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Energy Conservation through Hot Water Heat Recovery from Various Companies in an Industrial Complex and Gas Cogeneration, etc.

Kashima South Joint Power Corporation
Kashima Power Station
KMG Project Team

◎ **Keywords: Hot water and waste heat recovery, Gas cogeneration, and Rationalization of electricity conversion into motive power**

◎ Outline of the Theme

By cascade utilization of lower level hot water from various companies as a heat source for LNG vaporization and as a spare heat source for the existing boiler water supply, it was achieved to reduce the in-house steam consumption. Further, by supplying hot water derived through waste heat recovery from our company's existing boiler to demand companies, it was achieved to realize energy conservation in the demand companies through an alternative to their steam use for heating. Additionally, power generation of a cogeneration equipment coming along with hot water and steam generations through waste heat recovery with a high overall efficiency realized mutual utilization of heat in each company by substituting for the condensing power generation with the existing low pressure boiler. By these means it aimed to improve the overall heat efficiency of the entire power station and realize energy conservation of 24,000 kl/year in crude oil equivalent.

◎ Implementation Period of the said Example

July 2003 – July 2008

● Project Planning Period	July 2003 – April 2005	Total of 21 months
● Measures Implementation Period	July 2005 – September 2007	Total of 26 months
● Measures Effect Confirmation Period	August 2007 – July 2008	Total of 12 months

◎ Outline of the Business Establishment

- Items Produced Electric power, steam and pure water

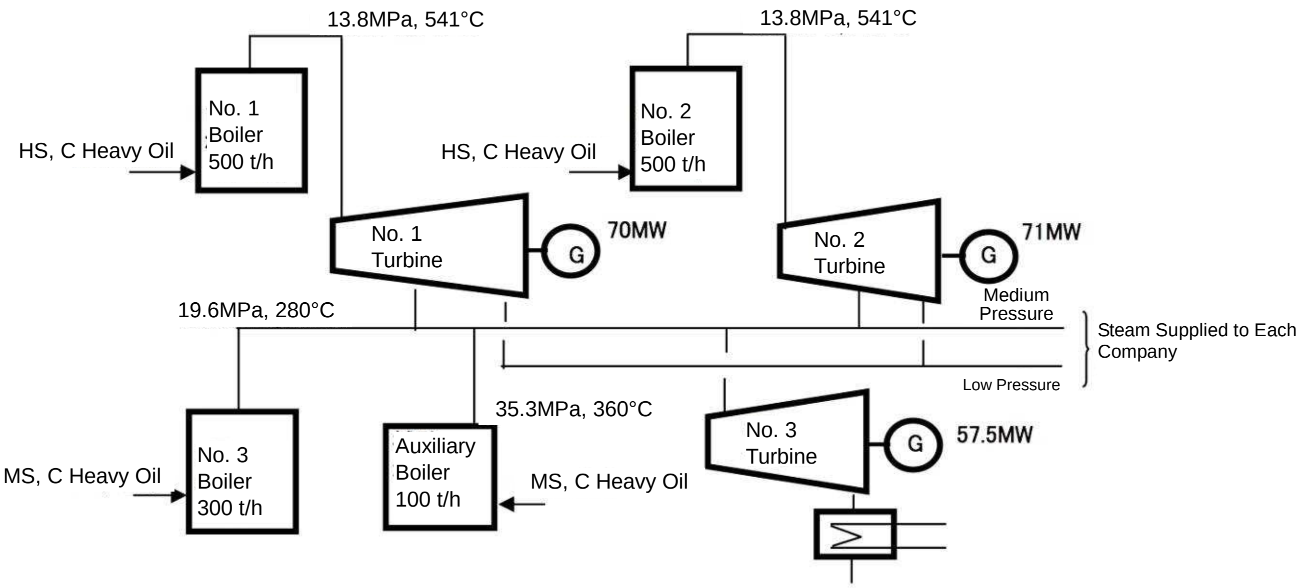
  (Production Amount: 15,299,014 GJ/year Actual results for fiscal year 2004)
- No. of Employees 75 persons
- Type 1 Designated Energy Management Factory

  Energy Usage Amount: 534,611 kl/year (Crude oil equivalent: Actual results for fiscal year 2004)

◎ Outline of Process Chart of Power Plant

Supply Capacity:

- Electric Power: 175 MW (Supply capacity of in-house generation portion)
- Steam: 700 t/h
- Pure Water: 450 t/h



1. Reasons for Theme Selection

At the time in 2004, the No. 1 and 2 boilers (High Sulfur C Fuel Oil Burning: 500 t/h x 2 units) and the No. 1 and 2 steam turbine generators (Output: No. 1: 70MW, No. 2: 71MW) were used for supplying a total of 460 t/h of medium and low- pressure steam to each company. The 200 t/h steam surplus, together with steam supplemented from the No. 3 boiler or the auxiliary boiler, was supplied to the No. 3 condensing turbine generator to increase the electric power generation. However, it was found to be insufficient to satisfy the electric power demand from all of the demand companies, and this leads to the situation that insufficient electric power had to be covered by purchasing electric power from a power company.

For this reason, while the investigations were made into enhancing the capacity of the power generating facilities with the mission of securing and providing a stable supply of cheaply priced energy, together with the investigations made into energy conservation measures inside the power station, an investigation based on the ‘Projects to introduce and promote energy conservation and new energy measures’ for fiscal year 2004 was carried out in the Kashima Industrial Complex. Among the investigations, as the effective use of lower level hot water from the demand companies was adopted as the theme, the investigation for energy conservation in the industrial complex was started.

2. Progress of Activities

(1) Implementation Structure

With the manager of our company’s power station appointed as the committee chief, six persons were selected as facilities investigating committee members from each of the industrial complex demand companies, together with four committee members from the power station, and a total of 11 person worked out implementation plan regarding energy conservation in the industrial complex after repeated discussions.

1) Committee activity contents

- Holding of committee meetings once every 2 months
- Investigation of actual situation on each company’s lower level hot water
- Identification of each company’s purpose for hot water usage and problem areas
- Investigation of power station efficiency improvement proposals
- Identification of power station energy conservation proposals

2) Arrangement of draft proposals by the committee

- Method of practically using each company's lower level hot water
- Supply of hot water recovered from the power station waste heat to each supply company
- Energy conservation through the introduction of high efficiency gas engine electric power generation equipment
- Energy conservation of large-sized electric motors
- Summarizing of investment amounts and pay back period

3) Approval of draft proposals arranged by the committee

- Shareholders' approval of draft proposals by the committee
  Following the receipt of approval for the draft proposals, the KMG (Kashima, Minami, Gas Engine) Project was launched and energy conservation activities were developed.

(2) Understanding of Current Situation

As global warming countermeasures in recent years, energy conservation and the reduction in CO_2 emissions have been urgently required. In addition, reductions in nitrogen oxide and sulfur oxide are being sought as environmental measures. Under these conditions, the use of an alternative low cost fuel or the introduction of new power generation facility was required because the power generation efficiency of the condensing turbine generator using the steam generated by the No. 3 boiler was low at 20% and the generation cost was high owing to the steep rise in heavy oil prices,.

(3) Analysis of Current Situation

1) Actual conditions of low-level hot water's flow-rate and temperature in each company

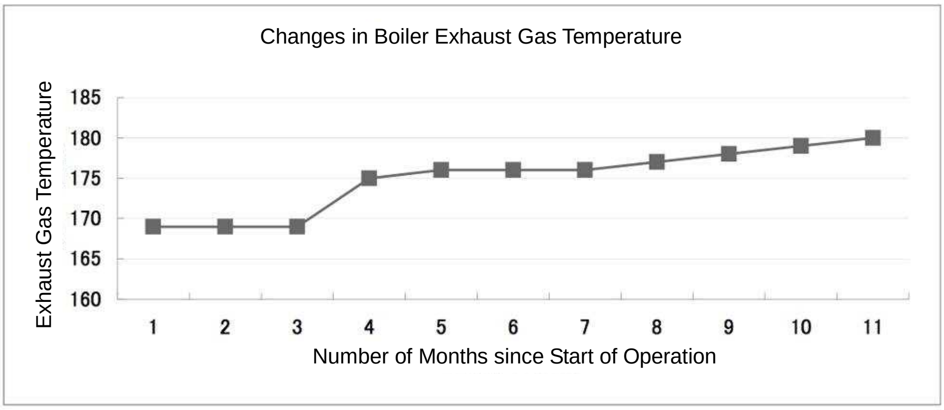
	Hot Water Temperature (□)	Hot Water Flow (t/h)	Conveyance Distance (km)	Contained Impurity
Company A	47	13	4	Small Quantities
Company B	80	45	3	None
Company C	55	17	2	None

As a result of the investigation of each company in the industrial complex, it was found that low-level hot Waters from three companies were possible to be used in our power station.

2) Thermal efficiency of condensing turbine generator using the steam from the No. 3 boiler

The No. 1 and 2 boilers are used for bleeder/back pressure turbine generators in which generated power, extracted steam and exhaust steam are provided to the demand companies while the remaining steam is supplied to a condensing turbine generator, and as a result the thermal efficiency is 70% or more. However, the thermal efficiency of the condensing turbine generator using steam from the No. 3 boiler was below 20%, and accordingly the generating cost was high.

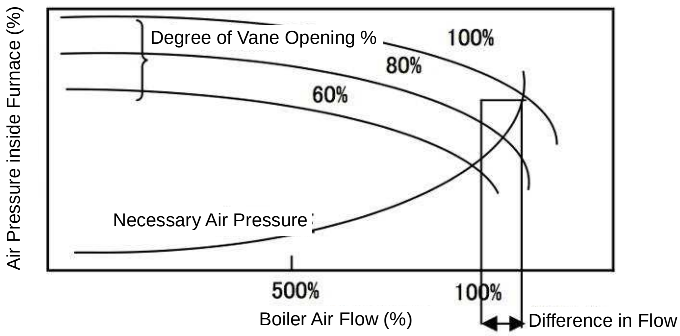
3) Quantity of waste heat from boiler exhaust gas



The exhaust gas temperature at the outlet (gas air heater outlet) of the No. 1 boiler was high at 169℃ from the time when the boiler started operations. It rose to 175℃ three months after the start of operations, and then gradually rose to reach 180℃ seven months later. The calculation of an annualized simple average showed the exhaust gas emissions at 175℃. Compared to general boiler exhaust gas temperatures of around 150℃, it was 25℃ higher, corresponding to an energy loss of 12,000 MJ/h (0.3 kl/h in crude oil equivalent).

4) Vane throttle loss of boiler forced draft fan vane

Because the boiler forced draft fans control the boiler combustion air flow by throttling air intake vane (degree of vane opening), air pressure loss (electric power loss) occurs due to this throttle.



At Boiler Load of 100%					
	Vane Opening (%)	Air Flow m³N/h	Electric Power Consumption kW	Air Flow at Vane Opening of 100% m³N/h	Air Flow Difference m³N/h
No. 1 Boiler	82	7,350	1,080	8,400	1,050
No. 2 Boiler	85	7,450	1,480	8,400	950
No. 3 Boiler	78	4,400	1,100	5,200	800

Allowance of the vane opening (Increased air flow at the vane opening of 100%) at the boiler load of 100% is equivalent to the pressure loss caused by the throttle.

(4) Target Settings

The energy conservation target was set at approximately 4% or more of the energy consumption in fiscal year 2004.

- Energy Conservation: 24,043 kl
- CO_2 Emission Reduction: 116,300 t-CO_2 (Using emission coefficient for the thermal power generation)
- Energy Conservation Rate: 4.50%

(5) Problem Points and Their Investigation

1) Utilization of lower level hot water from each company in the industrial complex

Because the overall efficiency of system comprising the low pressure boiler and condensing turbine generator was below 20%, a cogeneration system using a gas engine was adopted. However, there were the following concerns regarding the use of the lower level water from each company as a heat source for vaporizing the LNG that was to be used as the gas engine fuel.

① After use as a heat source in the LNG vaporizer, where will the lower level hot water from each company be recovered?

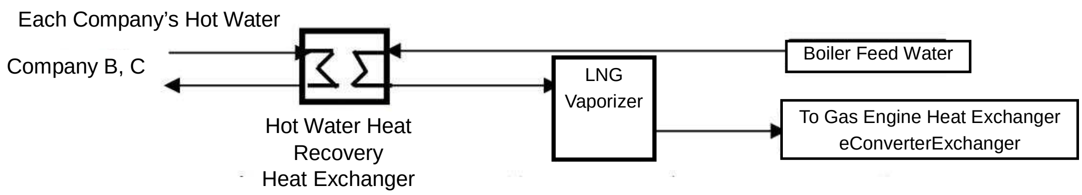
② Is the lower level hot water from each company contaminated by impurities (oil-based organic substances)?

As a result of investigating these concerns, it was planned to resolve the concerns by utilizing the following system:

① The adoption of the low temperature hot water suspected of containing impurities was called off this time.

	Hot Water Temperature (□)	Hot Water Flow (t/h)	Conveyance Distance (km)	Contained impurity	Adoption as judged	Judgment Reason
Company A	47	13	4	Small Quantities	No	Use of Company A's hot water will require high investment because of its contained impurities and long conveyance distance.
Company B	80	45	3	None	Yes	
Company C	55	17	2	None	Yes	

② A system was adopted in which a heat exchanger is installed in the heat recovery line of boiler feed water so that the water might be returned to each company after heat recovery without directly utilizing it in the LNG vaporizer to prevent the entry of impurities into the boiler feed water during the heat recovery.

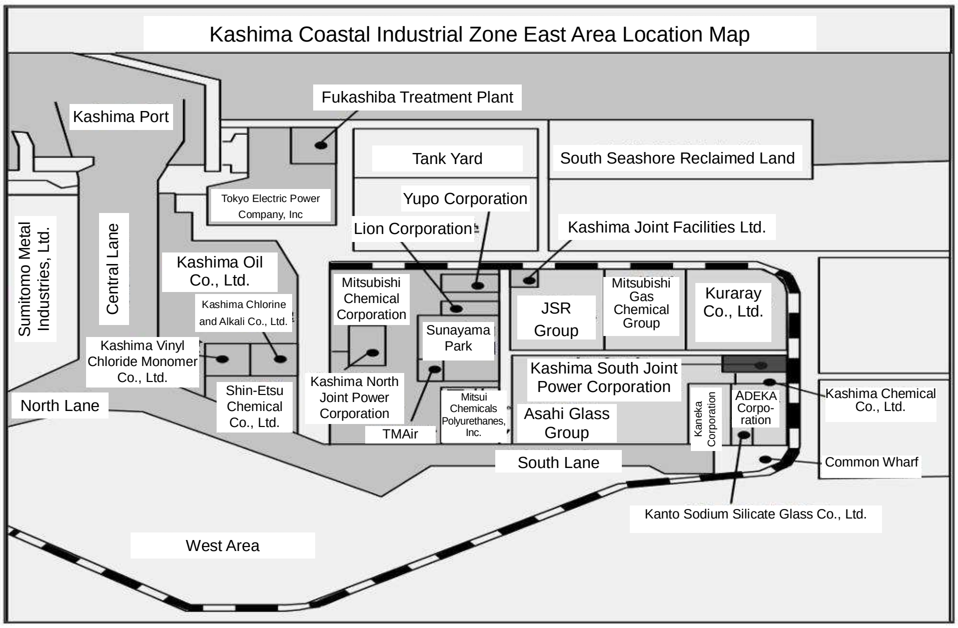


2) Introduction of a cogeneration system as a substitute for the condensing turbine generator with low pressure boiler

a. Selection of fuel

Our company is located at the north end of the Kashima Industrial Complex East Area. As the location conditions, it is away from Kashima port as an inland type facility and does not have a jetty. Accordingly, receiving measure of fuel is limited to the transportation through the pipeline from existing refineries, etc (the founding spirit of the industrial complex was that raw materials were to be transported by pipeline). Even if we intend to play a role in the liberalization of the electric power sector and the enhancement of competitiveness of industrial complexes, the situation is such that the purchase and transportation of cheap fuel are not possible.

In addition, due to the plant's location adjacent to private housing, the use of cheaper and inferior fuels will cause environmental pollution. The installation of pollution control facilities as a countermeasure would cause increases in natural resource and energy consumption, which would work against energy conservation.



Under these situations, the company received a proposal from a gas company for delivery of LNG by tanker, and as a result of carrying out a comparison investigation between the various fuels (LPG,' A' fuel oil, etc.), it was decided to adopt LNG.

b. Selection of cogeneration system

The demand from the various industrial complex companies both for electric power and for steam has been on an upward trend. When considering the balance between electric power and steam, the demand for electric power has been increasing more quickly, and thereby it is such a condition where the amount of electric power purchased from the power company has been increasing year by year. Therefore, a system that had good power generation efficiency with little steam generation was considered to be ideally suited.

As a result of carrying out a comparison investigation between gas engine and gas turbine cogeneration systems, it was decided to adopt gas engines, which have better power generation efficiency, generate less amount of steam, and also have higher overall efficiency.

Comparison between 10 MW Class Gas Engine and Gas Turbine Cogeneration system

	Power Generation Efficiency	Steam Generation	Overall Efficiency	Equipment Investment Amount	Maintenance Costs	Power Generation Cost	Overall Evaluation Result
Gas Engine	43%	5 t/h	84%	1	1	1	Excellent
Gas Turbine	37%	25 t/h	80%	1.2	1.2	1.2	Good

c. Selection of power generation capacity

The capacity of approximately 12 MW (6 MW x 2), which was within the range that would not fall below electric power to the previous fiscal year's power receiving agreement with the power company (equivalent to the increase in electric power consumed by industrial complex demand companies), was selected.

d. Utilization of hot water

The hot water recovered from the gas engine was supplied to the industrial complex demand companies, and the full amount of the remainder of the hot water was recovered as boiler feed water.

3) Heat recovery of boiler exhaust gas

The following items were considered in order to recover waste heat of the exhaust gas to the maximum limit (by lowering the exhaust gas temperature to the level of condensation temperature),

Items of Concern	Countermeasures
Blockages due to dust adhesion caused by exhaust gas condensation	Enhancement of cleaning equipment
Acid corrosion due to exhaust gas condensation	Double tubes made of SUS and with fluoride resin lining

In order to achieve the mutual utilization of hot water in each of the industrial complex companies, part of the recovered water is supplied.

4) Energy conservation of the boiler forced draft fans

In adopting an inverter for rotation speed control in order to relate the vane throttle loss to the maximum energy conservation, the following safety system was introduced.
The greatest concern regarding the conversion to inverter control of the boiler forced draft fans was the inverter reliability. Although the failure rate was low at around one time every 100,000 hours, in consideration of our company's mission to provide a stable supply, it would not be allowed to halt the boiler even at any unlikely failure. Accordingly, a simulation was requested from the boiler manufacturer to confirm that in the case of inverter failure an instantaneous (less than 1 second) changeover from the inverter to the commercial power would be made and that there would be no fluctuation in the air flow (to prevent flame out caused by excess or insufficient air flow), and the following control method was introduced:

a. Countermeasure on occurrence of a failure

① With regard to the switching of high voltage circuit breaker, the switching time between the residual voltage transition on the occasion of shutdown and the reclosing was selected as 0.7 seconds so that the starting torque could be limited within a level in which the mechanical strength of coupling and rotor of the motor and the draft fan can withstand, even if the difference in the voltage phase became maximum.

② In order that the changes in the discharged air flow of the boiler forced draft fans can be restricted as small as possible during the switching, the intake vanes were not kept fully open continuously and controlled according to the air flow within a opening level that affected the energy conservation as little as possible.

5) Realization of high economic efficiency through introduction cost reductions

By applying for the fiscal year 2005's financial support program of "New Energy and Industrial Technology Development Organization" and being awarded, the economic efficiency was greatly improved.

(6) Details of Measures

1) Heat sharing of each company's lower level hot water

By recovering each company's lower level hot water and sharing the heat, it was utilized for vaporizing the fuel for the LNG fired gas engines introduced to increase the overall efficiency of the power station (Utility Supply Center), and in addition the heat exchangers newly installed for pre-heating the existing boiler feed water.

a. Heat Exchanger A	Hot Water: 45 t/h, Inlet: 80℃, Outlet 35℃, Recovered Heat: 2,560 kW
b. Heat Exchanger B	Hot Water: 17 t/h, Inlet: 55℃, Outlet: 31℃, Recovered Heat: 495 kW

2) Heat recovery from boiler exhaust gas and hot water supply to each company

The pre-heated boiler feed water mentioned in the previous sub-section passes through a heat exchanger installed in the power station's No. 1 boiler flue so that the heat could be recovered from the exhaust gas to heat the feed water. In addition, it was planned to share the heat by supplying part of the hot water to each company.

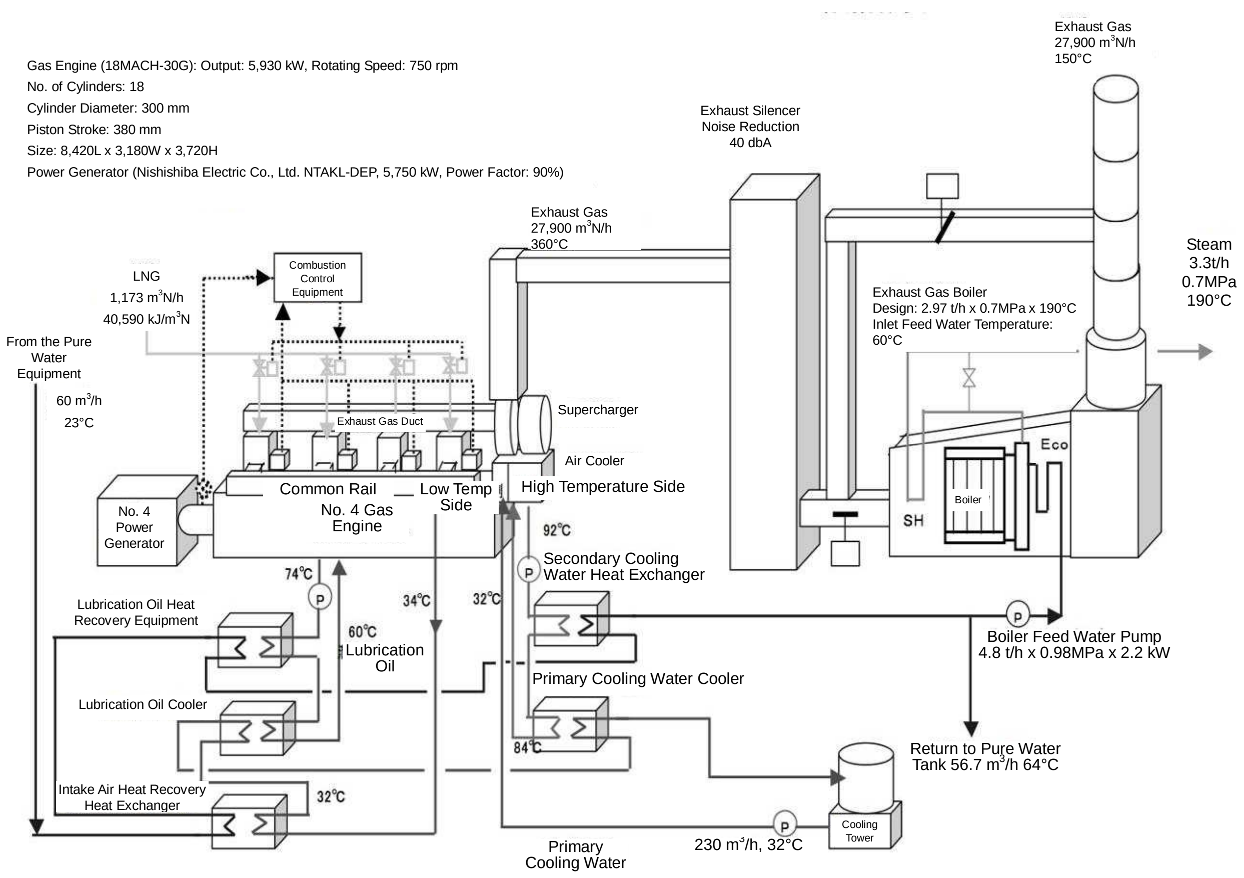
a. Exhaust Gas Heat Exchanger	Exhaust Gas Flow:	431,000 m^3N/h
		Inlet: 175℃ Outlet: 97℃
	Feed Water: 375 t/h	Inlet: 43℃ Outlet: 73℃
	Heat Transfer Area:	2,100 m^2
		Recovered Heat: 11,000 kW
b. Each Company Hot Water Supply		15t/h Temperature 73℃

3) Gas engine cogeneration and hot water supply to each company

The LNG fired gas engine cogeneration system recovers the heat from the gas engine cooling water and transfers to the existing boiler feed water, and exhaust gas boilers are installed in the stream of exhaust gas of the gas engines to recover low pressure steam. As a result of heat recovery from the cooling water together with generating output of the gas engine generator, it was planned to achieve a maximum overall heat efficiency of 84%.

As the power generation efficiency of the gas engines was 43%, it was planned to use these as a replacement for the No. 3 boiler, whose operation was halted in order to improve the overall efficiency of the power station.

a. Gas Engine Power Generator	5,750 kW x 2 units	
	Power Generation Efficiency: 43.5%	
	Fuel	LNG 1,173 m^3N/h x 2 units
	Diesel Oil for Ignition	9.8 l/h x 2 units
b. Hot Water Heat Recovery	3,145 kW x 2 units	Heat Recovery Rate: 23.3%
c. Exhaust Gas Boiler	Low Pressure Steam: 3.3 t/h x 2 units	Heat Recovery Rate: 17.4%
d. Overall Thermal Efficiency	84%	



4) Energy conservation due to introduction of inverters into boiler forced draft fan

Due to the heat recovery for heating the existing boiler feed water described in sub-sections 1 and 2 above, the in-house steam for heating the feed water will be reduced, and the boiler steam evaporation will also be reduced. In addition, although pressure loss has occurred since the air flow of the boiler forced draft fans has been controlled by throttling the inlet vanes, energy conservation is achieved through making the vanes fully open and reducing the rotating speed by the amount compensating pressure loss (by inverter control).

a. Trial Calculation of Energy Conservation: $Pw = P (1 – Q1/Q2)/ \eta$

P: Actual power

Q1: Air flow under actual load

Q2: Air flow when the vane is fully open (Rated value)

η : Conversion efficiency of inverter, etc.

b. Energy Conservation No. 1 FDF: 240 kW

No. 2 FDF: 280 kW

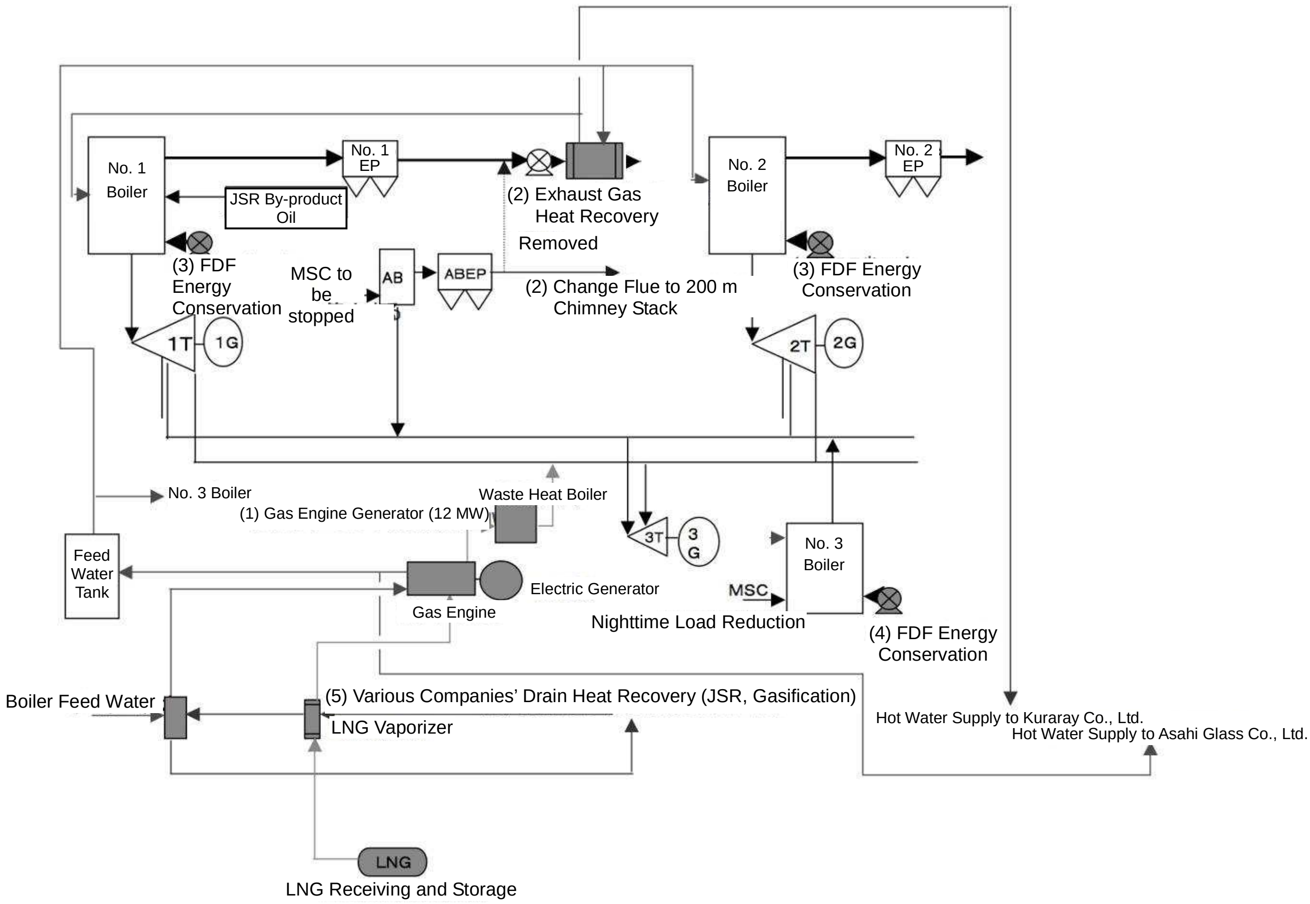
No. 3 FDF: 281 kW

5) Energy conservation through by-product oil combustion

By using by-product oil that was disposed of as waste in demand companies as fuel for the existing boiler, the consumption of high sulfur C fuel oil for existing boiler was reduced and this led to energy conservation.

a. By-product Oil Production (Energy Conservation amount) 2,088 kl/year

6) General diagram of the energy conservation project



Planned Energy Conservation due to Recovery of Hot Water Heat from Various Industrial Complex Companies, Gas Cogeneration, and Other Measures.

Energy Conservation: Crude Oil Equivalent (klyear)

	Plan
Energy Conservation due to Various Company's Lower Level Hot Water Heat Recovery	2,178
Energy Conservation due to Gas Engine Cogeneration	7,072
Energy Conservation due to Boiler Exhaust Gas Heat Recovery	9,151
Energy Conservation due to the No. 1-3 Boiler Forced Draft Fans	3,554
Energy Conservation due to By-product Oil Combustion	2,088
Total	24,043
CO_2 Emissions	63,700 t/year

(7) Effects Achieved after Implementing Measures

- Energy Conservation 24,080 kl
- CO2 Emissions Reduction 63,700 t-CO_2
- Energy Conservation Rate 4.5%
- Energy Conservation Amount ¥1,686 million (Crude Oil Unit Price: ¥70/l)
- Investment Amount ¥3,350 million
- Simple Pay Back Periods 2.0 years
- Cost Performance 719 kl/¥100 million

(8) Summary

By mutual interchange of lower level hot water with various companies in the industrial complex, our company could obtain energy conservation merits through recovering heat from the hot water. Because each of the demand companies previously used the hot water as make-up water for their cooling towers, the heat interchange that makes it possible to returns water at a normal temperature (around 35℃) achieved energy conservation in the companies' cooling fan operations.

In addition, the demand companies that previously produced hot water by steam could achieve energy conservation by utilizing the hot water recovered from the waste heat by our company.

Meanwhile, the energy conservation effects obtained inside the power station consists of reductions in unit consumption of the raw material and fuel and in the electric power and steam utility costs, together with a reduction in CO_2 emissions, which will be returned to the demand companies, who are the consumers of the energy.

The energy conservation achieved this time do not include energy conservation and merits achieved in the demand companies. If the energy conservation effects of each of the companies participating in the energy conservation activities were to be included, the effects would become much huger, greatly exceeding the target values.

(9) Future Plans

Although our company has been continually implementing activities to achieve energy conservation so far, further greater progress in energy conservation will be required to achieve the global warming gas reduction targets under the Kyoto Protocol.

However, because it is difficult to realize the above targets within the level of energy conservation progress developed this time found, our company is currently developing a plan to implement fuel switching for the existing boiler on the occasion coinciding with the completion of construction by the gas company of a natural gas pipeline between Chiba and Kashima laying of which is now in progress.