Semiconductor fab reduces air handler electrical consumption by 11.5%, saving $111,000 annually

NALCO Water
An Ecolab Company

CASE STUDY – MANUFACTURING

CH-1159

BACKGROUND

The air handling units (AHU) in a semiconductor fab perform a critical role – delivering reliable temperature and relative humidity control to the manufacturing environment. Even slight variations of the fab's air temperature and relative humidity can have a profound effect on chip quality, and the cost of downtime is very high. The air handling systems are also one of the largest energy consumers in a fab.

Air handlers perform by moving air through filters and across heat exchange coils to cool or warm the air to adjust the air's relative humidity and / or temperature. As with any other heat exchange surface, the cleanliness of the coil has a direct impact on the efficiency of that heat exchange process.

SITUATION

A semiconductor fab in the northeastern United States was seeking ways to reduce their energy consumption. Air handlers, being a large energy consumer, were a natural place to consider. The fab wished to clean the air coils, but wanted also to achieve two important goals: cleaning the coils without damaging them, and documenting the impact of the cleaning to ensure that the investment made in the cleaning provided a positive economic benefit.

There are four primary reasons for cleaning an air handler's coils:

- A dirty coil is a less efficient coil – this increases energy costs because more chilled water (or lower temperature chilled water) must be circulated through the coil to satisfy the fab's demand for conditioned air
- A build up of dirt will cause enough back-pressure to require an increase in energy in order to maintain proper air flow rate in the HVAC system

Customer Impact	eROI℠	Economic Results
Total kWh reduced by 1.22 million 900 tons of CO_2 reduced	ENERGY	Annual savings of $111,348

eROI is our exponential value: the combined outcomes of improved performance, operational efficiency and sustainable impact delivered through our services and programs.

"Energy Savings by Air Coil Efficiency Improvement" originally presented at SESHA (Semiconductor Environmental, Safety, Health Association) May 19, 2011, Scottsdale, AZ

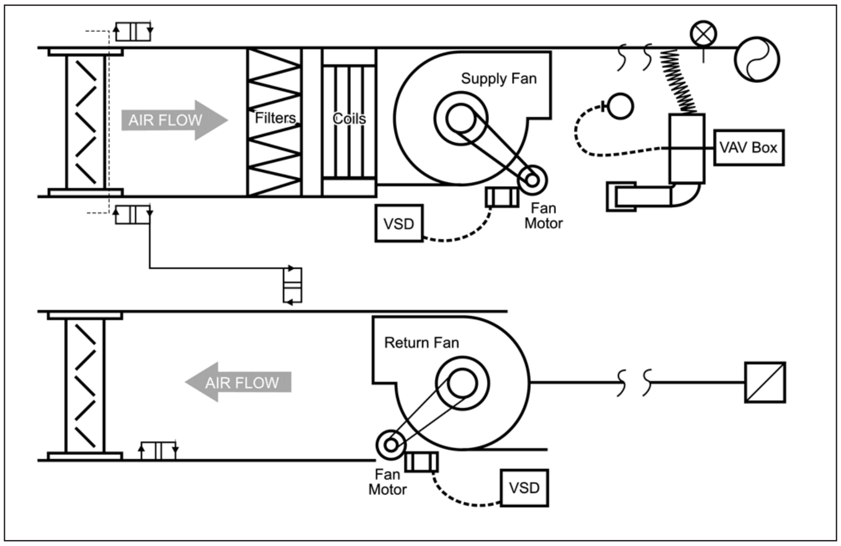
- Dirt acts as a site for under deposit corrosion, which reduces coil life
- If the dirt builds up to a sufficient thickness on the coils, it can slough off and enter the airstream and compromise indoor air quality standards

Yet, despite these compelling reasons, many facilities clean the coils too infrequently, clean them poorly, or clean them at irregular intervals. This happens for several reasons – lack of available trained labor, an incomplete understanding of the impact of not doing the cleaning, the challenge of performing a messy and unpleasant task, or the challenge of what to do with the "leftovers" of the cleaning process.

Until recently, any of three primary methods have been used for cleaning air coils – high pressure water, low pressure water and aggressive chemical application:

High pressure water

- Description – >100 psi (690 kPa) water sprayed into coil, usually cleaners added to water. If coil depth exceeds 6" (15 cm), both sides of coil are usually sprayed
- Benefits
  - Higher pressure's impingement aids in dirt removal
  - Higher pressure reduces cleaning time – reduces labor cost



Typical Air Handler Configuration

- Drawbacks and risks
  - Bent coil fins from higher pressure
- Damage and loss of efficiency
  - Driving dirt and debris further into the coil pack
  - Overflow of drain pan from insufficient draining of chemical / rinsing solution
  - Potential worker chemical exposure

Low pressure water

- Description – <100 psi (690 kPa) water sprayed into coil, cleaners (usually foaming) nearly always added to water. Followed by low pressure rinse.
- Benefits
  - Lower pressure minimizes damage potential to fins
- Drawbacks and risks
  - Insufficient pressure to remove dirt, debris and microbial film
  - Risk of driving dirt and debris further into the coil pack is higher, especially in coil packs > 3" (7.6 cm) deep
  - More time required to complete cleaning because of lower pressure
  - Potential worker chemical exposure risk is higher because chemicals used for low pressure cleaning are usually harsher

Aggressive chemical applications

- Description – application of highly alkaline, or highly acidic, foam cleaners, brighteners and non-rinse cleaners. Usually used for exceptionally dirty air coils, or where conventional cleanings have been unsuccessful. Selection of chemical is soil dependent.

- Benefits
  - If the cleaning chemical can reach the soil, the results can be impressive
- Drawbacks and risks
  - Brighteners often do not clean, only remove metal oxides to create a "shiny clean" look – reduces coil life
  - Metal removal increases chance of coil leakage
  - Foaming cleaners may drive dirt and debris further into the coil pack
  - Potential worker chemical exposure
  - Increased cleaning time

Recently, a new patented method has been developed that overcomes many of the disadvantages of the above described methods, and provides a key benefit that has proved of great value – performance measurements before and after to document success and quantify energy savings. The new method consists of the following steps:

- Baseline performance monitoring
  - Provides visibility and an understanding of baseline performance
- Using 500 psi with low water consumption application
  - Reduces risk of coil damage, and cuts disposal volumes
- The cleaner is a low alkalinity / surfactant blend mixed into water stream
  - Minimizes volume of water and chemistry needed and reduces risk of driving dirt into the coil pack
  - In most cases, the wash water can be sent to the fab's sanitary or waste water facility
- A unique coil surface biocide is applied after cleaning
  - Prevents quick re-establishment of biological slimes on the coils and extends time between cleanings
- Drain pan biocide is added at the conclusion of the cleaning
  - Reduces potential for microbially induced corrosion of drain pan, and diminishes microbial plugging of the drain pans
- Post cleaning performance monitoring
  - Quantifies the efficiency improvement of the coil cleaning
- Periodic performance monitoring
  - Monitor performance, in representative AHU's, to quantify the operating life cycle

The cleaners are applied by trained, qualified service personnel, using appropriate Personal Protective Equipment (PPE) and safe procedures.

A key aspect of this approach is the before, after, and periodic monitoring of representative air handlers, to ensure savings are achieved and maintained for ongoing sustainable energy savings.

IMPLEMENTATION

The next section of this paper discusses the specifics of this application of this process at the northeastern US fab.

Project scope was 137 AHU coils cleaned – most units had both hot and chill coils. The project took place between April 20 and June 8, 2010.

The perfomance validation process proceeded as follows:

1. Eight representative AHU systems were surveyed
   - Direct & indirect measurements were taken before the cleanings commenced
2. Cleanings on the AHU coils were conducted
3. Direct & indirect measurements were taken on the representative AHU's after the cleanings were complete
4. Overall projections, based on those representative AHU's were calculated to project savings or reductions in:
   - Annual Cooling Energy
   - Annual Fan Energy
   - Total Annual Energy
   - Greenhouse Gas Reductions

The data was collected and summarized in tabular form – an example is shown:

ENVIRONMENTAL/ECONOMIC RESULTS

Air side chill coil measurements resulted in an average heat transfer improvement of 24,235 BTU/h or 11.5% per AHU. Calculated air side heat transfer improvement is summarized in Table 1. Note that these readings do not include additional savings from a reduction in chilled water requirements.

Direct ammeter readings showed a total amp reduction of 194.8 amps. Calculated savings are summarized in Table 2.

The accompanying photos from a few of the fab AHU cleanings also support the energy savings calculations.

CONCLUSION

- The air handlers are the first point of contact between fab air and the HVAC system
- They are critical to proper control of the fab's successful manufacturing environment
- They are a large consumer of electrical power
- Air handler inefficiencies are carried and magnified throughout the entire cooling process
- Maintaining a clean air handler is an important, but often neglected, poorly performed, or woefully under-documented task
- Existing methods leave much to be desired (asset damage, incomplete cleaning, for example)

Table 1 – *Summary of Air Side Heat Transfer Measurements and Calculations*

COIL-FLO® | Large Systems Assumptions & Measurements — I-P Units

SYSTEM (▶ Data Inputs)	1	2	3	4	5	6	7	8
Description	AHU#6	AHU#4	AHU#9	AHU#30	AHU#20	AC-1	AHU#39	AHU#25
Date Cleaned	05/20/10	05/25/10	05/05/10	05/25/10	05/25/10	06/01/10	04/28/10	04/28/10
COOLING SYSTEM ASSUMPTIONS:								
Coil Face Area (Sq. Ft.)	24	258	114	80	50	60	60	60
CFM at Design (Calculated)	12,000	128,750	57,000	40,000	25,000	30,000	30,000	30,000
Annual Cooling Hours	4,380	1,108	4,380	4,380	4,380	4,380	4,380	4,380
System Efficiency:	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
Select units	kW/Ton	kW/Ton	kW/Ton	kW/Ton	kW/Ton	kW/Ton	kW/Ton	kW/Ton
Coefficient of Performance (COP)	4.69	4.69	4.69	4.69	4.69	4.69	4.69	4.69
FAN SYSTEM ASSUMPTIONS:								
Air Delivery Method	Variable	Variable	Variable	Variable	Variable	Variable	Variable	Variable
Fan System Efficiency (default 75%)	75%	75%	75%	75%	75%	75%	75%	75%
Annual Fan Hours	8,760	2,216	8,760	8,760	8,760	8,760	8,760	8,760
COIL MEASURMENTS - BEFORE CLEAN								
Date Measured	05/20/10	05/25/10	05/05/10	05/25/10	05/25/10	06/01/10	04/28/10	04/28/10
Time Measured	Morning	Afternoon	Morning	Afternoon	Afternoon	Afternoon	Morning	Morning
Outdoor Air Temperature (°F-db)	63.0	79.4	56.0	86.2	65.0	68.6	37.0	37.0
VSD Fan Set-point (Hz or rpm)	n/a	n/a	n/a	1.0	n/a	n/a	n/a	n/a
Coil Face Velocity (ft/min)	500	233	570	377	595	500	526	418
Normalized to After Clean Velocity	500	233	570	377	595	500	526	418
Calculated Air Flow (CFM)	12,000	59,998	64,980	30,160	29,750	30,000	31,560	25,080
Static Pressure Drop (Inches WG)	0.70	0.04	0.50	0.40	0.18	0.74	1.06	0.23
Normalized to After Clean Pressure Drop	0.70	0.04	0.57	0.42	0.18	0.74	1.06	0.23
Entering Air Temp (°F-db)	72.9	73.9	64.6	77.4	77.4	67.6	76.1	56.4
Leaving Air Temp (°F-db)	55.2	52.9	64.3	56.6	57.2	65.1	53.7	45.4
Temperature Drop	17.7	21.0	0.3	20.8	20.2	2.5	22.4	11.0
COIL MEASURMENTS - AFTER CLEAN								
Date Measured	05/20/10	05/25/10	05/05/10	05/25/10	05/25/10	06/01/10	04/28/10	04/28/10
Time Measured	Afternoon	Afternoon	Afternoon	Afternoon	Afternoon	Afternoon	Morning	Morning
Outdoor Air Temperature (°F-db)	73.0	85.6	77.0	92.7	65.0	72.1	37.0	37.0
Coil Face Velocity (ft/min)	500	235	610	388	602	500	527	418
Calculated Air Flow (CFM)	12,000	60,513	69,540	31,040	30,100	30,000	31,620	25,080
Static Pressure Drop (Inches WG)	0.51	0.04	0.48	0.28	0.14	0.54	1.01	0.21
Entering Air Temp (°F-db)	76.2	74.0	63.4	80.2	77.4	69.4	75.5	61.9
Leaving Air Temp (°F-db)	56.7	52.6	63.0	58.7	56.3	66.5	52.8	50.2
Temperature Drop	19.5	21.4	0.4	21.5	21.1	2.9	22.7	11.7
PERFORMANCE CHANGE								
Coil Face Velocity (fpm)		2	40	11	7		1	
Air Flow (CFM)		515	4,560	880	350		60	
Static Pressure (Inches WG)	0.19	0.00	0.09	0.14	0.04	0.20	0.05	0.02
Leaving Air Temperature (°F-db)	1.8	0.4	0.1	0.7	0.9	0.4	0.3	0.7
ANNUAL COOLING ENERGY								
BTU/h BEFORE Cleaning	229,392	1,360,743	21,054	677,514	649,026	81,000	763,500	297,950
BTU/h AFTER Cleaning	252,720	1,398,565	30,041	720,749	685,919	93,960	775,196	316,911
Sensible Capacity Change	23,328	37,822	8,988	43,235	36,893	12,960	11,696	18,960
Percent Change	10.2%	2.8%	42.7%	6.4%	5.7%	16.0%	1.5%	6.4%
Tons	1.94	3.15	0.75	3.60	3.07	1.08	0.97	1.58
kW	1.46	2.36	0.56	2.70	2.31	0.81	0.73	1.19
kWh	6,386	2,619	2,460	11,835	10,099	3,548	3,202	5,190
Estimated Cost Savings or (Increase)	574.74	235.72	221.44	1,065.19	908.95	319.30	288.17	467.14
ANNUAL FAN ENERGY								
Power (kW) BEFORE Cleaning	1.314	0.385	6.230	2.057	0.868	3.473	5.263	0.902
Power (kW) AFTER Cleaning	0.957	0.379	5.222	1.360	0.659	2.534	4.996	0.824
Power Change (kW)	0.357	0.007	1.008	0.698	0.208	0.939	0.267	0.078
Annual Power Change (kWh)	3,125	14	8,828	6,112	1,826	8,223	2,341	687
Estimated Cost Savings or (Increase)	281.22	1.30	794.56	550.09	164.32	740.04	210.73	61.87
TOTAL ANNUAL ENERGY								
Estimated Cost Savings or (Increase)	855.96	237.03	1,016.00	1,615.28	1,073.26	1,059.34	498.90	529.01

Table 2 – *Summary of Direct Ammeter Readings*

Total amp reduction realized	194.8
Total kWh reduced	1.22 million
Total number of AHU coils cleaned	137
Energy savings	$111,348
Cost to Clean Coils	$123,080
Return on Investment*	1.1 years
Reduction in CO_2 generation	900 tons

(*Savings does not include the added benefit of reduced chilled water demand)

Air Handler # 1 – before cleaning

Air Handler # 1 – after cleaning

Air Handler # 2 – before

Air Handler # 2 – after

This photo shows a set of coils during the cleaning, visually demonstrating the results in mid-process

Nalco Water, an Ecolab Company

North America: ***Headquarters*** – 1601 West Diehl Road • Naperville, Illinois 60563 • USA
Nalco Champion – 7705 Highway 90-A • Sugar Land, Texas 77478 • USA
Europe: Richtistrasse 7 • 8304 Wallisellen • Switzerland
Asia Pacific: 2 International Business Park • #02-20 The Strategy Tower 2 • Singapore 609930
Latin America: Av. das Nações Unidas 17.891 • 6° andar • São Paulo • SP • Brazil • CEP 04795-100

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