2007 Prize of Director General of Regional Bureau of Economy, Trade and Industry

Promotion of Energy Conservation in Factory-"Practice of Energy Conservation in Clean Room Facilities

MITSUBISHI ELECTRIC CORPORATION
Nagoya Works
Production System Promotion Department

◎ **Key Words: Rationalization of conversion of electricity to power and heat (electric power application facilities, electric heating facilities)**
Rationalization of conversion of electricity to power and heat (lighting facilities, elevators, office equipment, consumer appliances)

◎ Outline of Theme

The company decided to increase clean room facilities to improve the production environment of this factory production "Laser Processing Machine."
Significantly large-scale energy conservation has been achieved compared to the existing clean room facilities by introducing the utility facilities system which takes into account production conditions for clean room facilities and highly-efficient equipments and systems to new clean room facilities.

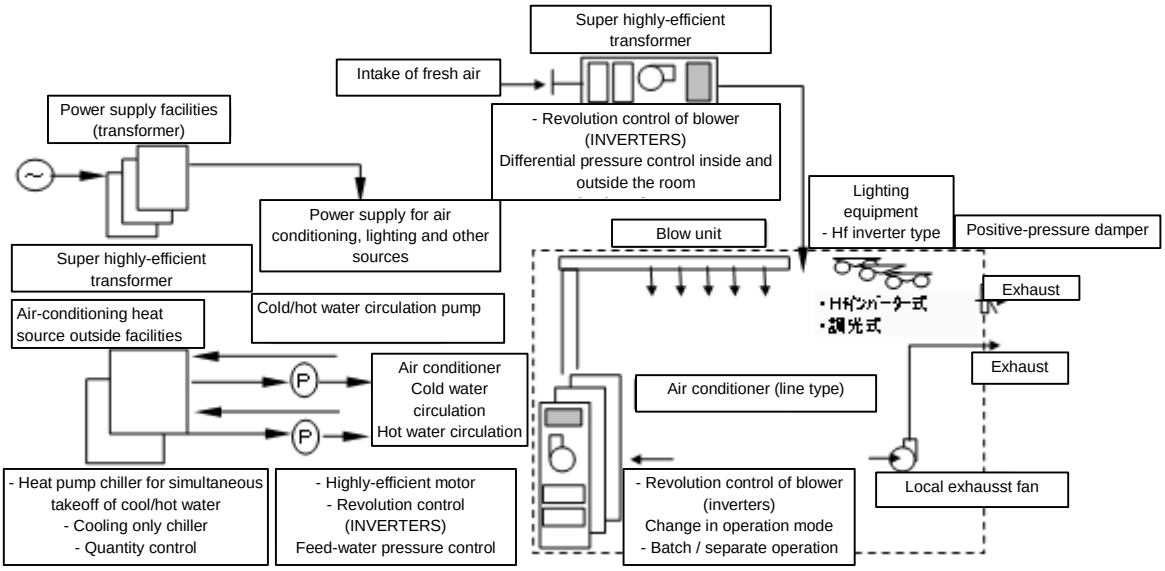
◎ Implementation Period for the Said Example

- Planning Period: (April 2005~ June 2005, Total of 3 month)
- Implementation Period: (July 2005~November 2005, Total of 5 months)
- Verification Period of Effectiveness: (December 2005 ~ July 2006, Total of 8 months)

◎ Outline of the Business Establishment

- Production items:
  - Driving products (inverters, AC servo, numeric control device, electric motor, and others)
  - Mechatronics products (laser processing machine, electric discharge machine, robot, and others)
  - Power distribution control products (transformer, electromagnetic switch)
- Number of employees: 1,900
- Type 1 designated energy management factory

◎ Process Flow of Target Facility



1. Reasons for Theme Selection

1) As a company's global warming prevention measure (reduction in CO2 emissions), it was required to establish a "voluntary action plan" for promoting energy conservation activities.

* Voluntary action plan: "Reduction in CO2 emission in sales intensity by 25% in FY2010 compared to FY1990"

2) The goal of “reduction in CO2 emission in sales intensity (ton-CO2/100 million yen) by 2.0% per year” was advocated as specific energy conservation improvement activities. It was also necessary for Nagoya Works to promote and deploy continuous energy conservation improvement activities to achieve the advocated goal. Activities should have been effective in pushing forward specific points for energy conservation such as (1) introduction of highly-efficient equipment, (2) promotion of EM activities (*1), and (3) fuel conversion.

3) Under such conditions, we decided to increase clean room facilities in order to improve the production environment of mechatronics products. We needed to address the control of CO2 emissions by introducing clean room facilities taking into account “flaws” and “wastefulness” found in energy usage of the existing clean room facilities as well as the above-mentioned “points of energy conservation improvement.”

(*1) EM activities: To enhance the production efficiency by automatically measuring energy consumption of each machine in the production line (visualization), finding wastefulness, and implementing measures

2. Understanding of Current Situation

While decisions were made on basic points concerning system, structure and management method of air-conditioning facilities, electric facilities, and energy management facilities of the newly-introduced clean room facilities, “flaws” and “wastefulness” found in energy usage of the existing clean room facilities were reviewed.

(1) Understanding of the current situations [Figure1 Overview of the current clean room facilities]

1) Type of clean room usage

- Works are conducted for prescribed time and there are no night shifts.
- Workload in the clean room is not uniform (workload varies with process)

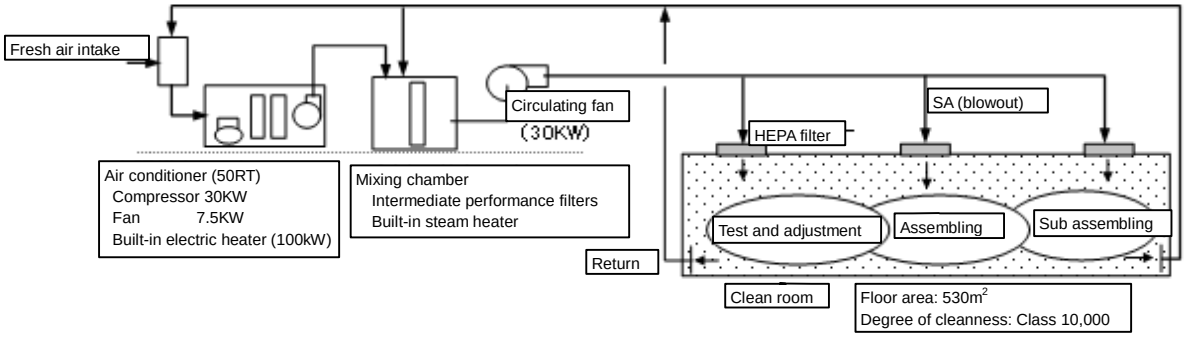
2) Type of clean room air-conditioning facilities

- Large air-conditioning facilities system has been adopted, and it is not flexible because there are only “full operation and shutdown.”

3) Heat source efficiency of the clean room facilities

- Steam and electric heaters were adopted as heat sources for reheating
- Fossil fuels were used as steam heat sources, and heat loss was generated in steam supplying pipes
- Electric heaters with low heat conversion efficiency have been used

Figure 1 Overview of the conventional clean room facilities



(2) Analysis of Current Situation

“Flaws” and “wastefulness” found in energy usage of the conventional clean room facilities were as follows:

[1] Use of the clean room is not continuous and uniform

[2] Air-conditioning facilities lack flexibility as they are large and concentrated system so that they are not in line with type of usage

[3] Systems and equipment whose efficiency is low have been used

The clean room facilities to be newly introduced should be ones taking into account the analysis of current situations mentioned, and deliberations were made.

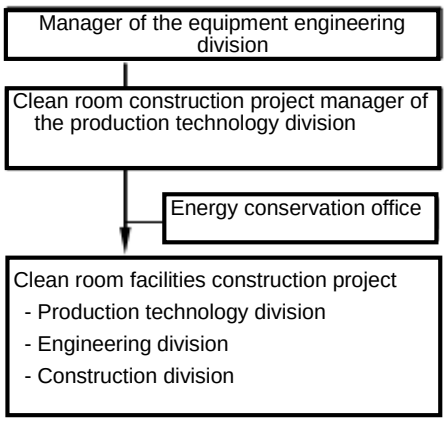
3. Progress of activities

(1) Implementation Structure [Table 1 Organization]

Activities have been conducted mainly by three divisions, “engineering division which

manufactures the relevant devices," "production technology division which is in charge of actual production facilities assembling," and "a division which is in charge of construction." In addition, the Energy Conservation Promotion Office in Nagoya Works has jointed the team to foster activities.

Table 1 Organization



(2) Target Settings

As the size of newly-introduced clean room facilities is different from that of the existing clean room facilities, power load per clean room unit area was set as a target value.

[1] Rated power: Reduction by 30% or more of 0.324KW/m2

[2] Controlling of CO2 emissions: 500t-CO2 per year

(3) Problem Points and their Investigation

Table 2 shows types of usage and sizes of both the existing and the newly-introduced clean room facilities, and Table 3 shows problems and deliberations on them under a condition in which there are no significant differences other than the size.

Table 2 Comparison of new and old clean rooms

	Existing facilities	Newly-introduced facilities
Type	Machine tool	ditto
Content of operation	Sub assembling, assembling, test	ditto
Working conditions	Fixed time (no night operation and around-the-clock operation)	ditto

Size	Area 530m^2	Area: about 4 times as big
Degree of cleanness	Class 10000	Class 10000
Temperature control	General air-conditioning (18~24℃)	Constant-temperature room (±1.0℃)

Table 3 Problems and Items to be deliberated

Problems	Items to be deliberated	Measures
① Unconformity to type of usage of clean room facilities - Efficient operation for partial work (e.g. overtime work and holiday work) is impossible - Facilities lack flexibility as they are big and centralized system ② Use of lower efficient system and equipment in the clean room facilities - Heating and reheating using electric heating system - Use of steam generated by fossil fuels as its heat sources ③ Inefficient operation management and energy management - Monitoring of conditions on site - Energy management is uniformly divided	① Introduction of clean room facilities matching with type of usage ② Introduction of highly-efficient equipment and system ③ Improvement of management efficiency - Operation in accordance with full/partial operation - Operation in accordance with workload - Operation with several machines and decentralization - Operation in accordance with heat load - Introduction of highly-efficient equipment - Introduction of recovery and effective utilization of waste heat - Segmentation and automation of energy management - Improvement of management efficiency associated with expansion of the clean room size	① Adoption of highly-efficient system - Decentralized Installment of several machines - Number control in accordance with load - Separate operation and shutdown - Selection of operation mode in accordance with type of operation ② Adoption of highly-efficient equipment - Motor, transformer, lighting equipment, air conditioner - Securing of heat source by the heat pump system ③ Improvement of management efficiency - Automated measurement by system and by application - Segmentation of air-conditioning as well as lighting systems in accordance with work area - Adoption of batch management of operation conditions

4. Details of Measures

(1) Example of energy conservation by the newly-introduced clean room facilities [Figure 2 Clean room facilities and energy-conservation equipment introduced]

1) Heat source equipment of the air-conditioning facilities

- Introduction highly-efficient cold/hot water generator
  - Heat pump chillers for simultaneous takeoff of cold/hot water (2)
  - Dedicated cold water chillers (4)
- Introduction of highly-efficient motors and inverter control to cold-water/hot-water pumps

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Highly-efficient energy conservation equipment
Quantity control in accordance with air-conditioning load
Revolution control in accordance with air-conditioning load
Effective utilization of exhaust heat

2) Air conditioners in air-conditioning facilities

- Introduction of line-type air conditioners (including duct-type)
  - Decentralized installation in the clean room (26)
- Introduction of inverter control to the above-mentioned air conditioners
  - Operation mode change by type of operation
  - Constant pressure difference control inside and outside the clean room

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Batch/separate operation in accordance with type of operation
Revolution control in accordance with type of operation

3) Other clean room facilities equipment

- Introduction of 4 top runner transformers to power transformers
- Introduction of light-control inverter type lighting equipment

- Introduction of IPM motor (*) to fan motors of air conditioners

(*) IPM motor (abbreviation of Internal Permanent Magnet)

Unique magnet implanted motor (downsizing and improvement of efficiency)

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Highly-efficient equipment for energy conservation
(improvement of energy conversion efficiency)

4) Clean room operation management

- Introduction of operation monitoring system of the clean room facilities
- Batch/separate management of areas
- Management of condition monitoring and operation history
- Web monitoring and control by touch panel

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Energy conservation supporting equipment
(Improvement of energy management efficiency)

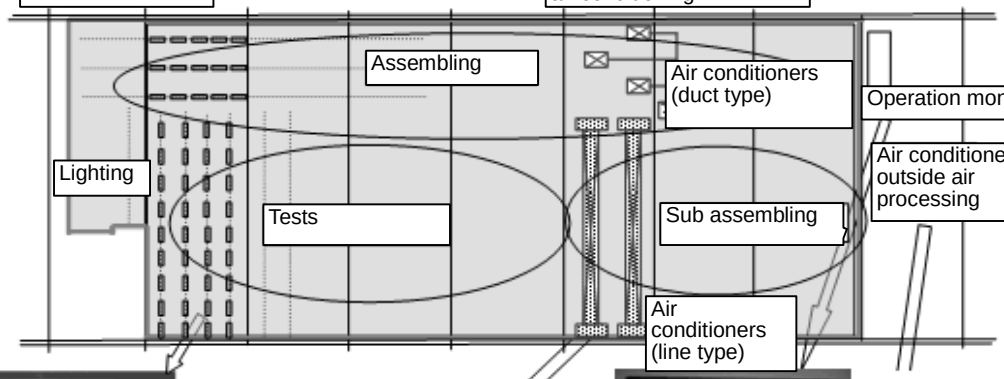
Fig. 2 Clean room facilities: equipment introduced for energy conservation

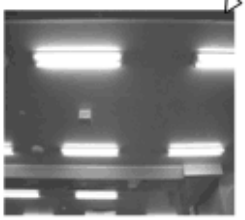
Heat source equipment for air-conditioning
- Heat pump chillers for simultaneous takeoff of cold/hot water (2)
- Dedicated cold water chillers (4)
- Primary and secondary cold/hot water circulation pumps (14)
  Highly-efficient motors
  INVERTERS (feed water pressure control/secondary side pumps

Transformer: top runner transformer (super high efficient) Total capacity 2,450KVA

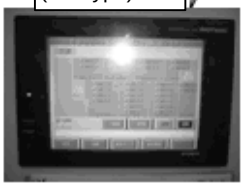
Power substation

Heat source equipment for air conditioning



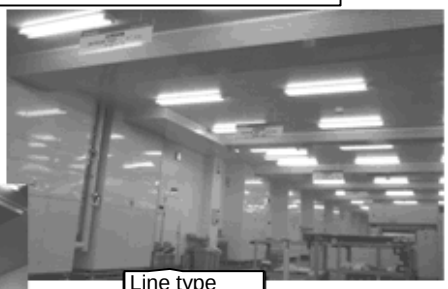


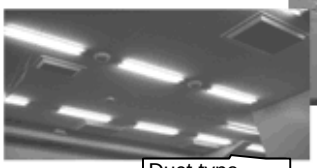
Air-conditioning facilities
- Cold/hot water coils, HEPA filter, fans
- Line type (18) and duct type (8)
- Installation of INVERTERS (switchover between daytime and night modes)
- Grouping in response to the working areas



Operation monitoring board
- Touch panel operation (display on the screen)

Lighting facilities
- Light-control type inverter lighting equipment
- Grouping in meeting with the working areas (grouping and conformity of air-conditioning facilities





Line type

Duct type

Air conditioners for outside air processing
- Cold/hot water coils, HEPA filter, fans
- INVERTERS (differential pressure control inside and outside the clean room)
- IPM motor

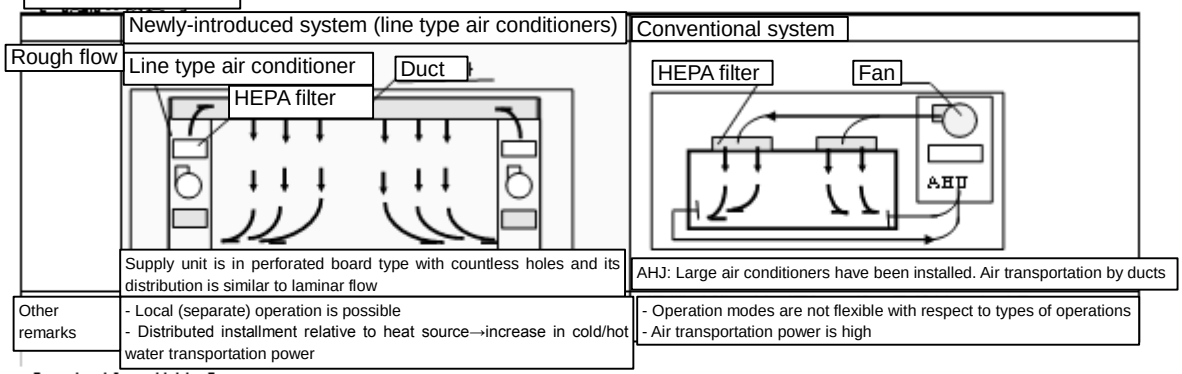
(2) Details of introduction case of energy conservation

1) Case-1 [energy conservation of air-conditioning facilities: reduction in air transportation power]

The concepts of newly-introduced line type air conditioners and energy comparison with the conventional air conditioning facilities (transportation power) are shown in Table 4 “Comparison with line type and the conventional type air conditioning facilities.”

- Newly introduced system = Separately-distributed installation (line type air conditioners)
- Conventional system = Large-scale centralized installation
- Rate of reduction in transportation power = reduction by 18% compared to the conventional system
- Estimation of reduction in power costs = 2.7 million yen per year compared to the large-scale centralized air conditioner

Overview of facilities



[エネルギーの比較]

	今回新規導入 (ライン式空調機)	従来方式
用途	工作機械の組立・試験	工作機械の組立・試験
性能	クリーン度 クラス10000	クリーン度 クラス10000
	温湿度 恒温室レベル	温湿度 一般空調レベル
面積/容積	床面積 2050mf 部屋容積 7600m3	床面積 530mf 部屋容積 2070m3
循環風量	循環風量 215000m3／Hr	循環風量 52000m3／Hr
	循環回数 215000／7600＝28回/Hr	循環回数 52000／2070＝25回/Hr
搬送動力	空調機ファン 80.8kW	空調機ファン 37.5kW
	冷温水2次ポンプ 27.6kW	冷温水2次ポンプ ——
	合計 118.4kW	合計 37.5kW
	単位動力 118.4／2050＝0.0577kW／m³ (82%)	単位動力 37.5／530＝0.0707kW／m³ (100%)

[Comparison of energy]

	Newly-introduced facilities	Conventional facilities
Purpose	Assembling and tests of machine tools	Assembling and tests of machine tools
Performance	Degree of cleanness: Class 10000	Degree of cleanness: Class 10000
	Temperature and humidity: constant-temperature room level	Temperature and humidity: general air-conditioner level
Area/volume	Floor area: 2050m^2, Room volume: 7600m^3	Floor area: 530m^2 Room volume: 2070m^3

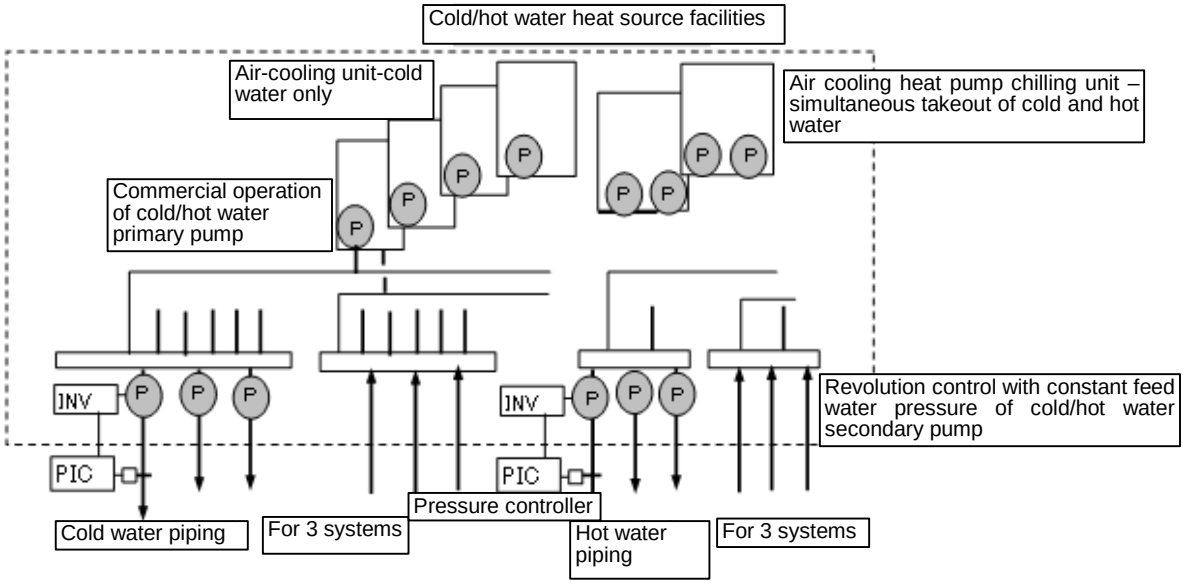
Circulating air volume	Circulating air volume: 215000m3/hr	Circulating air volume: 52000m3/hr
	Number of circulations: 215000/7600 = 28/hr	Number of circulations: 52000/2070 = 25/hr
Transportation power	Air conditioner fan: 90.8kW	Air conditioner fan: 37.5kW
	Cold/hot water secondary pump: 27.6kw	Cold/hot water secondary pump: -
	Total: 118.4kW	Total: 37.5kW
	Unit power: 118.4/2050 = 0.057kW/m^2 (82%)	37.5/530 = 0.0707kW/m^2 (100%)

2) Case-2 [Energy conservation of air-conditioning heat source equipment]

Figure 3 “Overview facilities flow of heat source equipment” shows overview of the facilities introduced as heat source equipment for cooling, heating and reheating of the clean room.

- Implementation of waste heat recovery operation by adopting chillers for simultaneous takeoff of cold/hot water
- Number control of chillers based on air-conditioning load conditions (water temperature sensor)
- Introduction of revolution control using inverters of the secondary pump for cold/hot water (control of cold water supply (constant pressure) in accordance with air-conditioning load)
- Estimation of reduction in power costs:
    - Waste heat recovery operation and quantity control operation of chillers = 13.3 million yen/ year
    - Optimized operation by inverters of cold/hot water pumps = 2.0 million yen / year

Fig. 3 Overview facilities flow of heat source equipment

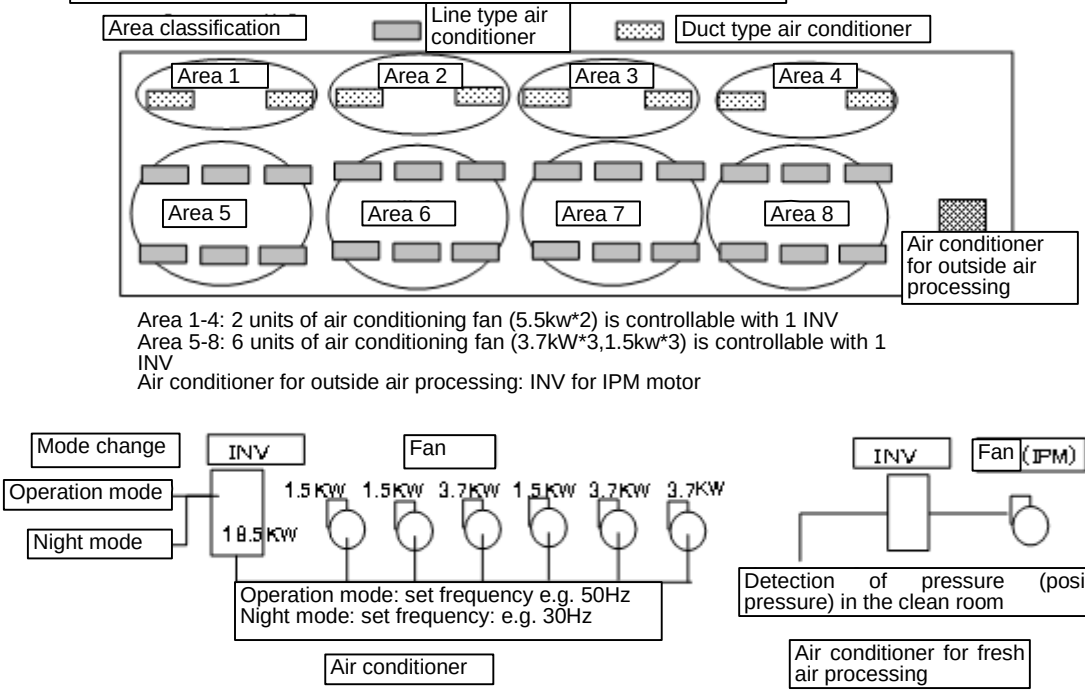


3) Case-3 [Inverter control for energy-saving fans of air-conditioning facilities]

Figure 4 “Overview of control of inverters on air conditioners’ fans” shows overview of installment of inverters to the air conditioning facilities (fans) and their control.

- Grouping of air conditioners by work type
- Revolution control by inverters of air conditioners’ fans
    - Mode change by operation type
    - Constant pressure control in the clean room
- Estimation of reduction in power costs: optimized operation by inverters=7.4 million yen / year

Fig. 4 Overview of control of inverters on air conditioners' fans



4) Case-4 [Energy conservation of lighting facilities]

As lighting facilities, light-control inverter type lighting equipment (Hf lighting equipment) has been introduced to enable optional control of illumination of the entire clean room. (refer to Table 5).

- Introduction of highly-efficient lighting equipment and system
- Lighting circuits by work type (synchronization of grouping of every air-conditioning facility)
- Estimation of reduction in lighting power costs: difference between conventional and new systems is 0.9 million yen / year

Table 5 Overview of lighting facilities

	Specification of continuous light control inverters	Conventional specification
Designed illuminance	700 lux	700 lux
Type	Light-control inverter type (Hf type)	Rapid magnetic type
Model name (equipment)	KV4382EF PX (32W* for 2 lightings)	KV4382A RUSH (40W* for 2 lightings)

(lump)	FHF32EX-N (32W)	FLR40SWM (40W)
Number of equipment	64 (index)	100 (index) (550 light)
Cost per lighting equipment	150 (index)	100 (index)
Cost per lump	240 (index)	100 (index)
Power consumption (per lump)	99w /light	86w/light
(per hour)	64 (index) (30KWH)	100 (index) (47KWH)
Facilities costs (equipment, etc., excl. construction)	101 (index) incl. control equipment	100 (index)
Annual costs (electric power and lump exchange)	71 (index) (assumed lump exchange rate: 40% per year)	100 (index) (assumed lump exchange rate: 40% per year)

5) Case 5 [Energy conservation of electric receiving/transformer facilities – introduction of super high efficient transformers]

As electric receiving facilities, super high efficient transformer which sits on the upper of top-runner transformer produced by the company has been introduced to enable reduction of electric power loss.

- Introduction of super high efficient transformers (total rated capacities 2450 kVA)
- Reduction in electric loss: difference from the conventional system = 0.8 million yen / year

Table 6 Comparison of super high efficient transformers

	Super high efficient transformer	Top runner transformer	Conventional transformer
Power loss rate	40 (index)	62 (index)	100 (index)

5. Effects achieved after Implementing Measures

Table 7 shows summary of energy conservation effects described throughout the cases.
Power load per unit area of the clean room, as advocated in the goal of this energy conservation activity, was reduced 0.159KW/m^2 compared to the target value of 0.097KW/m^2. Moreover, CO2 reduction of 795t-CO2 per year was achieved compared to the

target of 500t-CO2 per year.

Costs involving in the introduction of energy-saving equipment and system increased about 40.0 million yen.

Table 7 Summary of energy conservation effects

	Newly-introduced clean room facilities		Notes
1) Reduction in rated power	0.159KW/m2 (reduced by 50%, the goal of 30% was achieved)		0.324KW/m^2 in the conventional system
2) Reduction in power costs	In million yen / year		
① Air-conditioning facilities	2.7	Separated distribution (reduction in transportation power)	Large centralized systems
② Air-conditioning heat source equipment	15.3	Optimization by number control	Excessive load operation
		Use of waste heat	Use of electric and steam heat source
		Optimization by inverters	Constant-speed operation by commercial power source
③ Air-conditioning facilities (blowers)	7.4	Optimization by inverter	Constant-speed operation by commercial power source
④ Lighting facilities	0.9	Light-control inverter lighting equipment	Rapid magnetic type
⑤ Power substation (transformers)	0.8	Super high efficient transformers	Conventional oil transformers
Total costs	27.1		

6. Summary and Future Plans

(1) Points of out company's energy conservation activities (reduction in CO2 emissions).

[1] Introduction of highly-efficient equipment and system

[2] Promotion of EM activities (visualization of energy use)

[3] Promotion of energy conversion

Based on those activities, we are committed ourselves to continuing to explore and promote effective energy conservation activities in the future.