2008 Prize of Director General of Agency for Natural Resources and Energy

Reduction of Electric Power Consumption in Special Air Conditioner through "Implementation of the Industry's First Linear Control of Outside Air Heat Load"

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Profit Creation Group, Manufacturing Planning Office,
Diesel Injection Manufacturing Department

◎ **Keywords: Improvement of control to match outside air heat load**

◎ Outline of Theme

In our Department, as many as 11 large-sized special air conditioning units are used in the ultra-high precision component processing and assembly rooms (constant temperature rooms). Accordingly, the air conditioning energy consumption was in a situation of accounting for as high as 27% of the total (Annual amount of ¥420 million). Making full use of know-how on our past air conditioner maintenance, we promoted activities under the "Special Air Conditioning Eco Plan 330" with the target of reducing the energy costs of the overall special air conditioning by 30% over three years. From among these activities we introduce the case of the "Linear Control of Outside Air Heat Load" which was the first industry's improvement with a great energy-saving effect.

◎ Implementation Period for the Said Example

- Project Planning Period: April 2004 – June 2004
- Measures Implementation Period: July 2004 – June 2007
- Measures Effect Confirmation Period: July 2007 – September 2007

◎ Outline of the Business Establishment

- Production Items: Fuel Injection Products (Diesel fuel Injection and Gasoline Injection) and Heat Exchange Products
- No. of Employees: 7,000 persons (As of April 1, 2006)
- Type 1 designated energy management factory

◎ Overview of Target Facilities

An overview of the nozzle room special air conditioner, which is the target equipment of this case is as follows: There are two large rooms, the Grinding and Assembly Rooms, that are equipped with the air conditioners to control the temperature and humidity in the rooms utilizing the functions of “Cooling”, “Heating”, and “Humidification” . These air conditioners are extremely important facility for the production of ultra-precise components. The feature of the facility is that it is an air conditioning system that takes in 100% outside air and an large sized air conditioners which consume an energy equivalent to the amount of ¥78 million annually. (Fig. 1)

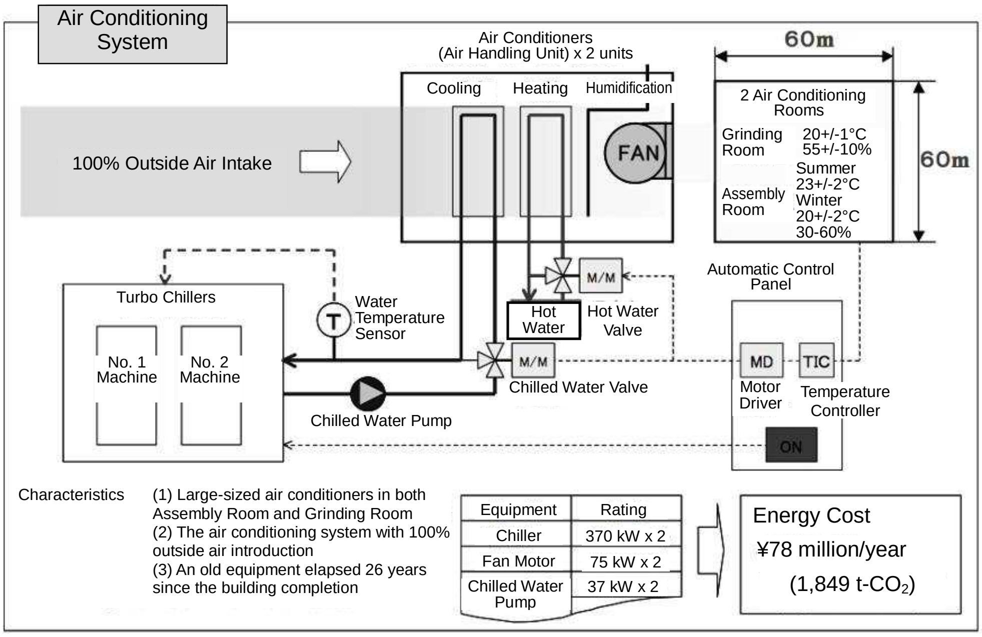

Fig. 1 Nozzle Special Air Conditioner Features

1. Reasons for Theme Selection

(1) Background of Activities

The “DENSO ECO VISION 2005”, the company’s environmental policy, has a major target of a 10% reduction in the company’s CO_2 emission by 2010 compared to that in 1990, and the whole company is striving to realize this target. In our department, in response to the target we established the Profit Creation Group as a group implementing energy consumption reduction activity linked with CO_2 reductions.

As a part of this activity, the previous Air Conditioning Maintenance Team has combined with an Energy Conservation Team. In addition to the previously conducted activities, the promotion of energy conservation activities was also started in fiscal year 2004 by making full use of the high technical skills of the members such as previously acquired know-how on air conditioning and special grade technical skills proficiency. (Fig. 2)

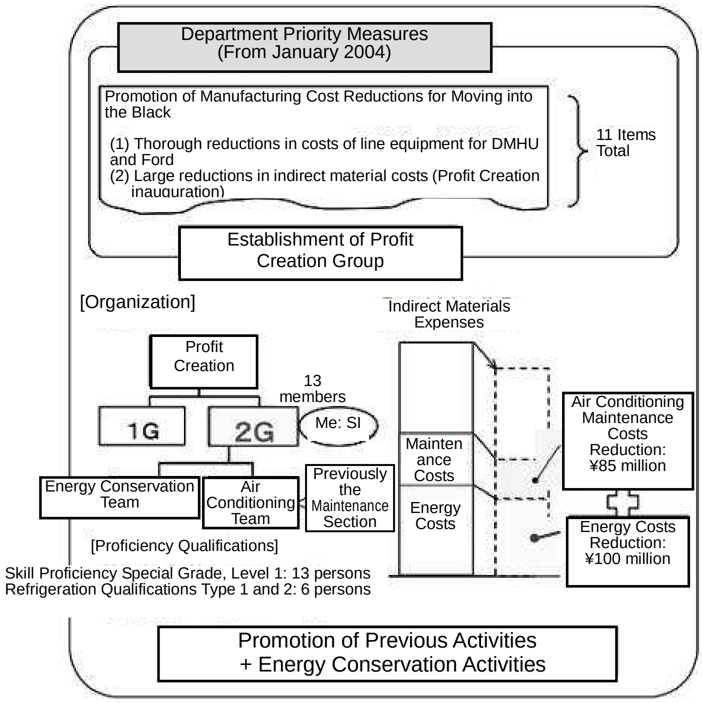

Fig. 2 Background to Activities

(2) Understanding of Current Situation

When looking at the energy consumption for fiscal year 2004, it was found that electric power accounted for 80% of the total, and out of this amount 27% was used by the air conditioning equipment, which was higher than the company average. Looking further into the details, owing to the situation where the number of special air conditioners owned by the department was the largest in the whole company, we found that the energy cost of the special air conditioners was extremely high, accounting for 52% of the total.

When we reviewed the air conditioning energy conservation activities that had been carried out previously, although as much as 25% reduction effect has been realized in general air conditioners through the measures including conversion to inverter control, for special air conditioners there was a situation where any measures had almost not been implemented because the previous Energy Conservation Team did not have any know-how on air conditioning. Accordingly, this time we decided to strive to realize energy conservation in the special air conditioners by concentrating all our efforts. (Fig. 3)

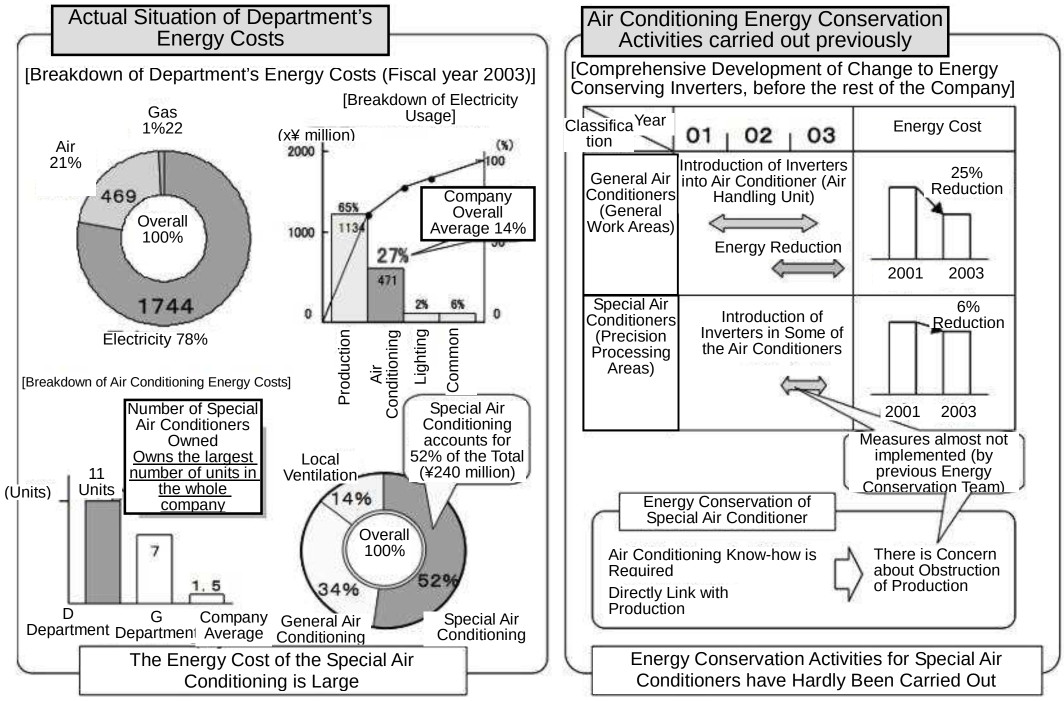

Fig. 3 Understanding of Current Situation

(3) Theme Selection

In the department, as many as 11 special air conditioner units were owned in four plants. When comparing the energy cost for each of these air conditioners, it was found that the nozzle room air conditioner was the highest in its energy cost. In addition, from the viewpoint of energy efficiency, that of the nozzle room air conditioner was also found to be poor when comparing the energy cost per air conditioned room volume. Hence, the ratio of air conditioning energy in the No. 405 Plant was the highest, and this was also contributing factor of worsening of the energy intensities in the summertime. From the above two points, the theme this time was proposed as "Electric Power Reduction of the Nozzle Room Special Air Conditioner", and activities were carried out. (Fig. 4)

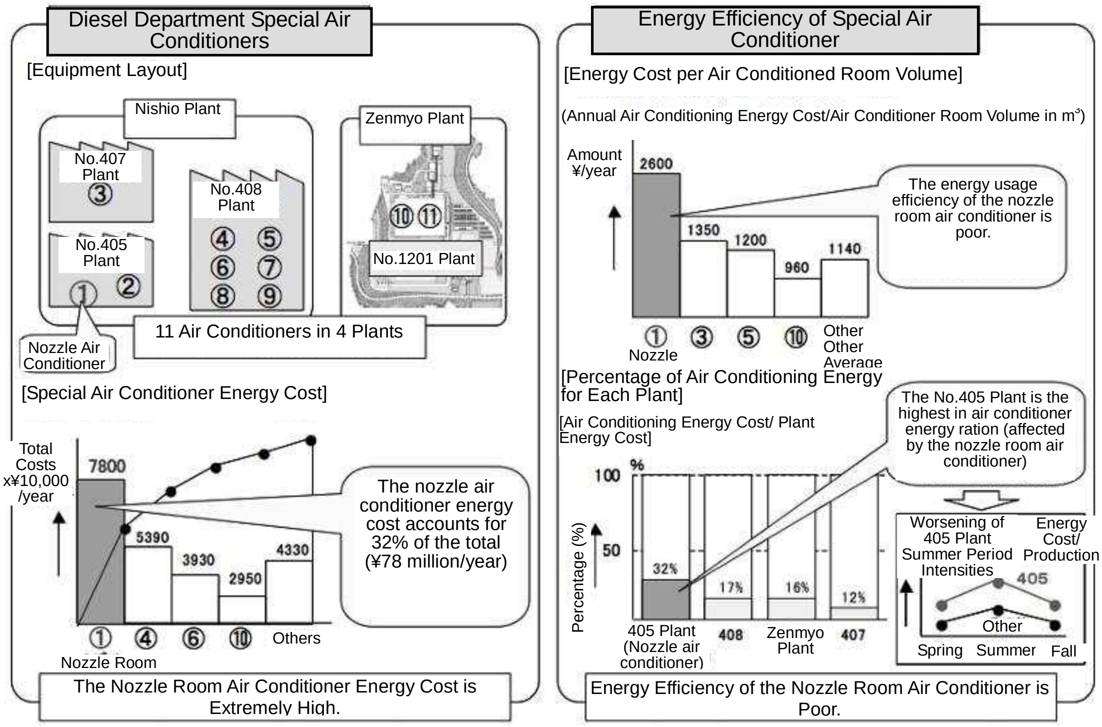

Fig. 4 Theme Selection

2. Methodology of Implementing Activities

(1) Identification of Perspective on Energy Conservation

As a result of investigating the causes for the worsening of the energy efficiency of the nozzle room air conditioning, the first factor identified was the air conditioning system that uses 100% outside air.

Although more than half the air conditioning load in air cooling is taken up by outside air heat load for cooling the outside air generally, the air cooling load was further increased because 100% outside air is introduced in case of the nozzle room.

The second factor was the deterioration of the equipment. The nozzle room air conditioner was the oldest one and only this equipment has been used for more than 25 years, resulting in worsening of efficiency due to deterioration.

Additionally, the third factor was the extremely low implementation rate of 16% in actual improvement activities for the nozzle room air conditioner compared to that for general air conditioner as far as the conversion to inverter control is concerned. In addition, the frequency setting was also incorrect, so that the reduction rate in energy use was also poor. For the above reasons, it was judged that great reductions could certainly be achieved by developing energy conservation activities with regard to these three perspectives of “Reduction of outside air heat load”, “Replacement of air conditioning equipment with energy conservation type equipment”, together with “Increased level of improvement and full expansion”. (Fig. 5)

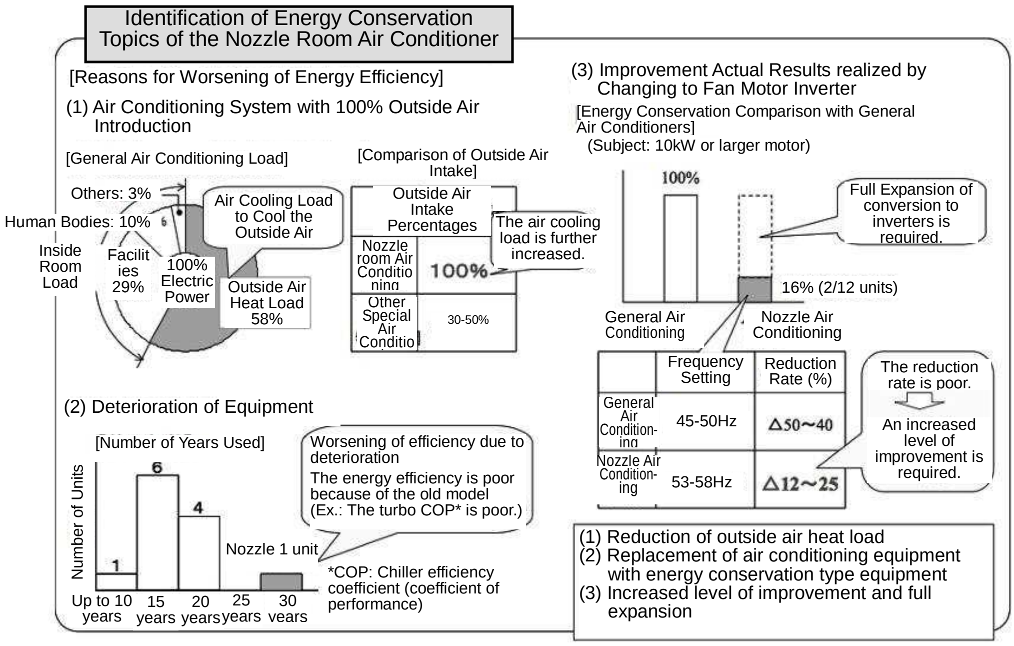

Fig. 5 Identification of Topics for Energy Conservation

(2) Schedule of Implementing Activities

Planning for the nozzle room air conditioning improvement and the overall scheme were made. For the nozzle room air conditioning, the proposed improvements materialized based on the above mentioned three perspectives were implemented to the schedule shown in the figure. It was our strategy to first undertake implementation activity in the nozzle room air conditioning which was the lowest in efficiency, followed by a full expansion to the remaining 10 special air conditioners after its successful completion.

Following this, we decided to develop activities named as the “Diesel Special Air Conditioning Eco Plan 330” with a large target of achieving a 30% reduction in the special air conditioning overall energy cost over a 3-year period.

Among these activities, we, hereinafter, give an explanation of the improvement case relating to the “Reduction of outside air heat load” which was the most effective in energy conservation effect. (Fig. 6)

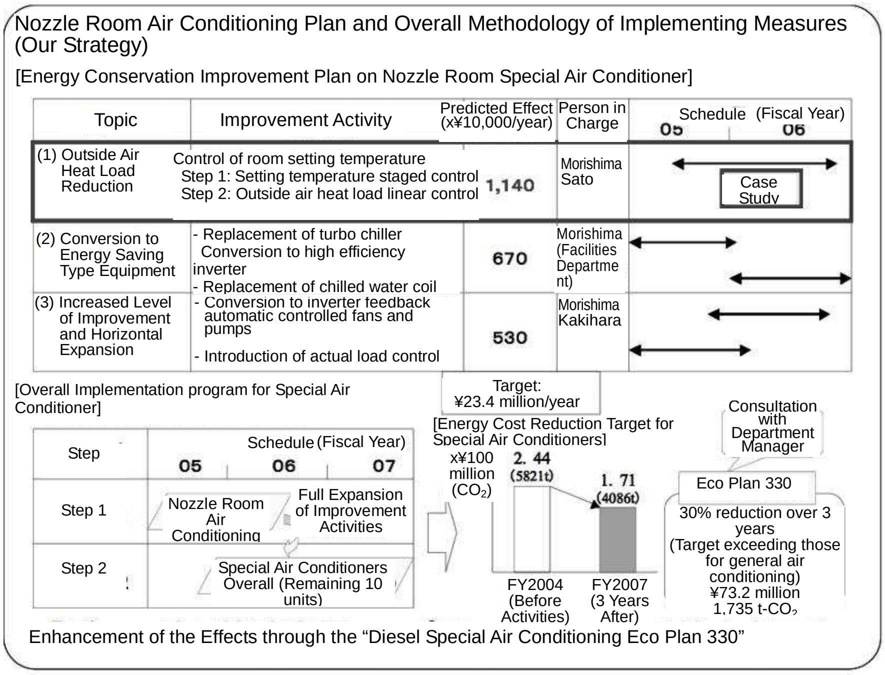

Fig. 6 Schedule of Implementing Activities

3. Reduction of Outside Air Heat Load

(1) Investigation of Proposed Measures

Firstly, as a proposed measure to reduce the outside air heat load, an investigation was carried out among the related departments, and three proposals were made as predicted.

According to the Facilities Department and the air conditioner manufacturer, the nozzle room was equipped with an old type air conditioner in which energy conservation measure had not been incorporated. Accordingly, although improvement proposals, which consist of introduction of the internal air circulating systems and total heat exchangers that are employed in recent air conditioners, gave us anticipation, the estimated cost and the pay back period for both proposals were much higher than expected, and the activities were turned out not to be implemented this time. (Fig. 7, Left-hand Side)

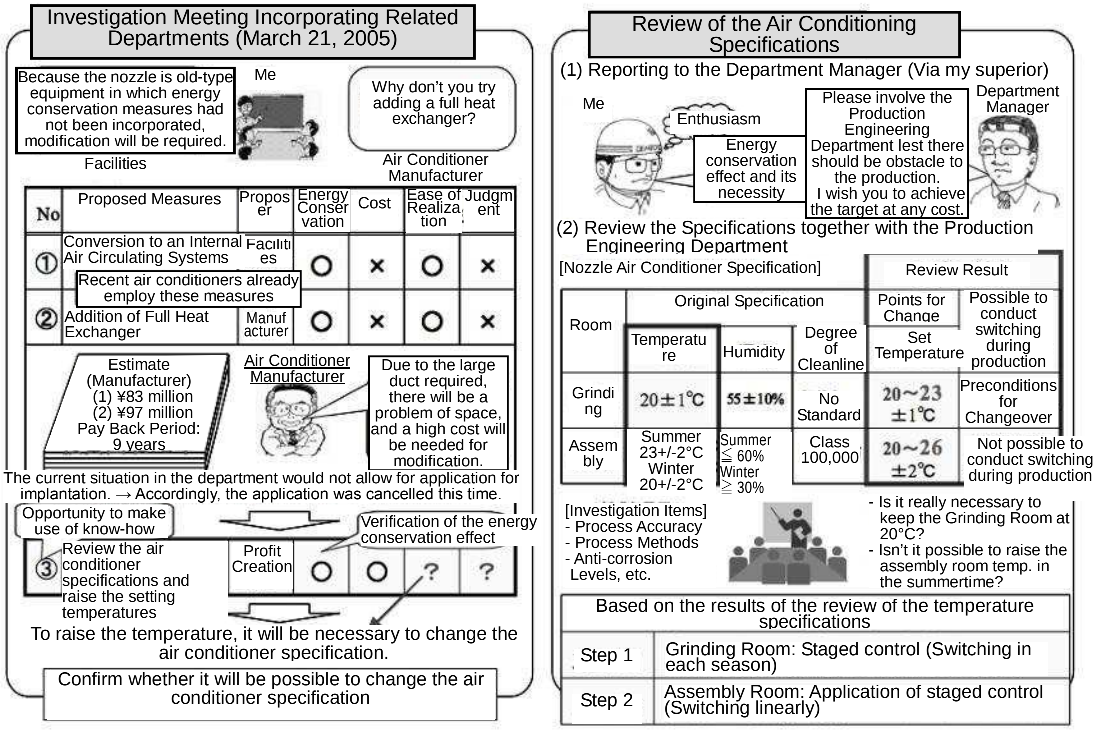

Fig. 7 Proposed Measures Investigation

Under such situation, it was decided that the team would proceed with the implementation of our proposal, “Review the air conditioning specification and raise the set temperature”, and to verify the effect using the air diagram shown below. An air diagram shows the relationship between the temperature and humidity in the air. The diagonal lines represent the enthalpy, the key factor of the measures implemented this time, that is, the energy held by the air. From this perspective, the existing energy condition is as follows:

Outside air temperature at 33℃ is cooled, first the temperature changes, then through further cooling progresses the moisture in the air condenses, dehumidification takes place, and this result in the change in the humidity. This cooling energy is directly linked with enthalpy, that is to say, with the chiller electricity cost. The important point in this process is that the energy for dehumidification was found to be three times higher than that for temperature change. Accordingly, the confirmation of the effects of the proposed measures to be implemented this time indicates that, if for example the temperature inside the room is raised by 3 degrees, the energy conservation as shown on the air diagrams on the right hand-hand side in the figure could be achieved. Its effect was estimated that an average reduction of 30% would be possible in summertime like general “Cool Business” activities. In other words, it was found that if the proposed measures could be successfully implemented it would be possible to achieve substantial energy conservation. (Fig. 8)

However, because a modification to the air conditioning specifications will be required in order to raise the set temperature, we immediately carried out a review of the specifications together with the Production Engineering Department under the approval of the department manager. As a result of an investigation of each item including the processing accuracy, agreement was reached to raise the set temperatures to the targeted level subject to certain constraints in the changeover of the temperature setting in both the Grinding Room and the Assembly Room. As an activity tackled based on the result of the review, we, hereinafter, give an explanation of the case for staged control of the Grinding Room carried out as Step 1, and that for the practical application of this control in the Assembly Room as Step 2. (Fig. 7, Right-hand Side)

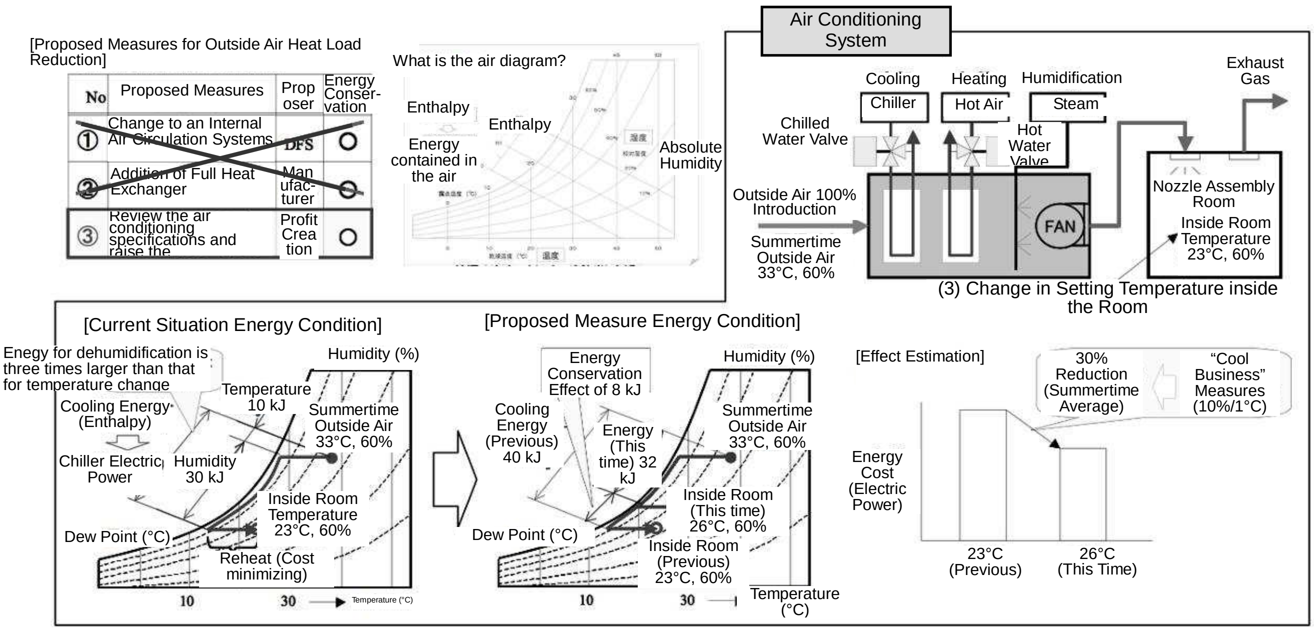

Fig. 8 Check of Proposed Measures

First, the staged control shown as Step 1refers to the control in which the set temperature is changed stepwise according to the outside air temperature in each season, while that has previously been kept fixed regardless of the outside air temperature. Thus, the air cooling load of the area portion shown in the figure will be reduced, and energy conservation will be achieved as a result. Further, because changeover of temperature setting is absolutely impossible during production time in the Grinding Room, product quality confirmation rules during the changeover were established. As a result, the measures introduced to the air conditioner in the Nozzle Grinding Room and expanded to the two other units were all implemented by in-house work only, so that a large effect was able to be produced with a small investment. (Fig. 9)

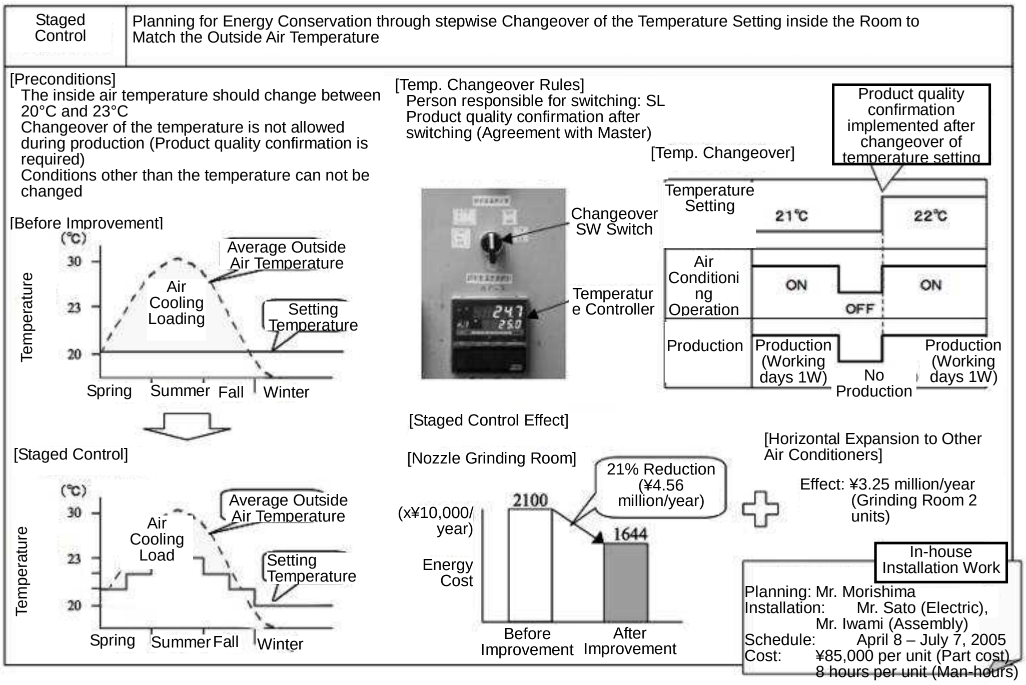

Fig. 9 Staged Control

Next, as a case of applying this staged control to the Assembly Room, it has been already understood there would be a certain effect, if staged control is similarly implemented. However, it was found that the temperature differences between daytime and nighttime were large as shown in the figure, and electric power had been wasted both in the air cooling and heating, when the daily energy conditions during the intermediate periods such as spring and fall were investigated in more detail,.

Accordingly, although in Step 1 limitations were placed on the changeover of temperature setting in the Grinding Room so that the measure shown below could not be applicable, it was possible to implement such measure in the Assembly Room. We, therefore, thought of setting the temperature linearly according to the daily changes in the outside air temperature to achieve even further energy conservation than staged control, and made an investigation into the actual control method. (Fig. 10)

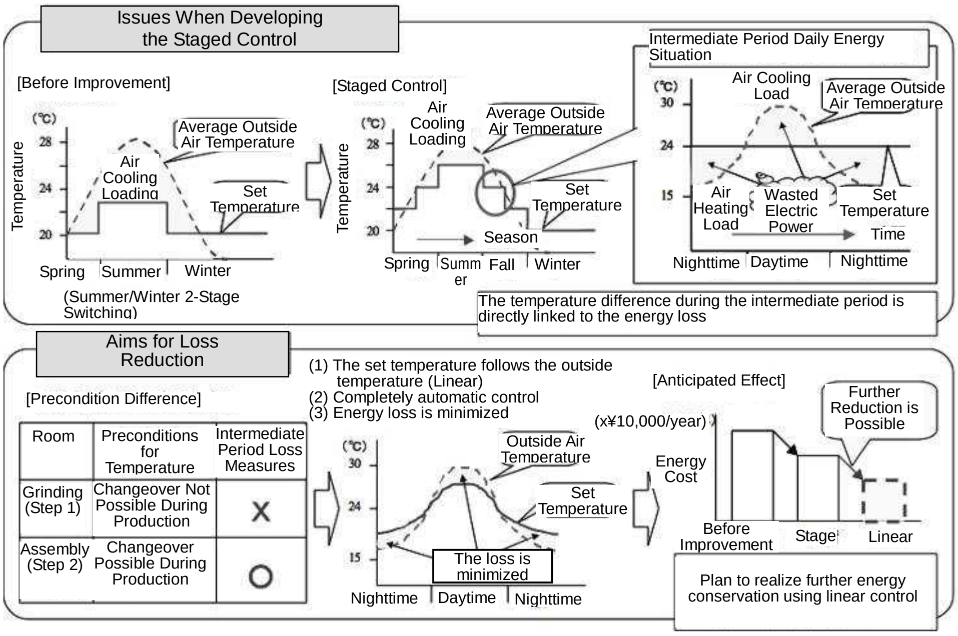

Fig. 10 Development in the Assembly Room

While the team was carrying out its investigations, the electrical expert Mr. A proposed proportional control. In this control, the set temperature of 20-26°C determined through the specification review is proportionally changed depending on the outside air temperature as shown in the figure to implement control that minimizes the losses. However, as explained previously, because three times as much as energy is required for dehumidification than for the temperature change, it was judged that selection of standard should be made taking not only the temperature but also the humidity into consideration. Accordingly, further investigation was made based on a simulation for all seasons to determine the selection method. (Fig. 11)

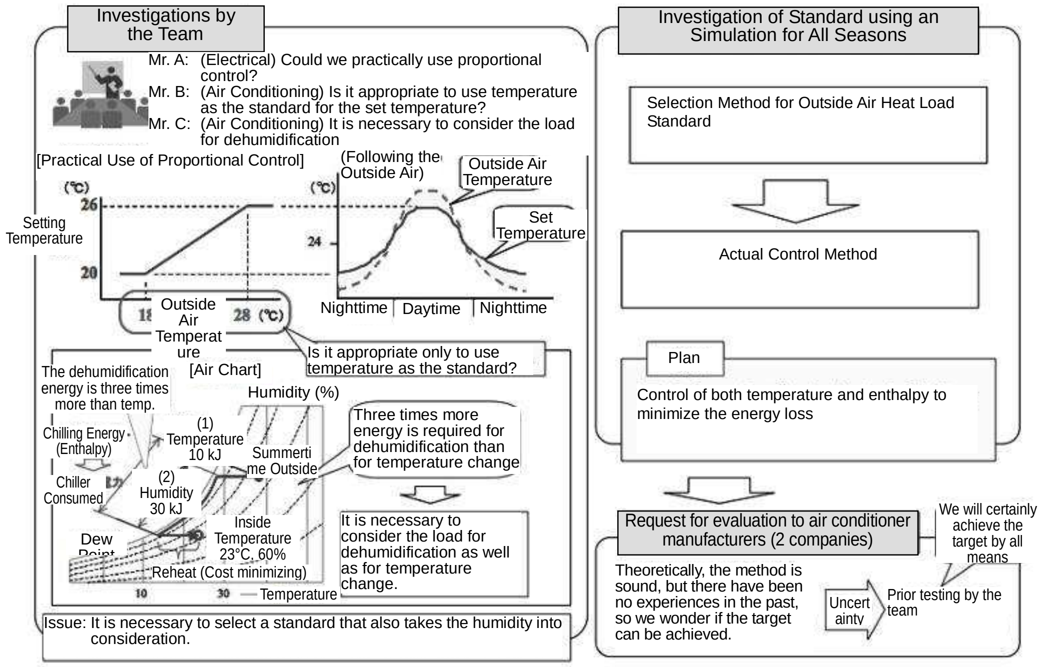

Fig. 11 Proposed Measure Investigation

The method used is to utilize the air diagram and the annual outside air temperature and humidity are plotted on the diagram as shown in the figure, together with the inside room conditions as the target value.

Next, we selected the 4 standards relating to humidity as the investigation item. For example, the enthalpy, one of 4 standards, is shown as diagonal lines in the figure.

Finaly,out of 4 standards, the standard that minimizes the amount of energy required throughout the year was selected. (Fig. 12)

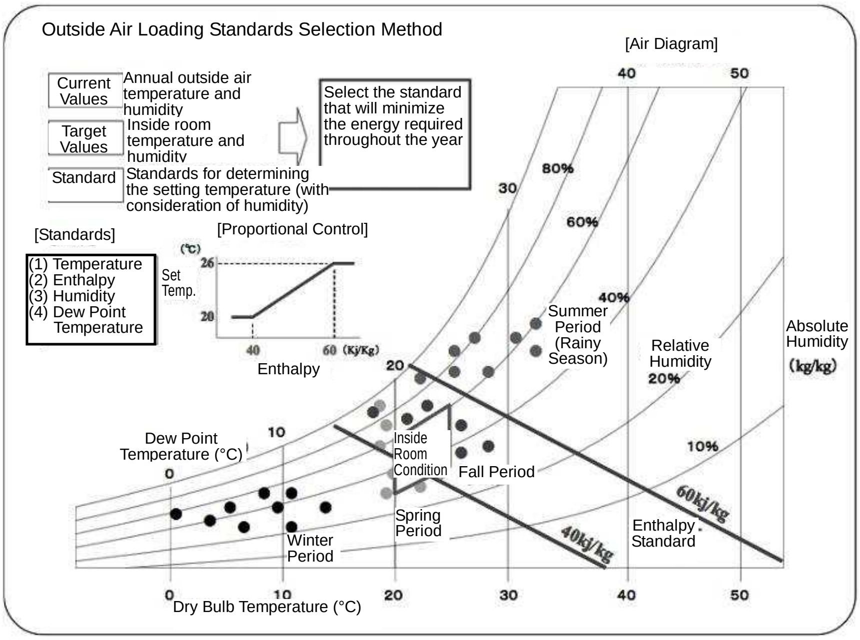

Fig. 12 Simulation Investigation (1)

As a result, for example, in the Zone A representing the condition in the Japan's rainy season, when the temperature is low but the humidity is high, in case of temperature standard the temperature will be set at 22.5℃ for the outside air temperature of 22℃, and reqiured energy is 20 kJ. However, in case of the enthalpy standard, as the set temperature can be increased to 26℃, only a half of the energy would be required compared to temperature standard, so that in Zone A the enthalpy standard should be selected. (Fig. 13)

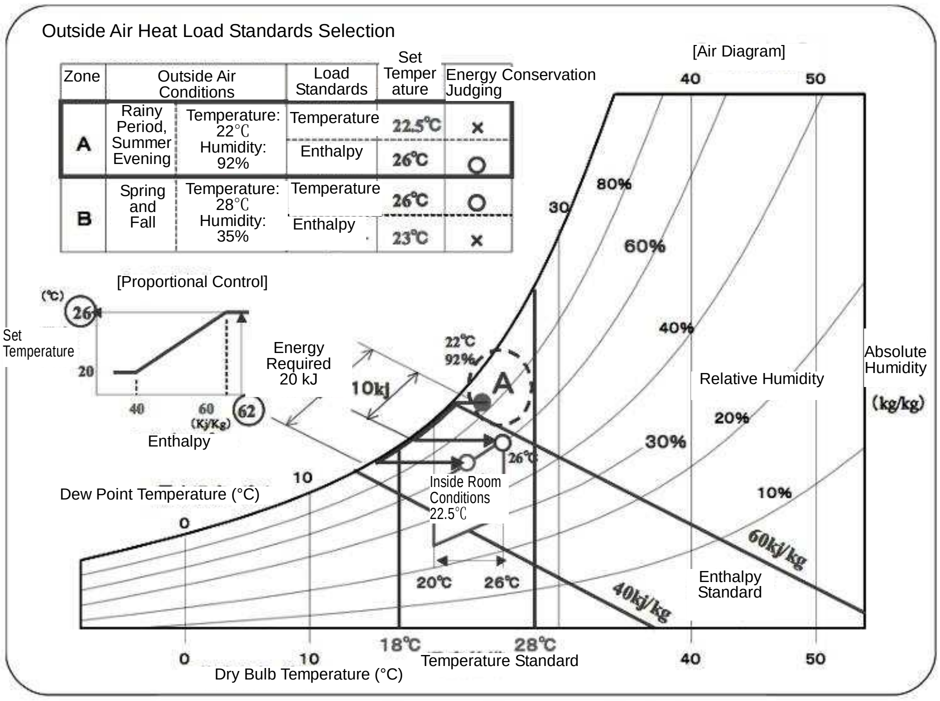

Fig. 13 Simulation Investigation (2)

However, in the Zone B, condition in spring and fall period, when humidity is low, in case of the temperature standard the required energy will be 4 kJ, which is half of 8 kJ for the case of the enthalpy standard, and hence the temperature standard should be selected instead of the enthalpy standard selected for Zone A. (Fig. 14)

From the annual evaluation results as above, using the 2 standards of the outside air temperature and the enthalpy, we have devised the control method that minimizes the energy loss by selecting the higher set temperature. (Fig. 15)

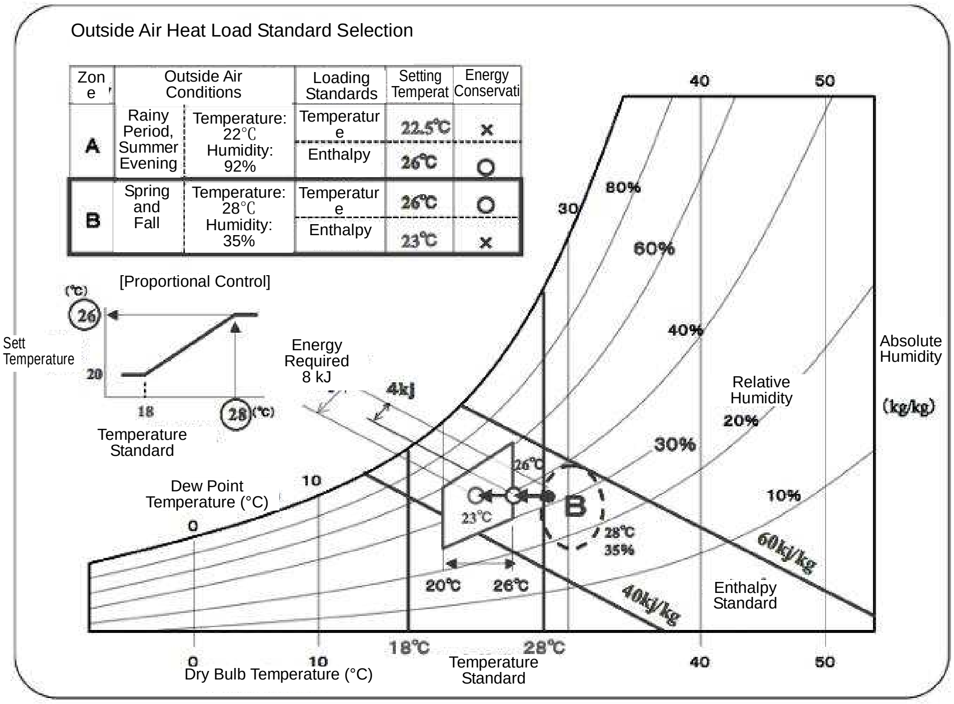

Fig. 14 Simulation Investigation (3)

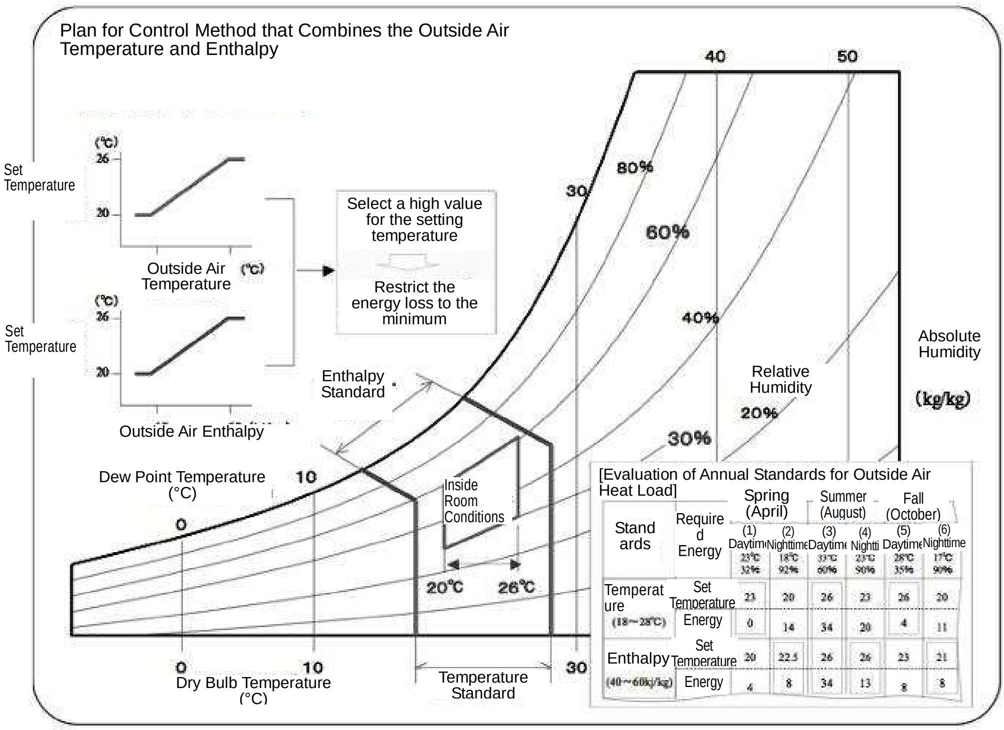

Fig. 15 Simulation Investigation (4)

Accordingly, we immediately approached the air conditioner manufacturers for their advice on our idea. They expressed a concern about whether it would work well or not because there were no precedents in the past, although theoretically there was no problem. Since we had strong desire that we should achieve the target by all means, we decided to carry out verification through prior testing.

The content of the test was to configure the test system based on the team's know-how, and to verify two items shown in the figure based on the data obtained.

As a result, for example, when the outside air conditions as input are 23℃ and 90%, both the enthalpy calculation and the set temperature as the control outputs went in accordance with theory and the judging was "OK". Thus, we could obtain the verification data as we had predicted. Based on these data, we promptly contact the manufacturers again for confirmation, and after they had expressed their agreement, we started implementing the measures with full confidence. (Fig. 16)

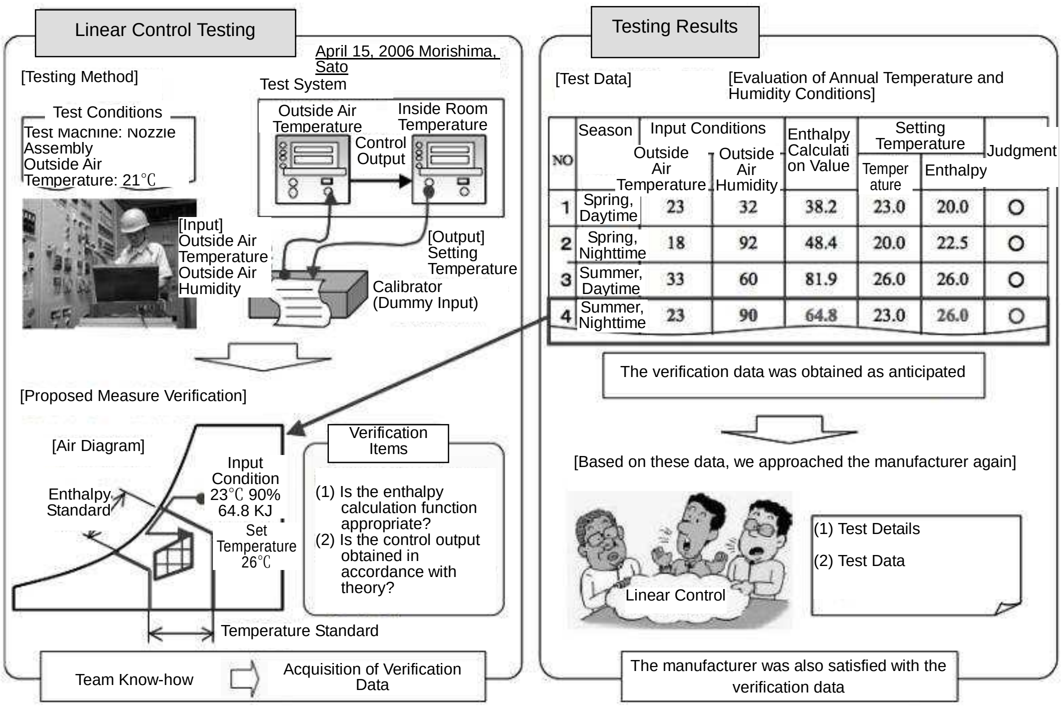

Fig. 16 Prior Testing

The measures were implemented as shown in the figure based on the modification drawing we had prepared. We were able to reduce the energy loss during the intermediate period to a minimum as shown, and as a result achieved a reduction in energy by 38% for the Nozzle Room, which was larger than predicted. In the horizontal expansion to the further six air conditioning units, we could achieve a great result totaled ¥32.92 million.

Further, since all of the improvements realized in this case were successfully implemented through in-house work, we received praise from the air conditioner manufacturer for this epoch-making improvement in energy conservation, the like of which they had never seen before, and we could complete the industry’s first “Linear Control of Outside Air Heat Load” system. (Fig. 17)

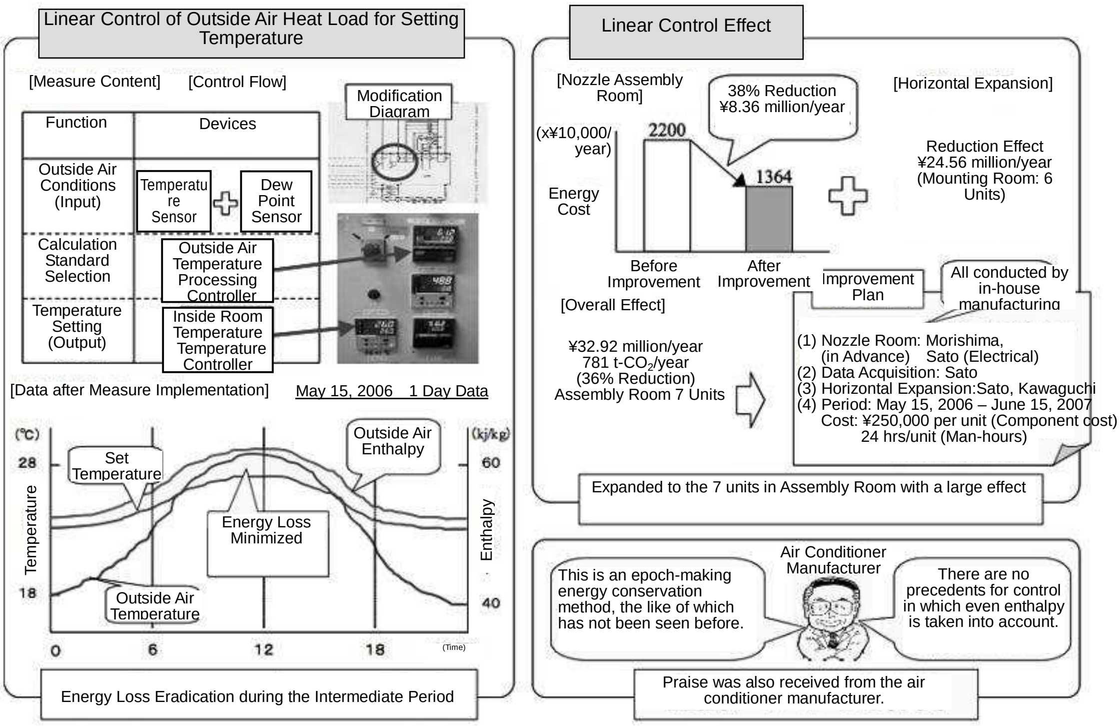

Fig. 17 Measure Implementation

The effects the Eco Plan 330 are summarized as follows:

Almost all the work in this case was carried out by in-house work, three patents were applied for, and the outstanding annual economic effects of more than ¥90 million were achieved through the modification of a total of 59 units.

As a result, we could fully achieve the Eco Plan targets including reductions in CO_2 emission. (Fig. 18)

Finally, as the overall effects of the Eco Plan, the energy conservation targets of the Profit Creation Group 2 were achieved for three consecutive years. In addition, CO_2 emission intensity was also reduced by 14% and is on an improving trend.

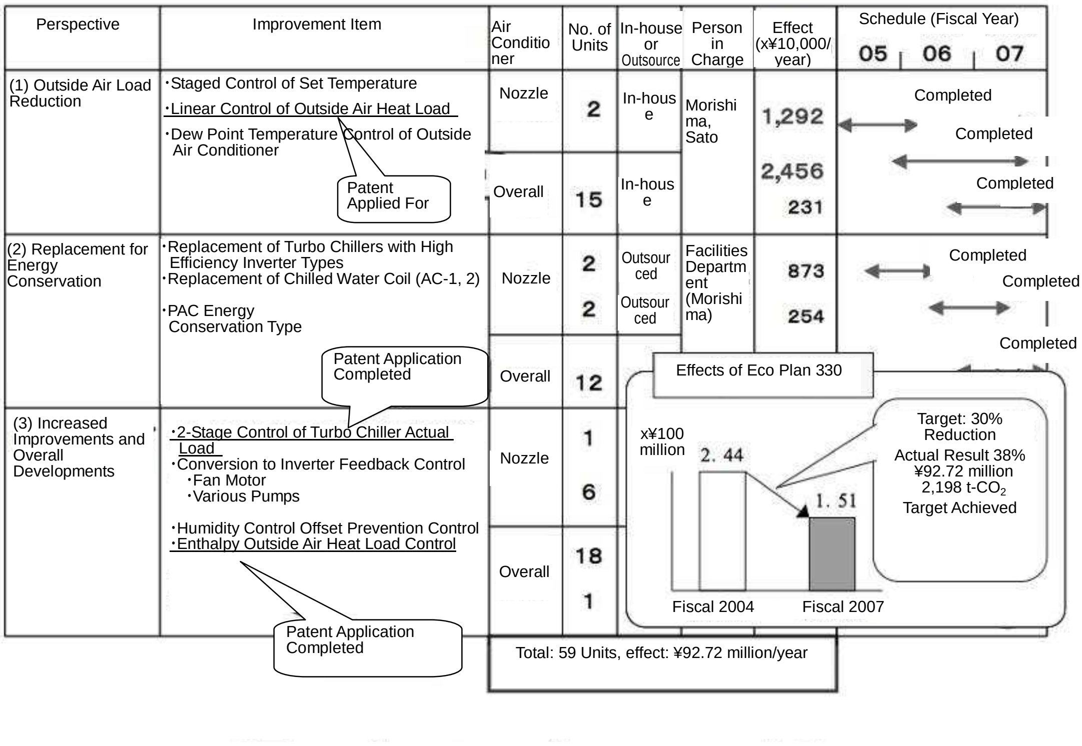

Fig. 18 Eco Plan 330 Actual Results

Looking back on the activities in this case, we could further improve our team's level by making good use of our strengths in air conditioning know-how to realize a high level of energy conservation improvement.

As the methods of proceeding with activities in the future, we are thinking of summarizing the improvement details in this case into an Energy Conservation Specification Sheet, which is to be provided to the Facilities Department, and from there it is to be transmitted to the entire company. We are thinking of aiming to play a leading role regarding energy conservation in air conditioning inside the whole company all the time. (Fig. 19)

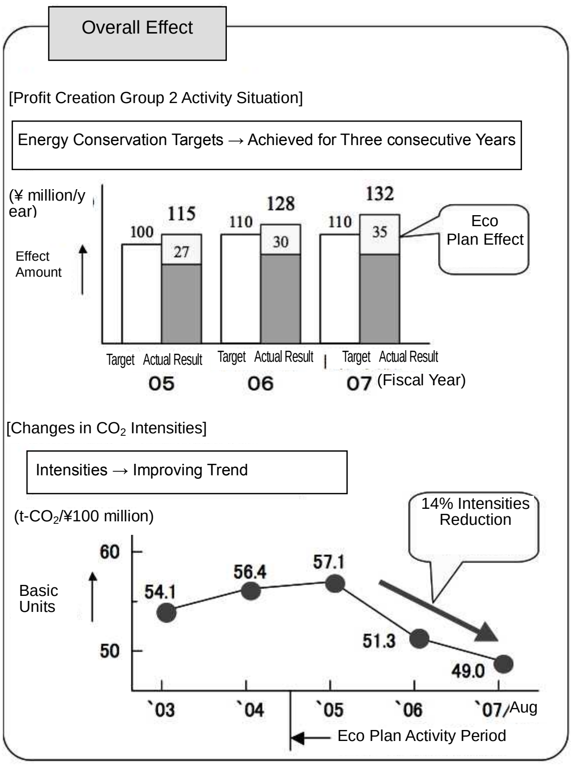

Fig. 19 Overall Effects