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Energy Conservation for Steam Loads at Semiconductor Manufacturing Plant

Toshiba Corporation
Oita Factory, Semiconductor Company
Facility Management Section, Facility Management Department

◎ **Keywords: Rationalization of fuel combustion
Recovery of exhaust heat for use**

◎ Outline of Theme

This is the company's major factory for semiconductors. The manufacturing process of semiconductor products consumes large amounts of energy. Furthermore, a large quantity of steam is used for the air conditioning of clean rooms and the heating of purified water for cleaning the wafers at the semiconductor manufacturing plant. The focus was on reducing this steam load and the conservation of energy for producing steam was sought by changing the air conditioning and humidifying method, as well as by recovering and reusing the heat exhausted from the manufacturing equipment to heat purified water.

◎ Implementation Period for the said Example

- Period for formulation of plan: April 2005 through July 2005 Total of 4 months
- Period for implementation of strategies:
  October 2005 through November 2005 Total of 2 months
- Period for verification of strategies:
  December 2005 through April 2006 Total of 5 months

◎ Outline of the Business Establishment

- Description of business: Semiconductor integrated circuits
- Number of employee: 2,576 persons
- Annual energy consumption: Electric power: 595,092 MWh
  Utility supplied gas: 13,961 km^3

◎ Process Flow of Target Facility

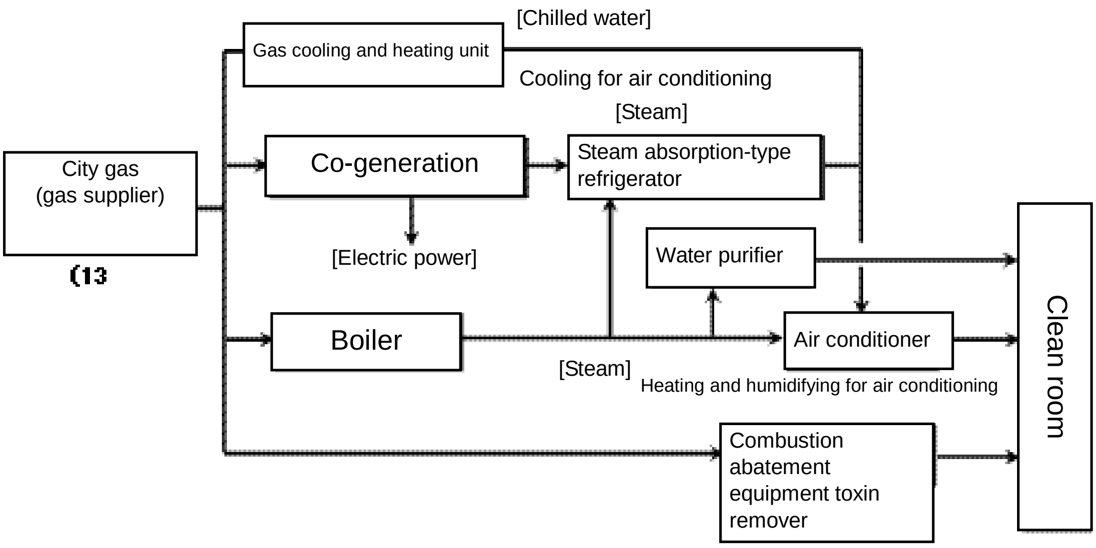

Figure 1: Heat energy flow diagram

1. Reasons for Theme Selection

This factory is a cutting-edge semiconductor manufacturing plant and uses large amounts of electric power and city gas as primary energy sources. A lot of consideration was given primarily to electric power, with a relatively high consumption ratio, as our target for reducing the energy in previous energy conservation activities. Since a reduction in fuel (heat energy) has become an urgent matter due to the impact of soaring crude oil prices in the recent past, energy conservation strategies were implemented for the purpose of reducing the total energy amount and energy costs, with steps considered to reduce the steam (utility gas) consumed by motive facilities, primarily air conditioning facilities, where a large amount of steam is used.

2. Understanding and Analysis of Current Situation

<Primary energy source investigation>

The manufacturing plant uses electric power and city gas as primary energy sources. The details are shown in Figure 2.

Electric power comprises 89% of consumption, whereas city gas accounts for 11%.

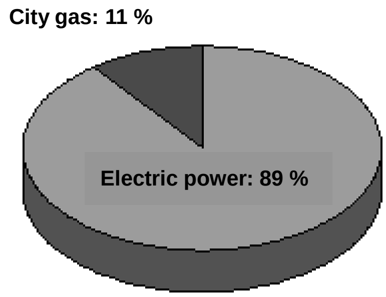

Figure 2: Primary energy consumption comparison by application

<City gas and heat load detailed investigation>

City gas is used as boiler fuel for generating steam and a gas absorption-type refrigerator used for producing chilled water, CGS, as well as a combustion abatement equipment, etc. The consumption ratio is dominated by the boiler, which uses 76% of the city gas. Figure 3: A breakdown of the steam generated by the boiler indicates its use in air conditioners for heating and humidifying, purified water for heating and degassing and a steam absorption-type refrigerator, etc. The air conditioning (heating and humidifying) uses 58% as the most, the water purifying (heating and degassing) uses 19% as followed. It was believed that by making improvements to these facilities, which consume large amounts of steam, an effective means could be found to deal with this issue. Figure 4:

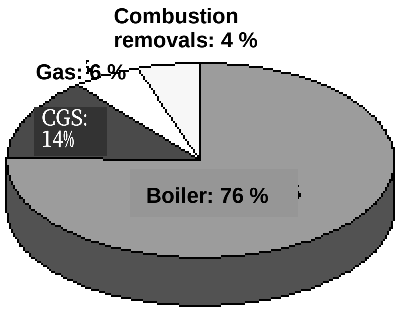

Figure 3: Breakdown of city gas consumption by application

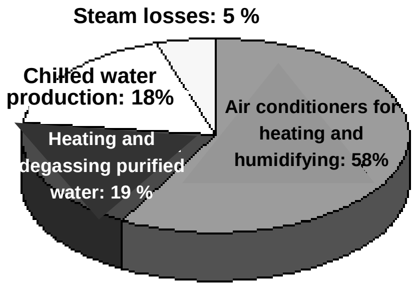

Figure 4: Breakdown of steam consumption by application

3. Progress of Activities

(1) Implementation Structure

The framework for implementing activities is primarily comprised of the Energy Conservation Promotion group that belongs to the Facility Management Section of the Facility Management Department of our company, to promote energy conservation activities for reducing steam energy.

(2) Target Settings

- Amount of conserved energy: 1,335 tons of carbon dioxide/year
- Cost reduction: JPY28,563,000 year (steam, through reduction of city gas)

The energy to be conserved was set to an amount equivalent to 1% of the energy consumption of the previous fiscal year (motive energy), which was the target for the environmental protection promotion plan for the factory.

(3) Problem Points and Their Investigation

Consideration was given to strategies for facilities with the largest energy consumption for conserving energy related to the steam load.

Improvements to three items were determined, as a result of the studies conducted on energy conservation based on the current amount of steam consumption.

[1] Reduce steam consumption by changing humidified air conditioning system

[2] Conserve energy used for water purifier 1 (expand recovery of exhaust heat from refrigerator)

[3] Conserve energy used for water purifier 2 (recover exhaust heat from manufacturing equipment)

4. Details of Measures

(1) Reduce Steam Consumption by Changing Humidified Air Conditioning System

1) Current status and Focal points for improvements (before improvements)

(a) Current status

External air conditioning units are used to supply external air to clean rooms. External air conditioning units take in a quantity of external air that corresponds to the amount of exhaust from clean rooms, and they remove dust with filters, cool/dehumidify/heat/reheat or humidify with coils and humidification by steam spray.

The humidification of external air conditioning units is performed with steam spray through injection from a steam spray humidifier using steam generated by the steam generator (boiler), which uses the city gas as fuel and is controlled using an automatic valve control to maintain the constant humidity inside the clean rooms (Figure 6).

(b) Focal points

A large quantity of exhaust emanates from the clean rooms at the semiconductor manufacturing plant, where a large quantity of external air is taken in. A significant amount of humidification is required for this purpose and a large quantity of city gas is used as fuel for the direct steam spray method. Furthermore, even larger quantities of steam are sprayed during extremely dry periods, for example during the winter season, and this is the source of the problem, as it causes filters to clog at the rear stages and causes dew condensation inside the air supply ducts, due to the impact of uneven humidification. To conserve energy and also provide a solution for such problems a change in the humidifying method was considered.

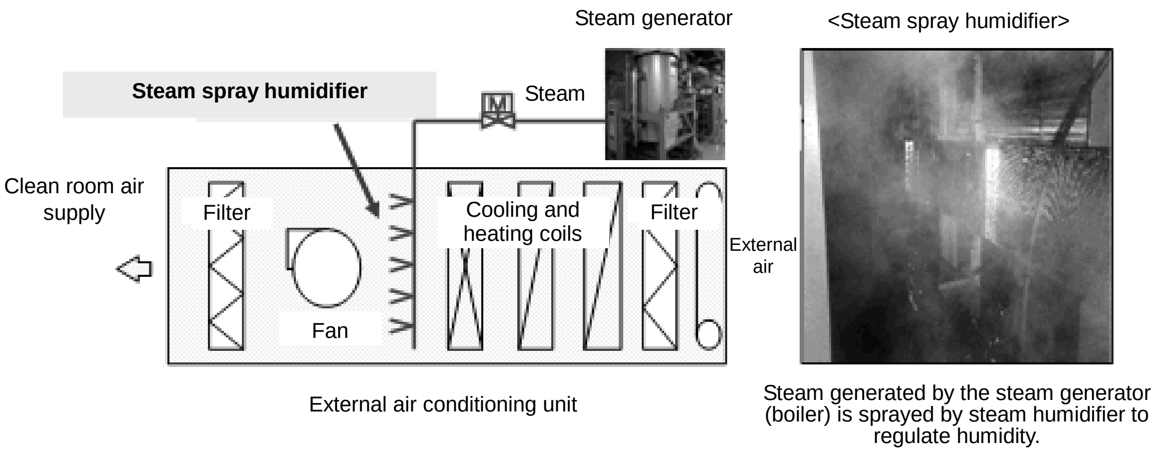

Figure 6: Air conditioner (external air conditioning unit) flow (before improvement)

2) Contents of Improvement (after improvements)

Steamless conditions were considered in order to change the humidifying method. As a result, it was discovered that two techniques ([1] a purified water dripping method using an air washer and [2] a purified water spraying method) were available. The advantages and disadvantages of these methods were considered and finally the purified water dripping method using an air washer was adopted (Figure 7 and Table 1).

A diagonally arranged ceramic honeycomb structure (water absorbing elements) is situated in the air washer, which is infiltrated with purified water and put into contact with dry external air. Moisture is evaporated by a sensible heat of the air and unlike the existing method, it uses absolutely no steam and results in the conservation of energy.

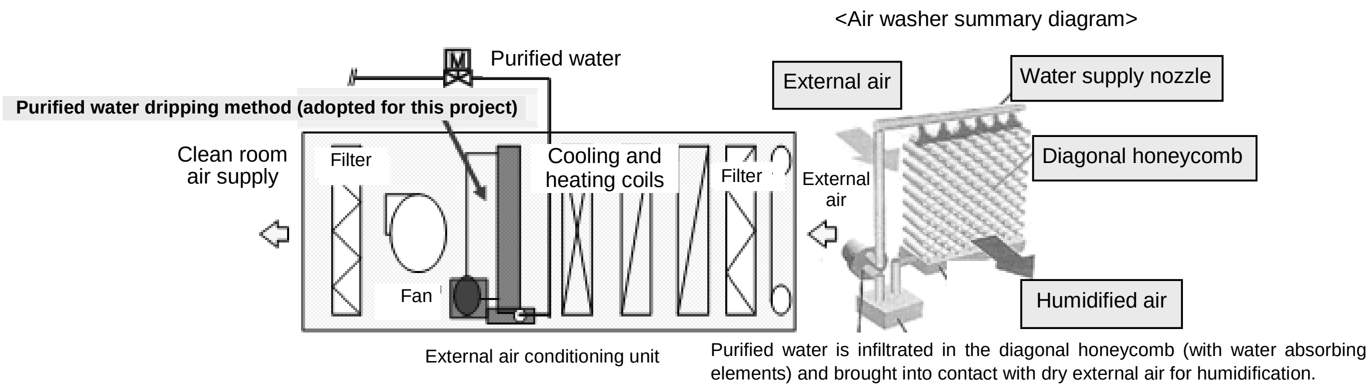

Figure 7: Air conditioner (external air conditioning unit) flow (after improvements)

Consideration was given to the installation space and the effects of the purified water dripping method, using an air washer and action, and it was implemented in the A wing of the manufacturing plant. Furthermore, gaseous pollutants in the external air (such as NH_3 or So_x) are problems for production at semiconductor manufacturing plants and the adopted air washer contributes significantly to the manufacturing process of this issue, as the effects of purified water dripping eradicates a significant amount of such pollutants (Figure 8).
Furthermore, the diagonal honeycomb (water absorbing elements) was selected the type as small pressure loss and small quantity of water (one-sixth of the existing method) out of consideration for conserving energy. The installation space for the external air conditioning unit was also a concern, but it became possible to conserve some space (one-half of our existing method) as a result of deliberations and adjustments made with the makers on the installation methods. The installation of the external air conditioning unit, therefore, was achievable without significant modifications.

Table 1: Comparison for determining humidifying methods

	Steam spray humidifier	Air washer water dripping humidification	Water spray humidifier
Humidifying medium	Steam (purified water)	Purified water	Purified water
Humidifying method	Steam spray	Purified water dripping	Purified water spray
Humidifying energy	City gas combustion	Natural evaporation	High pressure air
Required space for installation	Large	Medium	Small
Chemical removal	Bad	Good	Bad
Initial cost (%)	100	134	400
Running cost (%)	100	10	13
Comprehensive determination	Bad	Good	Fair

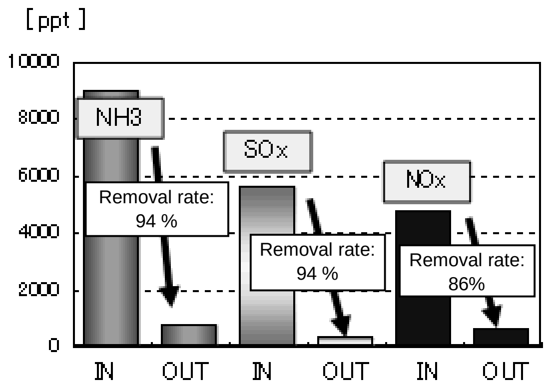

Figure 8: Air washer chemical removing performance

3) Results

Before the implementation of changes, humidification was performed with steam, primarily during intermediate to winter seasons when the external air was dry. The annual humidification amount (amount of steam used) was 9,550 tons, which was a substantial amount of steam (Figure 9).

After the implementation of improvements, however, the amount of steam used was nil, making it possible to realize a completely steamless process in A Wing, which was subject to the implementation of the project.

Furthermore, the clogging of HEPA filters in the air conditioners, which was due to uneven spray of steam , pressure loss rise and shortened life of the equipment, as well as condensation in the ducts and other issues, were all solved (Figure 10).

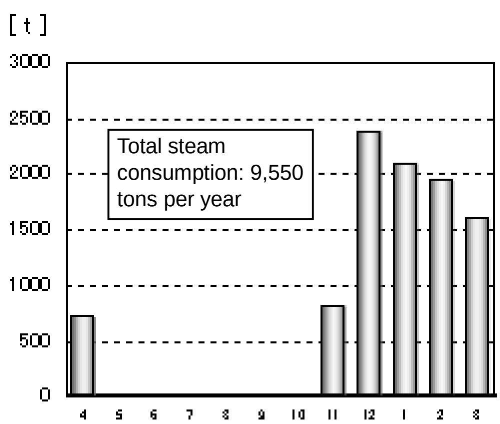

Figure 9: Steam consumption at A Wing (before changes)

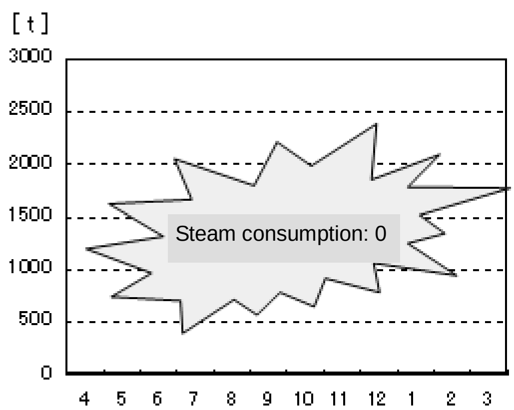

Figure 10: Steam consumption at A Wing (after changes)

Results from this strategy are as follows:

- [Steam reduction amount] 9,550 tons/year (A Wing)
- [Carbon dioxide reduction amount] 1,545 tons of carbon dioxide/year

  Reduction of steam consumption – Electric power for circulating pump, etc.
- [Monetary value of effects] JPY36,330/year (years for investment recovery: Approx. 1.9 years)

  Steam reduction cost: JPY32,470,000/year +
  Maintenance cost reduction (expenditure for statutory inspections of steam generators, cost (reduction) of air conditioning filter replacements due to longer life of filters
  = JPY4.6 million/year

(2) Conservation of Energy Used for Water Purifier 1 (Expanding Recovery of Exhaust Heat from Refrigerator)

1) Current status and focal points for improvements

A large quantity of purified water is consumed for cleansing wafers at the semiconductor manufacturing plant. This purified water is produced by a water purifier and is supplied to manufacturing equipment at a constant water temperature (24 degrees Celsius) throughout the year, regardless of the season. Waste heat from the refrigerators is recovered and used to regulate the water temperature of industrial water, the raw water, which becomes lower during the winter season however, steam is used for heating at a part of the facility, indicating that there was some room for improvement. Expansion of the recovered waste heat from refrigerators was considered for the project.

(a) Current status

Three systems of water purifiers are utilized for a part of the clean rooms in the manufacturing plant, specifically System A, System B and System C. Of these, the B and C systems are using recovered waste heat from the refrigerators, with a recovered carbon dioxide amount of 1,720 tons (Figure 11).
Furthermore, distribution of the recovered waste heat for System B and System C was 50% each (Figure 12).
Heating for System A was conducted entirely using steam (1,521 tons of carbon dioxide) (Figure 13).

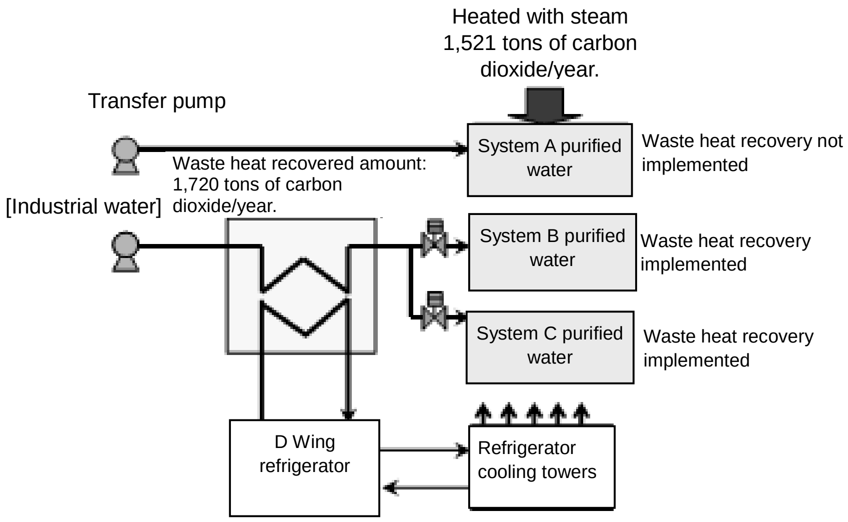

Figure 11: Refrigerator waste heat recovery system (former)

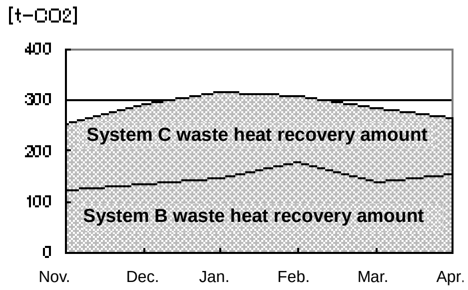

Figure 12: Waste heat recovery amount (former)

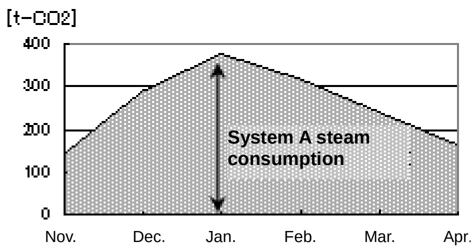

Figure 13: Steam consumption record (former)

(b) Focal points

The System C water purifier was removed as it became obsolete due to the planned changes of the processes in a part of the manufacturing plant (Figure 14).

A spare waste heat recovery capacity became available as a result and considerations were made to determine whether or not it would be possible to recover the waste heat using the

System A water purifier, for which waste heat recovery had not yet been implemented.

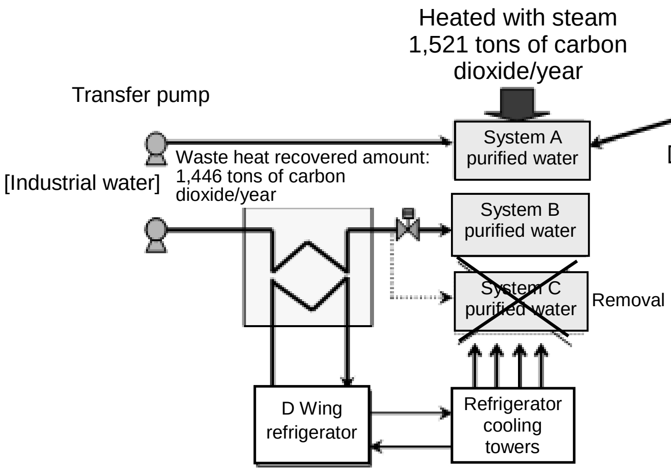

Figure 14: Refrigerator waste heat recovery system (current status)

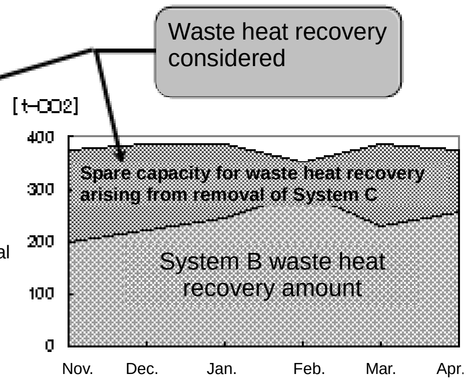

Figure 15: Waste heat recovery capacity and performance (current status)

2) Details of improvements

The System A water purifier line, which had in the past been entirely steam heated, was connected to the waste heat recovery line in order to effectively use the heat exchanger (waste heat recovery unit) that has a spare capacity and eliminated the total amount of steam heating for the System A water purifier (Figure 16).

The operating period continues from the intermediate season to the winter season, during which the water temperature drops and a reduction in steam is possible for approximately six months during these seasons.

Improvements were considered primarily for the following items:

[1] Consideration was given to the prospect of obtaining waste heat recovery effects and methods for taking actual measurements.

[2] Verifications were made to determine that no problems occur by determining the piping lengths and layout to ensure that no pressure is lost and that proper thermal insulation is in place.

[3] Pipe switching timing and methods were considered and switching was performed without impacting the manufacturing processes.

[4] Verifications were made to determine whether or not it was possible to transfer a required amount of water, in consideration of the balance of water. And no problem was confirmed.

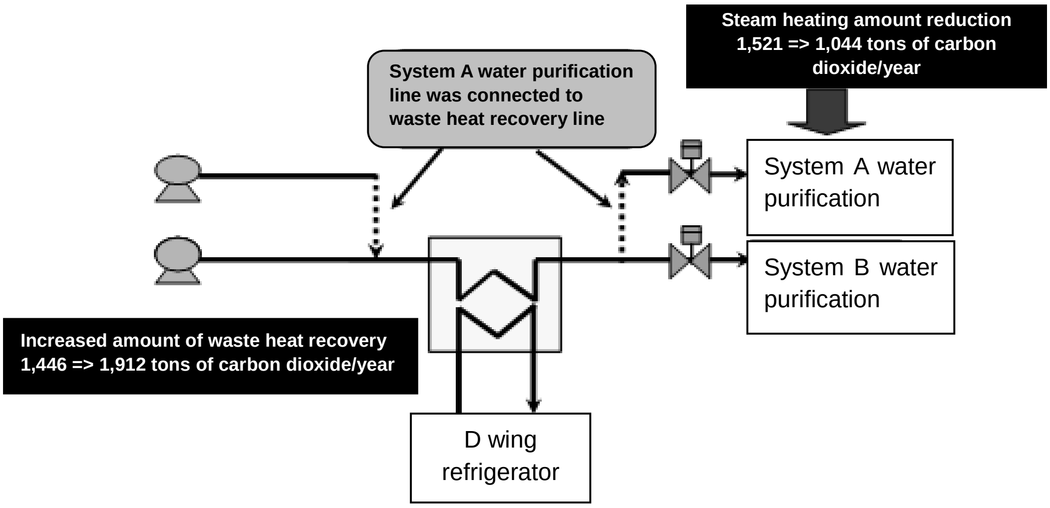

Figure 16: Waste heat recovery system (after improvements)

3) Results

The amount of waste heat recovery prior to the improvements was 1,446 tons of carbon dioxide per year, whereas the steam consumption for System A water purifier was 1,521 tons of carbon dioxide per year (9,207 tons per year).

The amount of waste heat recovery after improvements was 1,912 tons of carbon dioxide per year, an increase of 32.2%. The steam consumption was 1,044 tons of carbon dioxide per year (6,320 tons per year), a significant improvement with a reduction effect of 31.4%.

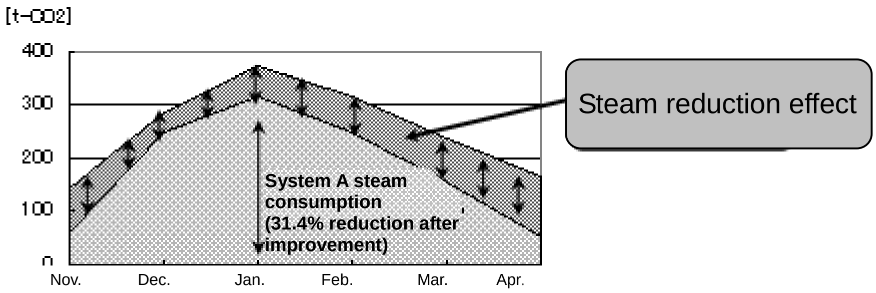

Figure 17: Steam consumption record (after improvements)

The effects of this improvement measure are as follow.

[Steam reduction volume]: 2,887t/year (System A water purification line)

[CO2 reduction volume]: 477t-CO2/year (by steam reduction)

[Cost of effect]: 9,800,000yen/year (Year payback; applox.0.5 years)

(3) Conservation of Energy Used for Water Purifier 2 (Recovery of Exhaust Heat from Manufacturing Equipment)

1) Current status and focal points for improvements

(a) Current status

Cooling water, with a temperature set to 30 degrees Celsius, is circulated for the purpose of cooling manufacturing equipment in clean rooms of this factory.

This cooling water releases waste heat to the atmosphere in cooling towers through the cooling process (Figure 21).

Furthermore, the purified water production unit needs a water temperature set to 26 degrees Celsius, due to the requirements of the manufacturing processes, but steam heating is used to increase the temperature during intermediate seasons and the winter season as the temperature of the external air drops, resulting in the consumption of a large amount of steam (Figure 22).

(b) Focal points

Waste heat from manufacturing equipment is discharged to the atmosphere by cooling towers and is being wasted as it is discarded.

Purified water is sustained at a water temperature of 26 degrees Celsius by the purified water production unit to be transferred to the manufacturing processes and the water temperature is regulated using a large quantity of steam.

A reduction in the steam for heating purified water by conducting heat transfer on the water filtration line and cooling water line was considered for this project.

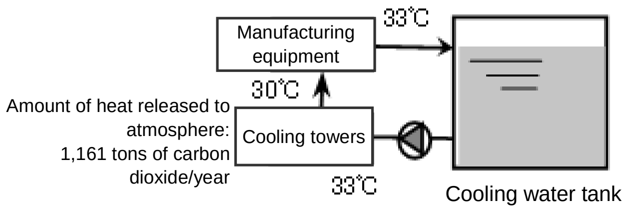

Figure 21: Manufacturing equipment waste heat flow diagram (before changes)

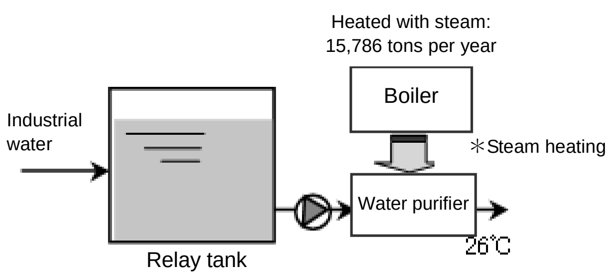

Figure 22: Purified water heating flow diagram (before changes)

2) Details of improvements

A heat exchanger was installed and waste heat was recovered by this heat exchanger using pumps operating on both the cooling water tank and water filtration tank of the purified water production unit (Figure 23).

This resulted in a rise by two degrees Celsius in the average temperature of filtration water used to produce purified water.

The operating period continues from the intermediate season to the winter season, during which the water temperature drops to 26 degrees Celsius or below. Steam can be reduced during six months approximately during these seasons.

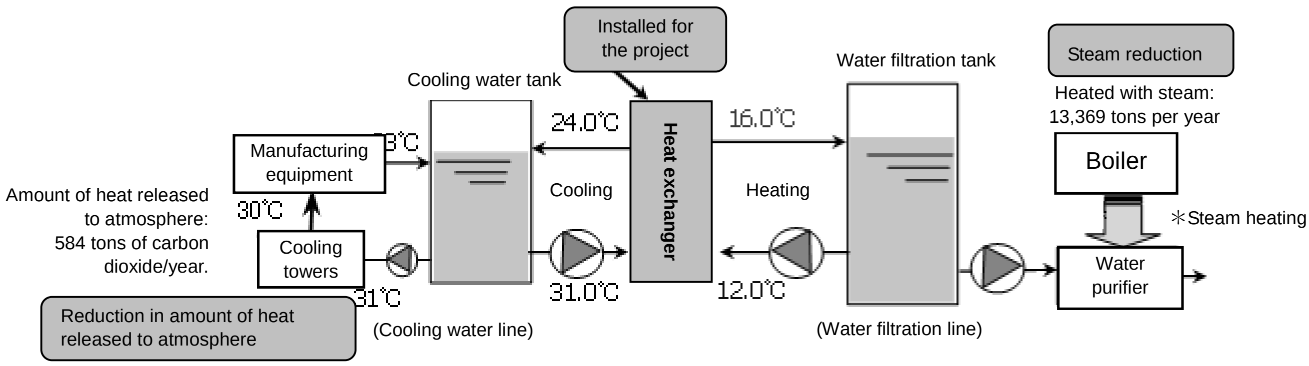

Figure 23: Purified water heating flow diagram (after changes)

3) Results

The operating period for waste heat recovery is a period of approximately six months continuing from the intermediate season to the winter season.

Through this operation during the prescribed period, a rise by two degrees Celsius in the water temperature is secured in the purified water production process, thereby realizing a reduction in the steam for heating.

Results from this strategy are as follows:

- [Steam reduction amount] 2,417 tons/year
- Steam consumption reduction (reduction by 15% for heating of purified water for clean rooms)
- [Carbon dioxide reduction amount] 326 tons of carbon dioxide/year

  Reduction of steam consumption – Electric power for circulating pump, etc.
- [Cost of effects] 6,700,000 yen/year (Year payback: Approx. 4.8 years).

5. Effects Achieved after Implementing Measures

Table 2: Energy conservation improvement effects

	Improvement item	Energy conservation amount (tons of carbon dioxide)	Monetary value of effects (million yen)	Investment amount (million yen)	Payback years
1	Reduction in steam consumption through change in humidifying method for air conditioning	1,545	36.3	68	1.9
2	Conservation of energy used for water purifier 1 (expanding recovery of exhaust heat from refrigerator)	477	9.8	5	0.5
3	Conservation of energy used for water purifier 2 (expanding recovery of exhaust heat from manufacturing equipment)	326	6.7	32	4.8
Total		**2,348**	**52.8**	**105**	**2.0**

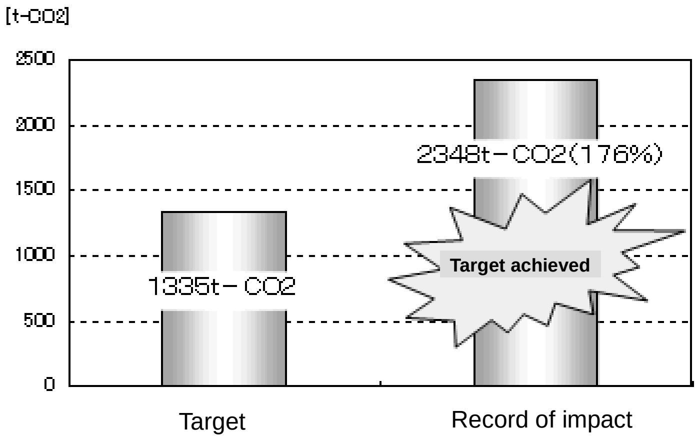

Figure 24: Target and effects after implementation of action

6. Summary

The focus was placed on reducing the steam load and conserving energy for producing steam, which was sought by improving the humidifying method of air conditioners, as well as by recovering and reusing the heat expelled from the manufacturing equipment to heat purified water. Although a reduction in the fuel (heat energy) was the urgent matter, due to the impact of soaring crude oil prices, through implementation of various improvement items, we were able to achieve effects that surpassed our target (176%) (Figure 24).

7. Future Plans

We believe that improvements to the humidifying method of air conditioners introduced here is a case example that can be repeated in other business lines, as a significant impact is attained by improving the currently dominant humidifying method of steam heating to steamless heating.

Although only a portion of the buildings in this factory were subject to the improvements made by this project, we intend to continue these improvements with changes by considering more practical improvements, including horizontal expansion into other buildings.

Furthermore, the conservation of energy through a reduction in the steam load is a case example that can also be repeated in other business locations of our company and as such, consideration will be given regarding horizontal expansion through coordinated efforts with other relevant corporate organizations.