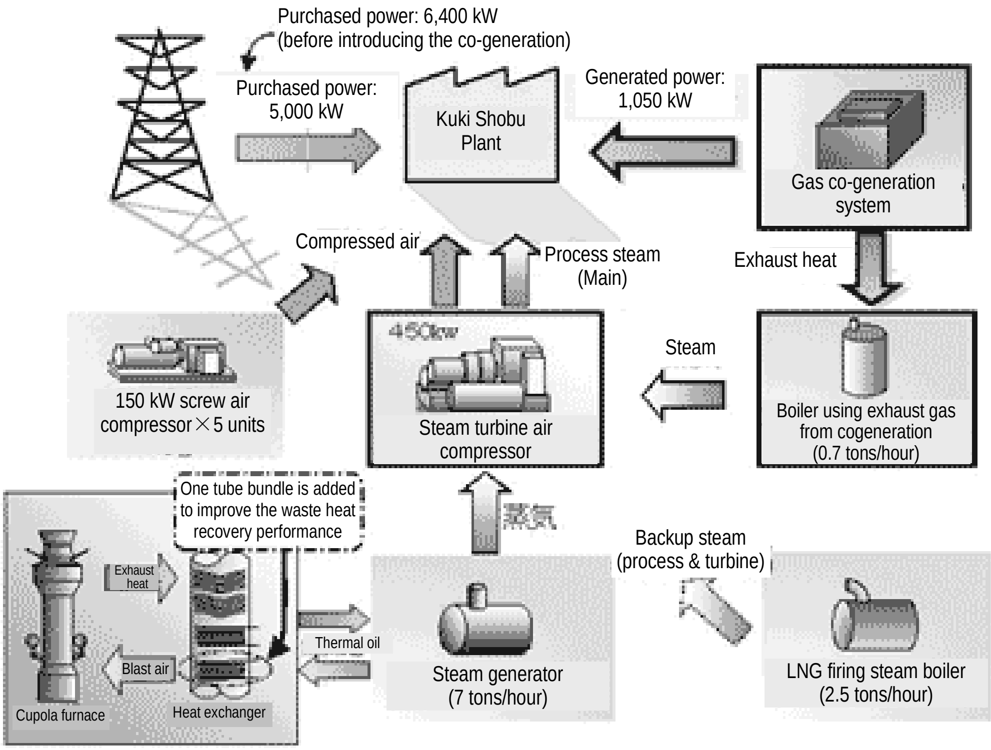


Fig. 18: Sketch drawing of the co-generation system

As described above, we were able to significantly reduce the energy consumption through various combinations of the existing equipment and the co-generation system.

Consequently, we could return to the conventional plant contract demand and reduced the total energy consumption at our plant by approx. 14%.

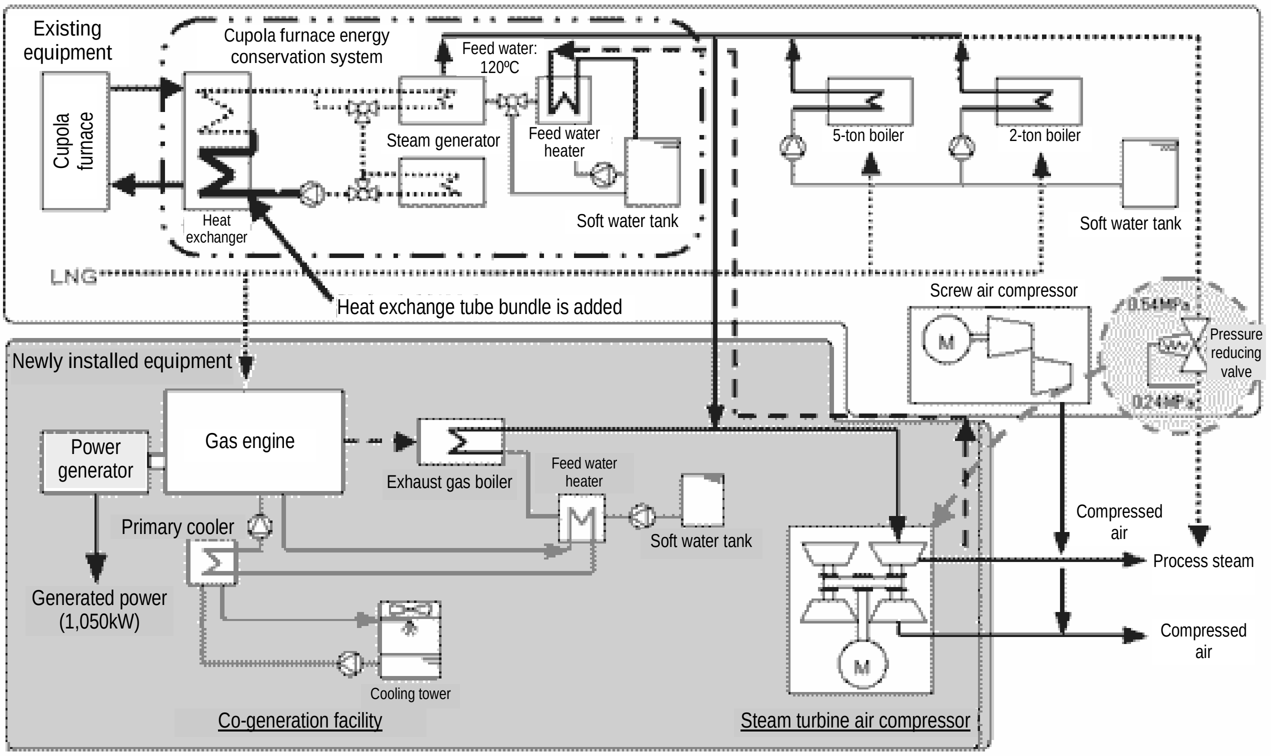


Fig. 19: Co-generation system flow diagram

5. Effects Achieved after Implemented Measures

The effects of the measures taken are summarized below:

(1) Introduction of a new type of heat exchanger to the cupola furnace	⇒ The cupola furnace exhaust heat recovery rate improved by 50%; the unit consumption of coke was reduced by 10 kg/ton; the city gas consumed by the boilers was cut by 60%; the unit consumption was reduced by 50%.
(2) Introduction of the inverter to the cupola furnace blower and exhauster	⇒ The unit power consumption by the blower and exhauster were reduced by 65%.
(3) Introduction of the regenerative burner to the annealing furnace	⇒ The unit consumption of the city gas by the annealing furnace was reduced by 50%.
(4) Introduction of the city gas burner instead of the heavy oil burner	⇒ CO_2 emissions were reduced by 30%.
(5) Introduction of the co-generation	⇒ The total energy consumption at our plant was cut by 14%.

Based on the effects shown above, we could reduce energy consumption and CO_2 emissions as follows:

The energy consumption in 2004 was reduced by 24.3% compared to the level in 2000, meaning we were able to achieve the goal of a 20% reduction. We could reduce the energy consumption by 18.3% compared to the level in 1990 and unit consumption by 3.4% compared to the level in 2000.

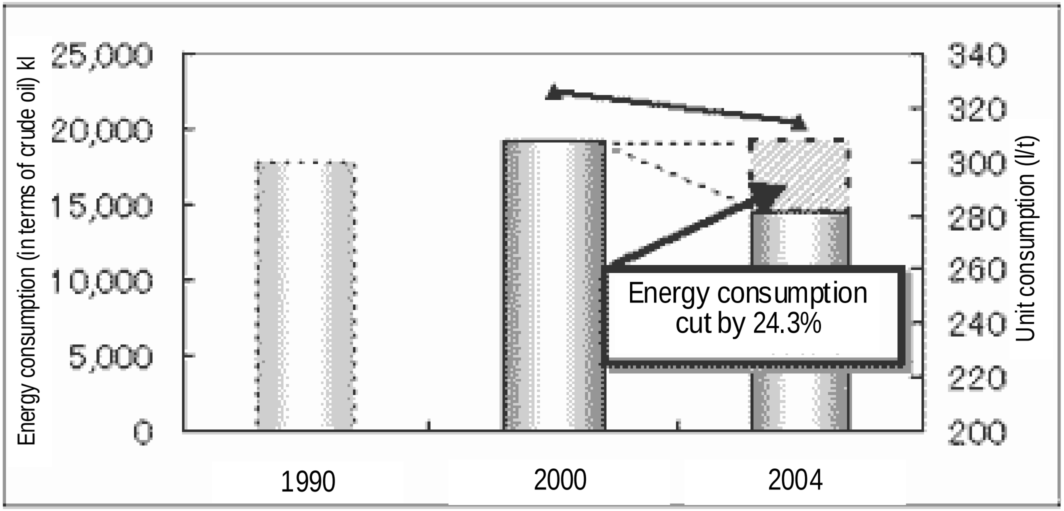


Fig. 20: Reduction of energy consumptions

CO_2 emissions were reduced by 24.7% in 2004 compared to the level in 2000; we could achieve the goal of 20% reduction, while we could reduce CO_2 emissions by 26% compared to the level in 1990.

This represents a reduction in unit consumption of 3.9%.

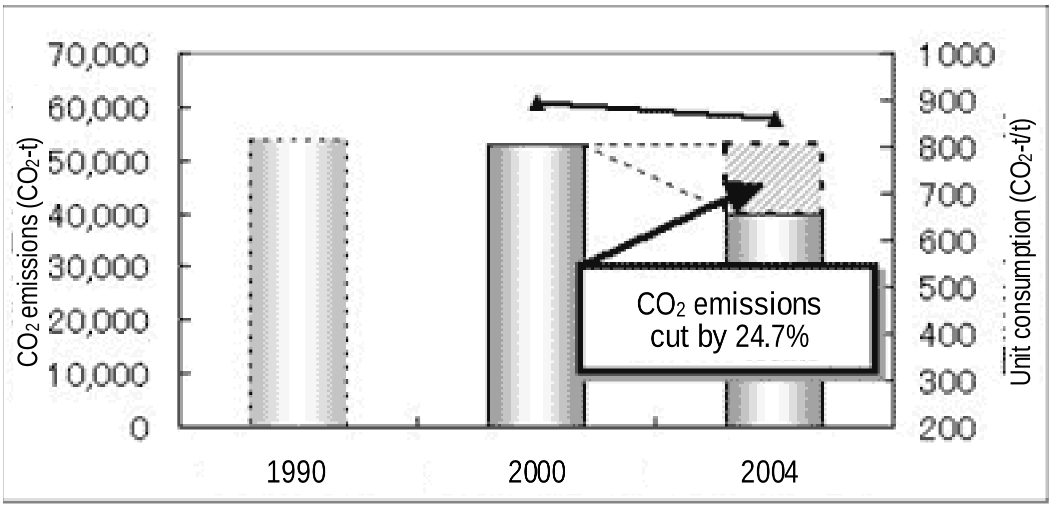


Fig. 21: Reduction of the CO_2 emissions

6. Summary

We turned our attention to examining how we could secure maximum effects through the introduction of new energy saving equipment and their combination with existing equipment in energy conservation activities. We know that even if co-generation is introduced, its energy conservation effects will vary widely depending on where the exhaust heat is recovered. We thus turned our attention to compressors that consumed a quarter of the total electric power consumption at our plant and discovered that, combined with the improved capacity of the existing cupola furnace heat exchanger, sufficient power conservation effects could be realized.

In addition, before introducing the new type of heat exchanger, we compared those manufactured by several companies and adopted the model made by Wurz in Germany, who had delivered them to many companies in Europe and U.S.A. Our company was the first to adopt this type of heat exchanger in our country and several other companies in our country have since followed suit. We are honored that we could contribute in the field of energy conservation technology, including the pioneering adoption of a new type of heat exchanger.

We were able achieve the above mentioned results because all the employees in our plant actively engaged in the energy conservation campaign. We should also remember to show our appreciation for the cooperation of all those concerned outside our company.
By the way, we utilized government subsidies to introduce regenerative burners to the annealing furnace, the introduction of city gas instead of heavy oil burners and the introduction of co-generation.

7. Future Plans

We will not only make plans for the medium and long term energy conservation plans but also implement plans such as those relating to the duty of the designated energy management factory, keeping in mind the revision of the Law Concerning the Rational Use of Energy in 2006. We will commit to the development of some ultimate energy conservation technologies with the aim of becoming a more earth-friendly plant.