2007 Prize of Director General of Agency for Natural Resources and Energy

Energy Conservation through Reduction in Amount of Circulating Air Flow in Clean Rooms (CR)

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◎ **Keywords: Rationalization of Fuel Combustions (reduction of electric power consumptions for air conditioning)**
Recovery for use of exhaust heat (cleanliness required of clean rooms)

◎ Outline of Theme

This is the major manufacturing plant of the company for semiconductor. The manufacturing process of semiconductor products consumes large amounts of energy.
Furthermore, an enormous amount of electric power is consumed for air conditioning at semiconductor manufacturing plants, as it is necessary to circulate a large amount of air in clean rooms to sustain a high level of cleanliness, as well as a certain level of temperature and humidity. The focus was placed on reducing this electric power consumption for air conditioning and conservation of energy for air conditioning was sought through easing the level of cleanliness which required by specifications of clean rooms as well as to the amount of circulating air flow necessary to maintain temperature and humidity to certain levels.

◎ Implementation period for the Said Example

(1) Period for formulation of plan:
March 2006 through April 2007 Total of 14 months.
(2) Period for implementation of actions:
June 2006 through May 2007 Total of 12 months.
(3) Period for verification of implementations:
June 2007 through July 2007 Total of 2 months.

◎ Outline of the Business Establishment

- Production items: Semiconductor integrated circuits.
- Number of employees: 2,478 persons.
- Type 1 Designated Energy Management Factory.

◎ Overview of Target Facilities

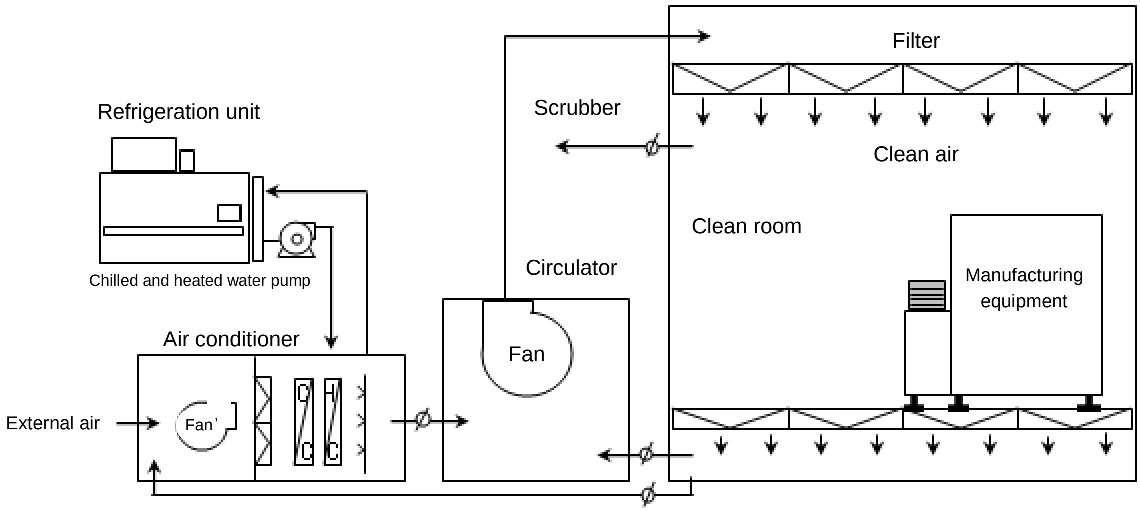

Figure 1: Circulation route of air conditioning in the clean room

1. Reasons for Theme Selection

This manufacturing plan is a cutting edge semiconductor manufacturing plant, and as such, it is essential to have a large amount of circulating air flow in clean rooms to sustain a manufacturing environment with a high degree of cleanliness. An enormous amount of electric power is consumed for this purpose. Although until now there were hesitations about implementation of actions relating to conservation of energy with regards to air conditioning for clean rooms, as such actions can potentially impact quality of products in a significant manner, actions were taken to conserve energy for electric power consumed by air conditioning. This was possible since in their consideration regarding energy conservation, it was discovered that there were still adequate amount of margins left as the actual recorded figures were compared against the required figures of particle control specifications. And thus it became possible to ease the amount of circulating air flow through investigation and analysis of their relationships between the circulating air flow in clean rooms and specifications relating to levels of cleanliness required of clean rooms as well as temperature and humidity of clean rooms comparing.

2. Understanding and Analysis of Current Situation

<Primary energy source investigation>

The manufacturing plant uses electric power and gas supplied by utilities as primary energy sources. Details are shown in Figure 2.

Status indicating domination of electric power as primary energy source by 89 %

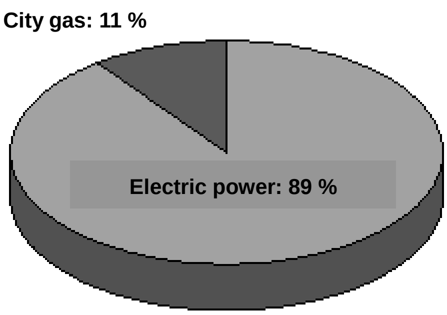

Figure 2: Primary energy consumption compared by applications

<Investigation on breakdown of electric power loads>

Electric power is used widely by manufacturing equipment, air conditioning facilities for the buildings, refrigeration units, etc., but the proportion used by the air conditioning facilities of the buildings is large next to manufacturing equipment and comprise 14.5 % of overall consumption as shown in Figure 3:

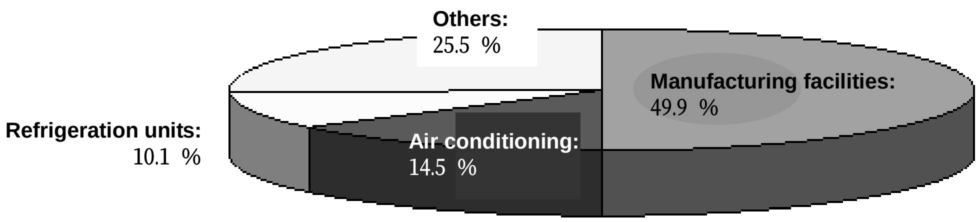

Figure 3: Breakdown of electric power consumption by applications

<Combinations of clean room structures and wafer space partitioning operation>

There are two types of clean rooms, [1] ball room clean room and [2] bay-method clean room, there are different two types of operations for wafer spacing partitions, [1] SMI Pod operation*[1] and [2] Lot Box operation*[2].

Clean room structure	SMIF Pod operation	Lot Box operation
Ball room clean room	○	-
Bay-method clean room	○	○

Table 1: Application of clean room structures and wafer spacing partitions

Note 1: SMIF Pod is a sealed container for transporting wafers, with super clean level maintained inside (with wafer spacing partitions).

Note 2: Lot Box is a case for transporting wafers, used for purpose of protecting wafers (without wafer spacing partitions).

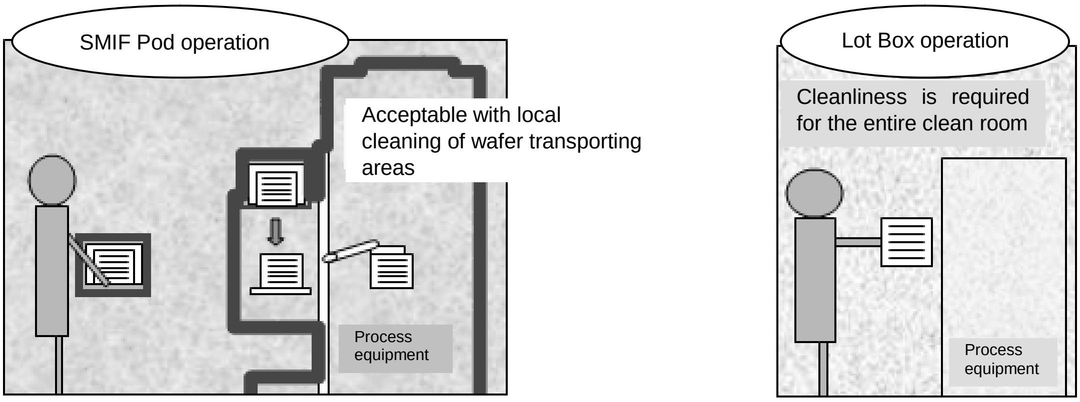

Figure 4: Characteristics and differences of SMIF Pod operations and Lot Box operations

<Investigation on specifications for cleanliness of clean rooms and current status of clean room particles>

Current status for clean rooms used for SMIF operations and clean rooms used for Lot Box operations both have a degree of margin against stipulated specifications (control limits), with regards to particle levels.

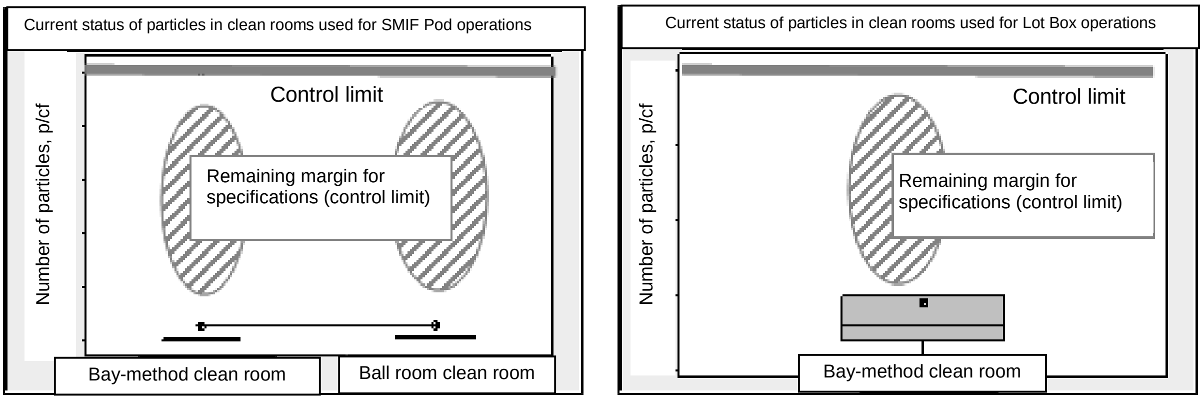

Figure 5: Current particle levels of clean rooms

3. Progress of Activities

(1) Implementation Structure

The energy conservation activities for reducing electric power consumed for air conditioning was promoted by the Energy Conservation Promotion group, which is made up of members from the Production Engineering and Planning Department of the company, and the Process Production Engineering Department, Facility Control Department and Manufacturing Department of the factory.

(2) Target Settings

- Amount of conserved energy: 1,482 tons of carbon dioxide/year
- Cost reduction: JPY31,585,000/year

The amount of energy conservation was set to 30 % of 4,940 tons of carbon dioxide, which is the target for the environmental conservation promotion plan for the manufacturing plant.

(3) Issues relating to reduction amount of circulating air flow in clean rooms

Settings for amount of circulating air flow in clean rooms vary in SMIF Pod operations and clean rooms to Lot Box operations, while reduction in amount of circulating air flow by the activity of this time should not be cause of fluctuation of clean environments and impact on products (yield rates).

1) SMIF Pod operation + Ball room clean room

Wafers are isolated from the clean room environment in the SMIF Pod and the level of required cleanliness is not very high, yet since there is no distinction between the working zone and utility zone, there is a relatively large equipment heat load*[3] in the clean room as whole, presenting an issue of large dispersion in equipment heat load among units of air conditioning blocks. (Note 3: Heat load is the load arising from removal of heat generated by equipment.)

2) SMIF Pod operation + Bay-method clean room

Wafers are isolated from the clean room environment in the SMIF Pod and thus the level of required cleanliness is not very high, and since there is distinction between the working zone and utility zone, there is a relatively small equipment heat load in the clean room, presenting no issues. [3] Lot Box operation + Bay-method clean room
Since wafers in the working zone are exposed directly to the clean room environment, the issue is that the increased amount of particles due to reduction in amount of circulating air flow reduces product yields.

(4) Aspects for reduction of amount of circulating air flow in clean rooms

SMIF Pod operation + Ball room clean room

The necessary amount of circulating air flow is not determined by the need to sustain the level of cleanliness, but rather, according to temperature control of clean rooms. The space temperature in clean rooms, therefore, becomes the critical parameter.

Lot Box operation + Bay-method clean room

The necessary amount of circulating air flow is determined by the need to sustain the level of cleanliness, the number of particles in clean rooms, therefore, becomes the critical parameter.

4. Details of Measures

(1) Details of actions taken for SMIF Pod operation + Ball room clean room

1) Investigation on current space temperature of clean rooms

When measurements of temperature were taken in terms of air conditioning control block units at a total of 176 points over the FFU, under the floor of the working zone and at the air intake vent at downstairs, the resulting figures indicated a significant gap between the temperatures over FFU and below the working zone floor area, indicating that there is a significant heat load in the working zone.

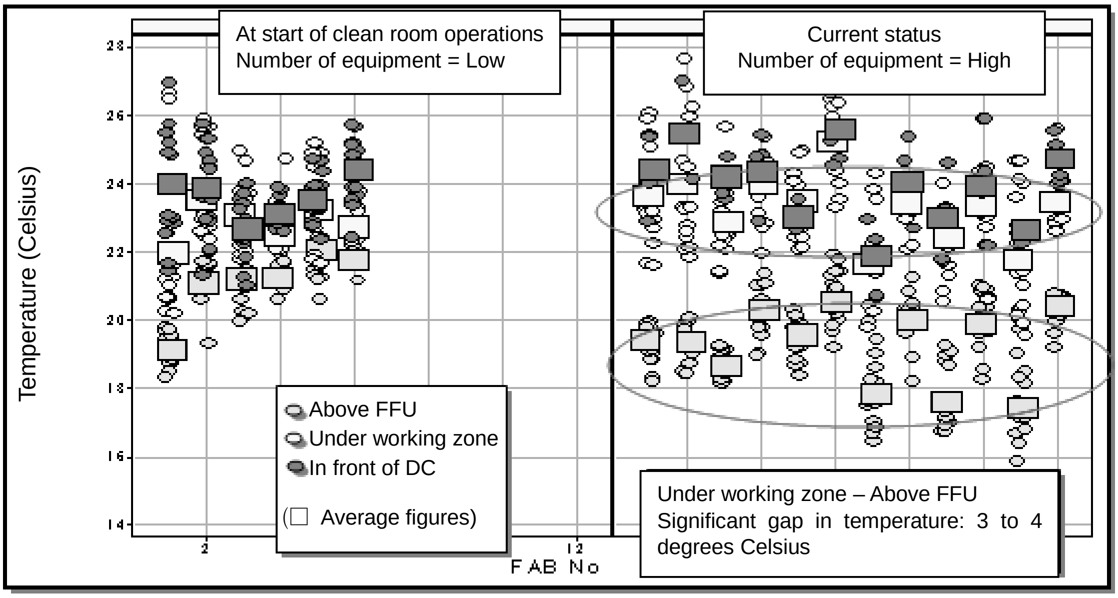

Figure 6: Measurement results of current space temperature of clean rooms

2) Heat load of clean room in units of air conditioning blocks

There were dispersions of spatial temperatures of areas, as well as heat load of clean rooms in terms of air conditioning block units.

Results from simulation of reduction in amount of circulating air flow indicated that the temperature rises in the areas where heat load becomes high as a result of reduction in amount of circulating air flow. The reverse is true in areas with lower heat loads, where the temperature drops and the widening of temperature dispersions within air conditioning block areas become a concern. For this reason, reducing amount of circulating air flow in the entire working zone, as a bundled whole, would be a difficult task to perform.

Accordingly, considerations were made to reduce amount of circulating air flow according to the heat loads in clean rooms and in FFU control units.

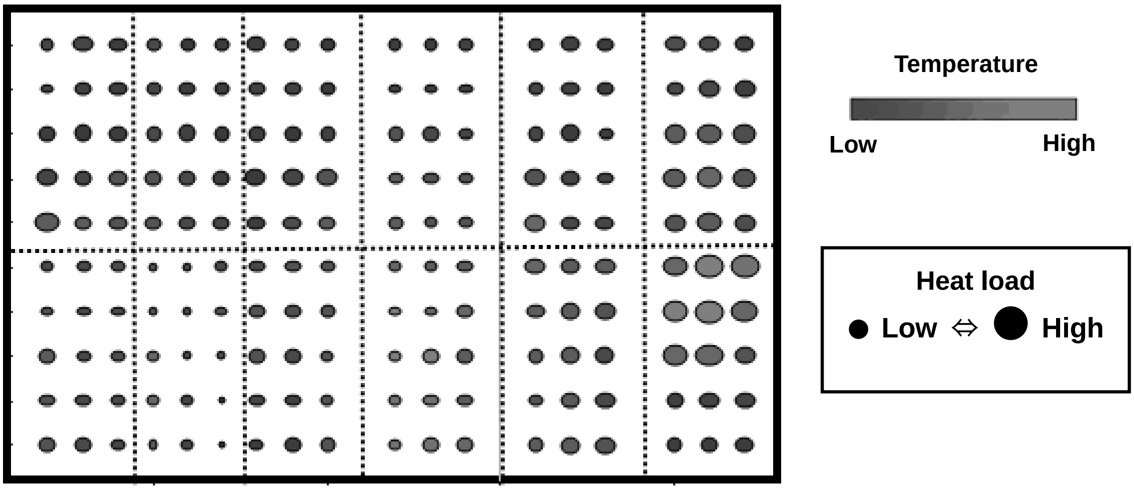

Figure 7: Heat loads and temperature in working zones (planar distributions)

3) Appropriate FFU air blowing speeds according to heat loads in clean rooms

FFU air speeds necessary to sustain the current space temperature fluctuation width (+3 to 4 degrees Celsius) of clean rooms was considered.

The proper air blowing speeds according to heat lords were calculated as bellow

580 W/m^2 or less: 0.22 m/s   Equivalent to FFU air flow rate level “3”.

580 W/m^2 to 670 W/m^2: 0.28m/s Equivalent to FFU air flow rate level “4”.

670 W/m^2 or more: 0.34m/s Equivalent to FFU air flow rate level “5”.

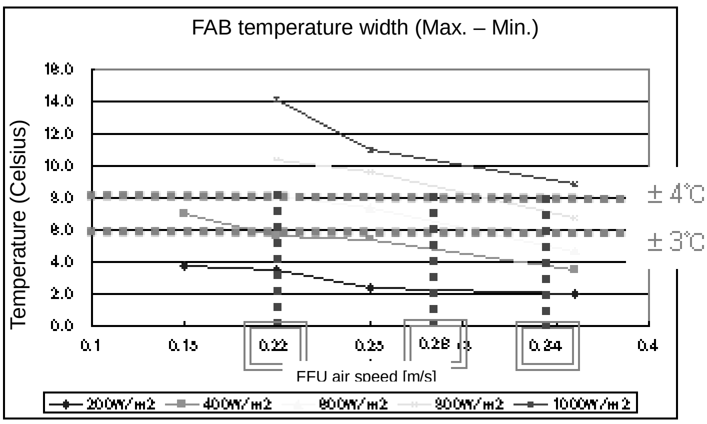

Figure 8: FFU air speeds necessary to sustain clean room space temperature fluctuations

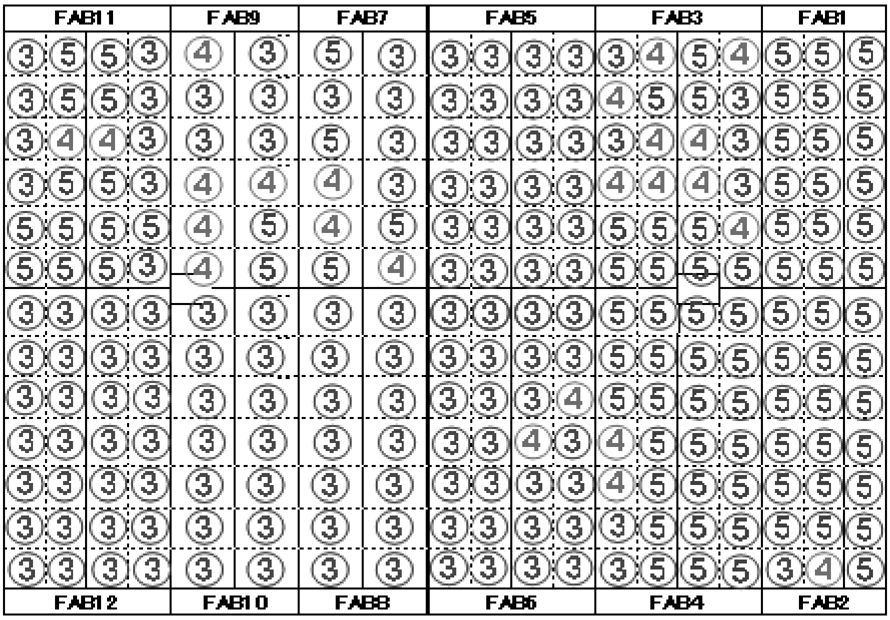

Figure 9: Air blowing speed settings in FFU control units

4) Environmental fluctuation of clean rooms due to reduction in amount of circulating air flow

No fluctuations occurred in environments of clean rooms, before and after reductions in amount of circulating air flow, which were applied to intended areas by FFU control units and according to the heat loads in the clean room. Transitions within the permissible range of required specifications for temperature, humidity and particle number in the clean rooms were verified.

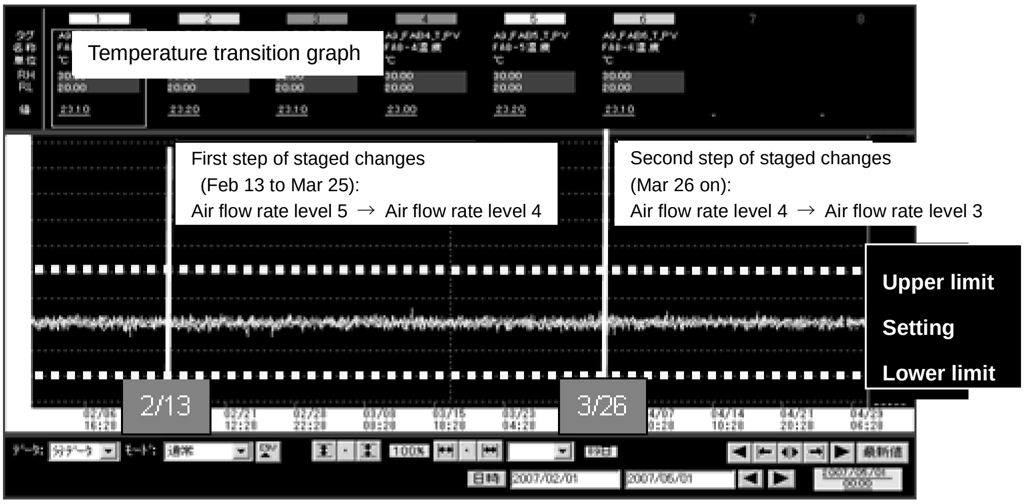

Figure 10: Transition of temperature before and after reduction in amount of circulated air (February 5 to April 30, 2007)

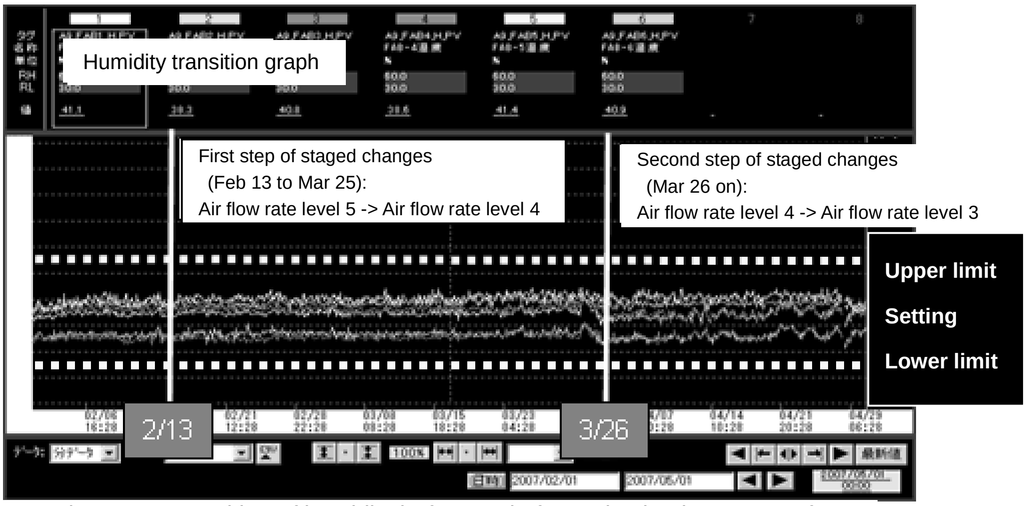

Figure 11: Transition of humidity before and after reduction in amount of circulated air (February 5 to April 30, 2007)

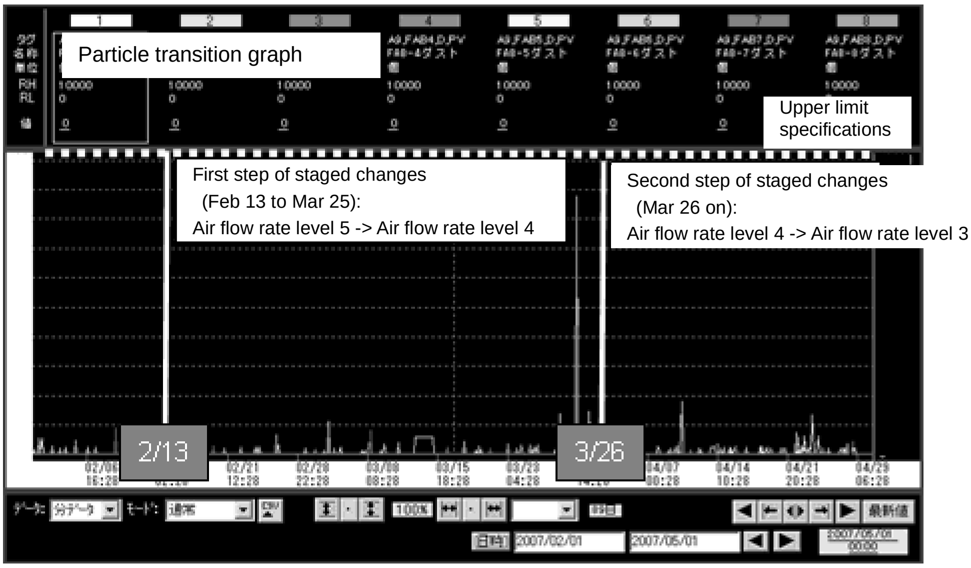

Figure 12: Transition of particle number before and after reduction in amount of circulated air (February 5 to April 30, 2007)

(2) Details of actions taken for Lot Box operation + Bay-method clean room

1) Deciding on policy for reduction in amount of circulating air flow

Since wafers are exposed directly to working zone in Lot Box operation clean rooms, presence of particles has significant impact on yield of products. For this reason, the number of particles are measured through two methods of the aerial dust counter and wafer collection*[4].

Furthermore, reduction of air speed is being implemented in stages to attain the targeted reduction of circulation air speed (reduction by 10 % from present speed). (Note 4: Wafer collection is adhesion of particles on the surface of a wafer under the same condition as wafers exposed to the environment.)

2) Investigating areas affected by particles

An investigation on the height from the floor that can be affected by dust generated by walking was conducted at the condition reducing air speed in stages.. Results indicated that there are no effects of dust arising from walking over height C level shown in figure below even if the circulating air speed is reduced by 10 %.

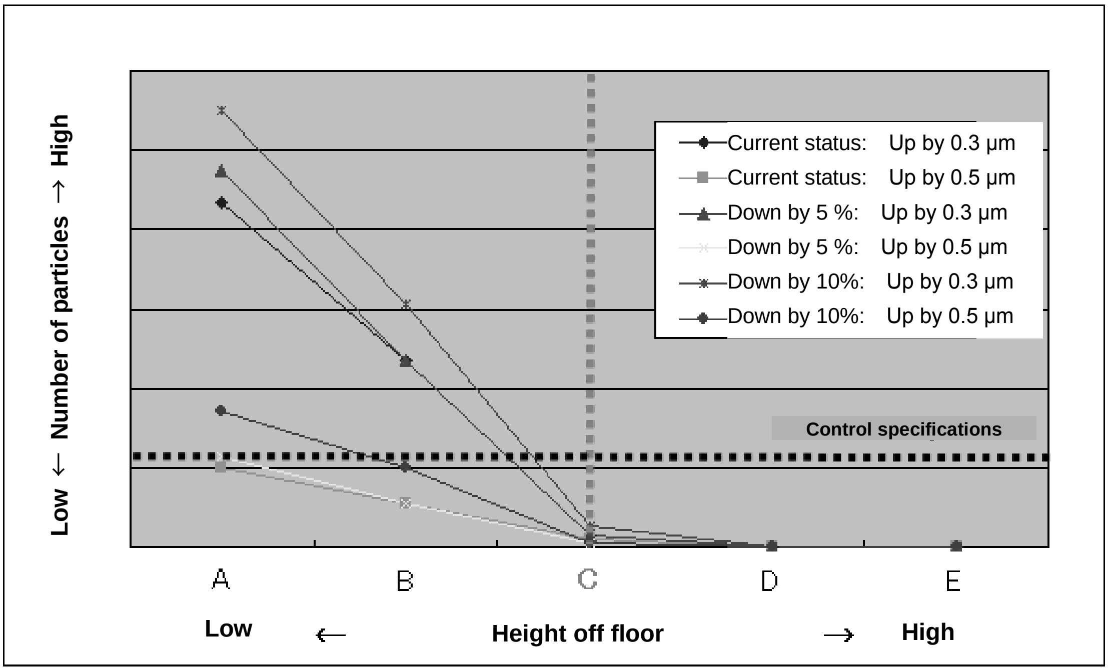

Figure 13: Relationship between walking dust and height off floor

3) Fluctuations of particle number and environmental fluctuation in the clean room due to reduction in amount of circulating air flow

No problems relating to dust both in terms of aerial dust and wafer collection, which fall within range permitted by control specifications, so long as position is C or higher off the floor even after reduction in amount of circulating air by 10 %.

Before reduction of circulating air amount

Measurement position	Dust counter measurement	Determi-nation	Wafer collection (5 hrs)	Determi-nation
A	0.3 μm or more	OK	0.2 μm or more (S)	OK
	0.5 μm or more	OK	0.5 μm or more (L)	OK
B	0.3 μm or more	OK	0.2 μm or more (S)	OK
	0.5 μm or more	OK	0.5 μm or more (L)	OK
C	0.3 μm or more	OK	0.2 μm or more (S)	OK
	0.5 μm or more	OK	0.5 μm or more (L)	OK
D	0.3 μm or more	OK	0.2 μm or more (S)	OK
	0.5 μm or more	OK	0.5 μm or more (L)	OK
E	0.3 μm or more	OK	0.2 μm or more (S)	OK
	0.5 μm or more	OK	0.5 μm or more (L)	OK

After reduction of circulating air amount

Measurement position	Dust counter measurement	Determi-nation	Wafer collection (5 hrs)	Determi-nation
A	0.3 μm or more	OK	0.2 μm or more (S)	OK
	0.5 μm or more	OK	0.5 μm or more (L)	OK
B	0.3 μm or more	OK	0.2 μm or more (S)	OK
	0.5 μm or more	OK	0.5 μm or more (L)	OK
C	0.3 μm or more	OK	0.2 μm or more (S)	OK
	0.5 μm or more	OK	0.5 μm or more (L)	OK
D	0.3 μm or more	OK	0.2 μm or more (S)	OK
	0.5 μm or more	OK	0.5 μm or more (L)	OK
E	0.3 μm or more	OK	0.2 μm or more (S)	OK
	0.5 μm or more	OK	0.5 μm or more (L)	OK

Figure 14: Comparison of wafer collected particle number before and after reduction in amount of circulating air flow

No fluctuations before and after reduction in amount of circulating air flow, when monitored with fixed dust counters located inside the process chamber.

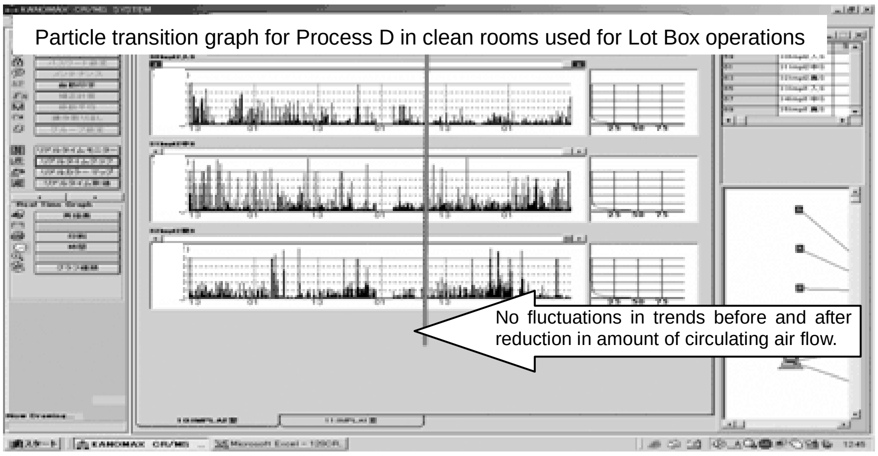

Figure 15: Transition of internal aerial particle number before and after reduction in amount of circulating air flow in the process chamber

No fluctuations were detected in terms of temperature or humidity before and after reduction in amount of circulating air flow, with transitions verified within the permissible range of required specifications for clean rooms.

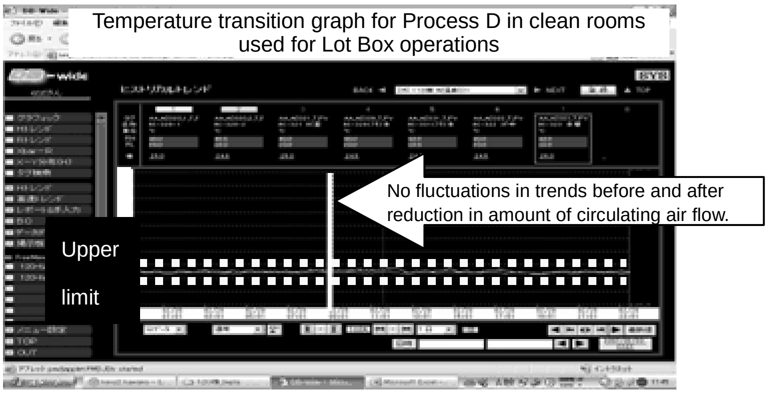

Figure 16: Transition of temperature before and after reduction in amount of circulating air flow

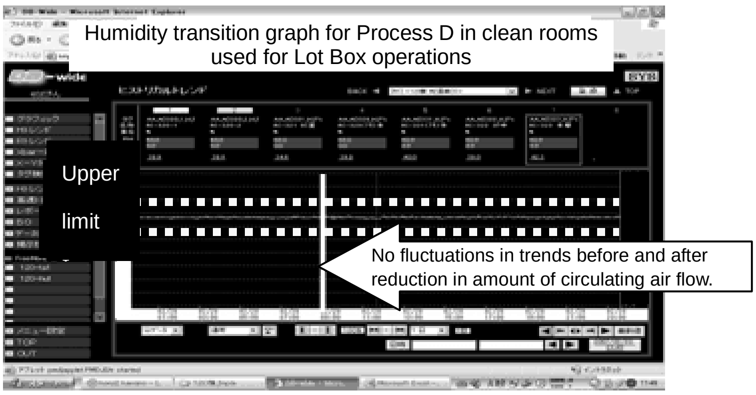

Figure 17: Transition of humidity before and after reduction in amount of circulating air flow

5. Effects achieved after Implementing Measures (Annual)

		Energy conservation amount (carbon dioxide in tons)	Monetary value of effects (JPY million)
A wing	Lot Box operation + Bay-method clean room	338.7	7.2
B wing	Lot Box operation + Bay-method clean room	728.3	15.5
C wing	SMIF Pod operation + Bay-method clean room	409.0	8.7
D wing	SMIF Pod operation + Ball room clean room	335.2	7.1
Total		1811.2	38.5

Table 2: Energy conservation improvement effects

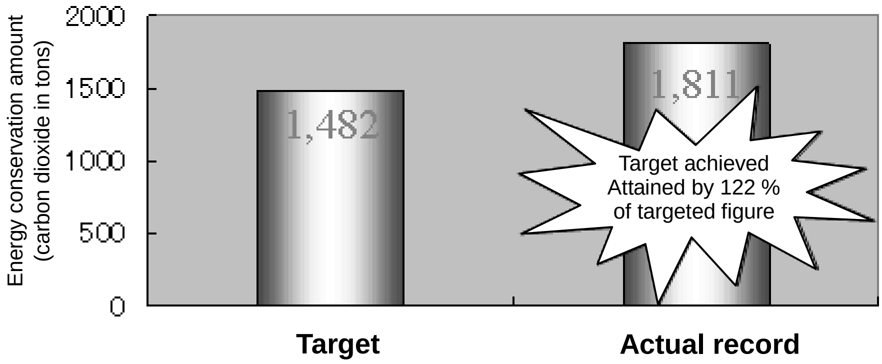

Figure 18: Comparison between target and effects of actions

6. Summary

Risk analysis for reduction in amount of circulating air flow for individual clean room operations was conducted, with focus on the reduction of electric power consumption for air conditioning, which comprise a large proportion of electric power consumptions at the manufacturing plant next to manufacturing equipment. Furthermore, conservation of energy was sought through easing the specified amount of circulating air flow to appropriate amount of circulating air flow in clean room, by investigating and analyzing the relationship between the amount of circulating air flow in clean rooms with fluctuation in cleanliness of clean rooms, as well as sustenance of temperature and humidity levels. With regards to Ball room clean rooms + SMIF Pod operations, the reduction in amount of circulating air flow was implemented in smallest controllable area units, according to the heat loads in clean rooms. The amount of circulating air flow was reduced in stages for clean rooms for Lot Box operations. Fluctuations of particle number in the clean room environment were carefully evaluated by aerial particle counters and wafer collections. It was possible to reduce the amount of electric power consumption for air conditioning without triggering fluctuations in clean room environments for both types of clean rooms.

7. Future Plans

The reduction in electric power consumption of air conditioning by reducing amount of circulating air flow in clean rooms introduced in this article is a case example that can be applied to other business lines, by ensuring that advance investigations and analysis are cautiously conducted.

This improvement method will be horizontally implemented to other clean rooms in the similar manufacturing plant, which have not yet been subjected to it, in order to raise the energy conservation effects arising from reduction in electric power consumption for air conditioning due to reduction in amount of circulating air flow in clean rooms. Furthermore, the reduction in electric power consumption of air conditioning by reducing amount of circulating air flow in clean rooms introduced in this article is a case example that can also be repeated in other business locations of the company and as such, considerations will be made regarding horizontal implementation through coordination with other relevant corporate organizations.