2007 Prize of the Chairman of ECCJ

"Fighting for Energy Conservation of Air conditioning" between Worksite and Management

Mitsubishi Electric Corporation, Fukuyama Mfg.
Eco Challenge Group

◎ **Keywords: Others ("Visual management of air conditioning", "Cooperative improvement between worksite and management")**

◎ Outline of Theme

While we, as identified above, renewed the air conditioners in the factory (from water cooling/steam heating type to heat pump type) based on the policy saying that "energy conservation and CO_2 reduction by renewal of the air conditioners to high-efficiency type and by operational improvement", both of our worksite and management made every effort to realize the energy conservation of the air conditioners by introducing a remote and central control system of air conditioners.

[1] Improvement of software aspect: Development and operation of a controller which interlocks air conditioners with demand, setting of upper and lower limit temperature, schedule management, rotation control, intake of outside air in early morning, etc.

[2] Improvement of hardware aspect: Introduction of high-efficiency air conditioners, attachment of light shielding films to window glass, double roofs of the building, etc

◎ Implementation Period for the Said Example

January 2006 – August 2007	Total 19 months	
Project Planning Period	January 2006 – May 2007	Total 16 months
Measures Implementation Period	June 2006 – August 2007	Total 15 months
Measures Effect Verification Confirmation Period		
	July 2006 – August 2007	Total 14 months

◎ Outline of the Business Establishment

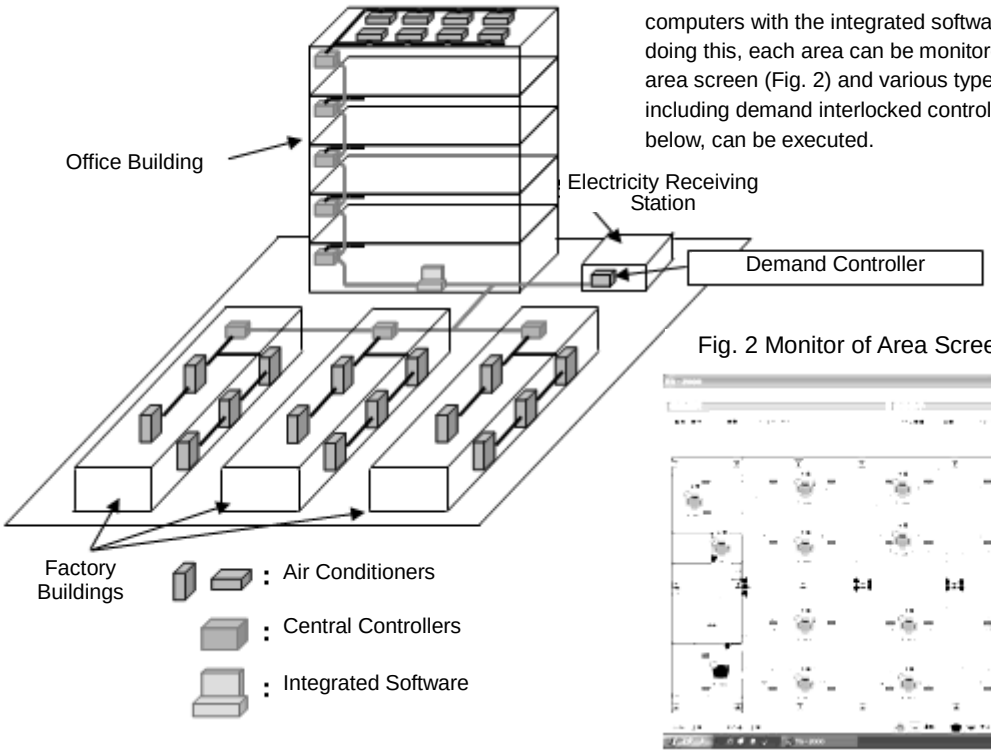
Items Produced　　Breakers for cabling, energy conservation equipment, measurement control system equipment, fuel pumps for automobiles

No. of Employees　　1,600

Type 1 designated energy management factory

◎ Outline of Target Facilities

Fig. 1 Schematic of Factory Air Conditioning System



The air conditioners of the whole factory are connected to the central controller and the demand controller, and the central controller is connected to the personal computers with the integrated software installed. By doing this, each area can be monitored on the monitor area screen (Fig. 2) and various types of control including demand interlocked control, as described below, can be executed.

Fig. 2 Monitor of Area Screen (Example)

1. Reasons for Theme Selection

(1) To understand the current situation, taking the office building as an example, we compared the electricity amount used in April (middle season) and in August (summer season). As a result, we found that the ratio of the electricity used by the

air conditioners is very high in August as shown in Fig.3 and 4 and its absolute use amount was approximately 10 times.

Fig. 3 Breakdown of Electricity Amount Used in April

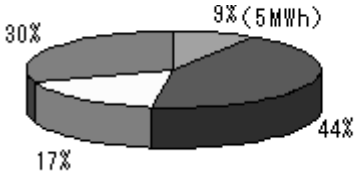
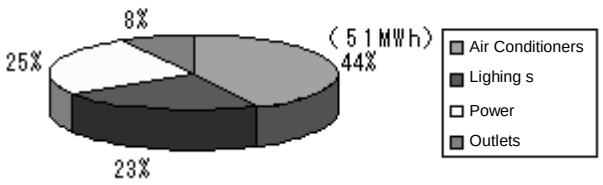


Fig. 4 Breakdown of Electricity Amount Used in August



(2) The air conditioners of the factory became old as a whole, so it was necessary for us to renew them to the high-efficiency type to realize energy conservation.

(3) Taking this opportunity, we decided not only to renew the air conditioners and improve its operation but also, as one of our activities, to propose and to develop the demand controller which makes it possible to interlock the demand with above mentioned system and make it one of our products to sell.

(4) We also considered that it is the importance of the activities to reduce the electricity amount used by air conditioners by using the integrated software of central controller, so we started the activities aiming to have a big effect without damaging the comfort of the work place.

2. Examples of Improvement

(1) Improvement of software aspects (renewal of air conditioners to high-efficiency type, introduction of remote monitoring and control system, and proposal, development and operation of the demand interlocked control system)

During the period from February to March, 2005, we renewed 156 air conditioners of the office building (1st to 5th floor) and 66 air conditioners of the factory building to high-efficiency type. And we proposed a way to do appropriate demand control by interlocking the demand control with the control of the air conditioners to the division for the development of energy conservation support equipment and made them develop and operate such a product. At the same time, we introduced the central controller with the integrated software and realized the “visual management of air conditioners” which could remotely monitor and control various air conditioners.

When doing this, we also changed the way to control the air conditioners, i.e. till then, a

number of air conditioners had been controlled by one remote control switch, but, considering the distribution of heat to the areas near windows areas along passages, etc., we changed the way which controls air conditioners of 2 to 3 units, meticulously with one remote control switch.

We also made the following improvements.

[1] Development and operation of the demand controller interlocked with the control of the air conditioners, and to make it one of our products to sell.

[2] Setting of upper and lower limit temperature for air conditioning from remote locations (to prevent over-cooling, over-heating).

[3] Automatic ON/OFF by means of schedule management (to prevent employees from forgetting to turn off the air conditioner and stopping air conditioning when not necessary).

[4] Automatic thinning operation by rotation control without damaging the comfort of the work place.

Before and after making the above mentioned improvements (FY2005 and FY2006), the daily electricity amount used by air conditioners in the office building and the average of the daily maximum temperature of each year were shown in Table-1, and it shows that the air conditioning electricity of a day increased.

But, this is because the average temperature was different. If we calculate it on the assumption that the average temperature of FY2006 was that of FY2005 using a regression equation based on the correlation graph of daily air conditioning electricity and average temperature of each year (Fig. 5 and Fig. 6), the air conditioning electricity of a day was 1,213 kWh and there was an energy conservation effect of -25.6% compared with FY2005.

This is equivalent to the reduction of approx. 90,000 kWh (50t-CO_2) of the cooling season (4 months).

Table 1 Air Conditioning Electricity of a Day and Average Temperature of Daily Maximum Temperature

Year	Average Air-conditioning Electricity of a Day	Average Temperature of Daily Maximum Temperature
FY2005	1,630 kWh	28.0℃
FY2006	1,654 kWh	31.2℃

In the correlation diagram of FY2005, we found that there was almost no correlation between the average temperature and daily air-conditioning electricity and, therefore, the operational management was insufficient (over-cooling, unnecessary operation, etc.).

To the contrary, the correlation diagram of FY2006 shows that there was correlation between the average temperature and the daily air-conditioning electricity, indicating that the air conditioning was properly controlled against temperature (operating only when air conditioning was necessary, appropriate temperature control, etc.).

The appropriate temperature control was realized by remotely controlling each air conditioner with remote control switches so that they do not cool too much.

To be more specific, when we prohibited the temperature from setting below 26□, there were a lot of complaints saying “hot!”, “the remote control is broken”, “lower the setting temperature”, etc. But at the work place meeting, we explained that the setting satisfied 28□, the requirement for the work place temperature, and appealed the importance of doing the energy conservation by all members of the work place. It was understood by work place people and it was a great achievement.

Fig. 5 Correlation Graph of FY2005

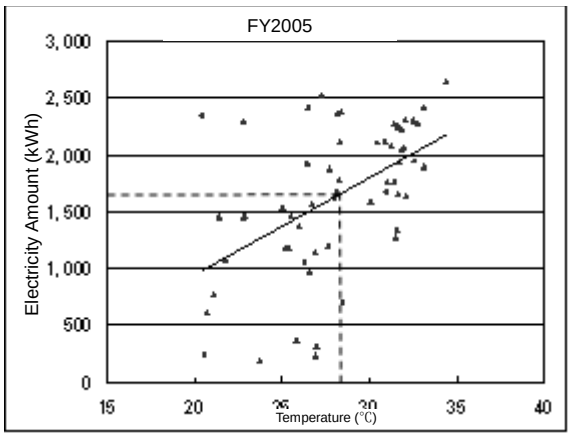
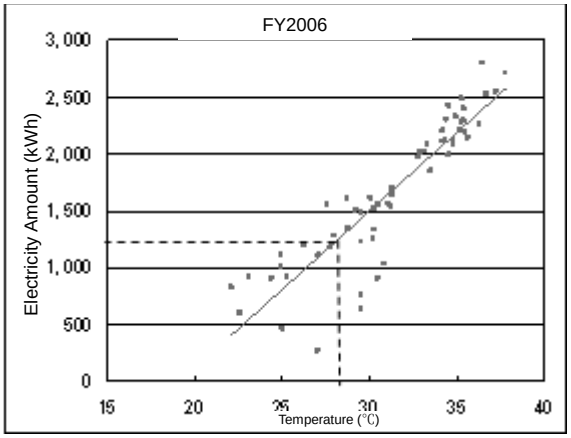


Fig. 6 Correlation Graph of FY2006



1) Development and operation of the demand controller interlocked with the control of the air conditioners

With the demand control then available, air conditioners had been simply stopped when over-demand was predicted.

As the new air conditioning system was introduced, we submitted a proposal that the power should be controlled in steps to the energy conservation equipment development division of this factory and made them develop and operatethe demand control which could interlock the controls of the demand and air conditioners.

Figure 7 shows the window of the demand controller in which the actual demand is predicted real-time and the energy conservation level signals (1 to 4) are output to the central controller. By interlocking these functions, it became possible to save the output in steps and implement the demand control without damaging the comfort of the work place.

Fig. 7 Demand Controller Window

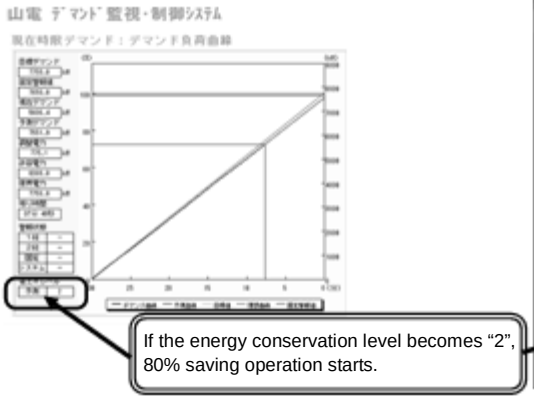


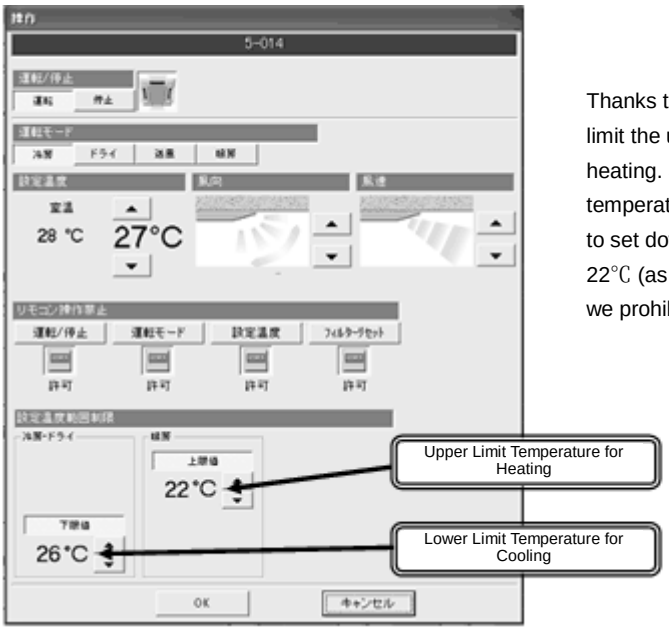
Fig. 8 Demand Control Setting Window of Central Controller

Figure 8 shows the demand control setting window of the central controller, where if the energy conservation level of Fig. 7 becomes “2”, 80% saving operation starts (step setting between 60% and 90% is possible), greatly enhancing the comfort of the work place is remarkably improved compared with the time when the air conditioners used to be simply stopped when over-demand was predicted.

However, when there were as many as 11 extremely hot days (exceeding 35□) in August, 2006, there were lots of complaints saying “air conditioning is not working!” and we were in trouble. But, we explained the circumstances to the employees and finally made them understand. It was a great achievement.

2) Prevention of over-cooling and over-heating by setting upper and lower limit temperature with handy remote controller

Fig. 9 Example of Window for Setting Upper and Lower Limit



Thanks to the remote control, it became possible to limit the upper and lower temperature for cooling and heating. So by making it not possible to set cooling temperature below 26℃ (as equipment it is possible to set down to 19℃) and heating temperature above 22℃ (as equipment it is possible to set up to 30℃), we prohibited over-cooling and over-heating.

3) Automatic ON/OFF by means of schedule management (to prevent employees from forgetting to turn off the air conditioners and to stop air conditioning when not necessary).

Fig. 10 Example of Schedule Management Window (Integrated Controller)

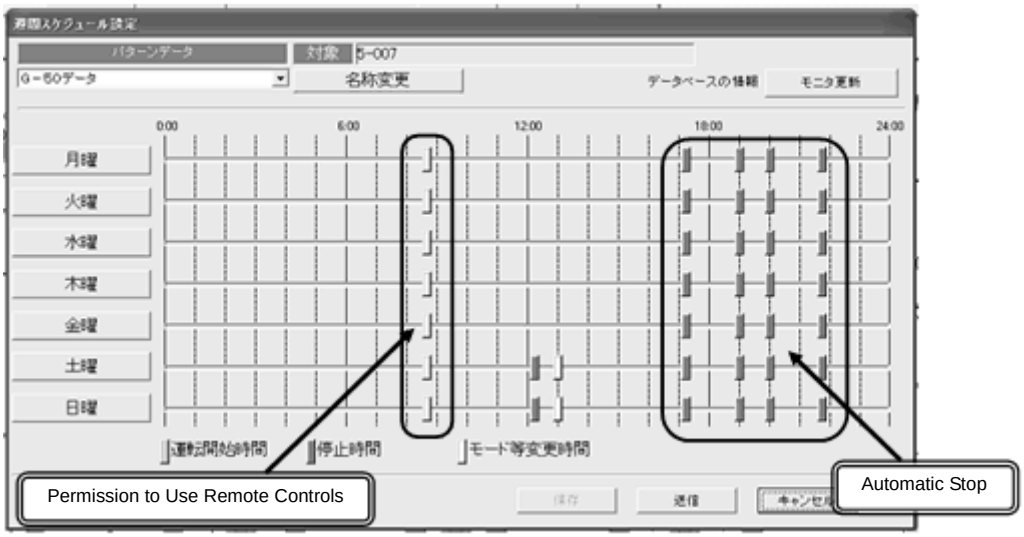


Figure 10 shows an example of a weekly schedule of air conditioners.

In this example, the remote controller and air conditioners cannot be started until there is permission for using the controller at the time of starting work.

Also, the air conditioners is automatically stopped at the time to finish work, finish overtime

work, every 1 hour after the work and the time to leave the company, to prevent employees from forgetting to turn off the air conditioners when they leave the company. At the same time, as all of the air conditioners on one floor are stopped all at once, only in the places where employees are doing over-time work, they can be turned on air conditioner by remote controller and the air conditioner for other places remains stopped.

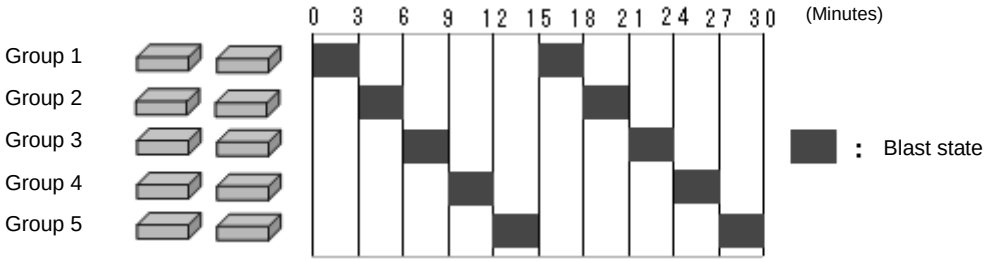
This control became possible because we installed the remote controller, based on the detail modification at the construction.

For this control too, there were complaints of employees saying “it’s not good because the air conditioning stops every 1 hour when we are doing overtime work”. But they gradually developed the energy conservation consciousness and finally started saying “it helps us remember to turn off”.

4) Automatic thinning operation by means of rotation control without damaging the comfort of the work place.

[Fig. 11 Example of rotation control]

(There are 5 groups of air conditioners in a block and they are controlled for energy conservation for 6 minutes)



The rotation control (thinning operation) is one of the features of the equipment controlled by this central controller, and it makes it possible to make the air conditioners on a floor stop or just send air for a few minutes which is set in advance. With this control, we could realize energy conservation without damaging the work place environment and without being noticed employees. This time, we did this by making 5 groups (each 2 air conditioners) just send air (If they are stopped, the employees might think that there is something wrong with the air conditioners) for 3 minutes in every 15 minutes.

This was very practical activity, because we could realize energy conservation without being noticed by employees and without complaints.

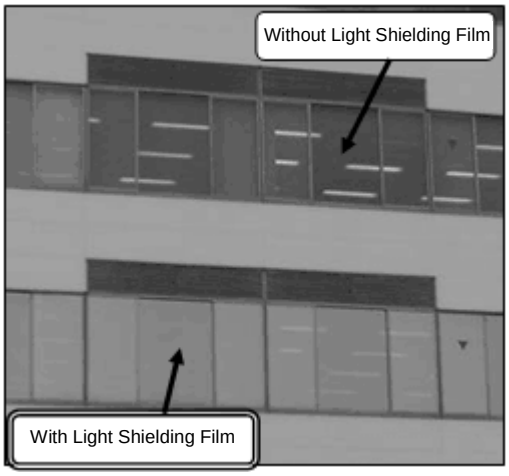
(2) Improvement of hardware aspect (Solving uneven work place temperature and improvement of air conditioning efficiency)

We mainly discussed operational improvements above, but there was a problem that the temperature of the work place in both office building and factory building became uneven due to the layout of windows, desks, doors, etc. even if the lower limit temperature was set same throughout the floor. Therefore, we improved the hardware aspect and solved the problem.

We also introduce in the later part of this presentation the improvement of hardware aspect to enhance the efficiency of the air conditioners which we implemented jointly with the work place people.

1) Lowering temperature of the area near the window by attaching light shielding films to window glass

[Fig. 12 Example of Light Shielding Films Attached to Office Building's Window Glass]



By attaching the light shielding film, the temperature of the area near the window was lowered by approx. 5℃ and the temperature of the area 2m away from the window was lowered by approx. 1.5 to 2℃ compared with that of the window without the light shielding film, thus solving the uneven temperature of the work places.

2) Thermal insulation by double layer roof of he factory building'

Fig. 13 Example of Double Layer Roofs of Factory Building

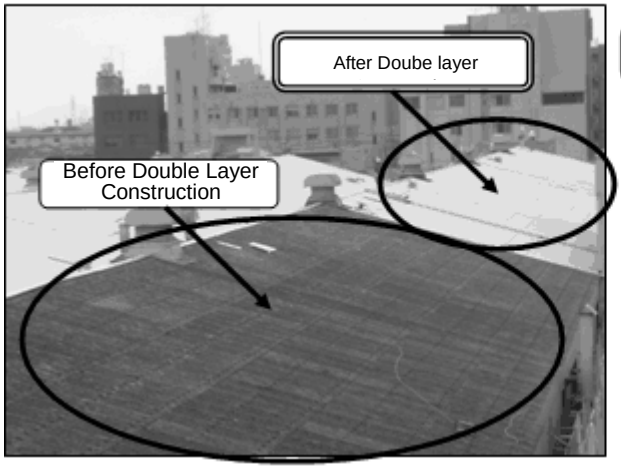
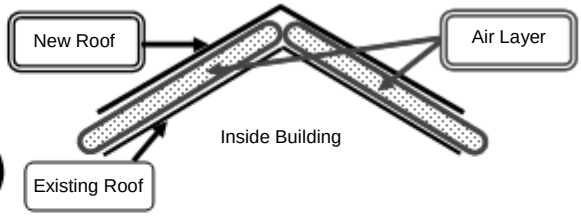


Fig. 14 Cross-section of Roof



By making a new roof on the existing roof, an air layer was made between them and heat transfer from the roof can be suppressed.

3) Other improvements of hardware aspect (Improvement of efficiency by thermal insulation of the main units of air conditioner)

We implemented the following various improvement activities jointly with work place people for the purpose of improving the efficiency of air conditioners, which include installation of screens named “Eco Yoshizu” (Fig. 15) for cutting the light and heat falling on the outdoor units of air conditioners and installation of curtains (Fig. 16) and aluminum plates (Fig. 17) behind the air inlets of indoor units of air conditioners for lowering the inlet temperature.

In any case, we made the improvement jointly with the work place people. It helped them develop the interest in energy conservation and it was an intangible effect.

Fig. 15 Eco Yoshizu

Fig. 16 Curtain behind Inlet Port

Fig. 17 Aluminum Plate behind Inlet Port

(3) Further improvement of cooling in the 2nd season (Lowering temperature by taking outside air in the morning before starting work)

As we were heading for the summer of 2007, the 2nd season of the cooling improved, we conducted a hearing research of problems from the work place people and we found as follows.

To reflect the voice saying “When I come to work and enter into the room, I feel hot”, we started taking outside air of low temperature into the building early in the morning (5 to 6 o’clock) using the outside air taking equipment. By doing this, the heat felt when coming into office was diminished, the starting time of air conditioners after starting work was delayed and the efficiency of the air conditioners was enhanced.

We calculated the effect using the correlation graphs of Fig. 18 and Fig. 19 and the regression equation. As a result, we could confirm that there was energy conservation of -20.8% compared with the average temperature (31℃) of 2006.

By similar activities just after the introduction, this could not have been achieved either if it had not been for the cooperation of the work place people. The awareness of the employees concerning energy conservation is for sure growing.

Fig. 18 Correlation Graph of FY2006

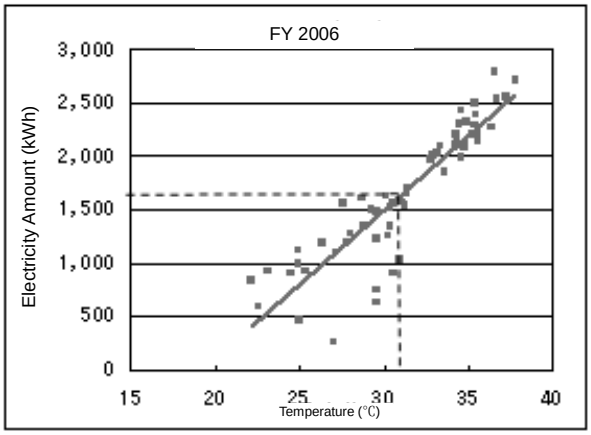
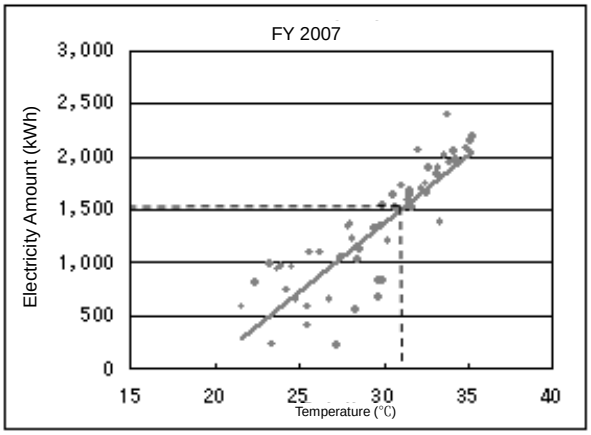


Fig. 19 Correlation Graph of FY2007



(Reference) Regression Equation of FY2007: Electricity Amount = 128.7 x Temperature – 2477.8 (kWh)

(4) Verification of cooling and heating

For the heating of the winter of FY2006, we verified the energy conservation effect using the same correlation graphs and regression equation as that we had used for the cooling in the summer.

We verified the office building which had renewed the air conditioners to high-efficiency type under the same electric conditions. As a result, we found that there was as much as -41.4% reduction of the air conditioning electricity used in a day as shown in Table 2, because the average temperature of 2006 was as much as 2.4℃ warmer than that of FY2005 before the introduction.

Even if compared with the daily average daytime temperature (6.9℃) of FY2005 without considering the warm winter, energy conservation effect as much as -25.2% was confirmed.

Table 2 Daily Air Conditioning Electricity Amount and Average Temperature of Daily Daytime Temperature of FY2005 and FY2006

Year	Daily Air Conditioning Electricity Amount	Average Temperature of Daily Daytime Temperature
FY2005	833 kWh	6.9℃
FY2006	488 kWh	9.3℃

Fig. 20 Correlation Graph of FY2005

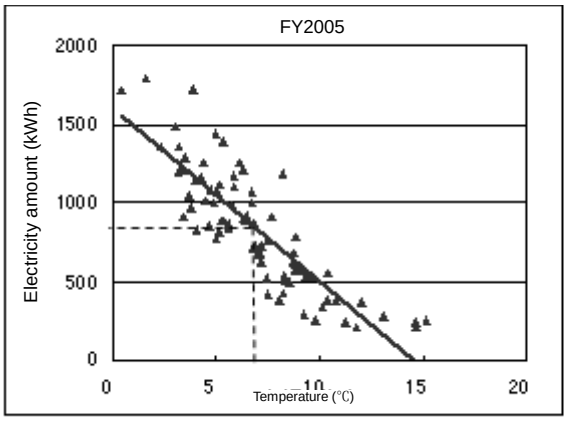
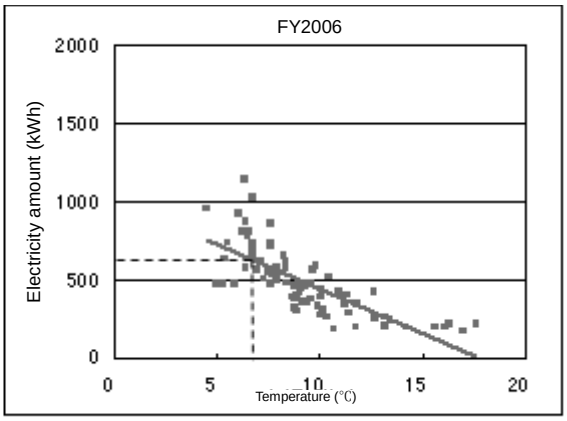


Fig. 21 Correlation Graph of FY2007



(Reference) Regression Equation of FY2006: Electricity Amount = -56.7 x Temperature + 1014.3 (kWh)

Meanwhile, as the air conditioning was renewed from the steam system to an electric system, the steam amount used, i.e. A heavy oil amount, was reduced by 353 kL from 1,006 kL (FY2005) to 653 kL (FY2006). This is equivalent to the reduction of 951 t-CO_2 emission. This is another great effect.

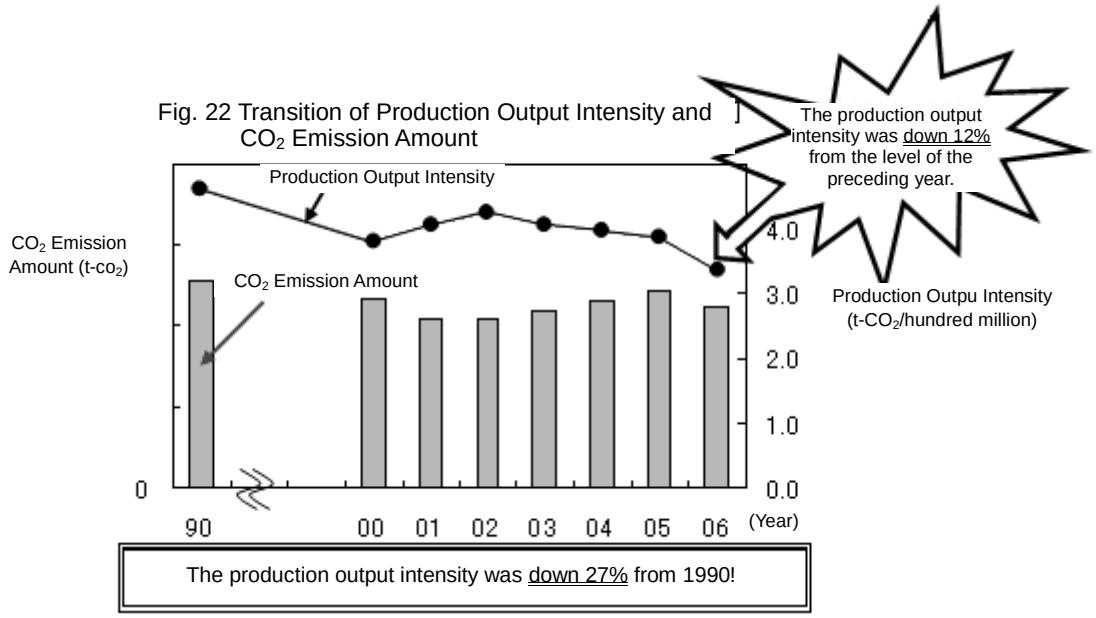
（Value of the factory as a whole）

3. Summary

Together with the renewal of air conditioners, we could develop and operate a new demand and air conditioning interlocking controller (using this work place as the location of the field test, it was made to be a product to sell) and reduce a great deal of electric power consumption by the air conditioners by improving both software aspect and hardware aspect including operational improvements. At the same time, the improvement activities implemented jointly with the work place people was useful for other the energy conservation activities, so we should continue them.

Meanwhile, the statistic technique with which we evaluated the energy conservation effect without being affected by the change of temperature before and after the improvement should be carried on to the next energy conservation activities.

By implementing improvement activities stated herein and other energy conservation activities, we could achieve the production output intensity of FY2006 which was -12% of FY2005.



4. Future Activities on Energy Conservation

In this case study, we focused on the reduction of the electric power consumption of air conditioning and we could realize certain effect, but, as the global warming is rapidly becoming intense, the electricity used for the air conditioning in the summer is sure to increase. So it is important to plan and implement the following measures and to proceed to further energy conservation as early as possible.

Although we renewed air conditioner's main units, next we have to introduce control equipment to air conditioners which are not controlled by remote control.

To review the schedule control.

To optimize the timing to take low temperature outside air early in the morning.

To improve the comfort of the work places by the saving operation interlocked with the demand controller, and to review the optimal contract electricity.

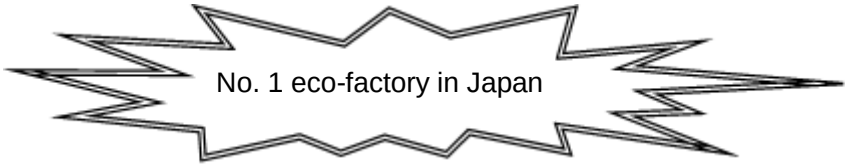
Besides the energy conservation of the air conditioning electricity, we will promote the following energy conservation.

To build and use an energy conservation model-line which is "visual" and "understandable".

Introduction of high-efficiency equipment.

Fuel conversion (to city gas).

We aim to be



By all coming together implementing these energy conservation activities.