2008 Prize of Director General of Regional Bureau of Economy, Trade and Industry

Large Reduction of Chilling Energy used for Clean Room Air Conditioning

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Semiconductor Company Oita Plant
Facilities Administration Section, Facilities Administration Department
Energy Conservation Promotion Group

◎ **Keywords: Rationalization of chilling system,
Reduction of heat radiation loss,
Improvement of chiller efficiency**

◎ Outline of Theme

In semiconductor manufacturing plants, manufacturing is carried out in clean rooms that are maintained at a constant temperature and humidity year-round. These clean rooms consume large amounts of chilling energy for use in air conditioning throughout the year. In the activities this time, we focused our attention on the chilling energy of this equipment which consumes a great amount of energy, realizing a large improvement in the chilling overall efficiency through improving the efficiency of the chiller units, reducing the supplying energy, improving the auxiliary unit efficiency, and building an energy conservation automatic control system, in addition to successfully implementing a renewal of the cold thermal source equipment while continuing the plant operations.

◎ Implementation Period for the Said Example

October 2005 – May 2008

- Project Planning Period October 2005 – May 2007 Total of 1 year and 8 months
- Measures Implementation Period
  January 2007 – May 2008 Total of 1 year and 5 months
- Measures Effect Verification Period
  May 2007 – July 2008 Total of 1 year and 3 months

◎ Outline of the Business Establishment

- Items Produced — Semiconductor integrated circuits
- No. of Employees — 2,537 persons (As of April 1, 2008)
- Type 1 designated energy management factory

◎ Overview of Target Facilities

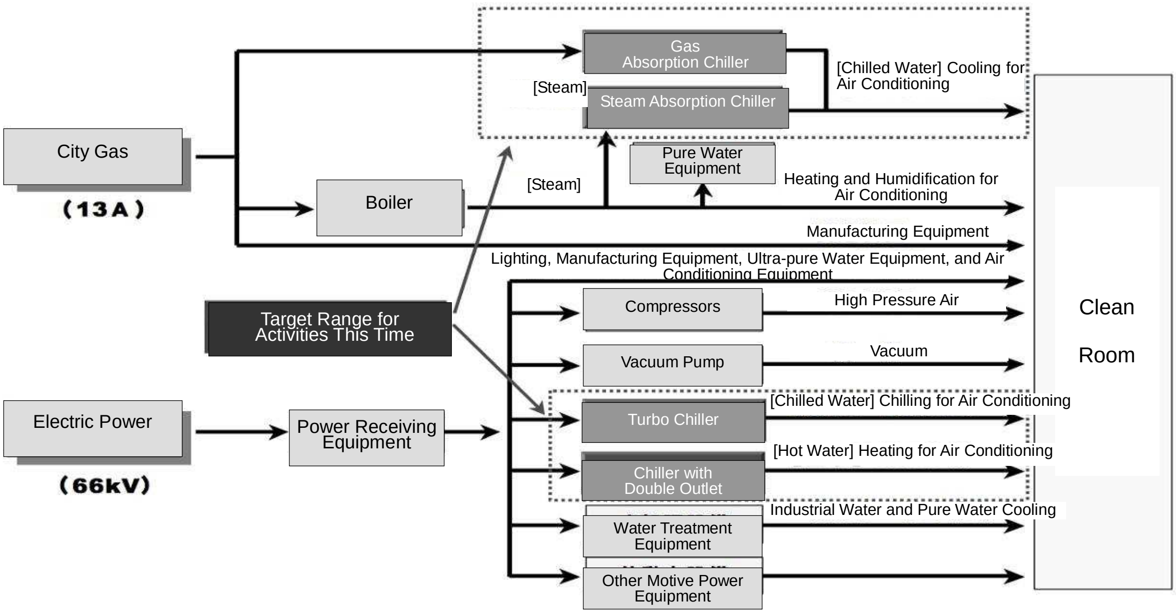


Fig. 1 Energy Supply Flow Diagram

1. Reasons for Theme Selection

This plant is a leading-edge semiconductor manufacturing plant of 24-hour operations. As its primary energy, the plant is consuming large amounts of electric power and city gas. In addition, to enhance its cost competitiveness as a business, the company is seeking to implement energy conservation and cost-reducing as key issues, and is also positively striving to reduce its CO_2 emissions. In the activities this time, attention was focused on chilling energy which takes up a large percentage of the total energy, and energy conservation and cost-saving measures were investigated including countermeasures for the aging of the equipment.

2. Understanding and Analysis of Current Situation

In this plant, electric power and city gas are being used as the primary energies. Fig. 2 shows the breakdown before improvement. As the usage, electric power takes up 87%, while city gas takes up 13%.

Next, the breakdown of energy usage is shown in Fig. 3. The application with the highest energy consumption is the manufacturing equipment. Out of the motive power equipment, the air conditioning has the highest energy consumption, followed by the chillers. In the air conditioning, because the implementation of "Energy conservation by reducing the clean room (CR) circulation air amounts" was introduced in last fiscal year's energy conservation case studies, this time attention was focused on the chillers, which have the second largest energy usage, and investigations were carried out into energy conservation measures.

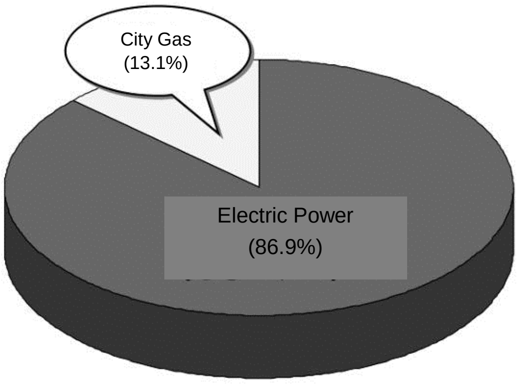


Fig. 2 Breakdown of Primary Energy Usage

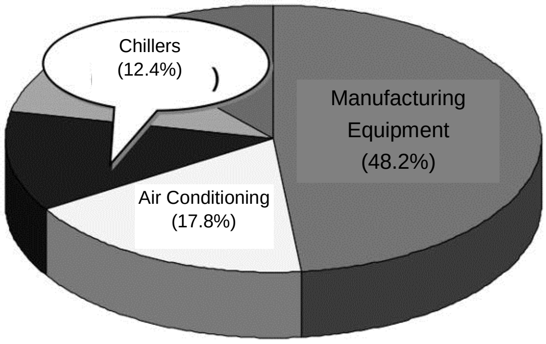


Fig. 3 Breakdown of Energy Usage

3. Progress of Activities

(1) Implementation Structure

In the program structure, the energy conservation activities were carried out with a central role played by members of the Technical Systems Energy Conservation Promotion Group (Motive Power Working Group) of the Facilities Administration Section, the Facilities Administration Department in this plant.

Further, from an investment efficiency improvement point of view, the NEDO subsidy system was utilized, and part of the activities were implemented as an ESCO business.

In addition, this company also implements the Clean Room Ecology Project and E-Cube, which is a unique energy conservation promotion system, so that investigations and horizontal development of each type of energy conservation and motive power cost reduction is being carried out. Fig. 4 shows the activity structure in this plant.

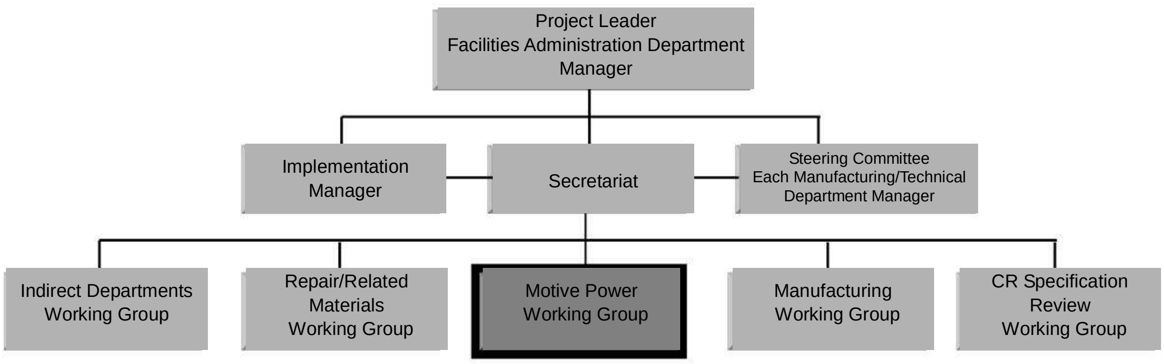


Fig. 4 Plant Energy Conservation Activities Structure (E-Cube)

(2) Target Settings

- Energy Conservation Amount: 11,952 t-CO_2/year
- Cost-savings: ¥306 million/year (Electric power and city gas)

The target settings for the energy conservation amounts correspond to approximately 5% of the plant overall energy amount before the improvement.

(3) Problem Points

Concerning the investigation of the energy conservation activities, attention was placed on the chiller equipment which uses a large amount of energy, and measures were investigated. Investigations were carried out within the group regarding the overall problem points of the chiller equipment, and as a result of identifying problems the points were narrowed down to the three items shown below and it was decided to proceed with measures for improving these points.

① **Problems and backgrounds of chiller individual units**

- Many types of chillers are being operated, including turbo chillers and steam and gas absorption chillers that have problems resulting from aging including low efficiency, high running costs and the use of specific CFCs. Motive power costs are increasing due to the rising unit costs of city gas and electricity.

② **System-related problems surrounding chiller auxiliary units**

- There are increases in the installation number of units due to heat radiation losses from heat storage tanks, pump header additions, and unmatched chilled water piping diameters/chilled water operation conditions.

③ **Problems relating to chiller operation**

- Operation of the chillers is implemented manually by the operator, and the operation condition is maintained at an excess in consideration of safety.

4. Details of Measures

In order to resolve the above problems, investigations were carried out regarding the following three points.

(1) [Measure 1] Improving the Efficiency of Individual Chiller Units

1) Current situation and points of focus for improvement (Before improvement)

Many chillers were operating in order to adjust the temperature and humidity in the clean rooms. The operation and halting of the chillers was carried out manually by the operators, and the chillers were operated at a surplus to give priority to the stable supply.
This time, the chiller equipment in the three heat source blocks A, B, and C in the plant were taken as the targets, and attention was focused on the following problem points to investigate improvement measures.

(1) Many of the absorption chillers have high fuel unit costs and high CO_2 emission coefficients. (Their efficiency is poor.)

(2) More than 18-20 years have passed since the chiller installation and those units are severely affected by aging. Their partial loading efficiency is also poor.

(3) Concerning the designed chilled water ⊿t value of 7/17℃, in actual operation this value is an unmatched 6/12℃, so that operation is only possible at around 60% of capacity. (Because the partial loading efficiency is poor, almost 100% of the energy is being used.) The number of chiller units that are operating is larger than necessary.

(4) There are specific CFC (CFC-11) specification chillers in use that incur issues for the global environment.

2) Improvement details (After improvement)

As efficiency improvements for chiller individual units, replacement with high-efficiency inverter turbo chillers was implemented. Concerning the replacement, it was not a simple replacement, instead an analysis was carried out of the past several years of operation data (Fig. 7) adequately considering the problem points in the current operations based on the points for attention described above and implementing measures to resolve all the problem points and obtain the maximum effect.

[Improvement Points]

① **Improvement of the chilled water temperature difference (℃) of the chiller was carried out**

The ⊿t of the chiller chilled water was only reaching around 60% of its designed values and a larger number of chiller units were operating than is necessary. (Fig. 8) This time the values were regulated to the actual operation and the ⊿t specification was changed (from 10℃→6℃).

Fig. 7 Survey and Analysis Investigation Condition

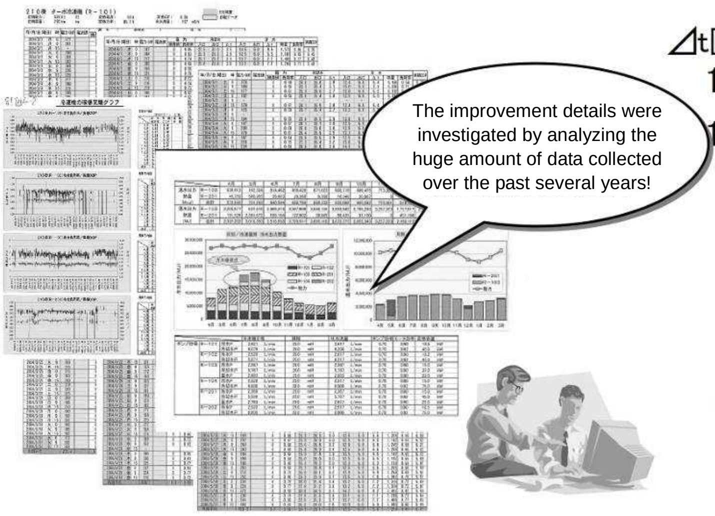
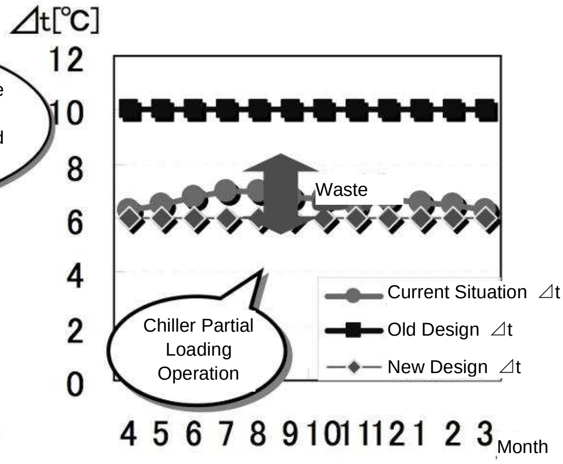


Fig. 8 Chilled Water ⊿t of the Chiller (℃)
Actual Results/Designed Value Comparison



② **Partial loading efficiency improvement**

In the current operation, all the chillers were in a partial loading operation condition, and were carrying out low accuracy operation. (Fig. 9) After the measures implementation, chillers with highly efficient partial loading were selected and were regulated according to the plant practical operation area. (Fig. 10)

Fig. 9 Chiller Loading Characteristics before Improvement

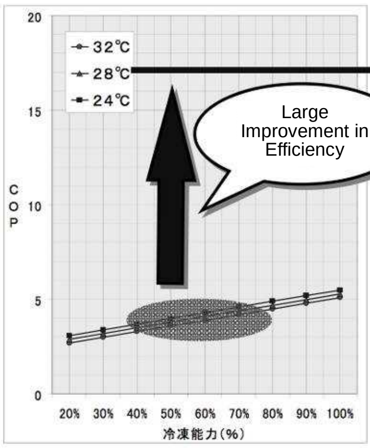
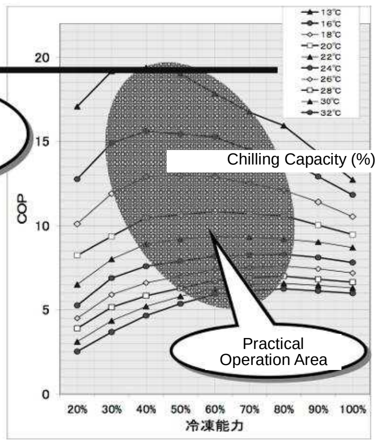


Fig. 10 Chiller Loading Characteristics after Improvement



From the above contents, the chillers were replaced with high efficiency type inverter chillers as shown in Fig. 11 that match the energy conservation operations of this plant.

By implementing the above measures, a large efficiency improvement of at least 3.5 times more was achieved in the overall general rated COP. In addition, the problems caused by equipment ageing were resolved, and the use of specific CFCs could also be completely abolished.

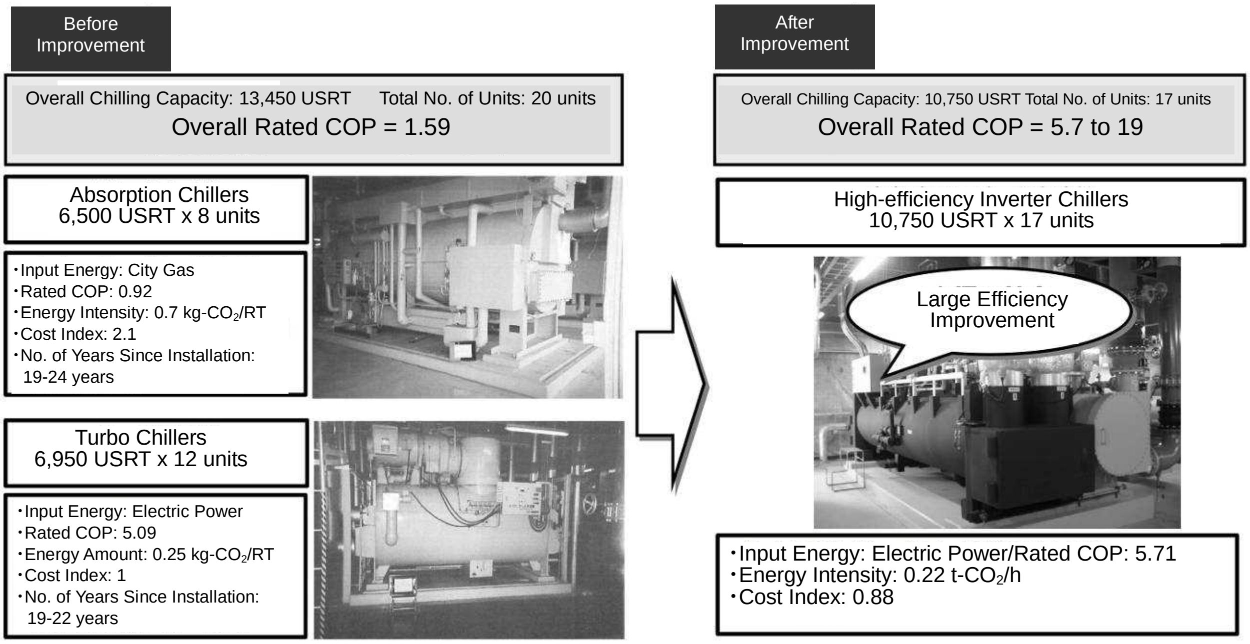


Fig. 11 Chiller Improvement Outline (Performance Comparison)

In the result of comparing each data before and after improvement, a large improvement was verified as described below.

① By reducing the number of chiller equipment units by three units, the chilling capacity was reduced by 20% (13,450 ⇒10,750 USRT) (Fig. 12)

② The total energy usage (Rated) was reduced by 60% (6.37 ⇒ 2.49 t-CO_2/h) (Fig. 13)

③ The chiller efficiency improvement (Winter period actual measured values) showed an electric motor input reduction of 70% (320 ⇒ 91 kW) (Fig. 14)

(Old type model versus the new type inverter model comparison under the same loading)

Fig. 12 No. of Chiller Units/Performance

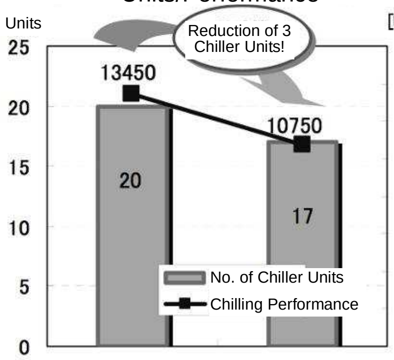


Fig. 13 Chiller Energy Amount Comparison

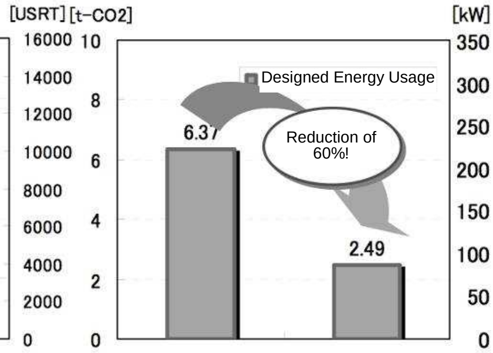
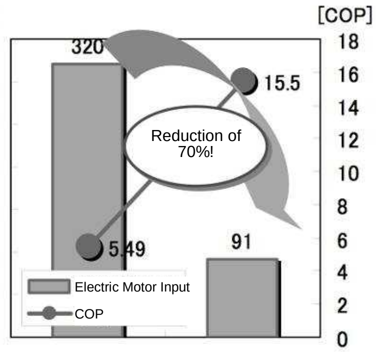


Fig. 14 Chiller Efficiency Comparison



(2) [Measure 2] Chiller Auxiliary Unit System Efficiency Improvement

1) Current situation and improvement attention points

Previously, the chilled water manufactured in the chiller was stored in the chilled water storage tank, and was supplied to the clean room air conditioner using the secondary chilled water pumps. (Fig. 15) In addition, almost all of the pumps of the cooling water/chilled water were operated in commercial operation, causing heat loss from the chilled water storage tank and requiring large amounts of motive power for the supply. Focusing attention on each of these problems, the following improvements were made.

2) Improvement details

① Discontinued use of chilled water hot water storage tank, and changing to closed loop system

As a result of investigating the manufactured amount of the chilled water and its usage before improvement, it was found that the storage heat loss was approximately 20%. Accordingly, by discontinuing use of the chilled water heat storage tanks and changing to a closed loop system, the stored heat loss was eliminated and the pump header was reduced. In addition, the piping diameter had its size increased to decrease the pressure loss in a plan to achieve normalization. By implementing these measures, the secondary chilled water pumps also became unnecessary and the auxiliary equipment (pump) operation electric power was reduced. (Fig. 16)

② Pump replacement and change to inverter operation

Regarding the chiller auxiliary equipment including the cooling water pumps and chilled water primary pumps, pump integration and the change to inverter control were carried out while referring to the appropriate water flow and appropriate headers, and the operation electric power was reduced. In addition, piping structure normalization was also carried out at the same time, so that the size of the piping diameter was increased in a plan to reduce pressure loss.

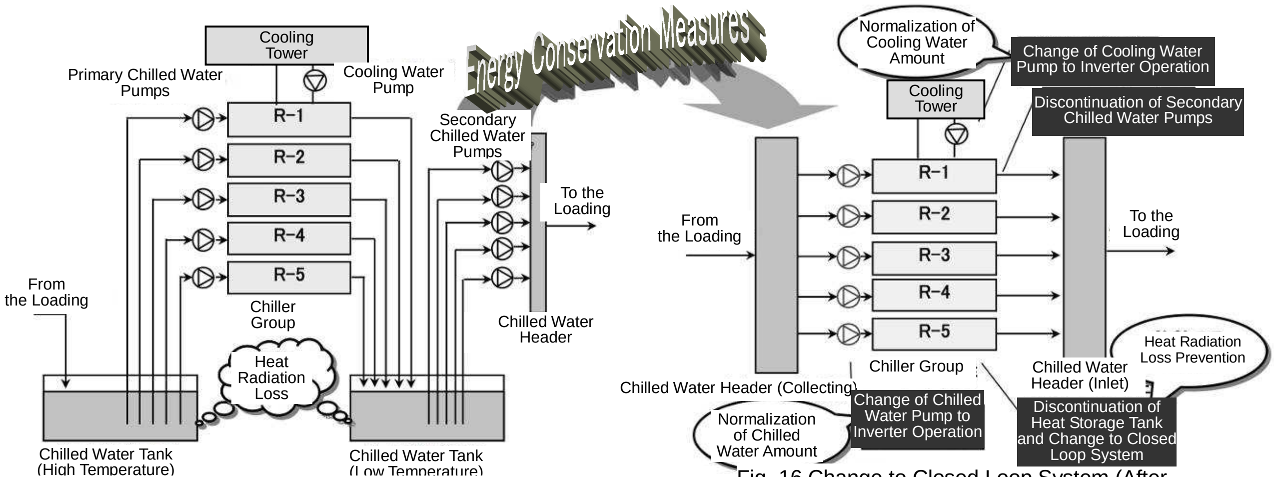


Fig. 15 Heat Storage Tank System (Before Improvement)

Fig. 16 Change to Closed Loop System (After Improvement)

(3) [Measure 3] Building a Chiller Automatic Control System

1) Current situation and improvement attention points

In the previous cold thermal source system, the operation of the chillers and auxiliary equipment was carried out by the operator using manual operation. Accordingly, the operation often did not match the loading requirements, and there were problems regarding the points of energy conservation and the economic efficiency.

2) Improvement details

In order to resolve the above-mentioned problems, a chiller automatic control system (Fig. 17) was built up. An explanation is given below regarding the main characteristics of this automatic control system, consisting of the control of the number of chiller units and the control of the chilled water/cooling water pump inverters.

① Control of the number of chiller units

Due to the prevention of surging, turbo chillers are difficult to maintain in stable operation at 20% or less of their chilling output and at 40% or less of their chilled water flow. Accordingly, control of the number of units was carried out based on these considerations. In the situation where a chiller is to be started, if the total chiller chilled water flow amount of the currently operating units reaches 60% of the sum total of the currently operating chiller total rated flow amount added to the rated flow amount of the chiller which it is planned to start up, the chiller will be started up as planned. On the other hand, in the situation where a chiller is to be halted, if the total chiller chilled water flow amount of the currently operating units reaches 50% of the currently operating chillers total rated flow amount, the chiller will be halted as planned. Fig. 18 shows the chiller startup and halting patterns. Using these patterns, the previous chiller surplus operation due to manual control was halted, and it became possible to carry out operation using an appropriate number of operating units.

Fig. 17 Monitoring Control Screen

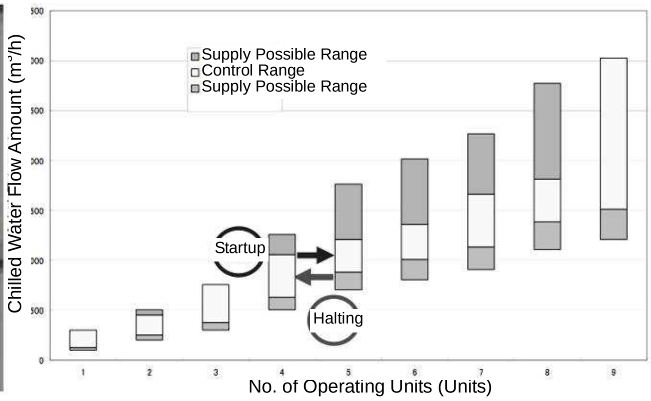


Fig. 18 Control of No. of Chiller Units Outline

② **Chilled water pump inverter control**

This measure is the most characteristic out of all the measures implemented this time. Previously, the chilled water header pressure was used for optional setting and operation in a system run manually by the operators. For this reason, in consideration of safety aspects, the flow of the chilled water was made larger than the amount actually required in an operation that caused a large energy loss.

After the improvement, a control system had been built up in which automatic calculation is conducted in real time of the appropriate header pressure using the chilling loading amount and piping resistance at that time, allowing operation to be carried out at the minimum necessary header pressure. Using this automatically calculated header pressure value, energy conservation can be realized through carrying out automatic operation of the chilled water pumps using inverters. In addition, in the system this time the chilled water flow amount of each chiller is distributed according to the chiller capacity and partial loading characteristics, and a function has also been added in which corrections are applied to the chilled water pump discharge pressure according to the piping resistance/pump characteristic curves and bias value input. The block diagram of this control system is shown in Fig. 19.

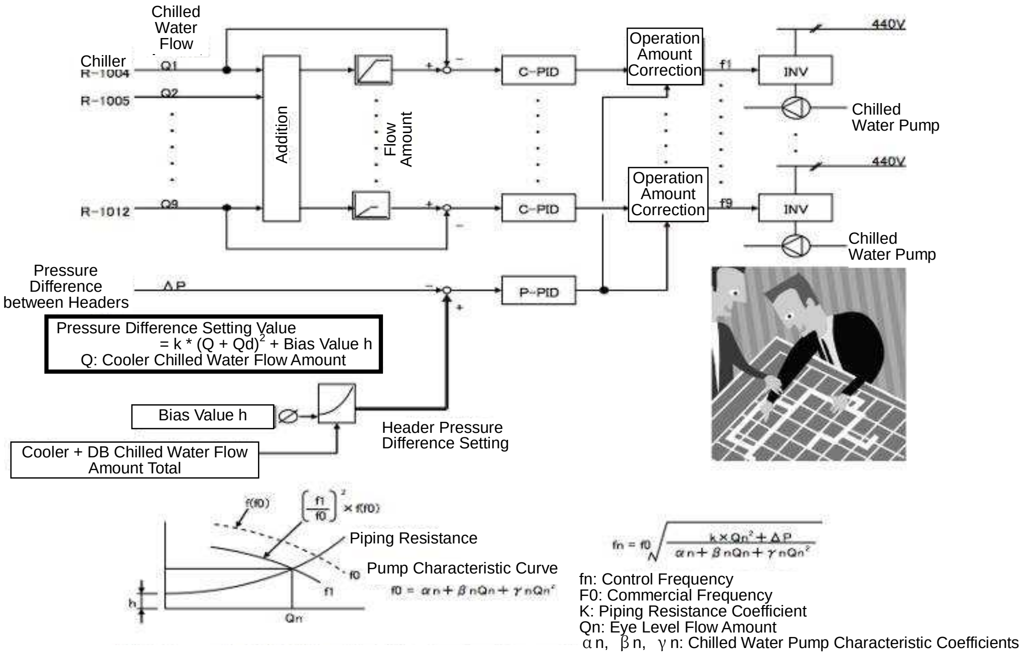


Fig. 19 Chilled Water Pump Inverter Control Block Diagram

③ Cooling water pump inverter control

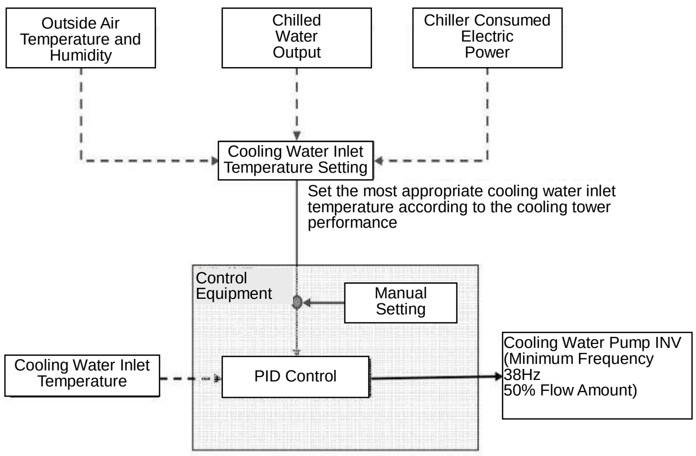


Fig. 20 Cooling Water Pump Inverter Control

Basically, the amount of cooling water required should be appropriate for the chiller loading. In this system, the chiller loading (chilled water output) and the chiller consumed electric power, together with the outside air temperature and humidity is taken into account to calculate the cooling water inlet temperature. By using this for the automatic setting, it was possible to improve the control system to one in which the total energy of the cooling water pump and the chiller main unit will become the minimum necessary amount. Previously, units were operated continuously at commercial operation throughout the year, but after the improvement automatic control is being implemented to comprehensively improve the efficiency to the maximum by considering the chilling loading and the outside air conditions.

In addition, because the chiller main unit efficiency will improve when the chilled water temperature reduces in the wintertime, improvements were also made to take this into account to realize comprehensive automatic control. Fig. 20 shows an overview diagram of this control.

④ Summary of measure details

A summary of the various measures implemented this time is shown in Fig. 21, and the overall processes are shown in Fig. 22. In order that there would be no influence on the semiconductor manufacturing, the improvement work was successfully implemented while the plant was operating. Note that the switching from the chilled water supply heat storage tank system to the closed loop system utilized a three-day fixed maintenance period when all the electicity was switched off.

	Measures		Business Format
A Block B Block	・Change of absorption chillers to inverter turbo chillers ・Change of turbo chillers to high efficiency operation ・Discontinuing of specific CFC use	・Change of chilled water/cooling water pumps to inverter operation ・Change of cooling tower fans to inverter operation ・Change of chilled water supply system to automatic control	NEDO
C Block	・Change of absorption chillers to inverter turbo chillers ・Change of turbo chillers to high efficiency operation ・Discontinuing of specific CFC use	・Change of chilled water/cooling water pumps to inverter operation ・Discontinuation of heat storage tank, and change of chilled water to closed system ・Change to automatic control of optimum water supply pressure ・Change of chilled water supply system to automatic control	NEDO＋ESCO

Fig. 21 Summary of Measures

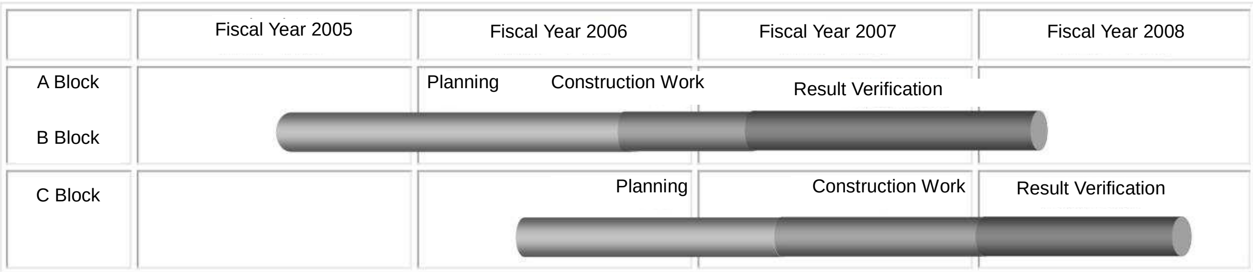


Fig. 22 Process Table

5. Effects Achieved after Implementing Measures

By implementing the three main measures described previously, it was possible to realize a large reduction effect of 12,291 t-CO_2/year, which approximately equaled to the targets (103%) as described in Fig. 23 below.

In the overall chilling energy, a large improvement of 43% was realized compared to before the improvement. (Fig. 24)

	Energy Conservation Amount (t-CO_2/year)	Electric Power Reduction Amount (MWh/year)	City Gas Reduction Amount (Nkm^3/year)	Cost-saving Amount (¥ Million/year)
A Block	1,779	2,431	375	45
B Block	1,594	1,350	465	41
C Block	8,918	8,312	2,483	228
Total	12,291	12,093	3,323	314

* Regarding the C Block, some of the values used are estimated values

Fig. 23 List of Energy Conservation Effects

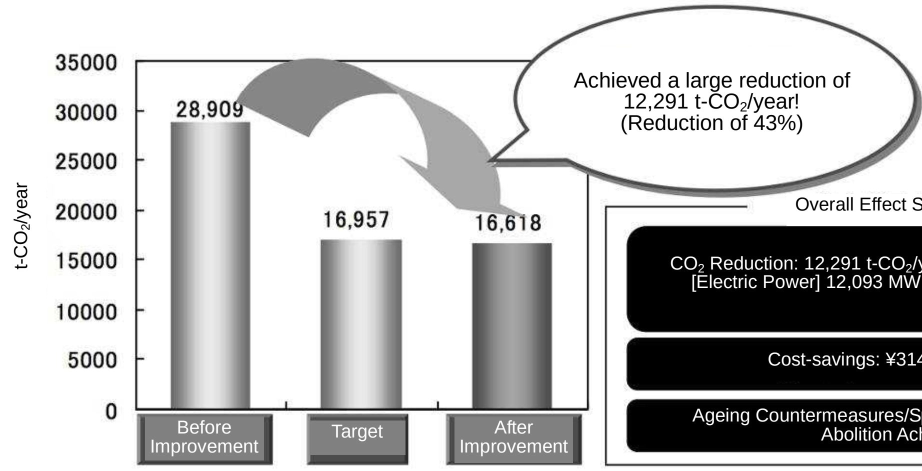


Fig. 24 CO_2 Emission Amount Reduction Effects

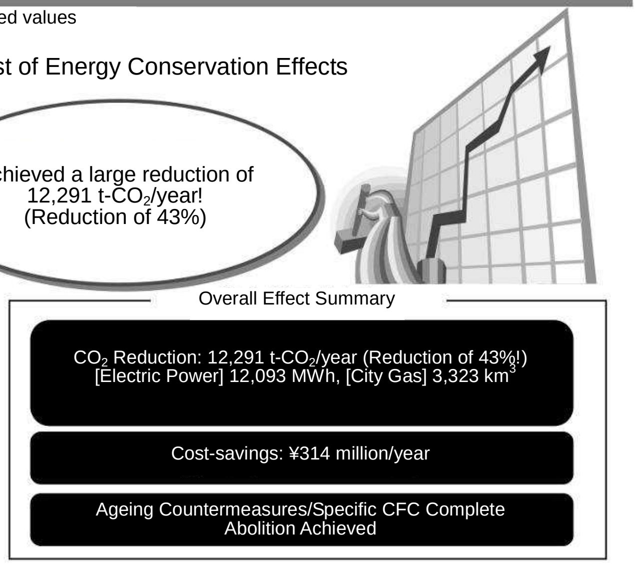


Fig. 25 Overall Effect Summary

6. Summary

The large reduction in chilling energy for the clean room air conditioning introduced this time was completed as a major improvement over a short period of 2 years from its conception, and it was possible to realize an extremely large energy conservation effect resulting in reduction of 12,291 t-CO_2/year (¥314 million). (Fig. 25) Further, in addition to the energy conservation effect, environmental preservation measures such as specific CFC reduction, equipment ageing countermeasures, and cost competitiveness enhancements were also achieved. As a point that required particular cares and efforts, the construction work was completed with the minimum amount of process switching while continuing to maintain stable operations of the plant, and for the appropriate control tuning adjustments all the related people worked together to achieve the target. Regarding the details of this theme, because subsidies were received from the New Energy and Industrial Technology Development Organization (NEDO) as an energy conservation measure example, and part of the work was implemented as an ESCO business, we would like to thank all the persons concerned.

7. Future Plans

In the case study introduced this time, it was possible to achieve a large reduction of 43% compared to before the improvement by realizing a switch from the previous chilling system that was manually implemented by the operators to full automation which considers energy conservation and cost-saving.

Energy efficiency improvements for air conditioning and chilling systems will also be effective in other industries, and it is believed that there are cases with adequate possibilities for carrying out horizontal developments. While contacting related divisions in this plant and in other companies, we intend to investigate the implementation of further horizontal developments.