2004 Prize of the Chairman of ECCJ

Reduction of the specific electric power consumption by reviewing the rotation speed of the induced draft fan for the converter exhaust gas

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◎ **Keywords: Rationalization of conversion of electricity to power and heat (Rationalization of electric power)**

◎ Outline of Theme

To improve the specific electric power consumption of the converter, we have focused on the induced draft fan (IDF)for the converter exhaust gas. Significant electricity cost can be reduced by controlling rotation speed if inverter is used, but it is difficult because a large amount of investment is required. We have surveyed and adjusted the actual status of factors that interfere effective energy use including degradation of the decontamination efficiency due to decrease of suctioned air when the rotation speed is controlled using existing torque converter, rise of hydraulic equipment temperature, axial fatigue due to repeated increase/decrease of the fan speed etc. Then we solved problems without any investment and optimize the rotation speed, significantly, contributing to reduction of power consumption.

◎ Implementation Period of the said Example

April, 2003 – February, 2004

● Project Planning Period	April, 2003 – May, 2003	total 2 months
● Measures Implementation Period	June, 2003 – February, 2004	total 9 months
● Measures Effect Confirmation Period	March, 2004 – July, 2004	total 5 months

◎ Outline of the Business Establishment

- Produced items: Steel plates, steel pipes, shaped steel, etc.

- Number of employees: 2,944 (as of March, 2004, number of employees of Kashima Steelworks)
- Annual energy consumption (Actual record in 2003).

Fuel	3,171,656 kl (Crude oil equivalent)
Electricity	2,743,531 MWh

◎ Process of Target Facility

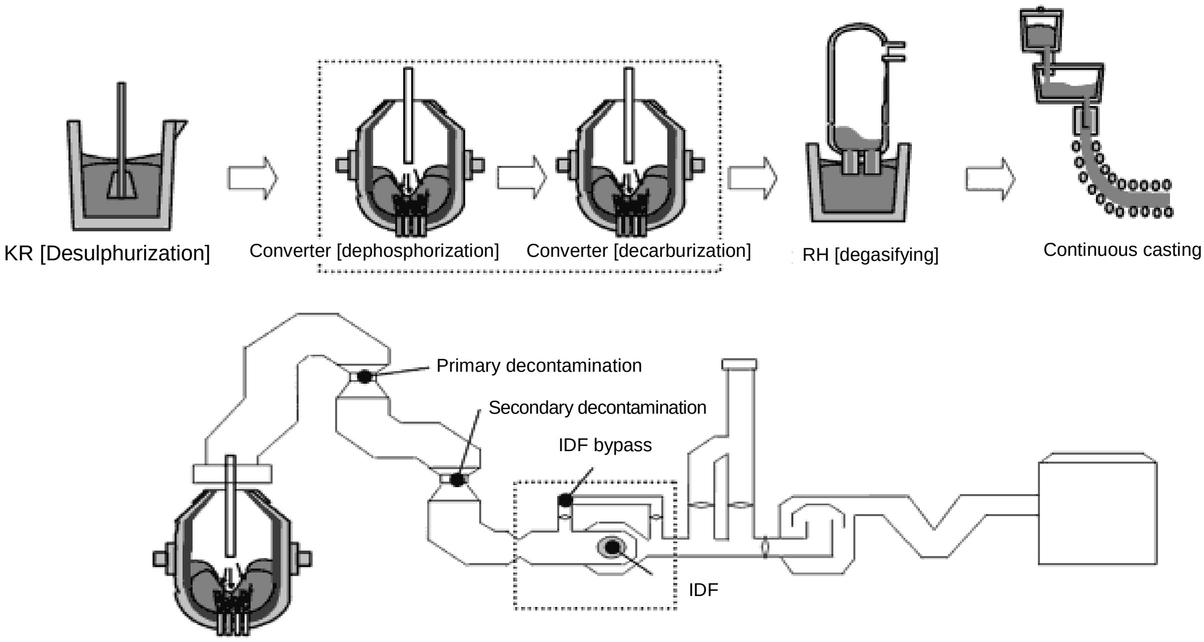

Fig. 1 Manufacturing process and target facility (OG facility)

1. Reasons for Theme Selection

(1) By focusing on IDF, which is most accountable for the power consumption in the converter facility and reviewing how it is controlled to adjust the rotation speed appropriately, we tried to reduce electrical power consumption cost.

(2) With production at the full capacity, energy conservation by stopping equipment while it is not operated as before is not effective. Therefore, it is essential how we can save energy during operation.

(3) Traditionally, it has been considered impossible to control rotation speed using torque converter, but we have thought there is a possibility for that by adjusting various related facilities.

2. Understanding and Analysis of Current Situation

(1) Understanding of the Current Situation

IDF is a large motor with 2600 KW-rating and large power consuming equipment that accounts for 26% of the converter power consumption. However, this equipment has a lot of restrictions from the view point of equipment protection, so it was assumed difficult to save energy any more. Also adopting inverter to control rotation speed needs as large amount of investment as 200 million yen, so it was excluded from the energy conservation activities.

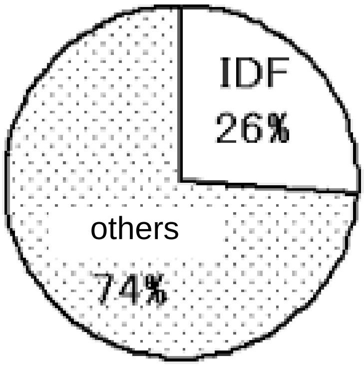

Fig. 2 Electricity consumption by equipment in Converter

(2) Analysis of the Current Situation

1) As shown in Fig. 3, the rotation speed of IDF is grouped into only two (non-metal making and metal making) for both dephosphorization furnace and decarburization furnace and the segmentation of the rotation speed is done in each facilities.

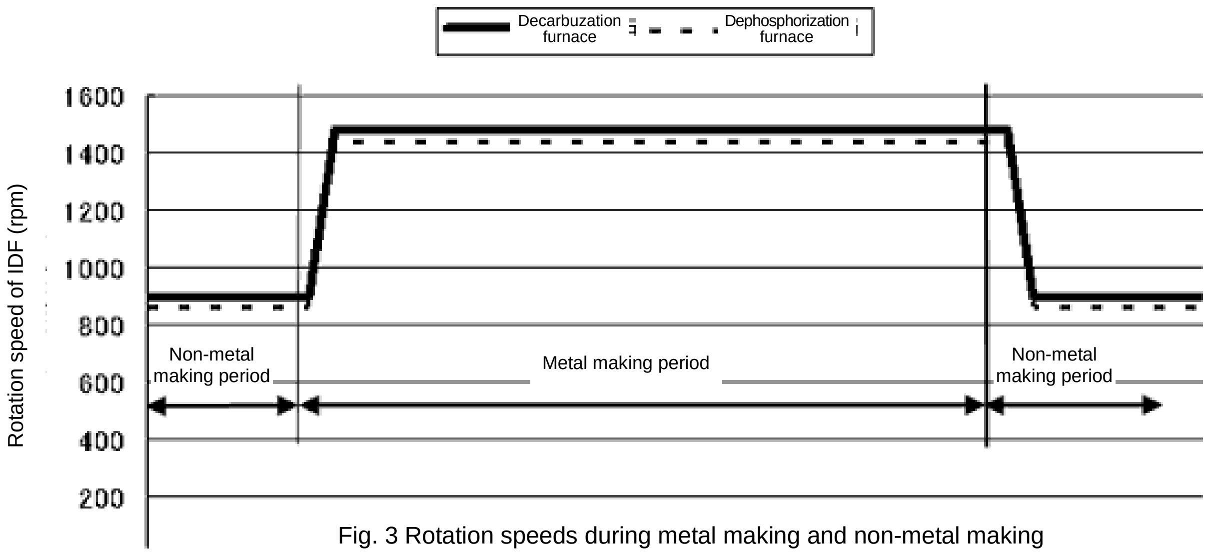

Fig. 3 Rotation speeds during metal making and non-metal making

2) The rotation speed of IDF is determined by the reasons indicated in Table 1.

Table 1 How to determine the rotation speed

	Status	Rotation speed	Reason to determine the rotation speed
Decarbuzation furnace	Metal making period	1480rpm	Max rotation speed according to the exhaust gas volume
	Non-metal making period	900rpm	Rotation speed is reduced to save energy
Dephosphorization furnace	Metal making period	1480rpm	Kept at maximum by ensuring the apparent exhaust gas volume using the bypass valve although exhaust gas volume is less than that of the decarbuzation furnace
	Non-metal making period	900rpm	Rotation speed is reduced to save energy

3) To protect IDF motor, starting within 2 hours is not allowed.

3. Progress of Activities

(1) Implementation Structure

It was necessary to repeat survey testing while continuing operation, so the factory director from the operation section joined the team so that the PDCA cycle including testing can be smoothly done. From the machine control section, technology staff as well as maintenance staff joined the group to provide proof of grounds of improvement from the view point of expert knowledge such as analysis of specifications. Furthermore, energy section joined the group, so we could address various challenges as we get advice from case experiences of other sections.

[Factory, maintenance division (machinery, control), technical division (machinery, control), energy division]

(2) Target Setting

To concur problems in controlling rotation speed and understand the optimum rotation speed focusing on the three points of energy loss shown in Table 2 to reduce IDF specific electric power consumption by 20%.

Table 2 Focused points and targets

Focused point	Current status	Target
1. Operation timing	Metal making period: fixed to 1480	Controlled block by block according to the exhaust gas volume
2. Non-metal making	Fixed to 900 rpm	Minimum rotation speed
3. Dephosphorization furnace	Metal making period: fixed to 1480	Rotation speed according to the exhaust gas volume (bypass circuit is eliminated)

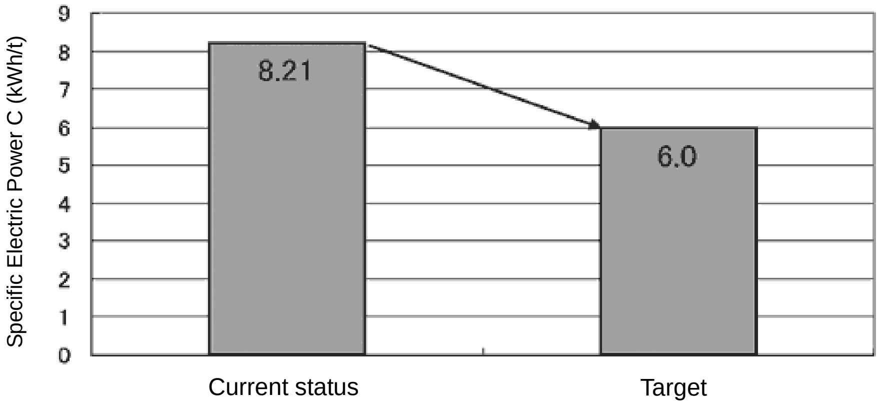

Fig. 4 Current status and target of IDF electricity consumption

* Expected benefit : 80 million yen / year

(3) Problems and Review

The expected problems in controlling rotation speed and the result of review are shown in Table 3.

Table 3 Problems and countermeasures for focus points

Focused point	Item	Problem	Countermeasure
1. Setting rotation speed according to blowing timing and exhaust gas volume (Fig. 5 ①)	Control mesh	Excess operation without grasping the exhaust gas volume for each blowing	* Breaking down the control mesh * Measurement of exhaust gas volume * Create new sequence [Detail -> 4-(1)]
2. Reduction of rotation speed during non-metal making (Fig. 5 ②)	fatigue load of IDF impeller	When the difference between the maximum and minimum rotation speed is large, fatigue load also increases and the life becomes shorter.	* Review the lower limit rotation speed based on the calculated fatigue load [Detail -> 4-(2)]
3. Reduction of rotation speed while blowing in the dephosphorization furnace (Fig. 5 ③)	Torque converter oil temperature rise	When operating the torque converter, heat generation is large between 900 and 1200 rpm due to the operation characteristics of the torque converter	* Improvement of performance by restore health of blocked area of the oil cooler * Assessment of relation between oil temperature and time [Detail -> 4-(3)]
	Surging (fan pulsation)	Surging occurs when the rotation speed is not appropriate for the exhaust gas volume.	* Adjust the balance between IDF rotation speed and exhaust gas volume [Detail -> 4-(4)]
	Decontamination performance	Decontamination performance may become worse due to reduction of rotation speed	* Ensure decontamination performance by pressure setting damper [Detail -> 4-(5)]

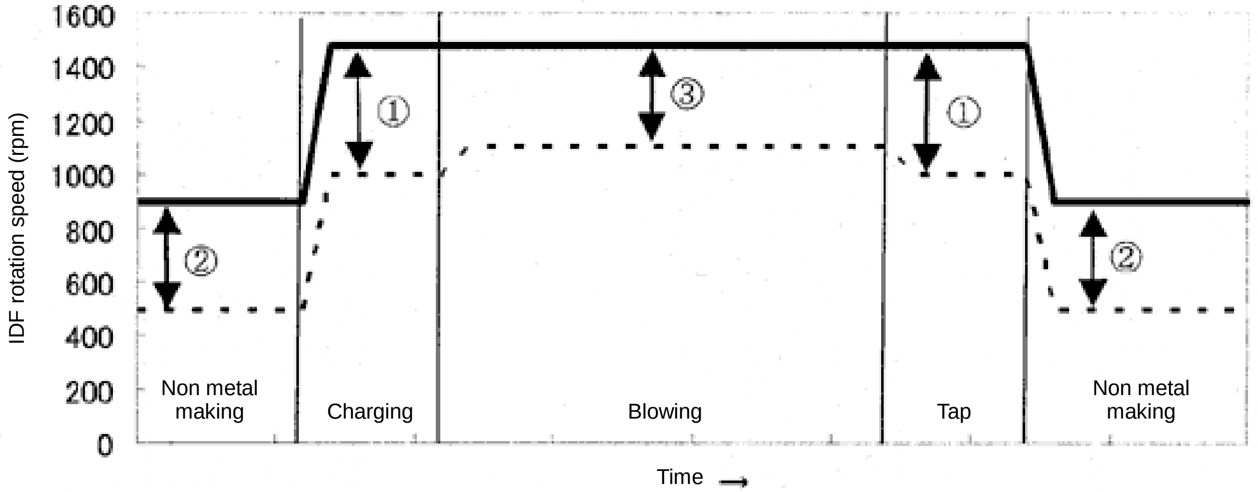

Fig. 5 Focus points of energy conservation

4. Details of Countermeasures

(1) Review of Breaking Down the Control Mesh

The setting values of the rotation speed of IDF has been grouped into to two groups of non-metal making and metal making, but we broke down the metal making phase into [charging], [blowing], and [tap] as shown in Table 4. In the [charging] and [tap] blocks, there is no oxygen top blowing and there is only bottom gas blowing. Despite that the volume of exhaust gas is medium, IDF is operated at the maximum rotation speed, which was excessive. Therefore, we gradually lowered the rotation speed of IDF from 1480 rpm and found that the optimum value with which exhaust gas can be induced completely was 1000rpm.

Table 4 Breakdown of exhaust gas during metal making period

Timing	Non-metal making	Metal making	Non-metal making
Exhaust gas volume	Little	Large	Little

Control mesh	Charging	Blowing	Tap
Oxygen top blowing	No	Yes	No
Bottom gas blowing	Yes	Yes	Yes
Exhaust gas volume	Middle	Large	Middle

(2) Review of IDF Fatigue Load and Life

Based on the document provided by the manufacturer, we have reviewed the impeller life considering the stress and annual number of loads on the impeller. The result is shown in Fig. 6. The past record of impeller replacement interval was about 35 years, so we determined that the lower limit of the rotation speed can be 500 rpm without any problems. Therefore, the rotation speed during non-metal making period was set to 500 rpm.

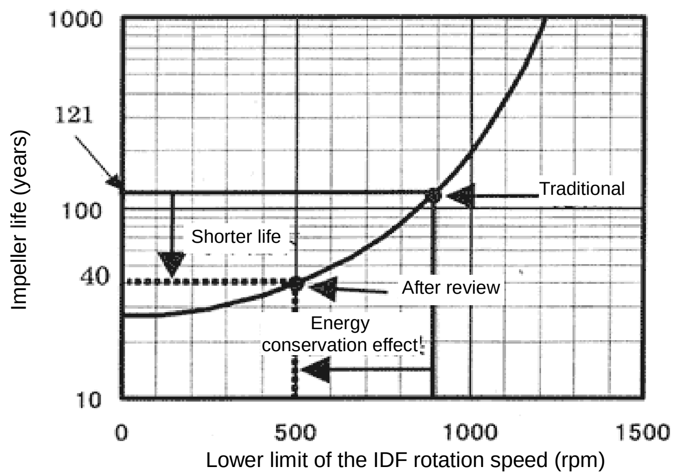

Fig. 6 Lower limit of the IDF rotation speed and impeller life

(3) Review of Torque Converter Oil Temperature

The result of calculation of IDF rotation speed and heat generation of torque converter is shown in Fig. 7. Traditionally, it was expected that the heat generation is in inverse proportion to the rotation speed, but the calculation showed that it is the peak in the range of 800 and 1100 rpm and decreases in other range. Then, we have calculated the heat removal capacity based on the measurements of temperatures before and after cleaning the oil cooler tubes shown in Fig. 8. The result is shown in Fig. 9. By keeping the flow rate of cooling water at 1000L/min or higher and the temperature difference between the inlet and outlet of the cooling water at 5.2 ℃or larger, heat removal exceeds the maximum heat generation. Therefore, the problem of temperature rise was solved by enforcing management of cleaning period (temperature difference between the inlet and outlet of the cooling water) without any capital investment.

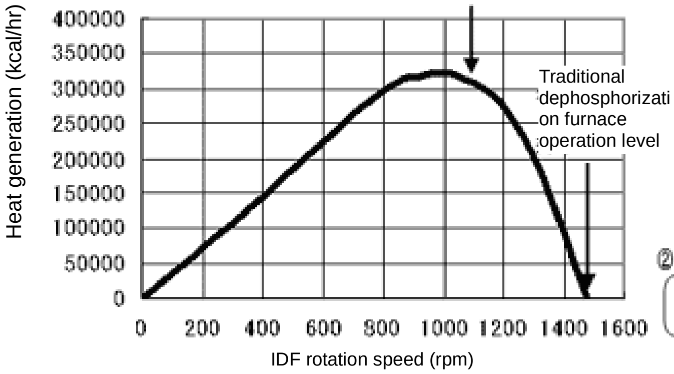

Fig. 7 Calculated heat generation of torque converter oil

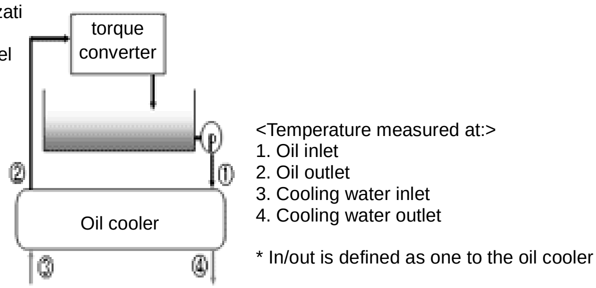

Fig. 8 Locations at which torque converter oil temperature is measured

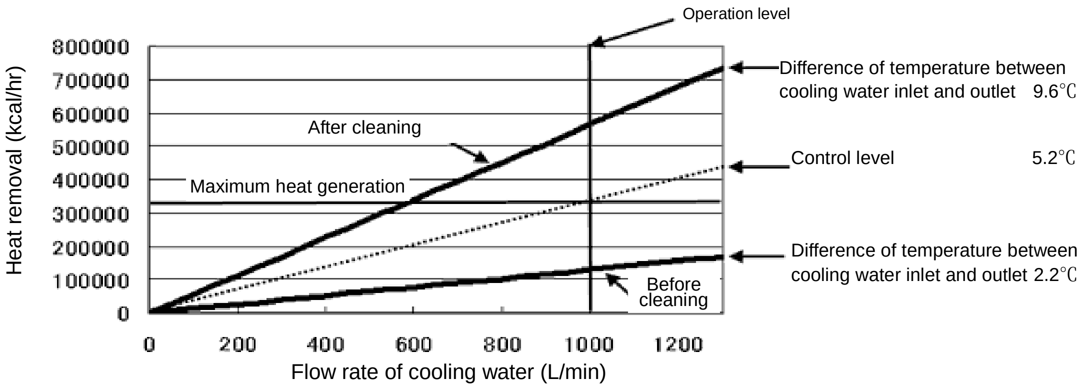

Fig. 9 Calculated heat removal of oil cooler

The heat removal capacity at the maximum heat generation was confirmed as described above, so we performed long continuous operation testing under the conditions shown in

Table 5 to further lower the rotation speed. As the result is shown in Fig. 10, the temperature sharply rises initially, but then its rise becomes virtually stable, so the problem regarding torque converter oil temperature was solved even in summer (outside temperature 34 degrees).

Table 5 Conditions of torque converter oil temperature measurement

Item	Value, content
IDF rotation speed	９００ｒｐｍ
Oil cooler cooling water volume	１，０００L／ｍｉｎ
Nnumber of months after the last cleaning of oil cooler	4.8 months (132 day)
Outside temperature	３４℃

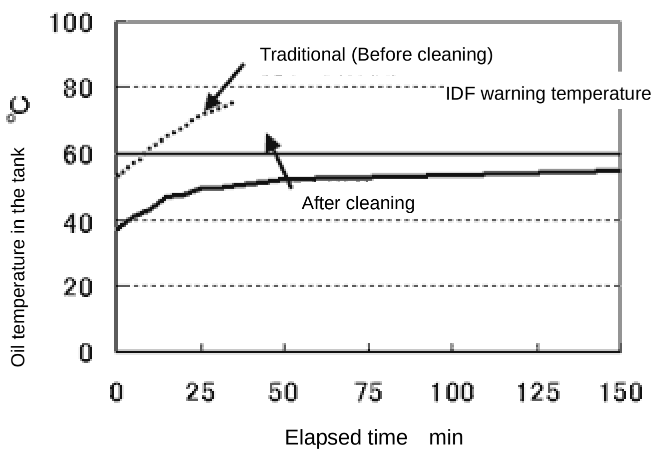

Fig. 10 Result of torque converter oil temperature measurement

(4) Countermeasures against IDF Surging

If IDF is kept at 1480 rpm in the dephosphorization furnace with fewer exhaust gas such as 40000 – 70000 Nm3/hr, surging has occurs when the exhaust gas volume goes under the surging occurrence line of about 50000 Nm3/hr indicated in Fig. 11. Therefore, a bypass line was installed and a part of exhaust gas is looped backin the IDF as shown in Fig. 12 so that apparent exhaust gas volume to IDF is kept and surging can be prevented. We have confirmed that surging can also be prevented by lowering the IDF rotation speed under the IDF performance line, so we could lower the IDF rotation speed and eliminate the loop by IDF bypass.

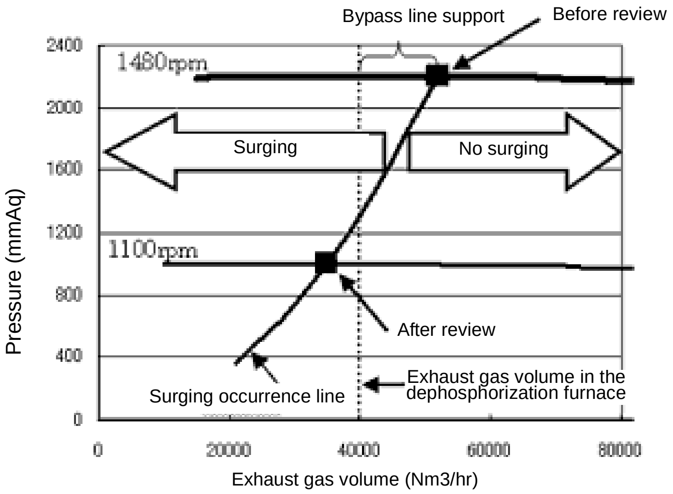

Fig. 11 IDF performance line

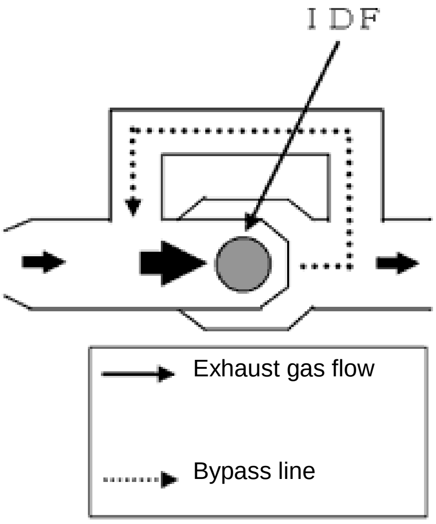

Fig. 12 Movement of exhaust gas in the IDF bypass

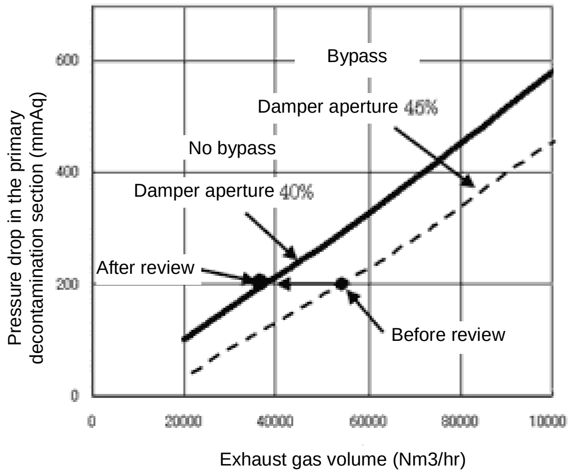

Fig. 13 Pressure drop in the primary decontamination section and exhaust gas volume

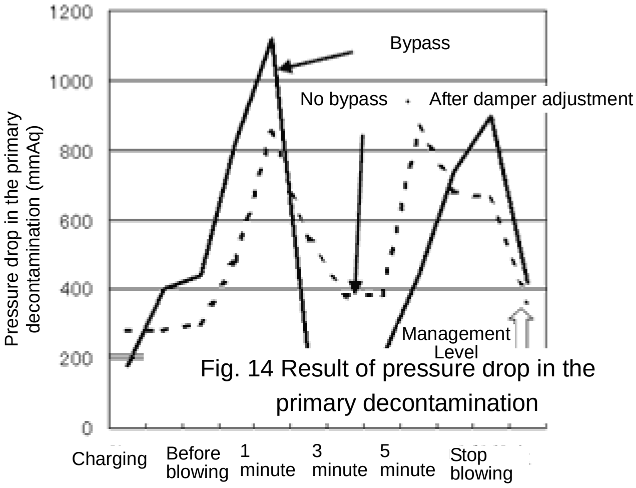

Fig. 14 Result of pressure drop in the primary decontamination

(5) Countermeasures to Keep the Decontamination Performance

Fig. 13 shows the relation between the pressure drop in the primary decontamination section and the exhaust gas volume. To maintain the decontamination capacity, 200 mmAq or higher pressure drop in the primary decontamination section is required, so it is necessary to adjust the pressure drop adjustment damper so that the pressure drop in the primary decontamination section at 200 mmAq or higher when the exhaust gas volume is 40000 Nm^3/hr. We have repeated testing during production operation, and as a result, we have adjusted the pressure drop adjustment damper aperture at 40% and IDF rotation speed 1100 rpm so that the induction capacity equivalent as before can be ensured.

5. Effects of Countermeasures

(1) IDF Electrical Power Consumption Rate

The actual performance is shown in Fig. 15. The electrical power consumption rate has been discernibly improved as we have enforced the focused points of 1, 2, and 3.

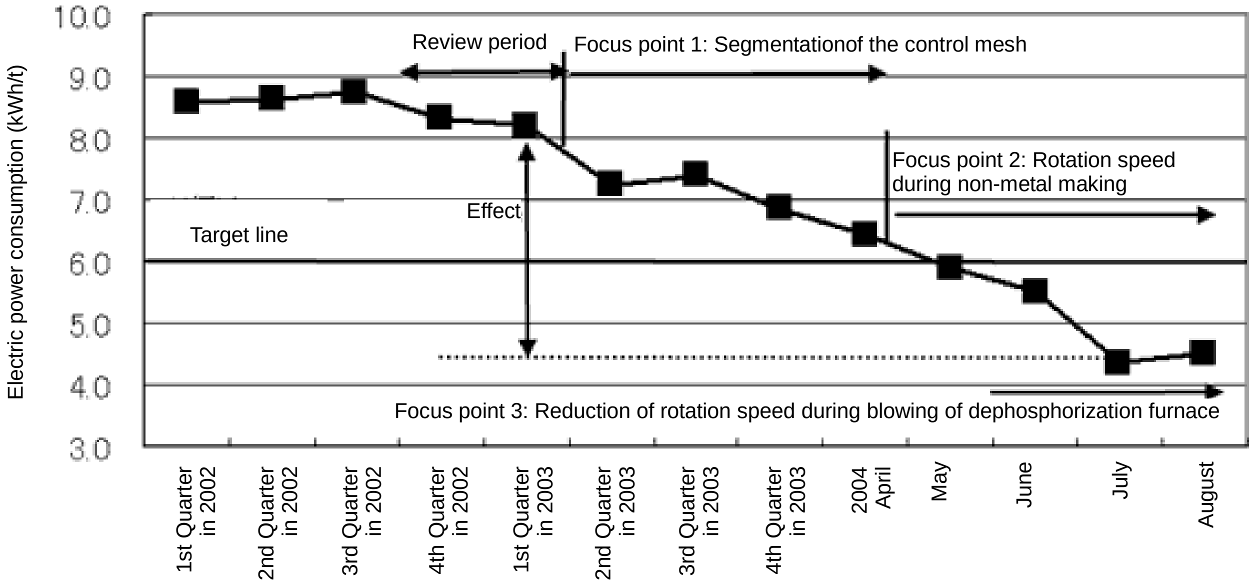

Fig. 15 IDF electric power consumption rate

(2) Benefits

Before activity		After activity
(8.2	-	4.4) kWh/t = 3.8kWh/t

When the unit price of electricity (kWh) is 10 yen, annual saving is 136,800,000 yen.

6. Summary

We have long assumed that further energy conservation was impossible with torque converter and there was nothing we can do other than adopting inverter. However, several sections worked together to understand the equipment characteristics and completely utilize its capacity so that the result exceeded the target value significantly. This led to each member’s self confidence. We think there is no impossibility if we make efforts with this confidence in the future energy conservation activities.

7. Future Plan

There are many projects that tried to save energy but discontinued due to the problem of capital investment. We would like to continue the cooperation framework that was established through this activity and challenge these projects again from different view points to promote energy conservation without investment, and contribute to improvement of our company performance and protection of the global environment.