Abridged version

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Multipurpose Turbine for Blower and Generator

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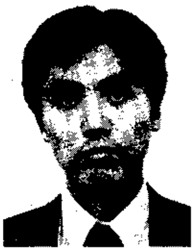
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1 Introduction

In any major steelworks today, rapid progress is noticeable in their efforts for energy conservation and efficiency improvement in energy use. In particular, promotion of waste heat recovery and installation of high-efficiency power plants contribute markedly to reductions in energy costs. The recent introdution of a multipurpose turbine at Chiba Works has made it possible to achieve stable blast furnace air supply using only steam from the waste heat boiler, thus solving a long-standing problem at the Works.

This equipment consists of the steam turbine, which uses steam from the CDQ (coke dry quenching) waste heat boiler as main steam, a blast furnace blower, and a generator. The steam turbine can use low-pressure process steam in addition to CDQ boiler steam, and, conversely, when low-pressure process steam is required, steam extracted from the middle stage of the turbine can also be supplied as process steam. The new equipment is an attempt to secure a blast furnace air supply from CDQ steam alone, and embodies a system for high-efficiency use of waste heat recovery steam.

This paper outlines the plan and functions of the multipurpose turbine for the blower and generator.

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2 Equipment Plan

2.1 Problems in Existing Equipment

Equipment for power generation, blast furnace air supply, and process steam supply at the East Power Plant of Chiba Works have undergone partial renovation, efficiency enhancement, and operational improvement on several occasion to date, all toward full-demonstration of its functions. Its steam conditions, however, greatly deteriorated to the levels of a 40 kgf/cm^2 pressure and a 420°C temperature. As shown in **Fig. 1**, CDQ boiler

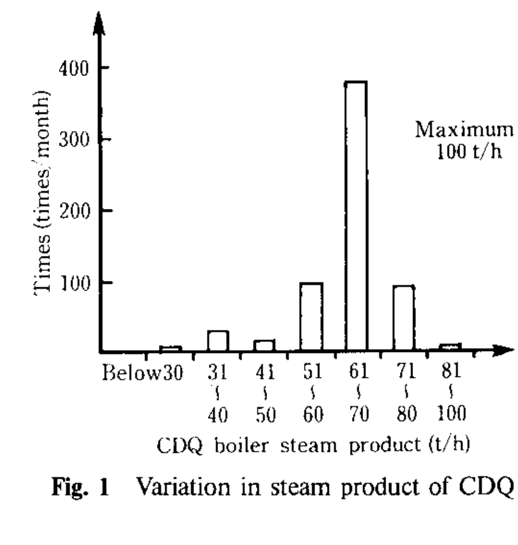


Fig. 1 Variation in steam product of CDQ boiler

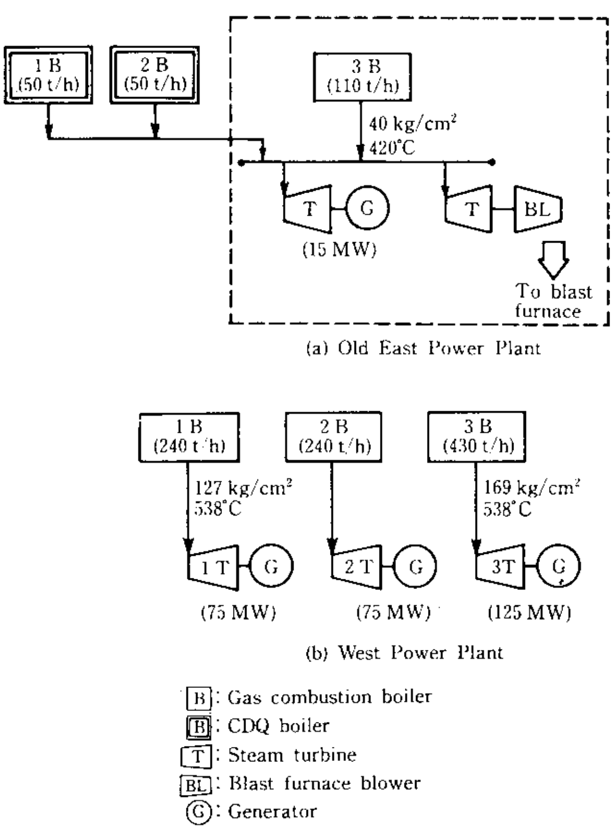


Fig. 2 System diagram before improvements

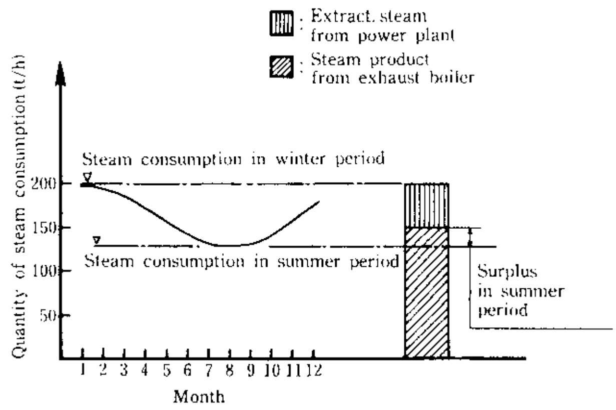


Fig. 3 Balance of process steam (mean) (1982)

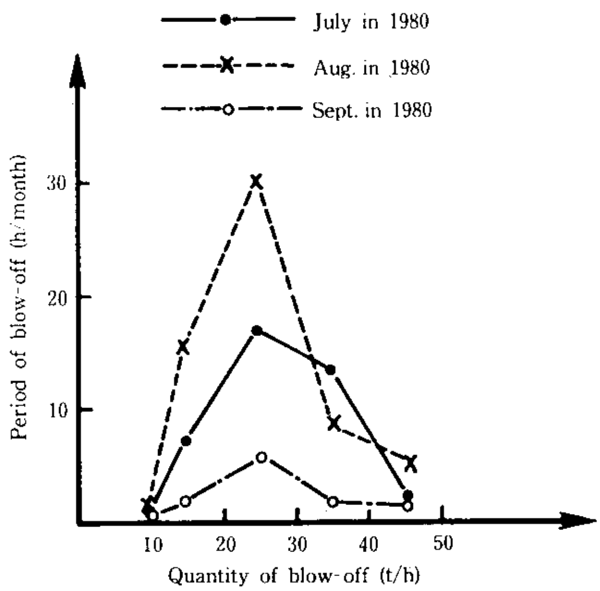


Fig. 4 Variation of steam blow-off

steam, with variations in steam generation, frequently lacked the dependability which was required for the blast furnace air supply.

The CDQ boiler was able to generate steam sufficient for blast furnace air supply, but it was necessary to operate it in conbination with gas combustion boiler as a back-up steam source. Surplus steam thus generated was used by the generator. As a result, it was necessary for Chiba Works to operate the generating turbine at the inefficient East Power Plant, despite the construction of the highly-efficient West Power Plant as shown in **Fig. 2**.

Process steam in the steelworks has conventionally been supplied by steam generated by the waste heat boiler. Since process steam consumption is reduced in summer, and since its generation varies widely, excess steam sometimes must be blown off.

Conversely, when process steam consumption increases in winter or if waste heat boiler operation is stopped, as in the example in **Fig. 3**, process steam supplies become inadequate. Process steam shortages and surpluses have occurred daily and even hourly, as shown in **Fig. 4**. These shortages and surpluses of process steam were adjusted by drawing steam from the generator turbine, but in summer, when process steam consumption drastically dropped, this adjustment was impossible. Surplus process steam had to be released into the open air, resulting in an energy loss.

2.2 Special Features of Equipment Planning

In planning for the new equipment, the following functions have been aimed through coordination with those of the existing captive power plant:

(1) The blast furnace blower and generator shall be assembled coaxially, so that air can be supplied to the blast furnace using steam from the CDQ boiler alone.

(2) Even when the CDQ boiler completely stops, blowing to the blast furnace shall be continued by using the generator as a motor.

(3) When a surplus of low-pressure process steam occurs, the surplus steam shall be mixed with CDQ boiler steam and converted into electricity.

(4) Conversely a shortage of process steam exists, steam extracted from the turbine shall be supplied as

process steam.

(5) The equipment shall be operated unattended, through remote control from the Energy Center: thus it can fully cope with emergency situations, as well as contributing to energy savings.

2.3 Turbine Capacity and Power Generating Efficiency

In determining the capacity of the mixed pressure steam turbine, the following have been incorporated into the planning for a maximum turbine output of 28 500 kW.

(1) Steam generation distribution (Figs. 1 and 3)

(2) Blast furnace blowers and power generator load.

3 Outline of Equipment

3.1 Equipment Structure and Heat Balance

3.1.1 Equipment structure

Main specifications of this equipment are shown in **Table 1**. The organization of the system is shown schematically in **Fig. 5**, and a cross-section of the turbine and the general arrangement of the equipment, in **Figs. 6** and 7, respectively. In this equipment, a steam-mixing and extraction turbine is placed at the center, and a generator and blast furnace blower are combined on its two sides. The turbine and blast furnace blower are run

Table 1 Main specifications

	Item	Specification		
Turbine	Type	Single casing, mixing pressure, condensing turbine with extraction port		
	Output	28 500 kW		
	Revolution	3 610 rpm		
	Steam	CDQ	Process	Extract.
	Pressure	40 kg/cm²	15～18 kg/cm²	7～10 kg/cm²
	Temperature	420°C	220°C	200°C
	Vacuum	722 mmHg		
	Mixing port	One		
	Extract. port	Two		
	Manufacturer	Kawasaki Heavy Industries Ltd.		
Blower	Type	Variable stator blade, multi-stage, axial blower		
	Max. air flow rate	5 000 Nm³/min		
	Max. discharge pressure	4.0 kg/cm²		
	Max. shaft power	23 500 kW		
	Manufacturer	Kawasaki Heavy Industries Ltd.		
Generator	Type	Three phase, AC synchronous generator		
	Rated capacity	25 000 kVA (12 500 kVA × 2)		
	Revolution	3 000 rpm		
	Voltage	11 000 V		
	Manufacturer	Meidensha Electric Mfg. Co., Ltd.		

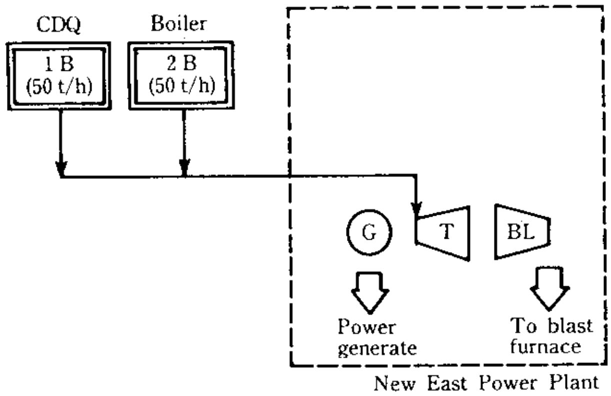


Fig. 5 System diagram after the improvement

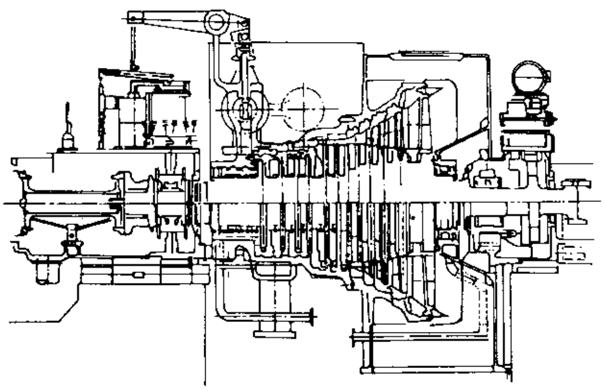


Fig. 6 Sectional view of the turbine assembly

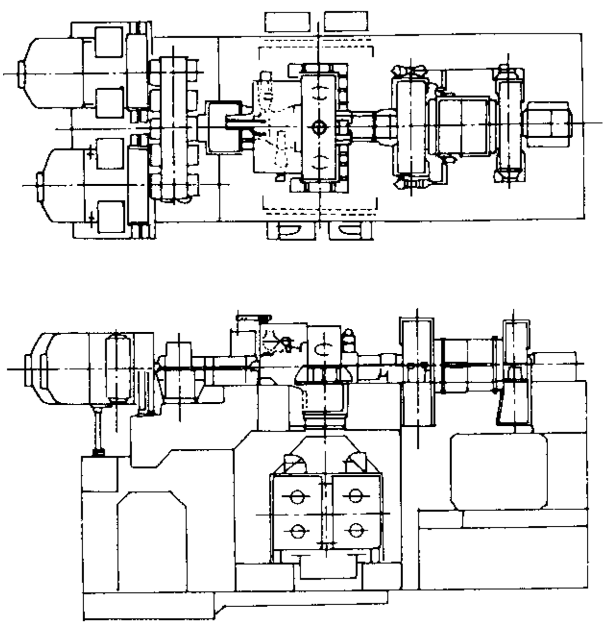
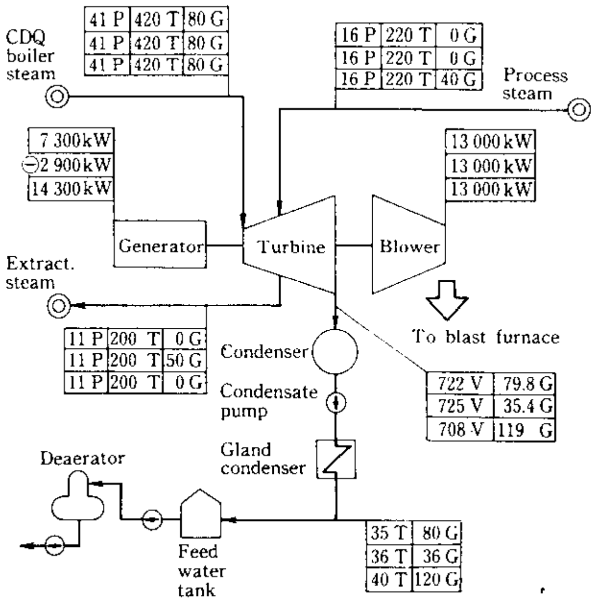


Fig. 7 General arrangement of the equipment



P: pressure (kg/cm^2 abs.)
T: temperature (°C)
V: vacuum pressure (mmHg)
G: flow rate (t/h)
kW: output (kW) or shaft power (kW)
⊖: Required power of motor
Upper line value : blast furnace air supply and power generation with CDQ boiler steam (80 t/h)
Middle line value: maximum extraction (50 t/h)
Lower line value : maximum mixing (40 t/h)

Fig. 8 Heat balance

at 3 610 rpm, and the generator at 3 000 rpm by means of reduction gears.

The equipment is of an in-door type, and the condenser is of an at-site assembly type.

3.1.2 Heat balance

The heat balance of the system is shown in **Fig. 8**. For the main steam of the turbine, steam (80 t/h) from the CDQ boiler is used. In normal operation, 13 000 kW of turbine output is used to power the blast furnace blower, with the remaining energy used at the generator to produce 7 300 kW of electricity.

When the supply of process steam is inadequate, a maximum of 50 t/h of steam may be extracted from the turbine and supplied as process steam. Conversely when process steam is in surplus, it is mixed at the intermediate stage of the turbine to increase power generation output.

3.2 Steam-mixing and Extraction Turbine

3.2.1 Steam Mixing

Points to be considered in designing the mixed steam turbine were as follows:

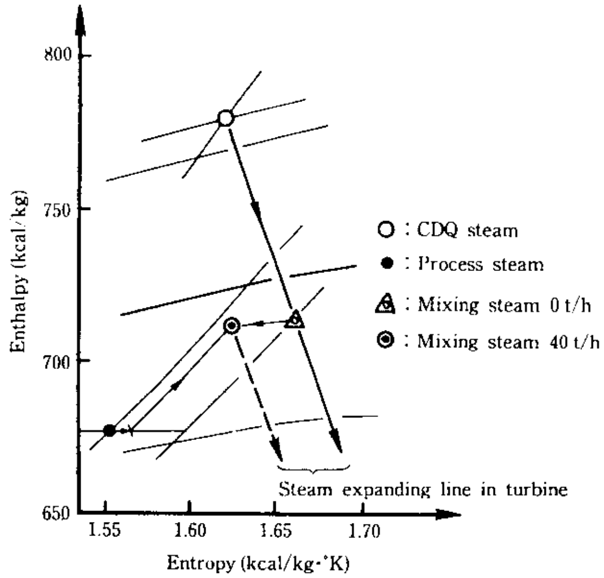


Fig. 9 Steam condition change at mixing point

(1) Capability of withstanding temperature changes at steam mixing
(2) The steam flow shall not be disturbed at the steam mixing point
(3) Ease of the steam mixing operation

Changes in the steam condition before and after mixing at the steam mixing point are shown in **Fig. 9**. Process steam has a low temperature, but when mixed, its pressure at the mixing point increases until it raises the temperature of the CDQ steam to mix with the CDQ steam. As a result, temperature changes at the mixing point are virtually eliminated. The steam mixing point is located at the stage where the steam passage changes from partial to full admission-flow. This position has been designed to have an ample steam passage to ease the mixed steam flow in the peripheral direction.

3.2.2 Steam extraction

Steam is extracted from the turbine by either outside extraction or inside extraction. When the extraction flow rate is high, the latter is more efficient. However, for this turbine the former was adopted due to dimensional limitations, since the existing building foundation was to be used.

In the outside extraction, only one extraction port is normally provided; this turbine, however, has two extraction ports in order to decrease throttle loss. **Figures 10** and **11** show the relations between pressure and flow rate at the first and second extraction ports. When the extraction flow rate is low, steam is extracted through the second extraction port with the first port totally closed. When the extraction flow rate increases, steam is extracted through the first port to reduce heat loss. For this purpose, the first extraction port is provid-

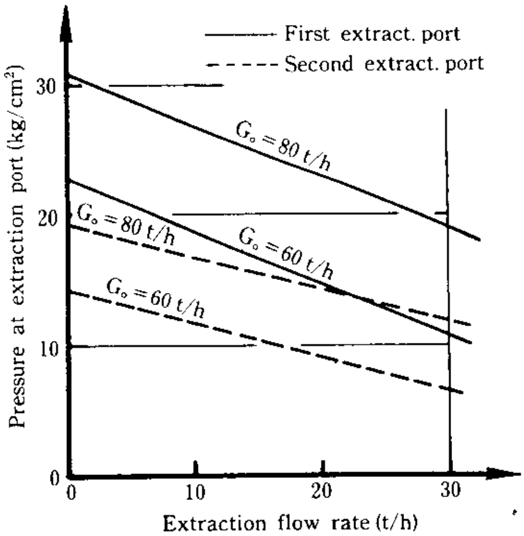


Fig. 10 Extraction diagram

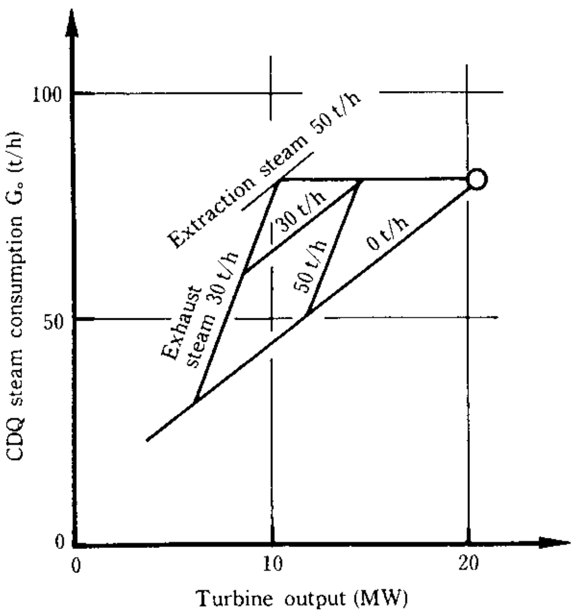


Fig. 11 Pressure at extraction port

ed with a shut-off valve of the ON-OFF type, and the second port with a non-return valve to prevent steam reversal.

4 Operation and Control

4.1 Operation

Turbine and blower operation may be controlled from either the plant floor or the central control room of the power plant. After both machines enter smooth operation, control of operation is transfered to remote-automatic control from the Energy Center. Daily adjustment of the steam flow rate and load changing are performed by remote control from the Energy Center, so that the power plant operates unattended. An example of the CRT screen at the Energy Center is shown in **Photo 1**.

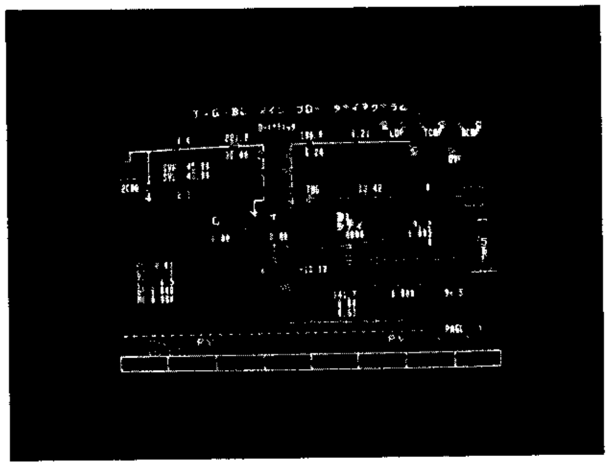


Photo 1 CRT graphic

As shown in **Fig. 12**, the turbine has six basic operational modes as summarized below.[1]

(1) In Normal Operation:
Blast furnace air supply and electric generation can be simultaneously carried out by CDQ steam. Generator output is 7 300 kW.

(2) When CDQ Boiler Steam Flow Rate Is Reduced to Half:
Since the turbine output in this case is less than the power required for the blast furnace air supply, the generator is used as a motor to back up the turbine.

(3) When CDQ Boiler Stops:
The generator is used as a motor with an output of 13 000 kW. The turbine rotates freely, while being cooled by process steam at about 5 t/h.

(4) When process Steam Is in Surplus:
Process steam is sent to the turbine to be mixed with turbine steam to increase generator output.

(5) When Process Steam Is Insufficient:
Steam is extracted from the turbine to supplement process steam. Insufficient turbine output due to this extraction is compensated by the motor or generator.

(6) When No Air Is Supplied to Blast Furnace:
In this case, the blower rotates idly with its air release valve opened to the atmosphere. Since blower load decreases, the generator output increases correspondingly.

4.2 Control

Figure 13 shows the control diagram of this equip-

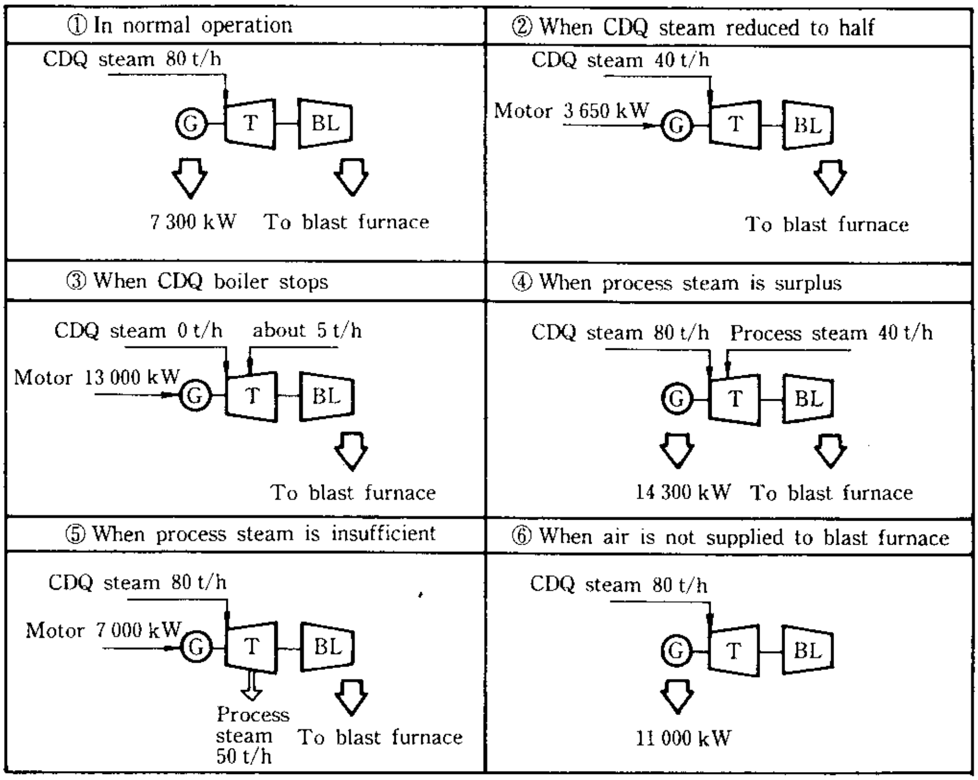


Fig. 12 Operation mode

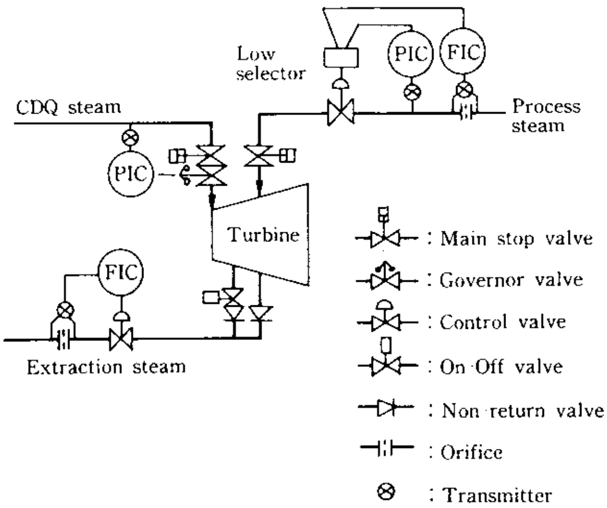


Fig. 13 Turbine control diagram

ment. An outline of the control system[2,3] is as follows:

(1) Pre-pressure control for the CDQ boiler steam system is performed by the turbine governor, so that main steam pressure can become constant. For this purpose, the load balance is adjusted by power generation and motor operation.
(2) To protect the generator, a maximum load limiter is provided to both the generator and motor.
(3) The low-pressure process steam system is controlled in the constant-pressure control mode by the turbine external control valve. The maximum flow rate of the system is also controlled.
(4) A constant flow rate is maintained by control of the extraction system, in addition to the above-mentioned cooperative control by two extraction ports.

5 Operation Progress

With completion of the installation of the present multi-purpose turbine for the blower and generator, the power plant system at the Chiba Works is now very simple, compared with its pre-modification state as shown above in Fig. 5. The turbine was completed in August 1984 and is now operating smoothly. Operation of the gas combustion boiler, which was used as a back-up unit for blast furnace air supply, has been discontinued, and only CDQ steam is now used for blast furnace air supply and power generation. As a result, the surplus by-product gas is converted into electric power at the highly-efficient West Power Plant. The improved operating condition is shown schematically in **Fig. 14**. Total generation output has greatly increased from 10 600 kW with the previous equipment, to 16 000 kW in the modified facility.

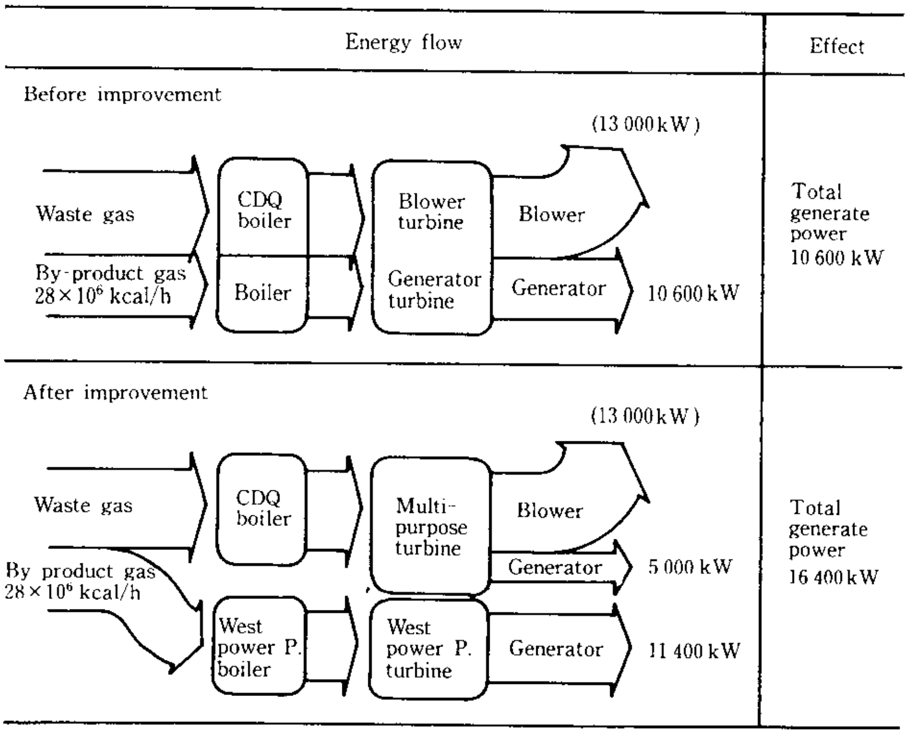


Fig. 14 Effect of multi-purpose turbine system

6 Concluding Remarks

As energy savings progress at steel mills, the steam system involving the waste heat boiler becomes increasingly complicated. It is comparatively easy to recover waste heat from steam, but it is difficult to absorb fluctuations in steam generation, and to supply and use the steam efficiently. Although steam generation fluctuations can be reduced to a certain extent by such means as the steam accumulator, the present turbine is a concrete example of absorbing the fluctuations into electricity.

The modified turbine has made it possible to use only unstable waste heat steam for air supply to the blast furnace and to achieve demand and supply control of process steam without causing turbulances to blast furnace blower operation. With its energy recovery through the generation of electricity, this system has greatly enhanced the value of steam recovered from exhaust heat.

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