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Full Length Research Paper

A case study on energy saving of the facility systems for 12-inch semiconductor wafer fabs in Taiwan

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In recent years, the semiconductor wafer fabs have begun to produce 12-inch wafers instead of 8-inch wafers as the new generation process technology has evolved. The production area increases, and the energy consumption of production buildings is also increased. In a semiconductor fab, besides the processing equipments, the plant facility system consumes most of energy. The facility system contains chilled water systems, outside air supply systems, circulating air systems, exhaust-gas treatment systems, vacuum systems, process cooling water systems, ultra-pure water systems and compressed-air systems. Considering the gradual depletion of energy sources and the soaring energy cost, energy saving has become an important project to high energy consumption semiconductor fabs. Therefore, this paper presents a case study on the energy saving of a clean air conditioning system and facility of 12-inch semiconductor fabs. The energy saving schemes contain four cases: (1) Case 1: The gas consumption of the organic substance processing system of direct firing type is compared with that of regenerative heat recovery type; (2) Case 2: The energy consumption of the cooling tower adopting high and low speed operations is compared with that adopting a frequency converter; (3) Case 3: The low vacuum system of the clean room adopts the phone call system to switch on/off the pump, and (4) Case 4: The make up air unit of the clean room adopts the run around system to recover heat. As for the energy saving efficiency, Case 1 can save NT$9,881,616 of gas cost annually; Case 2 can save NT$2,398,913 annually; Case 3 can save NT$317,004 annually, and Case 4 can save NT$1,738,758 annually. Through the aforementioned four manipulations, 25.24% of the total energy consumption of the corresponding facilities can be saved.

Key words: Semiconductor fab, energy consumption, energy saving.

INTRODUCTION

With the development of technology industry, Taiwan has three major science-based industrial parks as well as world-class high density 12-inch semiconductor fabs. The high-technology industry is one of economic backbones of Taiwan at present, and Taiwan's high-technology industry focuses on the semiconductor wafer production and the optoelectronics industry of the "Two Trillion Two Star Plan" promoted by the government, thus driving the wafer backend package test and photoelectric peripheral products manufacturing. The high technology industry requires a large amount of energy, and is the major power consumer in Taiwan (Hu and Chuah, 2003; Wu, 2002). A semiconductor wafer fab is not an energy-saving industry though it is a high- technology industry. The semiconductor wafer fab is indeed a large energy consuming industry. As the wafer production and the optoelectronics industry have high added values, the energy cost accounts for a small proportion in the overall manufacturing cost, so that the company policies always focuses on the productive capacity and the production schedule. Additionally, the science-based industrial parks provide highly reliable power supply, thus energy saving is neglected. However, the linear diameter of semiconductor products becomes smaller in design, and the wafer volume becomes larger, the complexity of the

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manufacturing process is increased. As the process precision raises, the requirements for the overall production environment and facilities such as the process equipment power, clean room, process cooling water system, pure water system, gases and chemicals become stricter (Yen, 2005). The operating cost increases as the process precision rises; the competition in the high-technology industry is violent from the beginning. The global economic tsunami in 2008 made the industrial operation severe, and the carbon dioxide emission is controlled as the worldwide energy concept develops. Thus, how to reduce the operating cost while minimizing the energy consumption has become the common subject in the semiconductor industry.

Tsao et al. (2008) improved the energy performance of the make up air unit (MAU) system by properly arranging compositions of components of a typical MAU applied in a semiconductor clean room. The result shows that the draw-through type accompanied by two chilled water temperature system with heat recovery function exhibits the lowest electrical power consumption. Genetic algorithms (GAs) for operating standard heating, ventilation and air conditioning (HVAC) systems in order to optimize performance primarily with regard to power saving was used (Congradac and Kulic, 2009). A simulation is conducted in order to demonstrate how much power can be saved by using the suggested method of CO_2 concentration control in a standard HVAC system. An energy management and control system (EMCS) to schedule electricity end-uses in the campus of the Universidad Politécnica de Valencia (UPV), Spain was developed (Escrivá-Escrivá et al., 2010). They presented an evaluation performed by using the EMCS of different control strategies for HVAC split systems. It analyzed the effect of different schedules for a common air - conditioning device and demand response strategies are tested in several situations. Nasif et al (2010) showed that in humid climate, a saving of up to 8% in annual energy consumption can be achieved when membrane heat exchanger is used instead of a conventional HVAC system. Nassif (2010) examined several operation strategies of the economizer dampers and investigated their effects on the performance of both the supply and return fans in HVAC system, and also discussed a new operating strategy for economizer dampers that can lead to lower fan energy use. He demonstrated fan energy saving in the range of 5 to 30% can be achieved, depending mainly on the number of hours when the system operates in the free cooling mode, damper characteristics, and minimum outdoor air. Yau (2010) recommended that heat recovery systems should be installed to enhance moisture removal and reduce energy usage of HVAC system operating in hospitals. Practical application: The good amount of technical information of real application conducted on heat recovery devices installed in HVAC systems in operating theatres in the tropics could be used as a comprehensive guide for building services engineers and researchers who are intending to apply heat recovery devices as coolness recovery and dehumidification devices in HVAC systems operating in tropical countries. A data-mining approach for the optimization of a HVAC (heating, ventilation, and air conditioning) system was used (Kusiak et al., 2011). They developed a multi-objective optimization model to minimize the energy while maintaining the corresponding IAQ (indoor air quality) within a user-defined range. Two new high efficiency boilers installed to provide space heating and domestic hot water, and the existing heating, ventilation, and air conditioning (HVAC) systems for energy savings were presented (Davis, 2011). The facility's gas use has been reduced by 53% since these equipments were installed in two years. Cheng et al. (2010) used a Lagrangian particle-tracking method to analyze the particle dispersion and deposition in a clean room with a negative pressure gradient in order to investigate the effects of air supply locations on the rates of restraining particles from entering the room and the rates of particle removal from the room.

This research conducted a case study on the energy saving of the facility systems of a 12-inch semiconductor wafer fabs and compared the cases of the facility systems of 12-inch wafer fabs A, B and C. It selected four energy saving cases for discussion and suggestion.

STUDY OF ENERGY SAVING CASES OF 12-INCH SEMICONDUTOR FABS

Comparison between gas consumption of organic substance processing system (VOC) adopting direct firing (TO) and that adopting regenerative heat recovery (RTO)

The volatile organic compounds (VOC) refer to generic terms of organic compounds. The waste gas treatment flow of VOC system is divided into two major parts.

1. Adsorption and concentration: The adsorbent with high porosity and high specific surface area was used to separate VOCs gas molecules from the organic solvent gas discharged from the production line directly through physical adsorption (reversible reaction) or chemical bonding (non-reversible reaction), discharge clean air after adsorbed by the zeolite adsorption tank.

2. Oxidizing fire: For saturated high concentration organic substances absorbed in adsorption tank (concentrated by 12 folds), the heat exchanger is used to generate 200°C high-temperature air to desorb high concentration organic substances from the saturated zeolite in the adsorber which are pumped by the blower fan to the combustion chamber to burn with gas and discharged to atmosphere. Most of VOC can be removed when the combustion temperature is higher than 800°C.

The VOC system contains six major items:

1. Zeolite rotor table: adsorb VOC gases

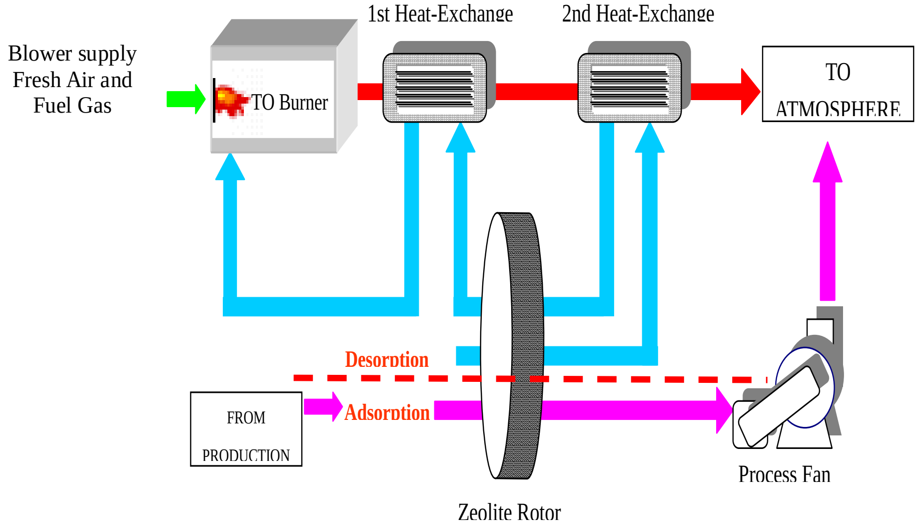

Figure 1. Flow chart of VOC (TO) system of fab A.

Table 1. Statistics of gas consumption of direct firing VOC system of fab A.

Year/month	VOC concentration (ppm)	Wafer gas day usage (m^3/day)	Wafer gas month usage (m^3/month)	Wafer gas day expenses(NTD/day)	Wafer gas month expenses (NTD/month)
2008/05	103	1,789	55,450	31,302	970,371
2008/06	135	1,772	53,162	37,568	1,127,039
2008/07	152	1,742	53,988	36,921	1,144,540
2008/08	143	1,811	56,129	38,385	1,189,927
2008/09	130	1,741	52,238	36,915	1,107,450
2008/10	140	1,714	53,074	36,296	1,125,176
2008/11	132	1,749	52,469	37,078	1,112,343
2008/12	135	1,701	52,721	29,932	927,890
2009/01	50	1,362	24,522	21,116	380,091
2009/02	50	1,211	21,806	18,777	337,993
2009/03	76	1,292	40,066	20,033	621,023
2009/04	73	1,318	39,552	20,435	613,056

2. Regenerative thermal oxidizer: burning VOC structure for destruction
3. Oxidizer fan:cool down zeolite and desorb concentrated VOC
4. Heat exchanger: thermal resource recovery
5. Process fan: maintain pipeline static pressure
6. Fuel system: Natural gas (supplied fuel) and diesel oil (guarantee fuel). Scheme 1 compares the gas consumption of 12-inch semiconductor fab A using VOC TO system with that of fab B using RTO system. The VOC systems of fab A and fab B circulate adsorption -> desorption -> combustion removing VOC. At present, the reduction rate of fab A is 95% and that of fab B is 92%, both of them are higher than the 90% specified by laws (Tsai, 1999).

The flow chart of VOC (TO) system of fab A is shown in Figure 1. The desorbed VOC is burnt in the furnace using natural gas, and two heat exchangers are used for preheating. However, the temperature inside the furnace must be increased by using fuel, so the TO burner consumes a great deal of fuel and its volume is large (heat exchanger volume). The VOC concentration, wafer output, wafer gas month usage, wafer gas day usage, wafer gas day expenses, unit wafer gas consumption, and monthly gas cost of the direct firing VOC system of fab A and the RTO VOC system of fab B are shown in Tables 1 and 2 (recorded during May 2008 to April 2009). Yearly maintenance was carried out in January and February 2009 as shown in Tables 1 and 2, so the wafer output is decreased.

The flow chart of VOC (RTO) System of fab B is shown as Figure 2. Its regenerative combustion technology uses

Table 2. Statistics of gas consumption of RTO VOC system of fab B.

Year/month	VOC concentration (ppm)	Wafer gas day usage (m^3/day)	Wafer gas month usage (m^3/month)	Wafer gas day expenses (NT/day)	Wafer gas month expenses (NT/month)
2008/05	328	1,175	38	663	20,563
2008/06	316	1,240	41	876	26,288
2008/07	320	1,198	39	819	25,398
2008/08	335	1,210	39	827	25,652
2008/09	318	1,231	41	870	26,097
2008/10	305	1,236	40	845	26,203
2008/11	185	10,500	350	7,420	222,600
2008/12	150	11,470	370	6,512	201,872
2009/01	80	6,574	365	5,661	101,897
2009/02	100	9,235	385	5,964	143,143
2009/03	156	11,564	373	5,782	179,242
2009/04	143	11,143	371	5,757	172,717

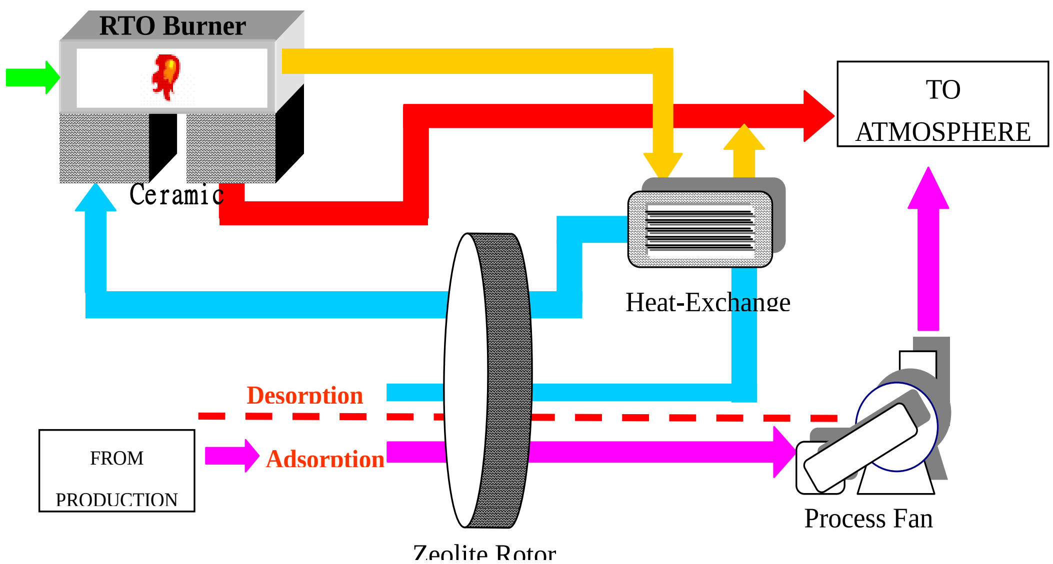

Figure 2. Flow chart of VOC (RTO) System of fab B.

the regenerative ceramic as the heat exchange medium. The burnt high temperature fume heat is recovered by the high heat retaining capacity of the regenerative ceramic to preheat the air required for combustion. The combustion air can be preheated to above 800°C, so that the stable region of the flame is enlarged that is helpful to the improvement of stability. The regenerative combustion technology adopts alternative combustion mode. This mode can promote the uniformity of the thermal flow field in the furnace and increase the mean heat flux in the furnace for high efficiency heat transfer. Therefore, the regenerative combustion technology can improve the combustion heat efficiency and reduce fuel consumption and equipment size (Chen, 2002).

The unit wafer gas consumption of fab A is compared with that of fab B. The sampled data of fab A are the mean values (recorded during May 2008 to December 2008) in Table 1,which are VOC concentration, wafer output, unit wafer gas consumption and monthly gas cost in turn; the data are 134, 22063 and 2.44 in turn. The sampled data of fab B are the mean values (recorded in December 2008, March 2009 and April 2009) in Table 2, which are VOC concentration, wafer output, unit wafer gas consumption and monthly gas cost in turn; the data are 150, 21721 and 0.524 in turn. As the mean value of wafer output of fab B during May 2008 to November 2008 is 3.3 times of that of fab A, the data are excluded. The yearly system maintenance was carried out during January 2009 to February 2009,so the data are excluded.

It is observed from the data that when the VOC

Table 3. Differences between chiller plant structures of fabs B and C.

Parameter	Unit	Fabs B	Fabs C
Floor area	m^3	185, 203	103,357
Factory	NA	12-in semiconductor fab	12-in semiconductor fab
Chiller type	NA	Centrifugal type R123	Centrifugal type R123
Chiller temperature	°C	5 and 9°C double-chilled	5 and 9°C double-chilled
Chiller refrigeration performance (single)	USRT	5°C 1250 USRT 9°C 1500 USRT 9°C HR 1250 USRT	5°C 1250 USRT 9°C 1500 USRT 9°C HR 1250 USRT
Chiller plant quantity	Set	17	8
Chiller system refrigeration performance	USRT	19,500	11,500
Cooling tower type	NA	Cross flow	Cross flow
Cooling tower flow rate	L/S	255	255
Cooling tower quantity	Set	22	22
Cooling tower power	HP	100	100
Cooling tower fan control mode	NA	High/low speed two-stage mode	Frequency converter mode
Cooling tower supplied water quality	NA	Conductivity < 60 us/cm pH 9	Conductivity < 60 us/cm pH 9
Conductivity	us/cm	1600	1600

concentration and wafer output data of fab A approach to that of fab B, according to the comparison in unit, wafer gas consumption, unit wafer gas consumption of the RTO system of fab B is one fifth of that of the TO system of fab A, the monthly gas cost can be decreased by NT$823,468.

Comparison between energy consumption of cooling tower using high and low speed operation and that using frequency converter

In HVAC systems, the heat of the cooling water, which is absorb from the condenser, should be dissipated into the atmosphere through the cooling tower. In scheme 2, the fan operating mode of the cooling tower of 12-in semiconductor fab B is two-stage high and low speed system, and that of fab C is frequency converter system. The chiller plant design structures of fabs B and C are identical, as shown in Table 3; both of them are secondary pump frequency conversion (VWV) and double-chilled water temperature system (5 and 9°C), and fabs B and C have the same chiller type, tower type and water quality control mode. The floor area, chiller quantity, cooling tower quantity and the tower fan control mode are different, therefore, this study will compare the energy consumption of unit refrigeration ton of the cooling tower based on the differences in the tower fan control mode.

The cooling tower fan control modes of fabs B and C are compared to determine the differences between the high and low speed two-stage and the frequency converter operating modes of the cooling tower fan; the cooling tower is controlled in the system, the tower outlet water temperature controls the stability; there are differences in the tower fan starting mode and running noise, stable outlet water temperature control and low running noise are required in actual operation control.

The energy consumption of cooling tower operating unit refrigeration ton of fab B is compared with that of fab C. The data of a year (January 2008 to December 2008) of fabs B and C are collected for systematic analysis.The outside air enthalpy value is compared with the refrigeration ton consumption of fabs B and C. The horizontal coordinate is the collection date, and the vertical coordinate is the enthalpy value and refrigeration ton. Figure 3 shows that the refrigeration ton consumption of fabs B and C is positively correlated with the outside air enthalpy value. Therefore, the unit refrigeration ton costs of cooling tower are compared according to the power consumption of cooling tower, fill displacement and water dosage.

According to the statistical data of power cost of cooling tower, water addition and discharge costs and water conditioning reagent cost, the unit operating cost of the two-stage high and low speed cooling tower used by fab B during January 2008 to December 2008 is higher (NTD/USRT) than that of the frequency converter used by fab C by NT$27 at most and NT$11 at least. Therefore, the operating cost of the frequency converter cooling tower of fab C is lower than that of the high and low two-stage cooling tower of fab B by 25.3% at most and 7.5% at least.

According to the analysis of differences in energy saving benefit, when the system load reaches its maximum in summer, the frequency conversion cooling

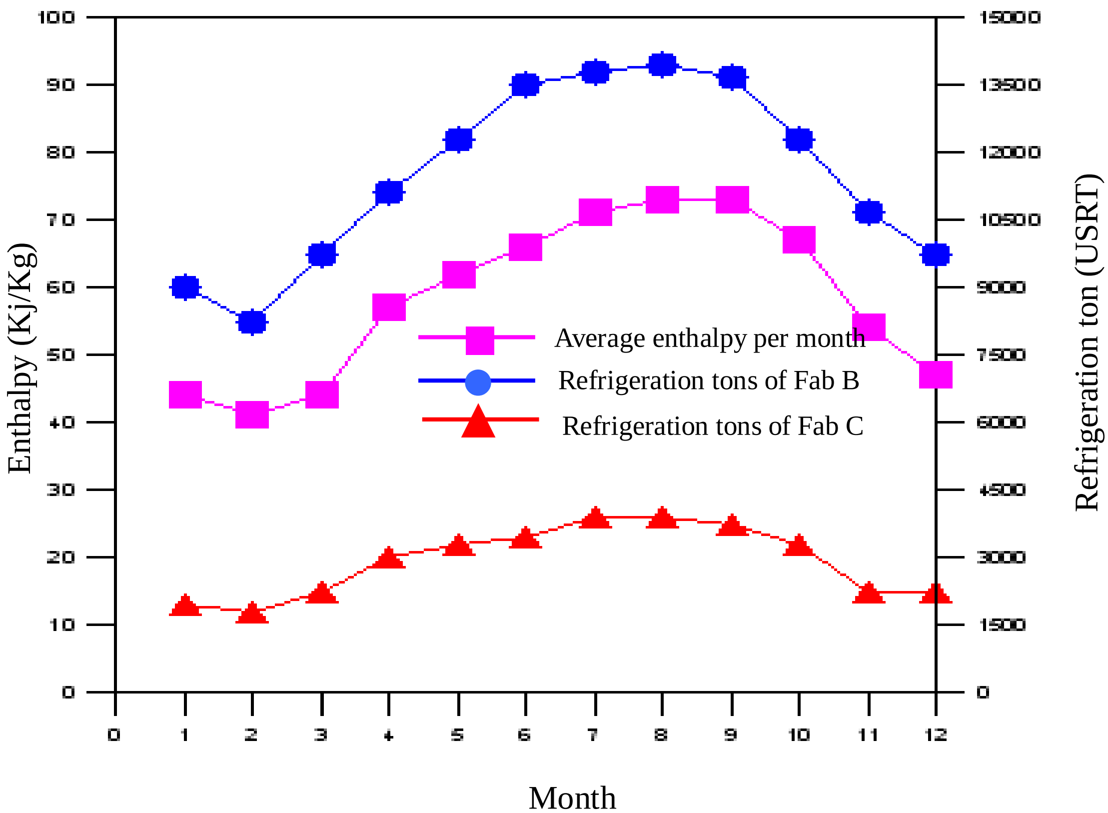

Figure 3. Comparison between outside air enthalpy value and refrigeration ton of fabs B and C in 2008.

tower keeps operating at a high capacity, thus, its energy saving benefit is lower than that of high and low speed cooling tower. On the contrary, the space of the frequency conversion cooling tower is enlarged in autumn and winter, thus, it has the maximum benefit. According to the difference comparison in Table 4, if the two-stage high and low speed cooling tower of fab B is refitted to frequency conversion type, NT$2,398,913 can be saved annually (recorded during January 2008 to December 2008).

Clean room house vacuum uses phone call to switch pump on-off

The house vacuum is used for the clean room dedusting and cleaning of production machines; there are three sets of house vacuums. Each set contains one filter vat, one dust container, three 15.3 kW large vacuum pumps and one 8.6 kW small vacuum pump. The system pressure of house vacuum is controlled below -220 mmHg; the system flow chart is shown as Figure 4. The system principle is that the vacuum pumps generate vacuum suction to take the dust derived from the clean room and production machine maintenance to the filter bag of the filter vat through pipelines for filtration. The dust is collected in the dust container, and the clean air filtered by the filter bag is discharged by the vacuum pumps through pipelines. Case 3 studies the house vacuum for cleaning of clean room machine maintenance. The original system is under full load all the day, and the system is still in operation when the clean room machine is not in maintenance that causes energy consumption. Therefore, the house vacuum function is improved; phone control is added to the system, and the phone system, repeater and monitoring system PLC (Programmable Logic Controller) are used for system function control. The system is set as started by phone call, and the system shutdown time can be set as 30 or 60 min. The system will stop when the set time is up. The trend of daily consumption of the house vacuum without phone call is shown in Figure 5. The horizontal coordinate is the time axis, and the vertical coordinate is the pressure axis. The tendency chart can be divided into four time intervals to analyze the vacuum pump operating state. The first time interval is 24:00 to 08:30, one large and one small vacuum pump are in operation; it is the valley period of process equipment maintenance, the vacuum pressure is -198 Pa. The second time interval is 08:30 to 12:00, three large vacuum pumps are in operation;it is the peak period process equipment maintenance.The third time interval is 12:00 to 18:00, two large and one small vacuum pump are in operation; it is the peak period of process equipment maintenance. The

Table 4. Differences in cooling tower operating costs of fabs B and C.

Parameter	Unit	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Fabs B operating cost unit USRT	NTD/ USRT	97	75	100	106	109	123	147	153	150	145	134	129
Fabs C operating cost unit USRT	NTD/ USRT	76	56	80	90	94	110	136	137	137	127	108	102
Saving operating cost unit USRT	NTD/ USRT	21	19	20	16	15	13	11	16	13	18	26	27
Saving efficiency	%	21.6	25.3	20.0	15.1	13.8	10.6	7.5	10.5	8.7	12.4	19.4	20.9
Refrigeration tons of fabs B use	USRT	9,146	8,232	9,827	11,353	12,317	13,405	13,851	14,168	13,701	12,260	10,653	9,779
Fabs B saving operating cost per month	NTD/M	191,151	156,408	196,540	180,513	188,450	170,247	157,904	226,680	175,378	215,783	274,847	265,011

fourth time interval is 18:00 to 24:00, two vacuum pumps are in operation; it is the valley period of process equipment maintenance. The daily power consumptions of vacuum pumps operating under full load in four stages of house vacuum without phone call are sorted out from the tendency chart in Figure 5. It is known that the house vacuum consumes 782.6 kWh per day. The average unit price of monthly power consumption of fab B is 1.88 NT/kWh (Chen, 2001). After system evaluation and energy saving improvement, the house vacuum is mounted with phone call. The trend of daily consumption is shown in Figure 6. The horizontal coordinate is the time axis, and the vertical coordinate is the pressure axis. The tendency chart can be divided into four time intervals to analyze the vacuum pump operating state. The first time interval is 24:00 to 08:30, there is no vacuum pump in operation; it is the valley period of process equipment maintenance, and the vacuum pressure is 0 Pa. The second time interval is 08:30 to 12:00, three largev acuum pumps are in operation; it is the peak period of process equipment maintenance. The third time interval is 12:00 to 18:00, two large and one small vacuum pump are in operation; it is the peak period of process equipment maintenance. The fourth time interval is 18:00 to 24:00, there is no vacuum pump in operation; it is the valley period of process equipment maintenance, and the vacuum pressure is 0 Pa. The daily power consumptions of vacuum pumps operating under full load in two stages of house vacuum with phone call are sorted out from the tendency chart in Figure 6. It is known that the house vacuum consumes 314.3 kWh per day. The average unit price of monthly power consumption of fab B is 1.88 NT/kWh, and the daily power cost of house vacuum is NT$591 after multiplication. According to the operation tendency chart of House vacuum, the daily power cost of house vacuum without phone call is NT$1,471. When it is mounted with phone call after system improvement, the daily power cost is NT$591. The cost is reduced by 60% when phone call is mounted compared with the former mode. NT$880 is saved per day.

Clean room MAU adopts run around system for heat recovery

The clean room of a semiconductor wafer fab must be kept at the indoor cleanliness class. The positive pressure inside the clean room is necessary in order to avoid outside air penetrating into the clean room and affecting the cleanliness of the clean room. The positive pressure is kept using the MAU (make up air unit), as shown in Figure 7, to take the clean air at constant temperature and humidity treated by primary filter

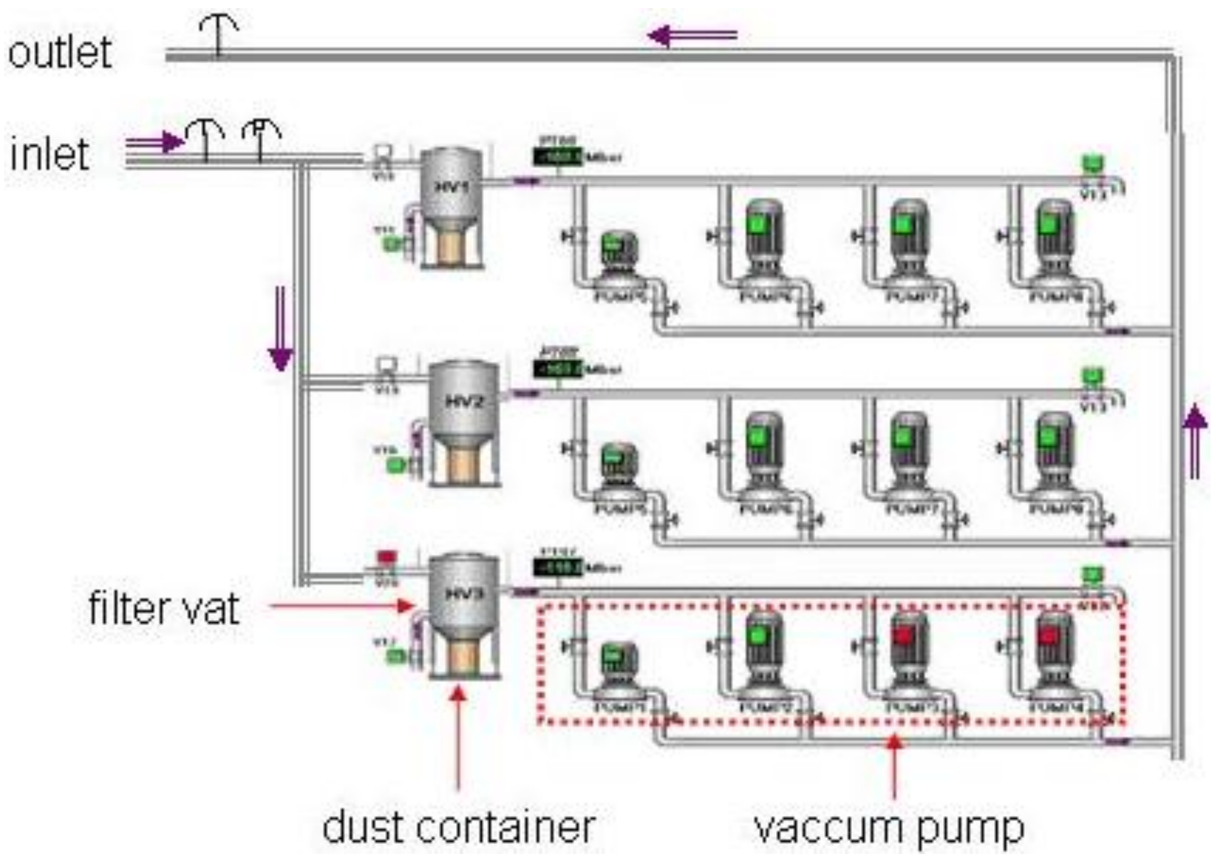

Figure 4. House vacuum flow chart.

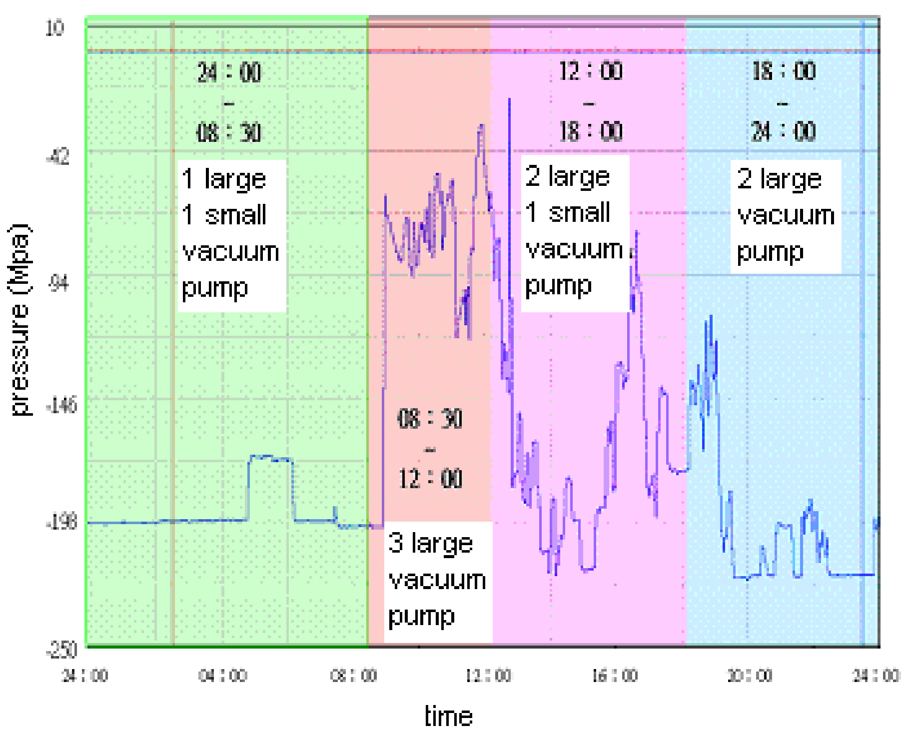

Figure 5. Daily consumption trend of house vacuum without phone call.

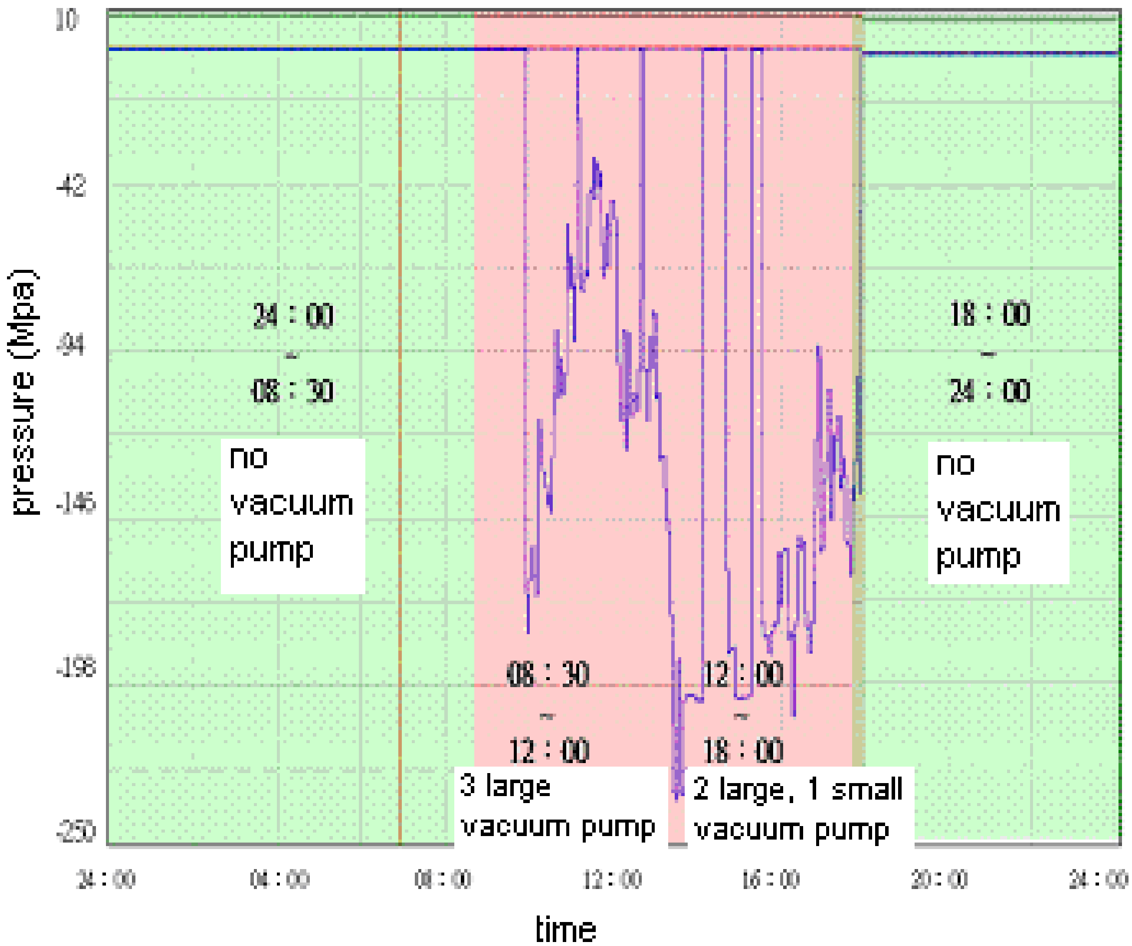

Figure 6. Daily consumption trend of house vacuum with phone call.

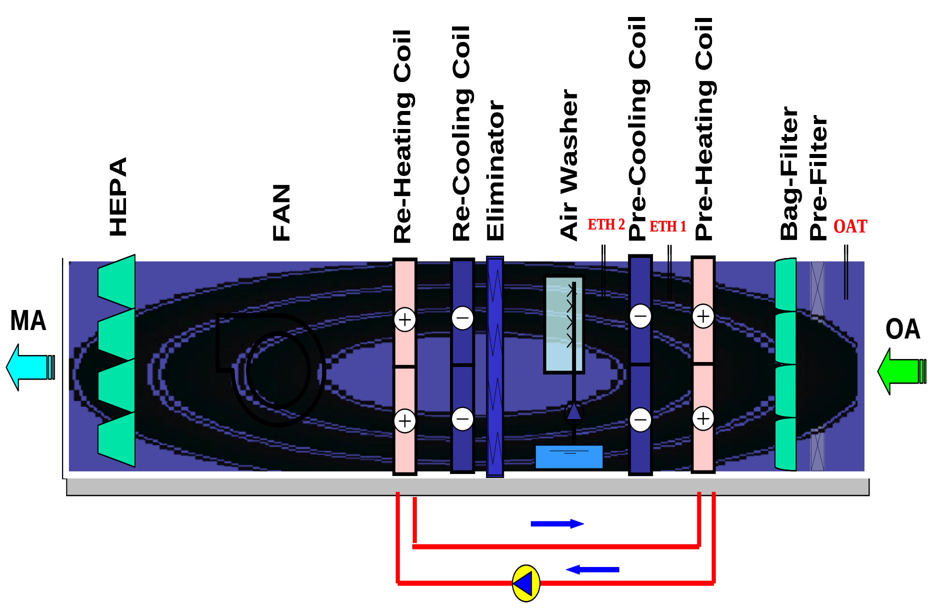

Figure 7. MAU system diagram.

Table 5. Energy saving cost of MAU R&R device.

Paramater	Unit	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
	Enthalpy (kJ/kg)	44.6	39.8	44.0	57.2	61.3	66.4	71.5	74.2	74.3	66.7	53.5	45.1
R&R device	Load(RT)/CMH	0.00030	0.00030	0.00036	0.00064	0.00085	0.00108	0.00177	0.00214	0.00216	0.00161	0.00119	0.00086
No R&R device	Load(RT)/CMH	0.00031	0.00033	0.00042	0.00082	0.00126	0.00147	0.00203	0.00235	0.00234	0.00172	0.00125	0.00087
Difference	Load(RT)/CMH	0.00001	0.00003	0.00006	0.00018	0.00041	0.00039	0.00026	0.00021	0.00018	0.00011	0.00006	0.00001
Electric cost	NTD	1.51	1.51	1.56	1.51	1.54	1.86	2.27	2.27	2.20	2.09	2.13	2.09
OA saving cost	NTD	10,875	30,520	67,410	189,434	454,729	505,575	425,057	343,316	275,996	165,572	89,071	15,052
circulating pump electric cost	NTD	69,142	64,681	71,432	66,912	70,516	82,421	103,942	103,942	97,487	95,700	94,385	95,700
R & R saving cost	NTD	-58,267	-34,161	-4,022	122,522	384,213	423,154	321,115	239,373	178,509	69,872	-5,314	-80,648

screen, bag filter screen, precooling and preheating coils, air washer, centrifugal type windmill and HEPA (High Efficiency Particulate Air) filter screen into the clean room to maintain positive pressure (Wang et al., 2002).

Case 4 mounts additional circulation lines and water circulating pumps to MAU, pre-heating coil and re-heating coil; the circulating heat recovery inside the pipeline is used, and the pre-cooling coil 9°C chilled water load and the re-heating coil 33°C warm water load are reduced. The outlet water from the re-heating coil is about 13°C. It is conveyed to the pre-heating coil through internal circulation pipe to be precooled with the outside air in the MAU. The temperature of the circulating water in the pre-heating coil increases after heat exchange, and the water circulating pump pumps the circulating water to the re-heating coil for heating action, so as to complete the water circulation of Run-around pipeline.

According to statistics, the difference in the refrigeration ton for MAU R&R ON and OFF can be calculated by multiplying the unit air quantity CMH by the total air quantity 1,210,000 CMH of this fab. The monthly cost saving of outside air can be determined from the unit electric cost of fab B. R&R device needs the water circulating pump to convey water. The specification of water circulating pump is 10 HP, and the efficiency is 75%. There are 11 water circulating pumps. The cost saving of R&R is shown in Table 5. As seen, the R&R device saves cost in January, February, March, November and December, and the difference between the OA cost saving and the electric cost of water circulating pump is negative. The R&R saves NT$122,522, NT$384,213, NT$423,154, NT$312,115, NT$239,373, NT$178,509 and NT$69,872 from April to October. The total is NT$1,738,758. According to the data result of this fab, the R&R device has recovery benefit from April to October in a year considering the operational stability. Since it has no recovery benefit in January, February, March, November and December, it is suggested to shut down R&R water circulating pump to avoid energy waste.

CONCLUSIONS

This study collected the energy saving cases of current 12-inch semiconductor wafer fabs in order to determine the energy saving effects.

1. The gas fuel cost of RTO VOC is lower than that of TO VOC; the unit wafer gas consumption of RTO is one fifth of that of TO, the equipment recovery period is 4.14 years. Adopting the RTO VOC, 80.12% of the gas fuel cost can be saved in comparison with that of TO VOC.
2. According to the power consumption of cooling tower, water addition and discharge and water conditioning reagent cost, as compared in unit refrigeration ton consumption, the frequency converter operation is more energy saving than the two-stage high and low speed operation, the equipment recovery period is 4.84 years. Utilizing the frequency converter operation, 13.78% of the electric power cost can be saved in comparison with that of the two-stage operation.
3. The clean room house vacuum is mounted with phone call to improve process equipment maintenance valley and vacuum system consumption; the energy can be saved and recovered only by modifying the settings of telecommunication system and central monitoring system, and the recovery period is 0 year. By mounting Phone Call, 60% of the electric power cost of vacuum system can be saved. 4. The OA conditioning cabinet is mounted with additional cold energy circulating pump, the pre-cooling coil load is improved. There are recovery benefits from April to October according to the comparison

of run around on-off. Adopting the run around system, 7.62% of the electric power cost of the make up air unit can be saved.

Through the four manipulations, 25.24% of the total energy consumption of the corresponding facilities can be saved. This energy saving effect can be used as the reference for the effects of various energy saving measures of 12-inch semiconductor wafer fabs. In addition, the energy saving effect and system recovery period of the energy saving measures having actual operation effects are described and quantified. These results can be consulted by various fabs for energy saving measures in the future. As the energy is short in the world and the cost increases at present, energy saving can reduce the system operating cost, and achieve environmental protection.

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