**Title**

# Energy and comfort effects of reducing the minimum diffuser flow rate in existing VAV (Variable Air Volume) systems



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**Final Deliverable**

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## Project overview

The purpose of this project is to quantify HVAC energy savings for buildings that are operated under reduced minimum diffuser flow rates, and to evaluate whether occupants' thermal comfort satisfaction responses are affected.

We installed a custom control program in 7 buildings of the Yahoo campus in Sunnyvale California. The control program allows the building operators to adjust the variable air volume system's minimum flow rate to different levels. We also installed energy measurement meters in all air conditioning units of 4 buildings. All the new metering gives separate sub-metering of heating (and reheat), cooling, and fan energy. The energy use was monitored under both 30% minimum flow rate (conventional level) and low minimum flow rate (around 10%). We conducted regression analysis to predict annual energy savings. The HVAC system operations were monitored to show the diffuser flow rates.

In March 2010 we surveyed 1200) occupants (about 33% of Yahoo employees) for their thermal satisfaction using the standard CBE background survey. For the winter season intervention tests from Dec. 3 – Dec. 23, 2010, we conducted 'right-now' surveys which asked the occupants' feelings regarding thermal comfort, air movement preference, perceived air quality, and acoustical satisfaction when the minimum flow rates were operated under both high and low levels. We received 7400 responses from about 600 occupants (16% of the Yahoo employees).

This report presents the comparisons between the two operation modes (30% and 10% minimum flow rates) for both energy measurements and occupants' surveys.

This project is being carried out in conjunction with another research project "Thermal and air quality acceptability in buildings that reduce energy by reducing minimum airflow from overhead diffusers" funded by ASHRAE. The ASHRAE project started in November 2010 and will be finished in May 2012. The focus of the CEC/PIER project is on the installations of energy meters and control re-programming, the energy measurements and saving analysis. The focus of the ASHRAE project is to characterize in detail the comfort effects of the different levels of VAV minima, and to do controlled temperature and velocity profile measurements for various types of diffusers and minimum flow rates in an environmental chamber at Price Industries in Winnipeg.

## Background

The flow rate from variable air volume (VAV) boxes changes with internal load. When the load is low, the diffuser flow rate is set at a minimum. The minimum flow rate is fixed in order to create a uniform and well mixed *thermal* environment. Existing guidance from diffuser manufacturers suggests minimum airflows ranging from 30%-50% of design airflow, but there is little or no published research validating these limits. Rates as low as 10% provide acceptable ventilation for air quality purposes, but at such levels there have traditionally been concerns primarily regarding draft sensation from "dumping" diffusers. However some designers are claiming successful comfort performance while employing minima in the range of 10% to 20% of the cooling maximum airflow, so these concerns need to be examined.

The VAV box minimum airflow setpoints have tremendous energy implications. By lowering the minimum airflow setpoint, it is possible to reduce HVAC energy on the order of 10%-30%. Savings can be achieved in new construction and in existing buildings for a retrofit option through control system re-programming with no modification to the buildings. Savings are especially high in California mild climates because the frequencies of systems operated under minimum diffuser flow rate are high.

## Task #1 – Intervention in an existing building to alternate sequences of minimum diffuser flow rate.

## Objective

The objectives of this task are to:

- Program a toggle switch to convert between conventional "high minimum" sequences to a "low minimum" sequence in all zones.
- Install energy meters in the identified buildings.

## Deliverable: Yahoo campus 7 buildings control re-programming and energy meter installation

### *1.1 Introduction & Study Site Summary*

The Yahoo Campus was built in 2001 and is located in Sunnyvale, California. It consists of seven buildings, totaling 980,000 ft2. An overview of the campus including buildings A – G and a view for Building D from outside are shown in Figure 1.1.1.


a. Site view b. Façade of building D

**Figure 1.1.1 Yahoo Campus**

Total there are 3850 employees. The sizes of each building and the number of HVAC units are summarized in Table 1.

**Table 1.1.1 Summary of Campus Buildings**

| Building | Area[1] ($ft^2$) | Stories | No. of packaged AC units | No. of chillers | Air terminal units |
|---|---|---|---|---|---|
| Building A (w. data center) | 180,700 | 4 | 2 | 3 | 186 |
| Building B | 180,700 | 4 | 2 | 2 | 188 |
| Building C (Dining) | 52,700 | 2 | 2 | | 56 |

| | | | | | |
|---|---|---|---|---|---|
| Building D | 180,400 | 5 | 2 | 1 | 225 |
| Building E | 212,600 | 5 | 3 | 3 | 243 |
| Building F | 91,000 | 3 | 2 | 1 | 92 |
| Building G | 79,700 | 3 | 2 | 1 | 83 |
| Totals | 977,800 | | 15 | 11 | 1073 |

There are 1073 VAV zones in the campus, 254 of which are cooling only, 246 that are fan powered, and 573 that have reheat coils. The table below summarizes the VAV zones in each floor of each building across the campus.

**Table 1.1.2 VAV Box types and counts by building.**

| | VAV Box Types | | | |
|---|---|---|---|---|
| | Cooling Only | Fan Powere d | Reheat | Grand Total |
| **Building A Totals** | **45** | **51** | **90** | **186** |
| Bldg A - Floor 1 | 18 | 6 | 16 | **40** |
| Bldg A - Floor 2 | 14 | 14 | 19 | **47** |
| Bldg A - Floor 3 | 13 | 16 | 21 | **50** |
| Bldg A - Floor 4 | 0 | 15 | 34 | **49** |
| **Building B Totals** | **53** | **46** | **89** | **188** |
| Bldg B - Floor 1 | 26 | 3 | 16 | **45** |
| Bldg B - Floor 2 | 13 | 16 | 20 | **49** |
| Bldg B - Floor 3 | 14 | 12 | 20 | **46** |
| Bldg B - Floor 4 | 0 | 15 | 33 | **48** |
| **Building C Totals** | **16** | **0** | **40** | **56** |
| Bldg C - Floor 1 | 16 | 0 | 21 | **37** |
| Bldg C - Floor 2 | 0 | 0 | 19 | **19** |
| **Building D Totals** | **52** | **62** | **111** | **225** |
| Bldg D - Floor 1 | 15 | 6 | 21 | **42** |
| Bldg D - Floor 2 | 13 | 15 | 21 | **49** |
| Bldg D - Floor 3 | 12 | 17 | 17 | **46** |
| Bldg D - Floor 4 | 12 | 12 | 22 | **46** |
| Bldg D - Floor 5 | 0 | 12 | 30 | **42** |
| **Building E Totals** | **52** | **69** | **122** | **243** |
| Bldg E - Floor 1 | 15 | 8 | 20 | **43** |
| Bldg E - Floor 2 | 13 | 15 | 21 | **49** |
| Bldg E - Floor 3 | 12 | 16 | 21 | **49** |
| Bldg E - Floor 4 | 12 | 15 | 23 | **50** |
| Bldg E - Floor 5 | 0 | 15 | 37 | **52** |
| **Building F Totals** | **21** | **9** | **62** | **92** |
| Bldg F - Floor 1 | 9 | 7 | 14 | **30** |
| Bldg F - Floor 2 | 12 | 1 | 18 | **31** |
| Bldg F - Floor 3 | 0 | 1 | 30 | **31** |
| **Building G Totals** | **15** | **9** | **59** | **83** |

| | | | | |
|---|---|---|---|---|
| Bldg G - Floor 1 | 5 | 5 | 14 | **24** |
| Bldg G - Floor 2 | 10 | 1 | 18 | **29** |
| Bldg G - Floor 3 | 0 | 3 | 27 | **30** |
| **Grand Total** | **254** | **246** | **573** | **1073** |

### *1.2 Description of Site Control System and Trending Capability*

The site controls system is an Automated Logic Controls system. This provides zone level control throughout the campus. Trends of system operation were obtained for the previous 2 years and analyzed. Table 1.2.1 shows typical trend information available for different type of equipment in the historical data base currently available for Yahoo.

This research project upgraded upgraded the trending functions of the system as follows:

- All available I/O points and Setpoints are trended, not a select subset.
- All VAV zone control points are trended on 1 minute time intervals.

- The control systems own data base is used for trend storage as opposed to the current trend storage method, which is an export to a custom Excel sheet in two week periods, resulting in one spreadsheet per building every two weeks without a consolidated single database that can be queried.

**Table 1.2.1 Trended information**

| |
|---|
| **Building** |
| Outside Air Temperature |
| KW Demand |
| **AC unit** |
| Supply Fan VFD Speed (%) |
| Return Fan VFD Speed (%) |
| Cooling Stages On |
| Condenser Fan Stages |
| Economizer Position (%) |
| Outside Air Flow (KCFM) |
| Duct Static Pressure (in. w.c.) |
| Duct Static Pressure SP (in. w.c.) |
| Return Air Temperature (deg. F) |
| Supply Air Temperature (deg. F) |
| Supply Air Temperature SP (deg. F) |
| RA-CO2 (ppm) |
| **VAV Terminal (Reheat)** |
| Discharge Air Temperature (deg F) |
| Zone Temperature (deg F) |
| Cooling Setpoint (deg F) |
| Heating Setpoint (deg F) |
| Zone Cooling (%) |
| Zone Heating (%) |
| Air Flow Actual (CFM) |
| Heating Valve Position (%) |
| **VAV Terminal (Fan Powered)** |
| Discharge Air Temperature (deg F) |
| Zone Temperature (deg F) |
| Cooling Setpoint (deg F) |
| Heating Setpoint (deg F) |
| Zone Cooling (%) |
| Zone Heating (%) |
| Air Flow Actual (CFM) |
| Heating Valve Position (%) |
| **Chiller (trends for building E only)** |
| Chiller-1 Current (amps) |
| Chiller-2 Current (amps) |
| Chiller-3 Current (amps) |
| Chiller-1 CHWS (deg F) |
| Chiller-2 CHWS (deg F) |
| Chiller-3 CHWS (deg F) |
| Chiller-1 CHWR (deg F) |
| Chiller-2 CHWR (deg F) |
| Chiller-3 CHWR (deg F) |
| SCHWS Temperature (deg F) |
| SCHWRTemperature (deg F) |
| CHW System Pressure (PSI) |
| CHWP-1 Status |
| CHWP-2 Status |
| CHWP-3 Status |
| Cooling Requests |

### *1.3 Calculation of new zone minimums*

The minimum flow that a VAV box can operate is limited by the code required minimum ventilation rate and by the limitations of the controllers that become unstable or inaccurate at very low flow. Ventilation rates are prescribed in the California Title 24 Building Code and for office buildings are determined by the maximum of 15 CFM/person or 0.15 CFM/sq.ft. VAV controllers are limited by the pressure transducer that reads the velocity pressure at the VAV flow cross sensor. VAV pressure transducers can read down to 0.004” $H_2O$ column.

For each zone on campus we gathered the following information:

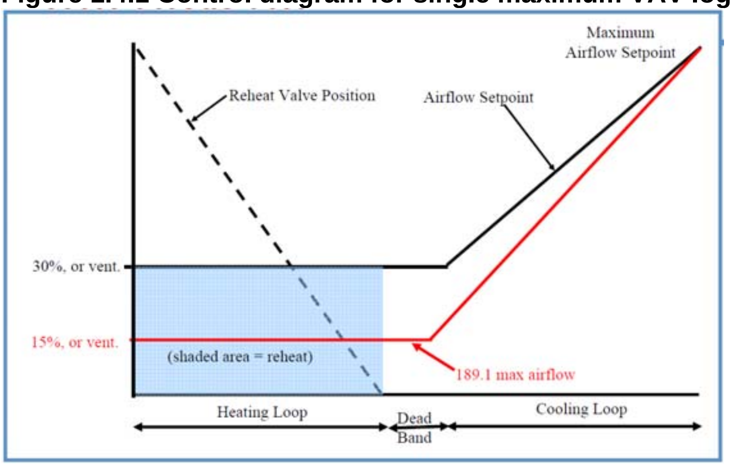
- Zone area (sq.ft.) – Measured off of CAD drawings
- Number of people in high occupancy zones (conference rooms)
- VAV box size (to determine the controllable minimum)

A new minimum flow was calculated for every zone from this data.

### *1.4 Controls re-programming*

We hired a controls contractor to reprogram all 1017 VAV units in 6 Yahoo buildings so that the buildings can be operated at different minimum flow rates (building C is a dining facility with unique controls so was excluded). A diagram of the new control sequences is shown below.

**Figure 1.4.1 Control diagram for single maximum VAV logic (black line)**




Our specification asked for the zones to have a program with both the existing minimum flow setpoints and the new minimum flow setpoints, but it turned out that the existing Automated Logic U-line controllers did not have the memory capability to perform this extra functionality. The controls contractor proposed an alternative that used a SOAP/XML connection to the building management system that would read/write to the minimum flow parameter from an external spreadsheet. An example of the SOAP/XML worksheet is shown in figure 1.4.2. This interface is providing more control over the system than we expected because it allows the research team to change the minimum flow setpoints to any value in a matter of minutes. So far we have operated at the new low minimums and at 30% minimums, but in the future we will be operating at other minimum flow setpoints to and measure the energy and comfort impacts.

**Figure 1.4.2 SOAP/XML interface for uploading new flow setpoints.**

**Yahoo Sunyvale Campus Building A**

| Total Number of VAVs: | | 187 | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Current Parameters<br>Read | | | | | Write Parameter Set 1<br>Write 1 | | | | | Write Parameter Set 2<br>Write 2 | | | | |
| | | Airflow Parameters | | | | | | | | | | | | | | |
| Airflow Microblock Reference Names: Bold Parameter Reference Names to Include in Read/Write Parameters) | | /legacy_fb/parameters/cd/cma | /legacy_fb/parameters/cd/hma | /legacy_fb/parameters/cd/oma | /legacy_fb/parameters/cd/uma | /legacy_fb/parameters/cd/ahmf | /legacy_fb/parameters/cd/cma | /legacy_fb/parameters/cd/hma | /legacy_fb/parameters/cd/oma | /legacy_fb/parameters/cd/uma | /legacy_fb/parameters/cd/ahmf | /legacy_fb/parameters/cd/cma | /legacy_fb/parameters/cd/hma | /legacy_fb/parameters/cd/oma | /legacy_fb/parameters/cd/uma | /legacy_fb/parameters/cd/ahmf |
| Equipment | GQL Reference Name Bold GQL Reference to Include in Read/Write Parameters) | Cool Max | Heat Max | Occupied Min | Unoccupied Min | Aux Heat Flow | Cool Max | Heat Max | Occupied Min | Unoccupied Min | Aux Heat Flow | Cool Max | Heat Max | Occupied Min | Unoccupied Min | Aux Heat Flow |
| VAVRH-A-1-1 | **#rha11** | 1835 | 20 | 100 | 0 | 160 | | | 0 | | 0 | | | | | |
| VAVRH-A-1-2 | **#rha12** | 1635 | 200 | 100 | 0 | 160 | | | 0 | | 0 | | | | | |
| VAVRH-A-1-3 | **#rha13** | 1925 | 450 | 190 | 0 | 190 | | | 300 | | 300 | | | | | |
| VAVRH-A-1-4 | **#rha14** | 1400 | 140 | 500 | 0 | 140 | | | 300 | | 300 | | | | | |
| VAVRH-A-1-5 | **#rha15** | 2100 | 700 | 300 | 0 | 210 | | | 385 | | 385 | | | | | |
| VAVRH-A-1-6 | **#rha16** | 1635 | 490 | 165 | 0 | 165 | | | 300 | | 300 | | | | | |
| VAVRH-A-1-7 | **#rha17** | 450 | 400 | 150 | 0 | 100 | | | 90 | | 90 | | | | | |
| VAVRH-A-1-8 | **#rha18** | 450 | 200 | 150 | 0 | 50 | | | 90 | | 90 | | | | | |
| VAVRH-A-1-9 | **#rha19** | 810 | 300 | 200 | 0 | 85 | | | 145 | | 145 | | | | | |
| VAVRH-A-1-10 | **#rha110** | 2015 | 425 | 500 | 0 | 200 | | | 385 | | 385 | | | | | |
| VAVRH-A-1-11 | **#rha111** | 1600 | 605 | 300 | 0 | 200 | | | 385 | | 385 | | | | | |
| VAVRH-A-1-12 | **#rha112** | 1340 | 450 | 200 | 0 | 130 | | | 300 | | 300 | | | | | |
| VAVRH-A-1-13 | **#rha113** | 450 | 180 | 45 | 0 | 45 | | | 190 | | 190 | | | | | |
| VAVRH-A-1-14 | **#rha114** | 1500 | 450 | 200 | 0 | 150 | | | 300 | | 300 | | | | | |
| VAVRH-A-1-15 | **#rha115** | 1250 | 600 | 200 | 0 | 205 | | | 385 | | 385 | | | | | |
| VAVRH-A-1-16 | **#rha116** | 1560 | 510 | 300 | 0 | 150 | | | 300 | | 300 | | | | | |

The controls contractor was also hired to setup all the trends required to gather data for our research analysis. The scope of trending reconfiguration included:

- Add new trends to include key parameters for every zone: cfm, supply air temperature, reheat valve position, cooling loop output, heating loop output.
- Add new trends to monitor new power meters: amps, volts, cumulative energy use, instantaneous power draw.
- Add new trends to monitor VFD drives on supply and exhaust fans: volts, amps, power
- Change trend storage to be in an SQL database native to the Automated Logic control system and configure trends to store for 3 months.
- Add new larger hard drive to store trends.

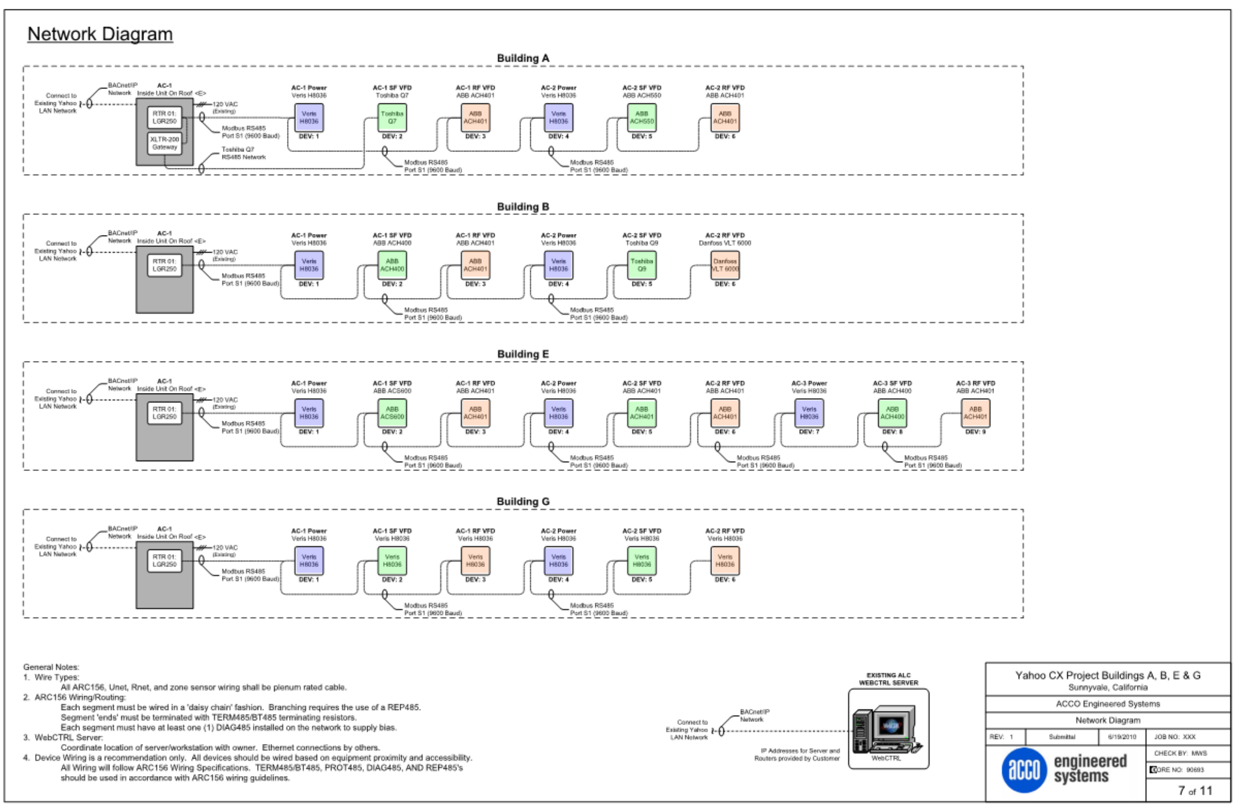
### *1.5 Installation of power meters and gas metering*

We hired a control contractor to installed energy meters in 4 buildings (Buildings A, B, E, and G) of the 7 Yahoo Buildings.

- A total of nine power meters were added to the input to each AC unit and connected the controls system with a BACnet interface so that power could be trended continuously and stored simultaneously with other trend data.
- Twelve existing VFD drives on the supply and exhaust fans were connected to the BACnet system so that power input could be trended.
- The controls specification included BTU metering of boilers, but the price way much higher than the project budget for. Further conversation with the facilities managers revealed that the only gas appliance in these buildings was the boiler (domestic hot water is provided by electricity) so monitoring of the PG&E gas meters would measure boiler energy input. The existing gas meters did not have pulsed output so we decided to monitor the analog meter dials with digital time lapse photography. The method proved to be very cost effective with the only draw back being that the photographs need to be transcribed. The image below shows one of the gas metering setups.

**Figure 1.5.1 Gas Meter digital photography**

**Figure 1.5.2 Control diagram for new power metering. Blue indicates new power meters, green indicates supply fan power from VFD, and orange indicates return fan power from VFD.  See appendix for detailed controls drawings.**




All the new metering gives separate sub-metering of heating  (and reheat), cooling, and fan energy.  Each of these is impacted by changing VAV minimums and the metering gives us the capability to measure the magnitude of savings for each end-use.

### *1.6 Results*

Trends for all the new power meters, VFD power input, and all the zones have been collected for many months. The database grows by about 10 GB per week which is a significant amount of data. Zone setpoints have been changed 2 times, once to lower the minimums from their existing (pre-study) state to the newer low minimums we calculated, and a second time to raise the minimums to 30% which is the typical setting in most commercial buildings.

## Task 2 – Monitoring energy uses of sub-systems and predict energy savings

Electricity data is recorded at 15 minute time intervals 24 hours per day and gas data is recorded at 10 minute intervals during daylight hours. From the measured electricity and gas data for both cooling and heating operations, and under both 10% and 30% minimum flow rates, we developed regression equations which shows the HVAC energy use based on the outside air temperature. From these regressions, we predicted annual energy use under both minimum flow rate based on typical annual hourly whether data. Then we compared the savings when the minimum flow rate is lowered from 30% to 10%.

The measured energy hourly results for 10% minimum flow rate covers period from Nov.4 to Dec. 13 2 PM before the minimum flow rate was adjusted to 30%. The measured energy hourly results for the 30% minimum flow rate cover a period from Jan 3 to Jan 23. In this report, we only present the results from 3 of the measured buildings (Building A, B, and E). The data from building G is in a different format, we will do the analysis for Building G in the near future.

## Objectives

The objectives of this task are to:

- Monitor electricity and gas meters for cooling and heating energy use under both high and low minimum flow rates
- Monitor the diffuser flow rates from trend report under both high and low minimum flow rates

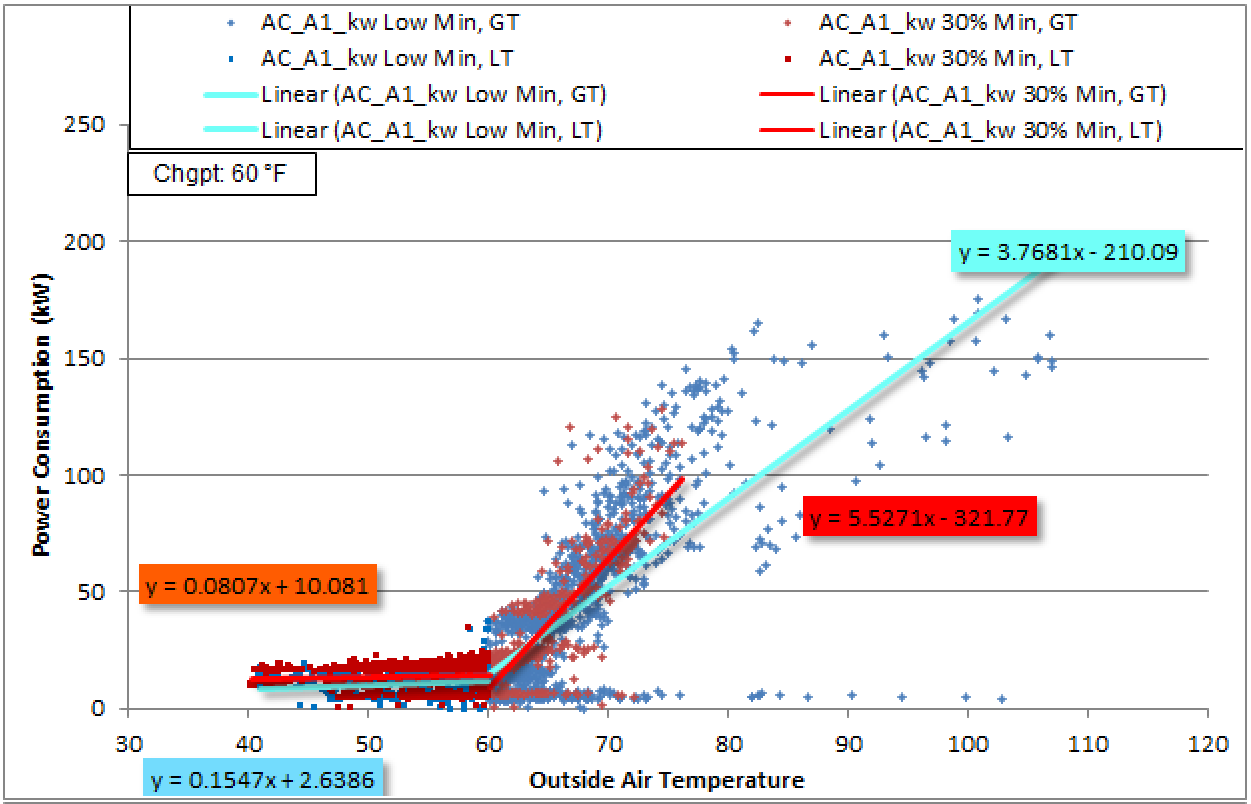
## Deliverable: Energy measurement and trend report

### *2.1 Energy savings under 30% and 10% minimum flow rates*

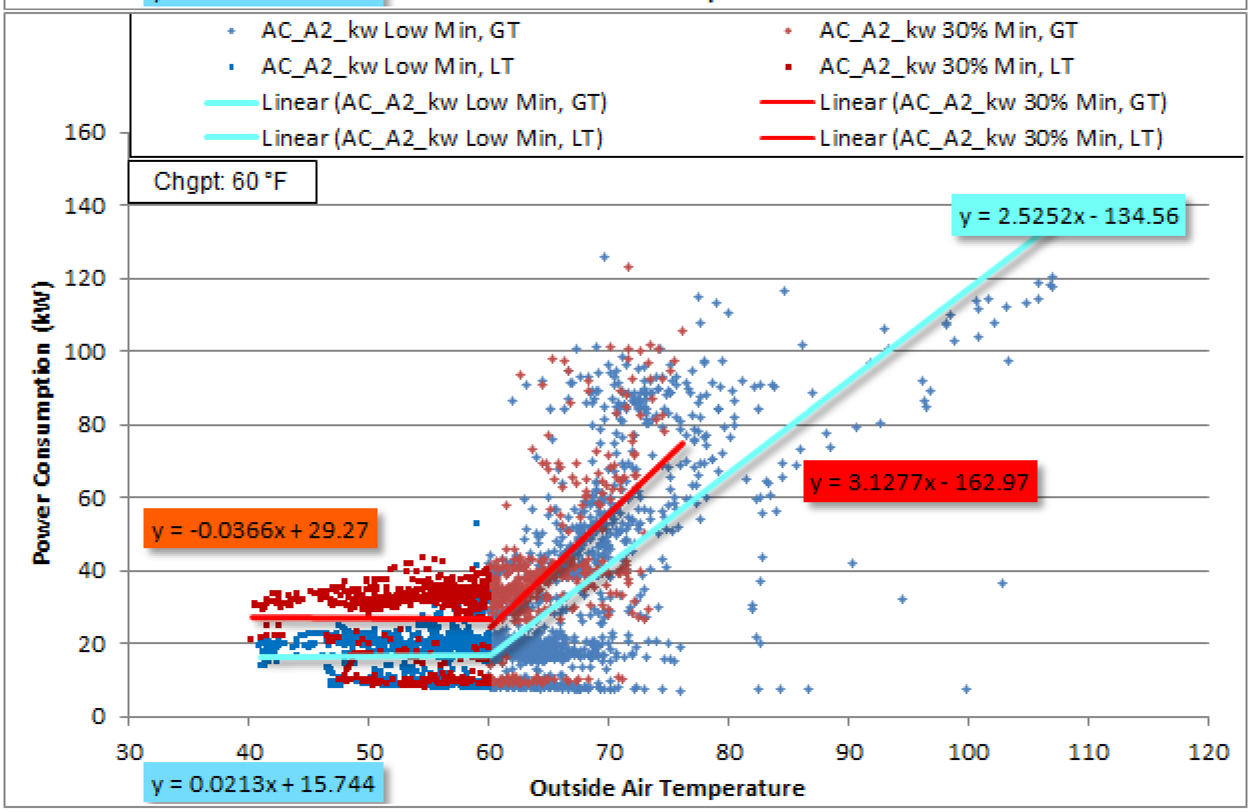
### *2.1.1 Cooling energy analysis*

To measure the impact of the VAV low minimum toggle on cooling energy, the energy consumption of all seven packaged AC units in buildings A, B, and E was analyzed. Each AC unit contains a supply fan, exhaust fan, and a DX cooling coil, and the total energy consumption is the sum of these two components. A change-point regression model of the consumption as a function of the measured outdoor temperature at the site was computed, allowing the effects of climate to be accounted for. The change-point method was used in order to model the behavior of the AC units in two distinct load conditions. The data represent daytime conditions between 5:30am and 8pm. Figure 2.1.1.1.below shows the measured energy use and regressions for different AC units in the three buildings.

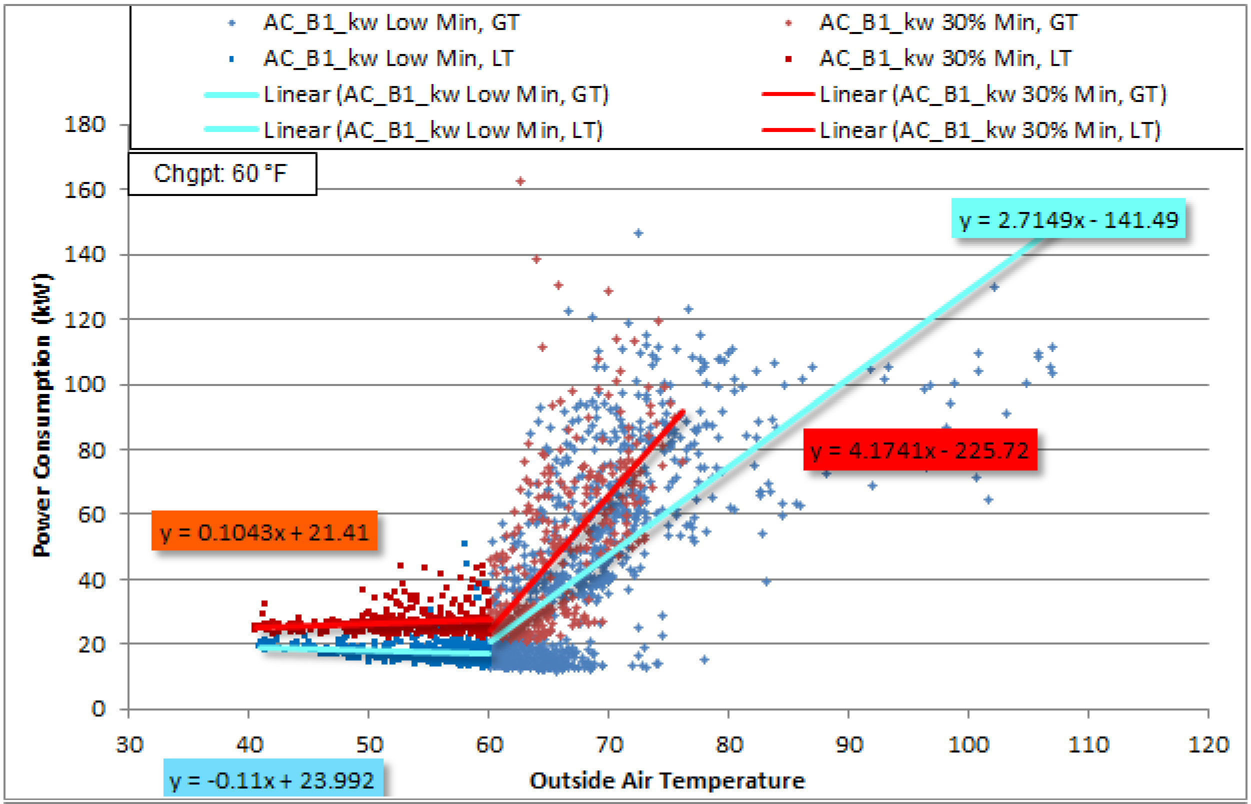
**Figures 1.1.1.1 Regression models of AC unit power consumption as a function of outside air temperature in 10% and 30% VAV operation modes**

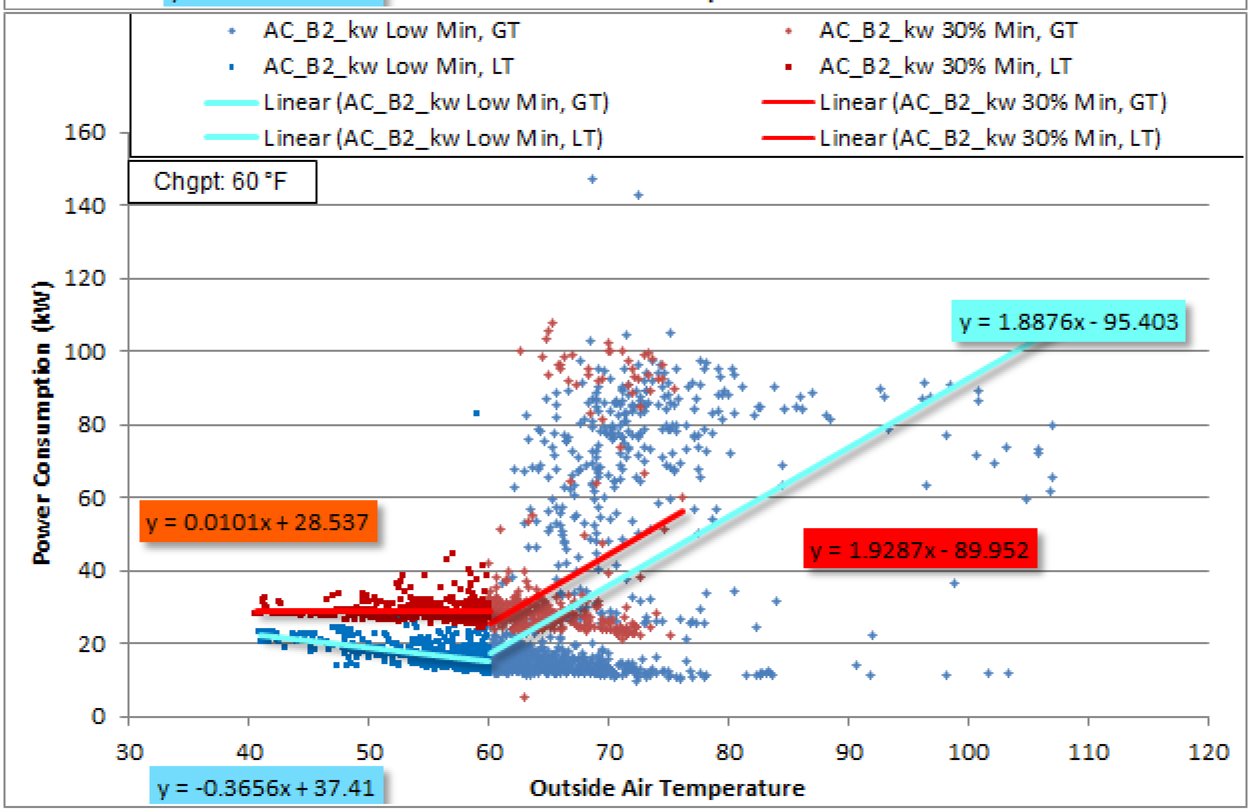


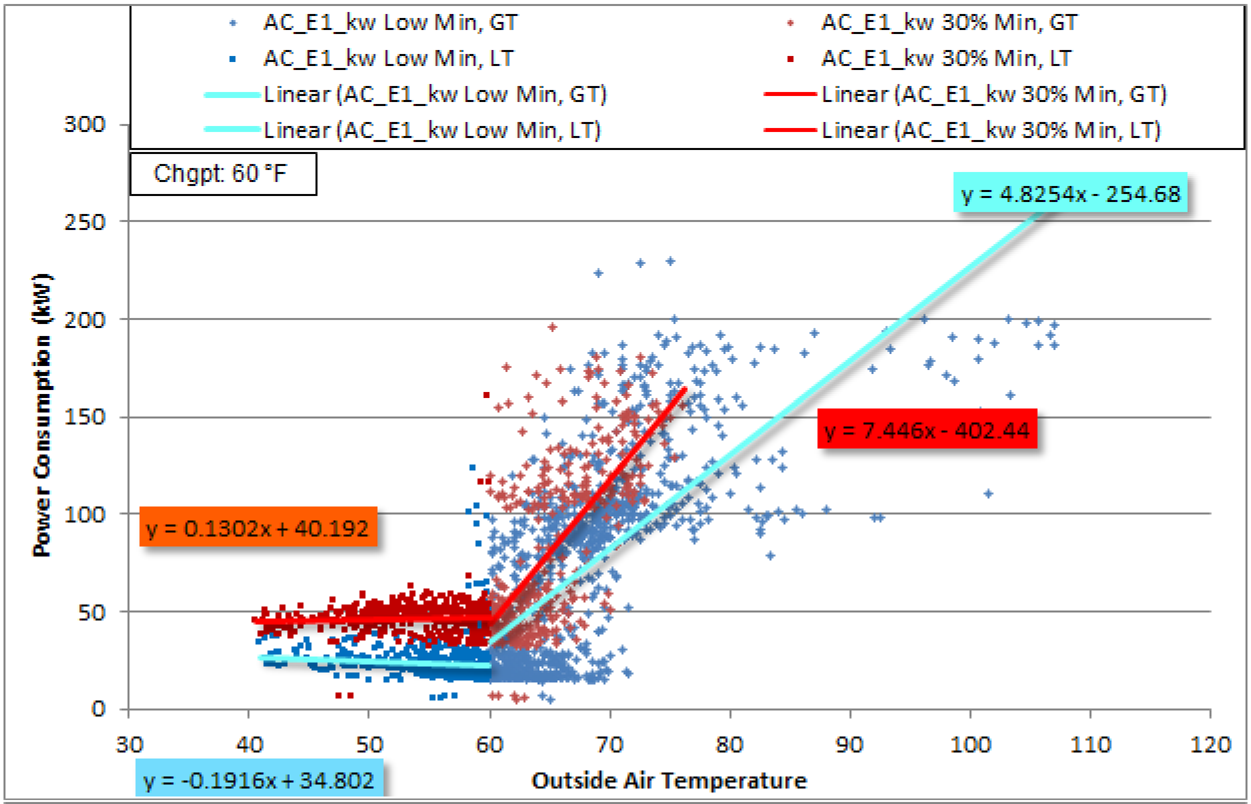
AC_A1_kw Low Min, GT
AC_A1_kw Low Min, LT
Linear (AC_A1_kw Low Min, GT)
Linear (AC_A1_kw Low Min, LT)
AC_A1_kw 30% Min, GT
AC_A1_kw 30% Min, LT
Linear (AC_A1_kw 30% Min, GT)
Linear (AC_A1_kw 30% Min, LT)
Chgpt: 60 °F
y = 3.7681x - 210.09
y = 5.5271x - 321.77
y = 0.0807x + 10.081
y = 0.1547x + 2.6386
Power Consumption (kW)
Outside Air Temperature

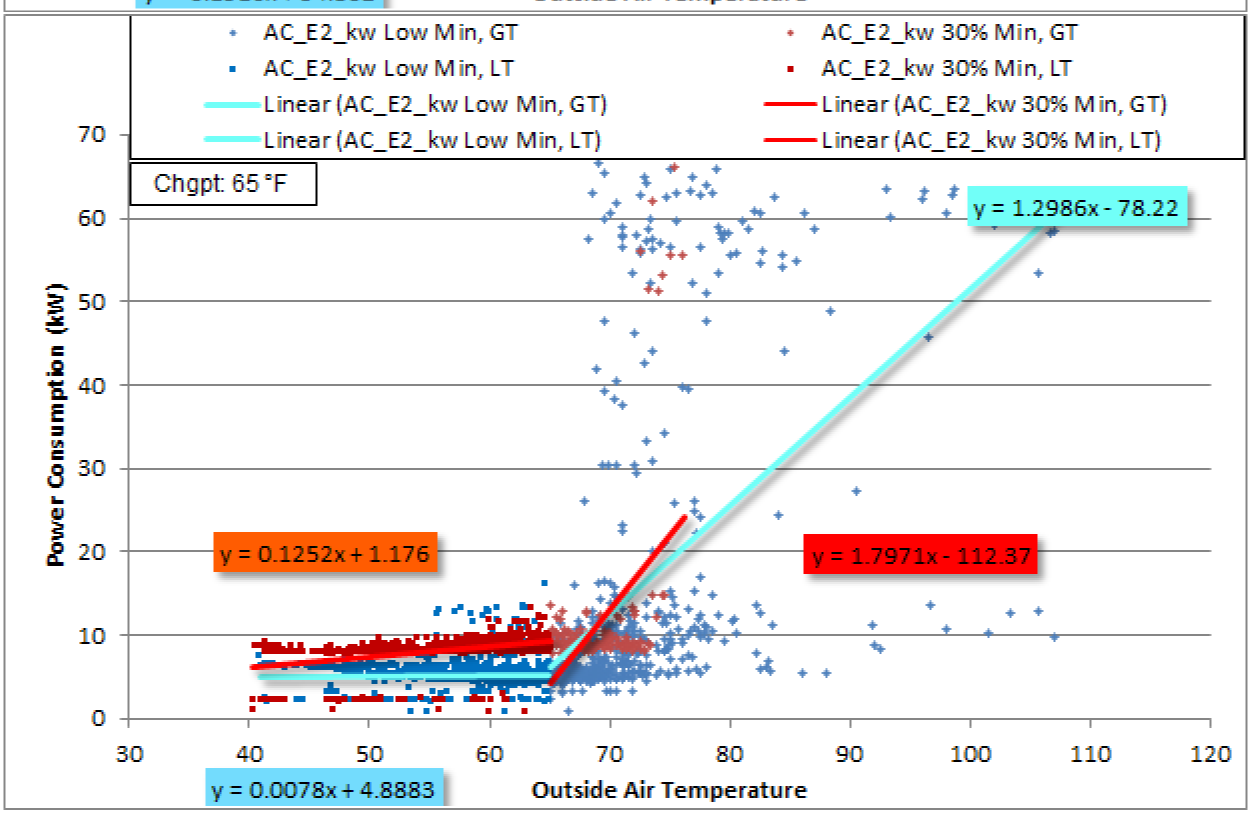



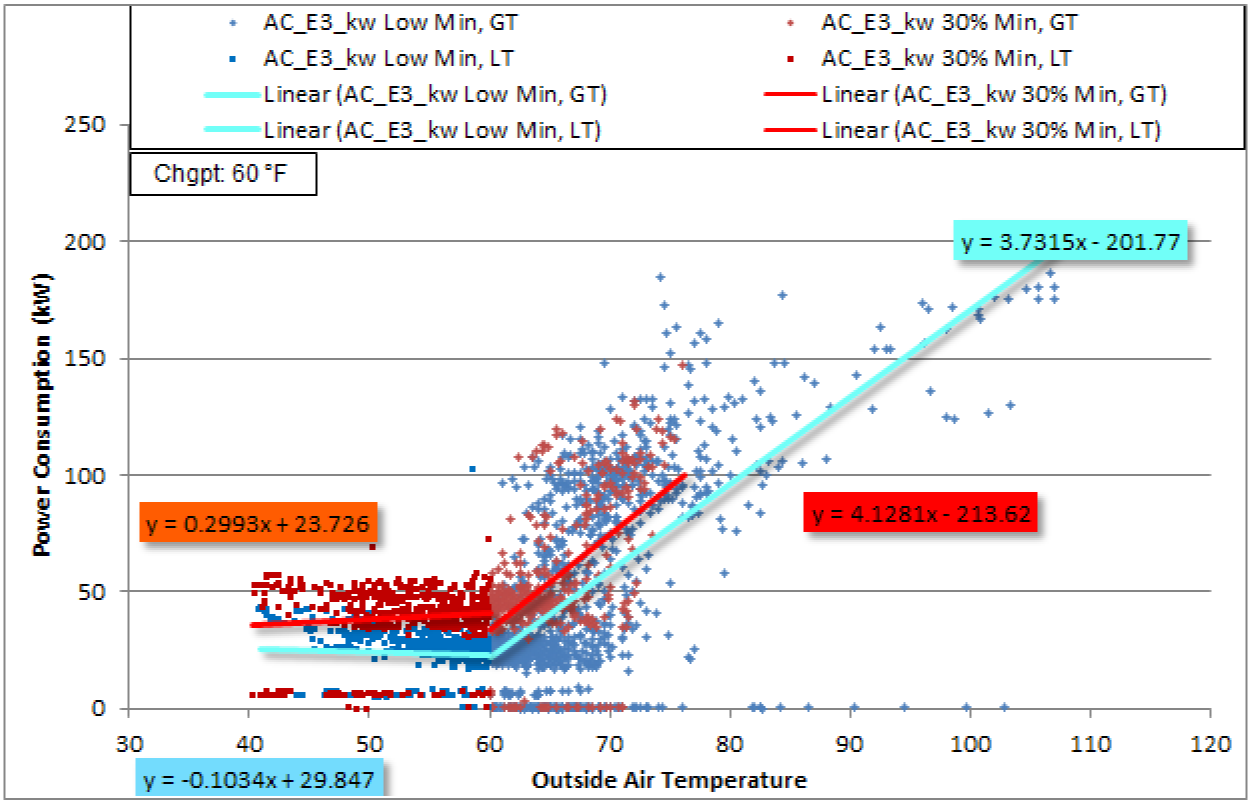
AC_A2_kw Low Min, GT
AC_A2_kw Low Min, LT
Linear (AC_A2_kw Low Min, GT)
Linear (AC_A2_kw Low Min, LT)
AC_A2_kw 30% Min, GT
AC_A2_kw 30% Min, LT
Linear (AC_A2_kw 30% Min, GT)
Linear (AC_A2_kw 30% Min, LT)
Chgpt: 60 °F
y = 2.5252x - 134.56
y = 3.1277x - 162.97
y = -0.0366x + 29.27
y = 0.0213x + 15.744
Power Consumption (kW)
Outside Air Temperature


AC_B1_kw Low Min, GT
AC_B1_kw Low Min, LT
Linear (AC_B1_kw Low Min, GT)
Linear (AC_B1_kw Low Min, LT)
AC_B1_kw 30% Min, GT
AC_B1_kw 30% Min, LT
Linear (AC_B1_kw 30% Min, GT)
Linear (AC_B1_kw 30% Min, LT)
Chgpt: 60 °F
y = 2.7149x - 141.49
y = 4.1741x - 225.72
y = 0.1043x + 21.41
y = -0.11x + 23.992
Power Consumption (kW)
Outside Air Temperature


AC_B2_kw Low Min, GT
AC_B2_kw Low Min, LT
Linear (AC_B2_kw Low Min, GT)
Linear (AC_B2_kw Low Min, LT)
AC_B2_kw 30% Min, GT
AC_B2_kw 30% Min, LT
Linear (AC_B2_kw 30% Min, GT)
Linear (AC_B2_kw 30% Min, LT)
Chgpt: 60 °F
y = 1.8876x - 95.403
y = 0.0101x + 28.537
y = 1.9287x - 89.952
y = -0.3656x + 37.41
Power Consumption (kW)
Outside Air Temperature


AC_E1_kw Low Min, GT
AC_E1_kw 30% Min, GT
AC_E1_kw Low Min, LT
AC_E1_kw 30% Min, LT
Linear (AC_E1_kw Low Min, GT)
Linear (AC_E1_kw 30% Min, GT)
Linear (AC_E1_kw Low Min, LT)
Linear (AC_E1_kw 30% Min, LT)
Chgpt: 60 °F
y = 4.8254x - 254.68
y = 7.446x - 402.44
y = 0.1302x + 40.192
y = -0.1916x + 34.802
Power Consumption (kW)
Outside Air Temperature
0
50
100
150
200
250
300
30
40
50
60
70
80
90
100
110
120


AC_E2_kw Low Min, GT
AC_E2_kw 30% Min, GT
AC_E2_kw Low Min, LT
AC_E2_kw 30% Min, LT
Linear (AC_E2_kw Low Min, GT)
Linear (AC_E2_kw 30% Min, GT)
Linear (AC_E2_kw Low Min, LT)
Linear (AC_E2_kw 30% Min, LT)
Chgpt: 65 °F
y = 1.2986x - 78.22
y = 0.1252x + 1.176
y = 1.7971x - 112.37
y = 0.0078x + 4.8883
Power Consumption (kW)
Outside Air Temperature
0
10
20
30
40
50
60
70
30
40
50
60
70
80
90
100
110
120




All AC units analyzed showed a clear decrease in overall energy consumption in the low minimum (10%) mode of operation. Binned site weather data was used with the linear models in order to estimate annual energy use in both 10% and 30% operation modes. At the building level, savings in the range of 24-30% in buildings A, B, and E were found.

**Table 2.1.1.1 Summary of estimated AC unit annual energy consumption in 30% and Low Minimum VAV operation modes**

| | Consumption 30% (kWh) | Consumption Low Min (kWh) | Savings (%) |
|---|---|---|---|
| AC A-1 | 210516 | 172111 | **18%** |
| AC A-2 | 216940 | 154874 | **29%** |
| AC B-1 | 244606 | 175384 | **28%** |
| AC B-2 | 191531 | 142462 | **26%** |
| AC E-1 | 434685 | 285193 | **34%** |
| AC E-2 | 53957 | 46511 | **14%** |
| AC E-3 | 298863 | 219198 | **27%** |

**Table 2.1.1.2: Total estimated building AC unit energy savings**

| | Area (ft^2) | Consumption 30% (kWh) | Consumption Low Min (kWh) | Total Savings (kWh) | Savings per ft^2 (kWh/ft^2) | % |
|---|---|---|---|---|---|---|
| Bldg A | 180700 | 427456 | 326986 | 100470 | 0.56 | **24%** |
| Bldg B | 180700 | 436138 | 317846 | 118292 | 0.65 | **27%** |
| Bldg E | 212600 | 787505 | 550902 | 236603 | | **30%** |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | | 1.11 | |

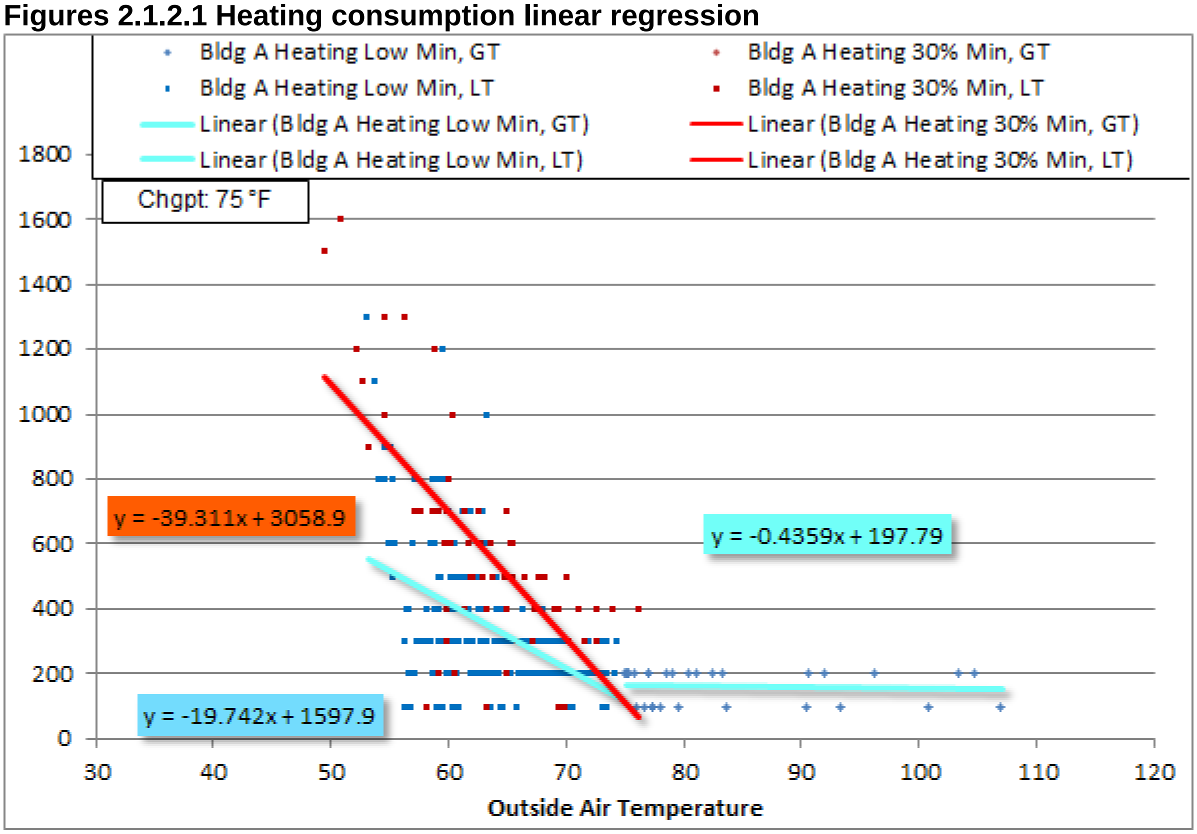
More detailed energy analysis is planned to continue. Constituent fan and cooling energies will be analyzed, and the collection of data during summer conditions will improve the robustness of the models.

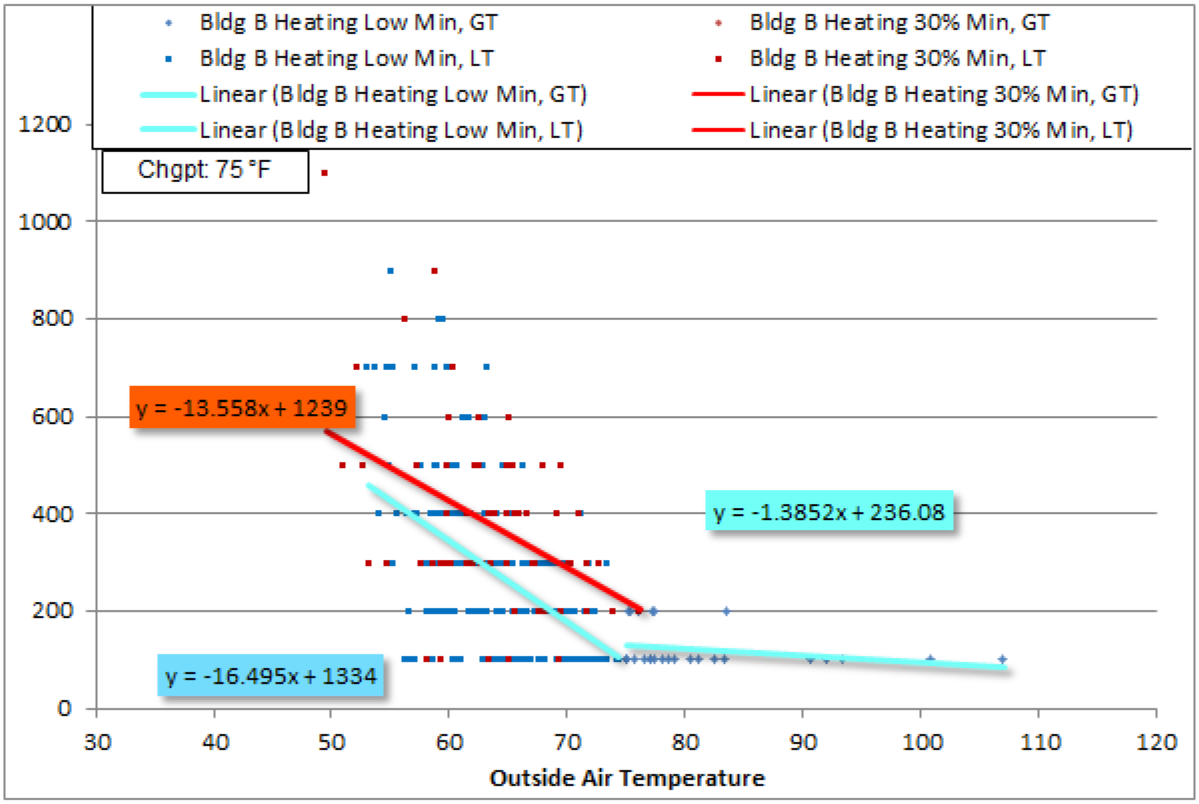
### *2.1.2. Heating energy analysis*

A similar approach was taken to analyze heating energy use as was for cooling energy use. We chose not to extrapolate annual energy use because, unlike cooling, heating energy use is much different in the summer. The measured data and the regression models shown in Figure 2.1.2.1 do not include data during the warm-up period in the buildings. This warm-up happens reliably before 10am every morning, and is not affected by the low flow conditions. A change-point method was used here as well, so that the data during weather conditions in which there is effectively no heating (outdoor air temperature greater than 75F) is not included in the pre-change-point regression. The result shows reliably lower levels of consumption for the low flow condition. Preliminary estimates for winter heating energy savings can be found in table 2.1.2.1.

Further analysis and summer data is needed for a more robust estimate of annual savings. However, the preliminary results show a distinct difference in energy consumption between the 10% and 30% VAV operation modes.

**Figures 2.1.2.1 Heating consumption linear regression**





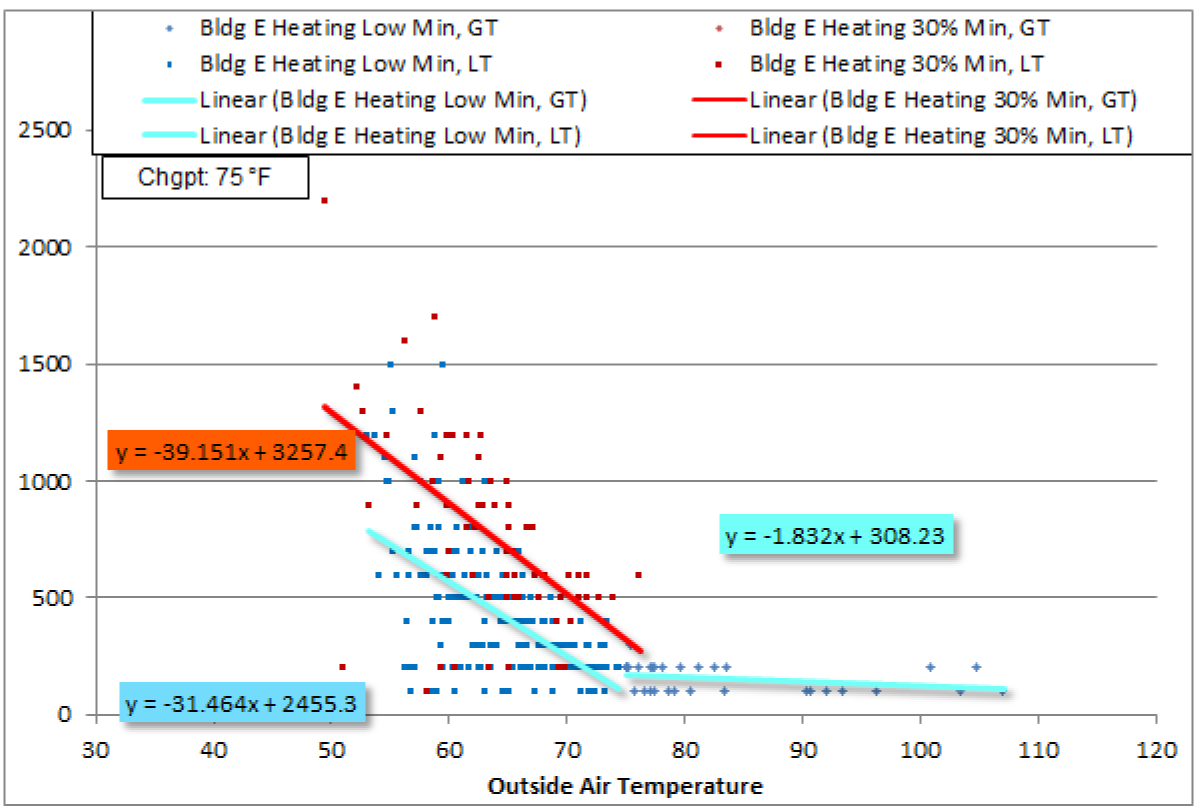




**Table 2.1.2.1 Daily heating consumption summary during monitored period**

| | Consumption 30% per day (cf/day) | Consumption Low Min per day (cf/day) | Savings (%) |
|---|---|---|---|
| Bldg A | 14261 | 8755 | **39%** |
| Bldg B | 7994 | 4978 | **38%** |
| Bldg E | 14725 | 8183 | **44%** |

## *2.2 Observed flow rates before and after intervention*

### *2.2.1 Low minimum flow setpoint distribution in existing Yahoo buildings*

The original HVAC engineering and controls drawings for the Yahoo campus stipulated 30% minimum flow rates for all VAV boxes and the Yahoo facility managers believed that the campus will still operating at the original 30% minimums. Analysis of the controls programming revealed that the Yahoo buildings were in fact operate with low minimum flow rate setpoints before the intervention. Figure 2.2.1.1 shows the existing minimum flow setpoints for the entire campus.

**Figure 2Analysis of airflow data for 872 of 1,100 zones on campus**

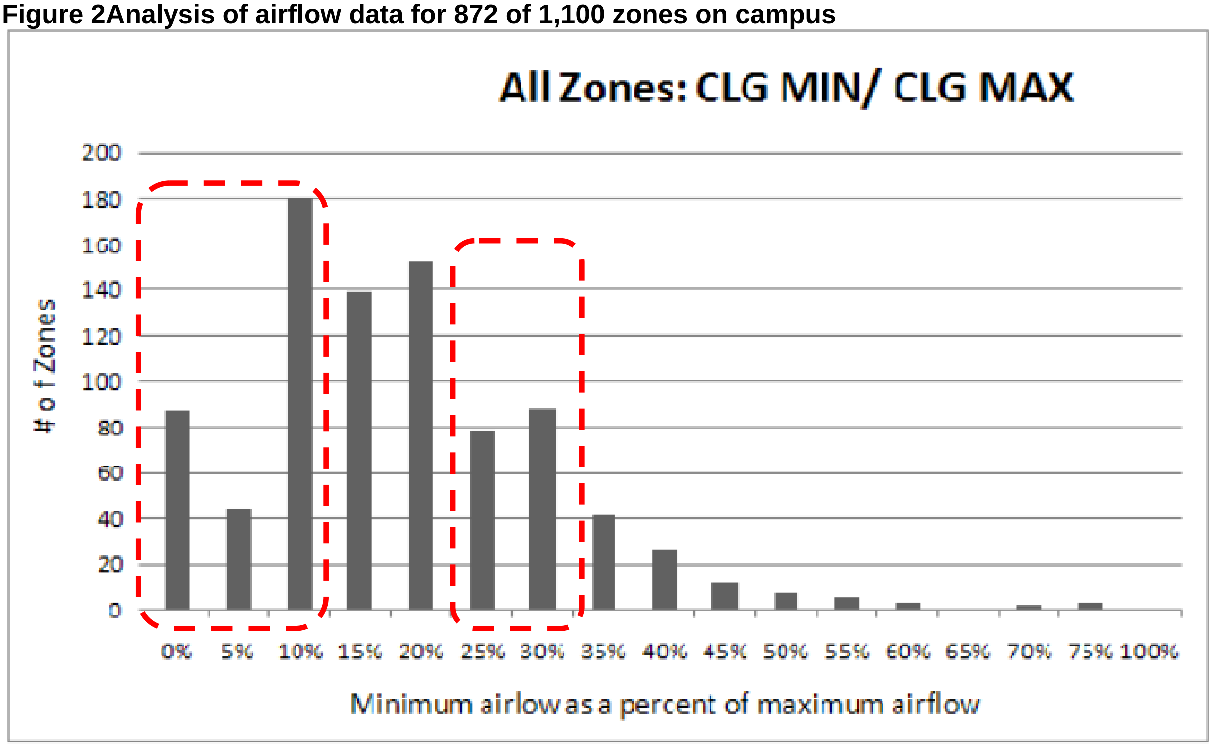



**Table 2.2.1.1 Zone airflow analysis**

| | | | |
|---|---|---|---|
| 0% | 85 | 9.7% | |
| 5% | 42 | 4.8% | |
| 10% | 180 | 20.6% | 35% |
| 15% | 138 | 15.8% | |
| 20% | 150 | 17.2% | 33% |
| 25% | 78 | 8.9% | |
| 30% | 88 | 10.1% | 19% |
| 35% | 42 | 4.8% | |
| 40% | 28 | 3.2% | 8% |
| 45% | 12 | 1.4% | |
| 50% | 10 | 1.1% | 3% |
| 55% | 8 | 0.9% | |
| 60% | 4 | 0.5% | |
| 65% | 3 | 0.3% | |
| 70% | | | |
| 75% | 4 | 0.5% | 2% |
| | 872 | | 100% |

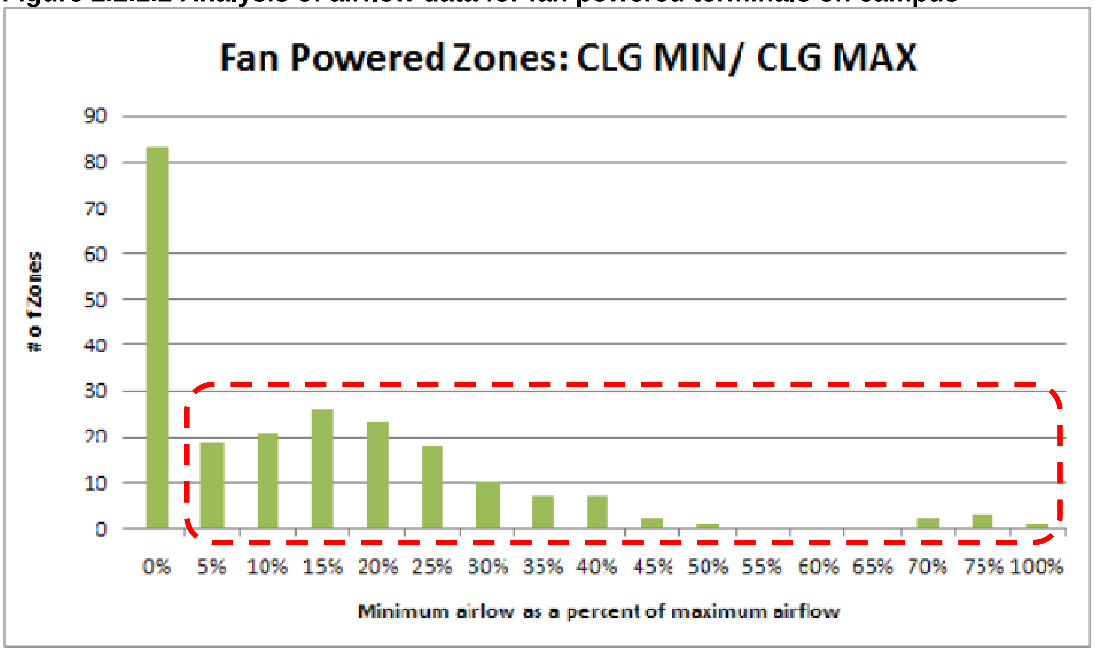
We analyzed roughly one year's worth of trend data for zones on campus. Roughly 870 zones had been trended, and provided usable data.

Actual behavior was categorized in terms of the airflows that occurred during heating and cooling, and broken out by type of air terminal: Cooling only, Reheat and Fan Powered terminals were reviewed separately.

Table 2.2.1.1 shows that the minimum airflow as a fraction of maximum airflow varies quite widely: some zones already have a 10% minimum airflow (about 180 total). There are 35% zones with their minimum flow rate below 10%. There are 68% zones with the minimum flow rate below 20%, lower than the conventional value 30%. Therefore, the existing Yahoo buildings are operated under low minimum flow rate.

Fan Powered terminals show a large number of zero-minimum airflow settings (Figure 2.2.1.2). This makes sense, because fan-powered terminals can operate without air from the air handlers when the terminal itself is placed above an open office area, and its fan operates to re-circulate air from the open office into a conference room..

**Figure 2.2.1.2 Analysis of airflow data for fan powered terminals on campus**




Reheat terminals show almost no zero-minimum airflow settings, while cooling only terminals show some (Figure 2.2.1.3, 2.2.1.4); both types show a significant number of terminals with minimum airflows below 30% of maximum airflow. For cooling only terminals, this is a common occurrence in real buildings, since cooling only terminals tend to overcool interior spaces, especially on Monday mornings, when they are at their code minimum settings of 0.15 cfm/sqft.

Providing the ventilation airflow from adjacent reheat terminals works well in an open office plan and thus allows cooling only terminal minimums to be reset down to zero to prevent drafts.

It's not clear why the reheat terminals were reset to values of less than 30%, is most likely due to various changes over time by facilities staff. Typically facilities staff operate in a reactive mode responding to occupant complaints as they occur. Various hot, cold, draft, or ventilation complaints were probably dealt with by adjusting zone parameters. The zone maximum flow setopints also varied from the original design drawings indicating that most setpoints have been adjusted at some point in time.

Figure 2.2.1.3 Analysis of airflow data for cooling only terminals on campus

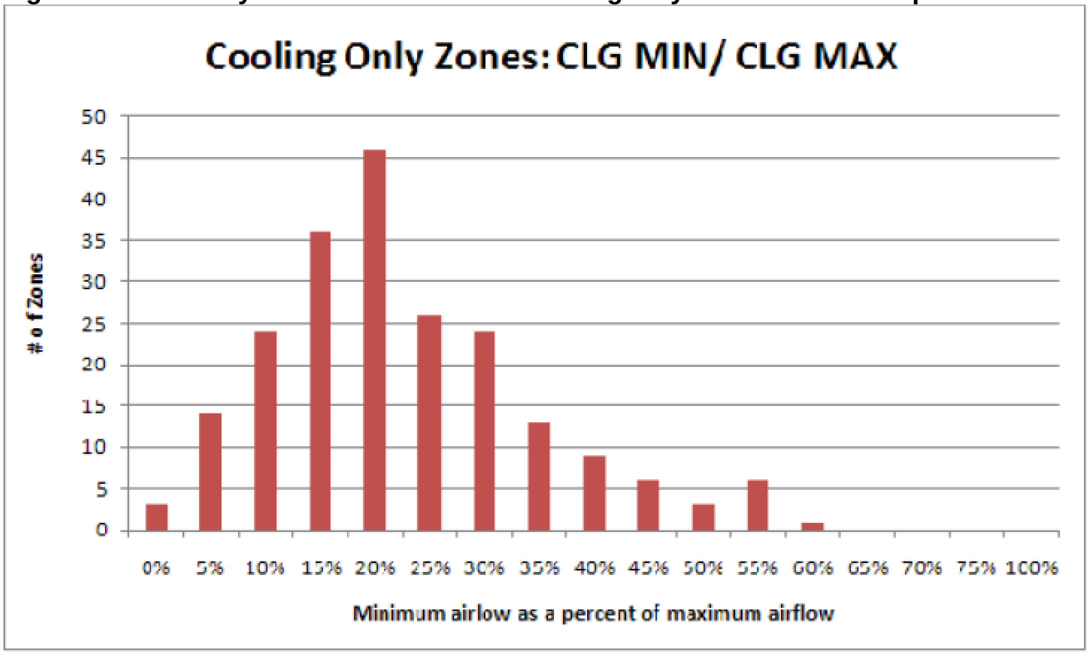
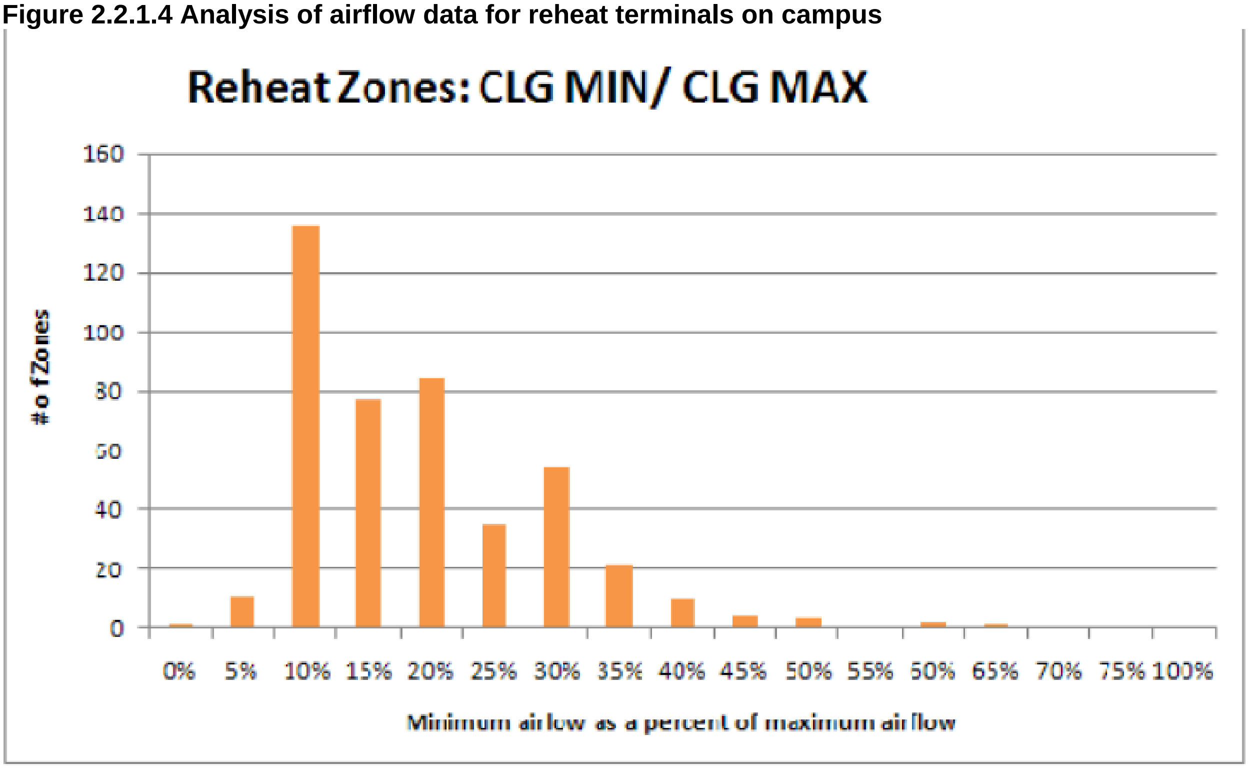



Figure 2.2.1.4 Analysis of airflow data for reheat terminals on campus




### *2.2.2 Actual flow rate distribution in Yahoo building A*

In the previous section, Figure 3.2.1.1-4 show the setpoints of the minimum flow rates for zones and different types of terminals in the Yahoo buildings before intervention. In this section, we will show the actual flow rate distribution in existing Yahoo buildings by showing one example.

The area that will show is in Building A, 3rd floor, Facade 109°WSW (corresponding to Area D in Figure 3.2.2.1)


Figure 3.2.2.1 Building A, 3rd floor, plan view

The actual flow rate summary for an entire year (July 2009 – July 2010) is displayed in Figure 3.2.2.2. These VAV units serve adjacent zones, with preheats daily. From the actual flow rate distribution, we see that high percentage of time the VAV units were operated under low minimum flow rate. That indicates the potential to save energy when the minimum flow rate is lowered.

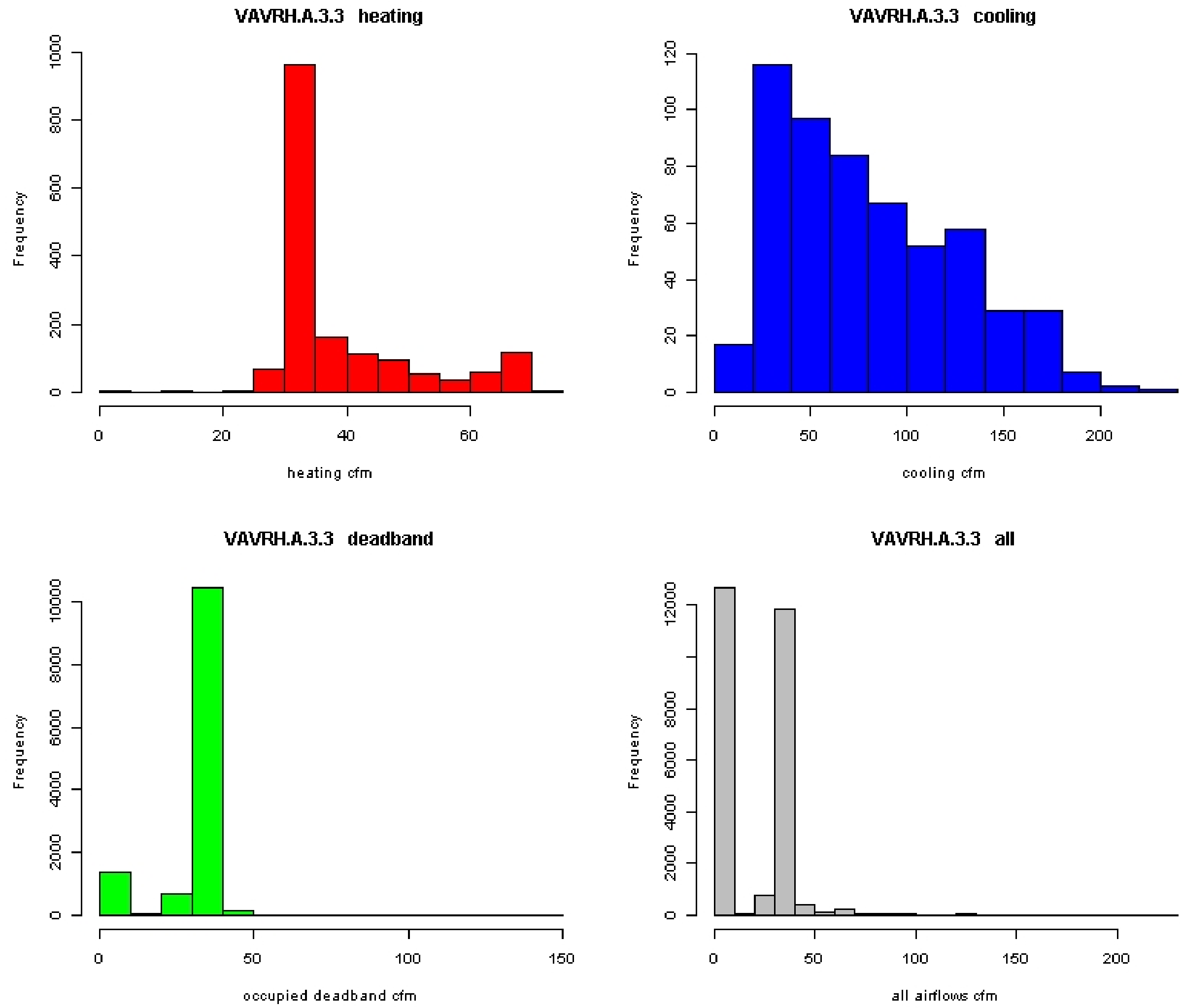
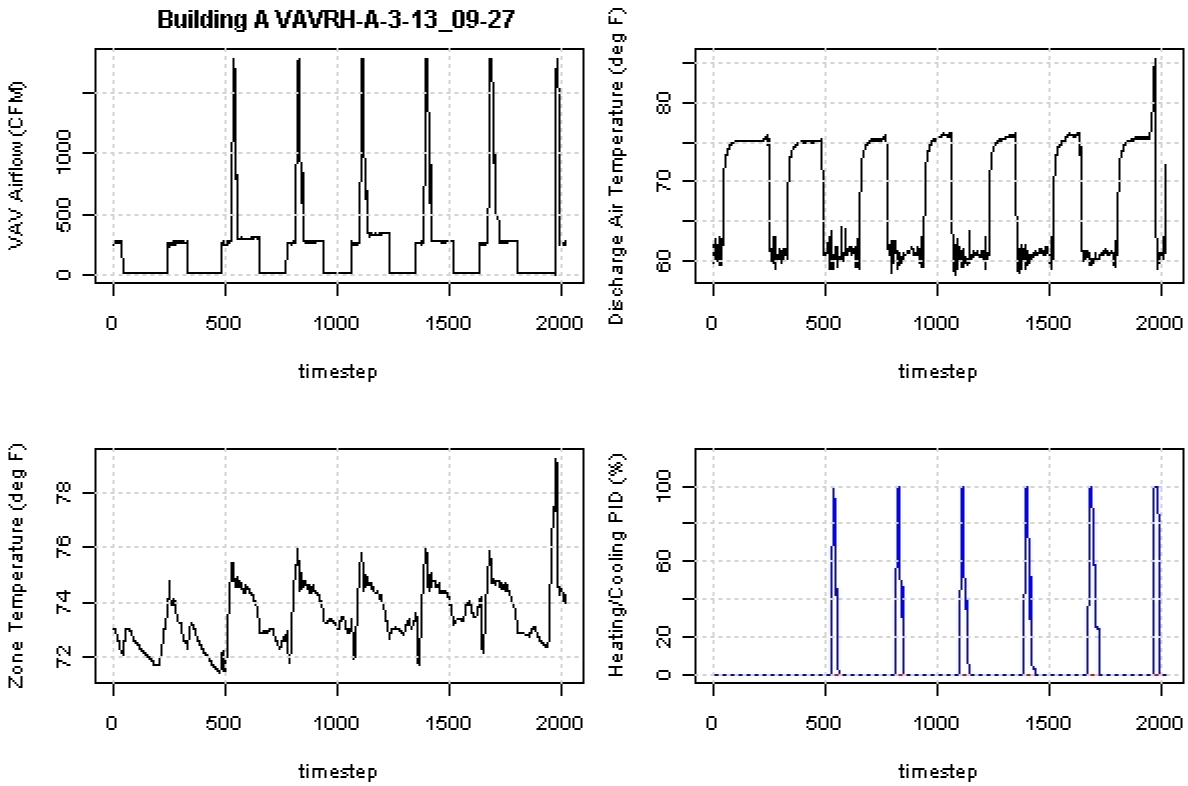
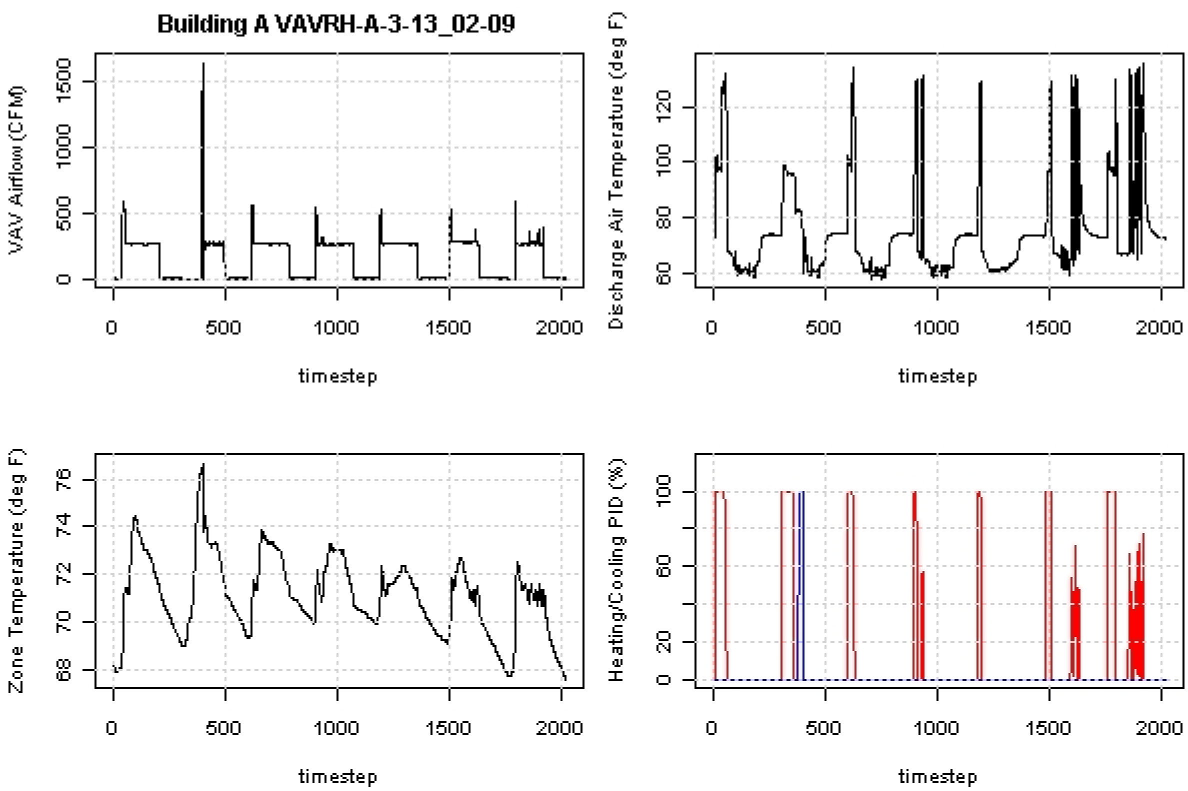



Figure 2.2.2.2 Actual flow rate distribution for Building A 3rd floor area D

Figure 2.2.2.3 shows detailed actual flow rate, discharge and zone air temperatures, and heating and cooling PID control loop output for a week in summer (week of Sept 27, 2009) and a week in winter (week of Feb. 2, 2009) for a typical zone in the same area, Building A 3rd floor, area D. The figure shows the flow rate changes over the time of a day when loads were different. It is quite frequently that the flow rate was at the minimum level. The figure also shows zone ambient and discharge temperature changes corresponding to the flow rate change.




Summer season (week of Sept. 27)




Winter season (week of Feb. 9)

Figure 2.2.2.3 An example showing actual VAV flow rate, zone ambient and discharge temperatures, and heating/cooling PID for a week in summer and a week in winter in Building A 3rd floow area D.

### *2.2: Observed flow rates before and after intervention*

We switched the minimum flow rate from 10% to 30% on Dec. 13 2 PM. We analyzed energy savings when the minimum flow rate is lowered to 10% in section 2.1. Figure 2.2.1 in this section is the summarized actual flow rates for Builing E under both 10% (Nov. 4 – Dec. 13 2 PM, 2010) and 30% (Jan 3 – Jan 23, 2011) minimum flow control periods. The figure was achieved by analyzing the trend reports of all VAV units in Building E and shows the sum of the airflow setpoints for all the zones. We see the shift in airflow rates in the building, which contributes to the energy savings described in section 2.1.

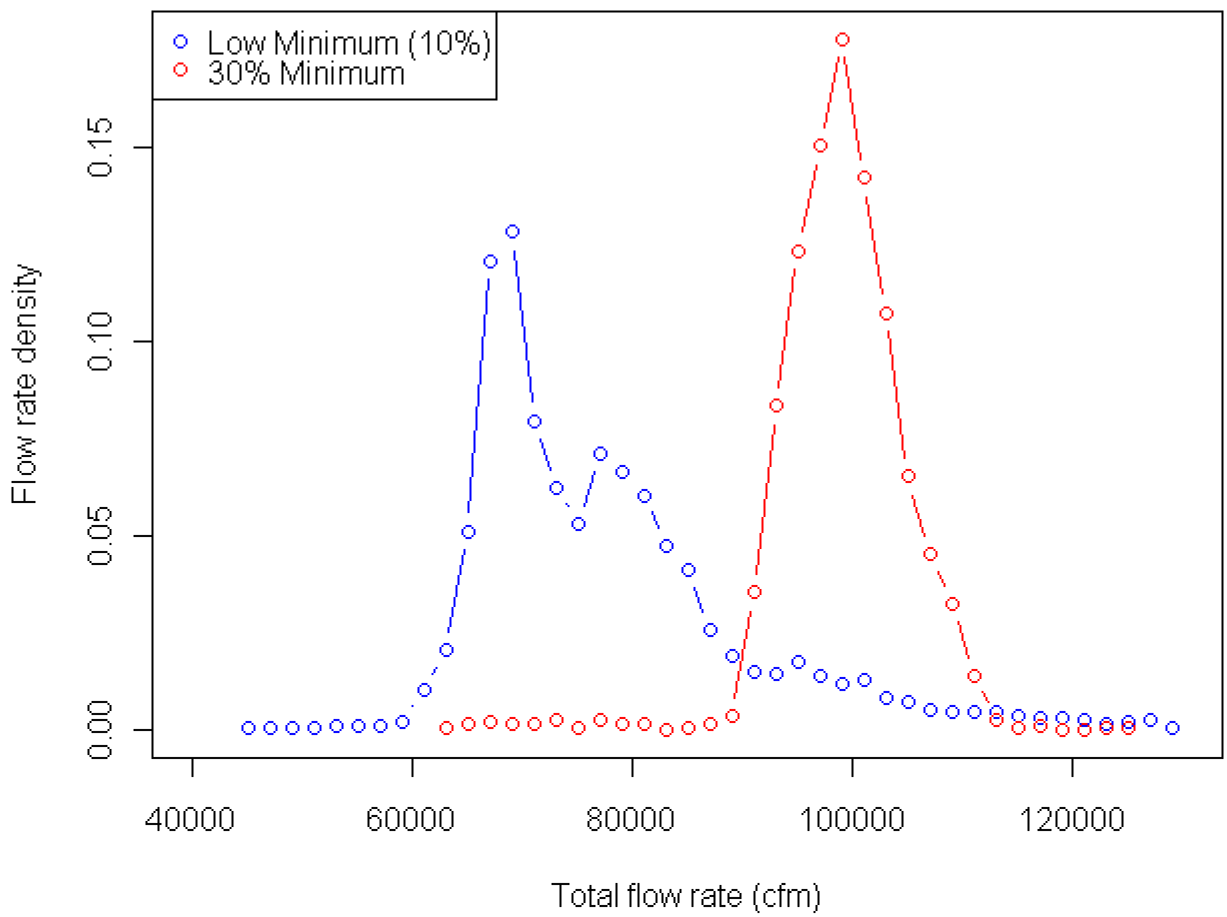



Figure 2.2.1 Building E VAV flow rate for 10% and 30% minimum flow rate

## Task #3 – Occupants satisfaction surveys for indoor environments

Two types of occupants' satisfaction surveys regarding the indoor environment were administered. The standard CBE background survey obtains occupant time-integrated satisfaction about various areas of indoor environmental quality. This tends to pick up any instance of dissatisfaction occurring in periods of a month or more. The 'right-now' survey asks for specific occupants feelings at an instant in time. Its responses allow us to analyze the subjective responses together with measured environmental conditions at the same moment, such as the ambient air temperature, diffuser flow rates etc.

## Objective

The objective of this task is to:

- Survey occupants' satisfaction before and after the VAV minimum intervention

## Deliverable: Occupants satisfaction surveys

### *3.1 CBE's Occupant Satisfaction background survey*

Between February 26 and March 12, we conducted the background survey in the 7 Yahoo buildings using the CBE web-based occupant satisfaction survey. This survey has been used since 2000 (http://www.cbe.berkeley.edu/research/survey.htm) and the unique size of the database (about 60,000 votes in 550 buildings) provides a stable benchmark for evaluating the indoor environmental qualities of the Yahoo buildings. The background survey measures occupants' satisfaction with, and assessment of, their work environments in terms of thermal comfort, perceived indoor air quality, and other indoor environment related questions. The background survey includes branching questions that appear whenever occupants express dissatisfaction in response to a survey question, to help identify the source of dissatisfaction.

The offices in Yahoo are mostly cubicles in an open interior plan. There are two types of partitions, high and low (see Figure 3.1.1). For a typical layout, about 6 cubicles share 2 supply diffusers.

Building A, 3rd floor

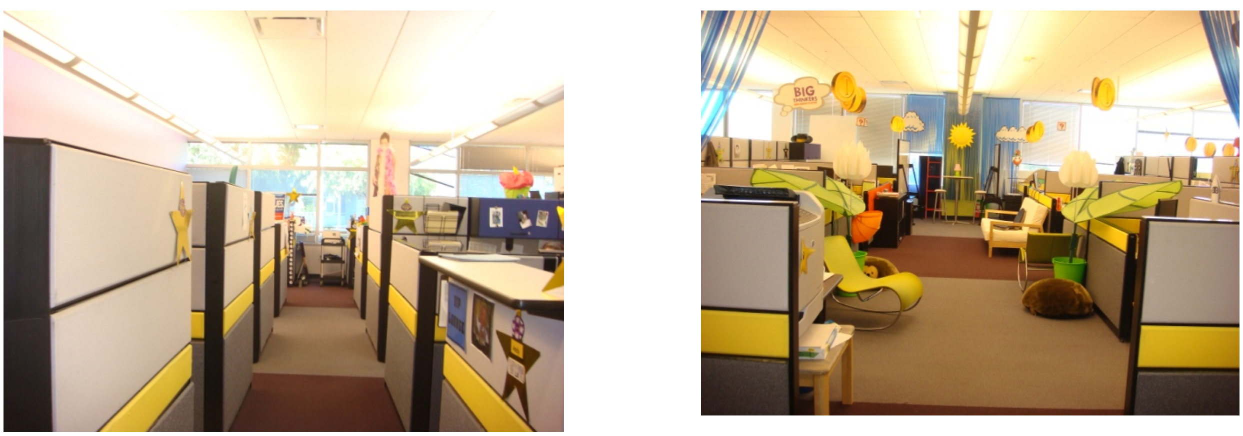


Figure 3.1.1 Office layout and high/low partitions of yahoo buildings

1279 people participated in the background survey (33% of the Yahoo population). The comparison of the mean values of the 9 categories surveyed between Yahoo buildings and the entire database is shown in Figure 3.1.2. From this figure, we see that the thermal comfort and perceived air quality in Yahoo buildings are much better than the average for the CBE database. This is an interesting finding, because in Section 2.2.1 we described that the minimum flow rates in Yahoo buildings were in fact already being operated at low level. The major concerns with the low minimum flow rate are for thermal comfort and also for perceived air quality due to less mixing of the room air. The results from the Yahoo buildings do not show that comfort or perceived air quality are low or poor.

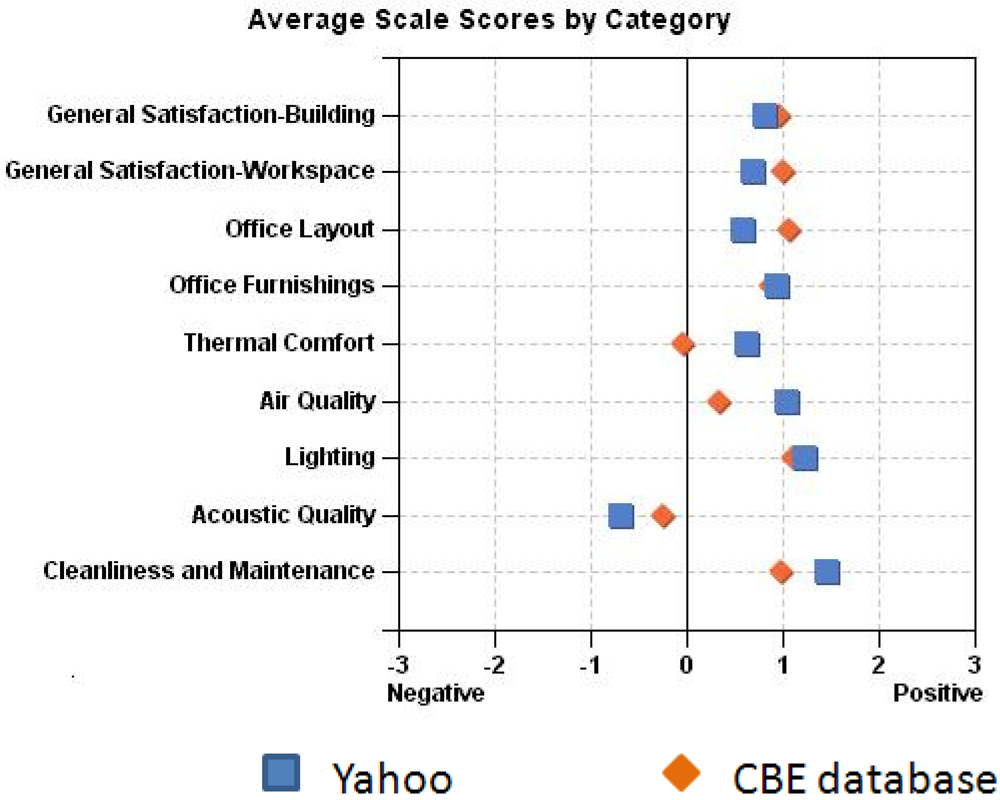



Figure 3.1.2, CBE background survey comparison between Yahoo 7 buildings and the entire CBE database

The thermal comfort satisfaction level (from neutral to very satisfied) of the population in Yahoo buildings is high at 77% (Figure 3.1.3), compared to the 57% from the entire CBE database (Huizenga 2006). 79% of the surveyed population indicated that the thermal comfort in their workspaces enhanced (including the neutral votes) their ability to get their work done.

## 2.7 Thermal Comfort

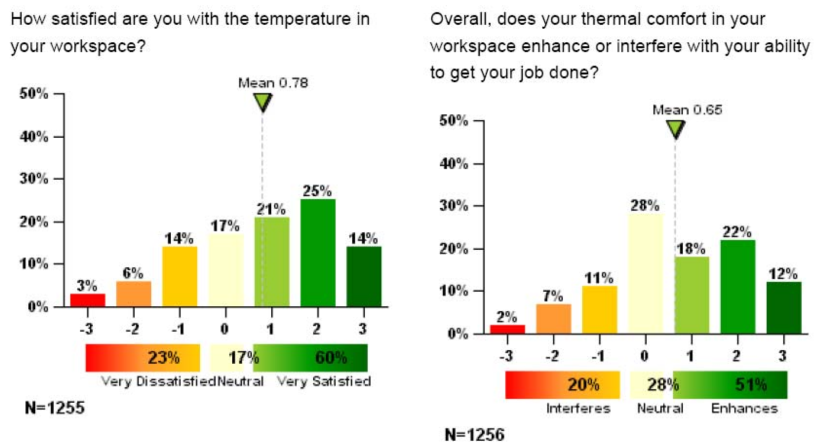
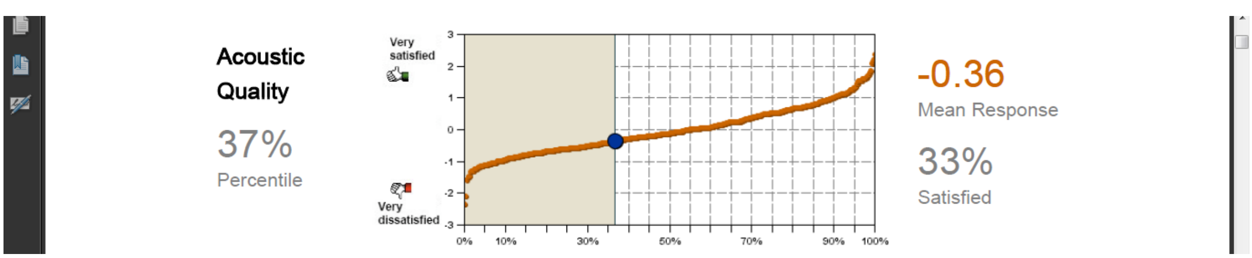



Figure 3.1.3, Distributions of thermal comfort and its impact on work performance in Yahoo buildings

The acoustic quality satisfaction, however, is much lower in Yahoo buildings than the average result of the CBE database (Figure 3.1.2). The survey asked occupants to describe noise sources in open comment section. The analysis of the comments shows that the noises were indoors, mainly from speaker phones, conference rooms and cafeteria. A few comments suggest that using headphones would reduce noise disturbances to others when playing online games or performing other noisy activities. Another possible reason for the low acoustical quality satisfaction in Yahoo buildings might be that computer programmers need high acoustical quality for their work.

The general satisfactions of the buildings and the workspaces in Yahoo Buildings are similar to the CBE database.

The rankings of the Yahoo buildings to the entire database for a few areas (thermal comfort, perceived air quality, acoustical quality, general satisfactions of the building and workspace) are presented in Figure 3.1.4. Again, the rankings show that it is very high (89th percentile) for thermal comfort and 76% for perceived air quality. The ranking for acoustic quality is low in the 37th percentile.



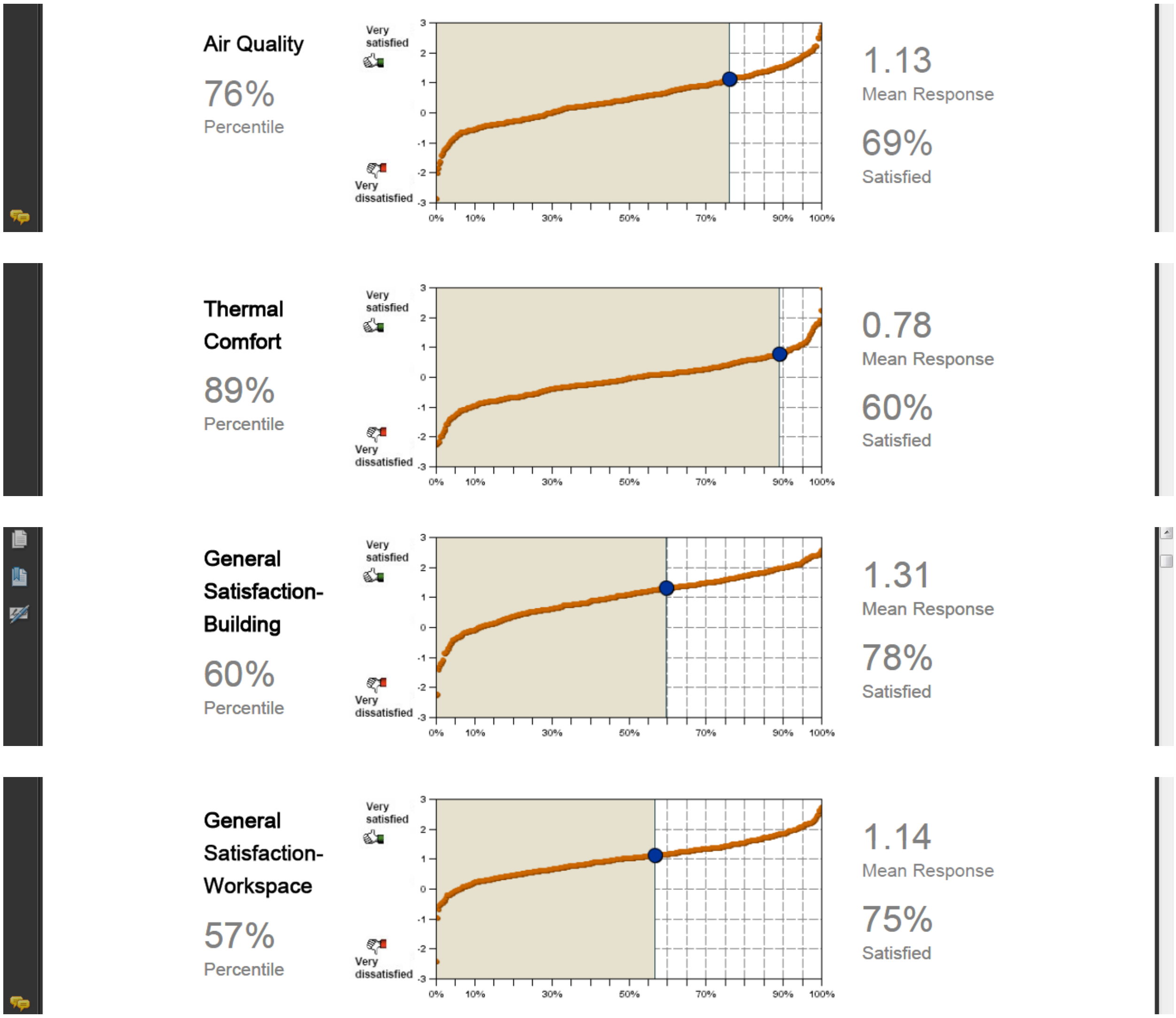



Figure 3.4. The rankings of the Yahoo buildings to the entire database

### *3.2 Right-now survey before and after the intervention*

We administered right-now occupant surveys in 7 Yahoo buildings between Dec. 3 and Dec. 23. The survey measures occupants' satisfactions in terms of thermal comfort, local body part discomfort, air movement perception, perceived indoor air quality, acoustical quality, and other indoor environment related questions. The survey also includes branching questions that appear whenever occupants express dissatisfaction in response to a survey question, to help identify the source of dissatisfaction. The branching questions ask about diffuser dumping, drafts, cold feet, and other issues that might pertain to low diffuser airflows. The low minimum flow rate was set at 10% before Dec. 13 2 PM and was switched to 30% at 2 PM for all 7 Yahoo buildings, in order to compare the occupants' satisfactions under both minimum flow rates. 600 people (about 17% of the yahoo population) participated, responding to repeated surveys three times three times per day. We received 7400 responses in total.

Figure 3.2.1 shows the percentages of dissatisfaction for each day during the survey period (Dec. 3 – Dec. 23).We see that there was obviously higher dissatisfaction when the survey just started. The dissatisfaction dropped 5% between the first and second day of the survey. This probably represents residual impressions from a longer time period. The volunteered comments were also far more prevalent in the first two days than when the survey settled down.

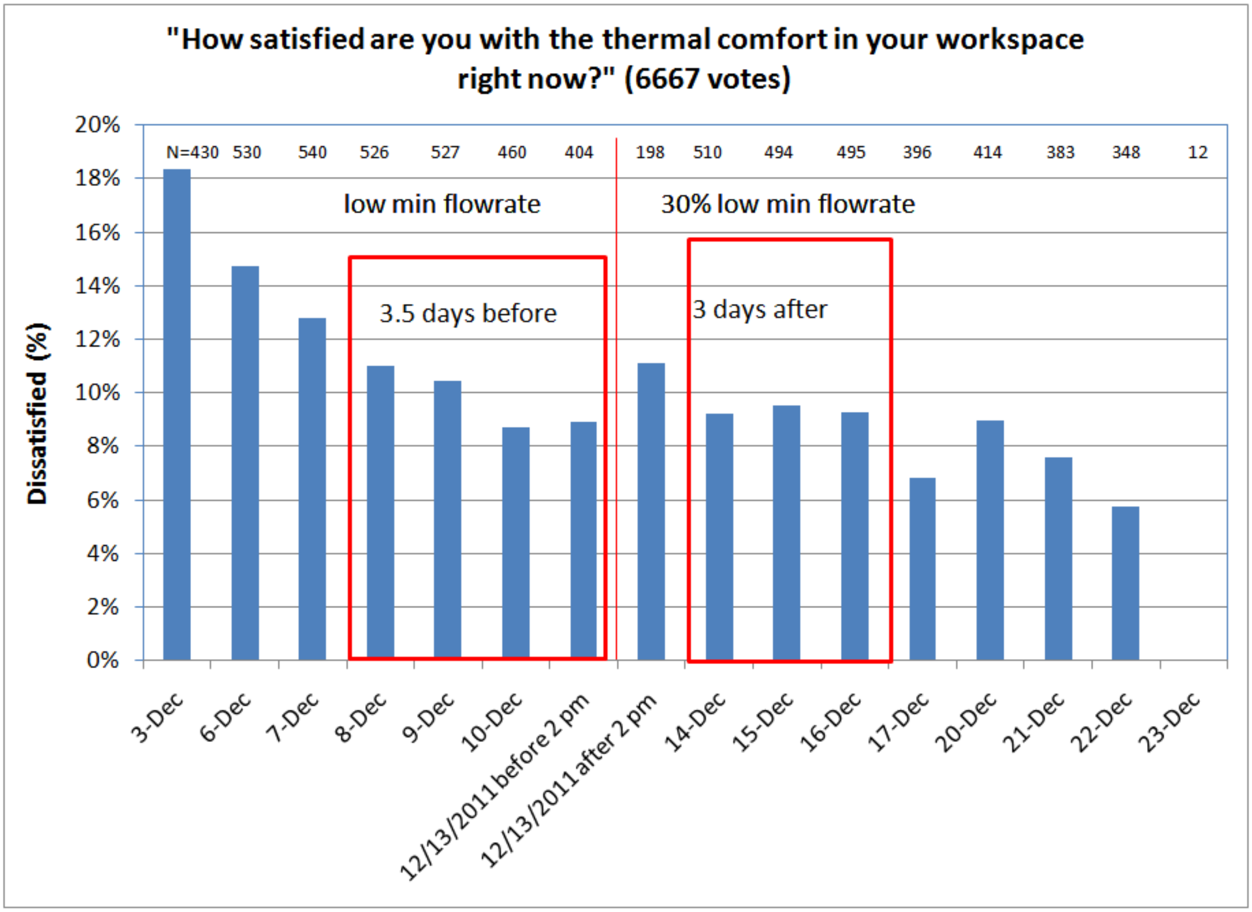


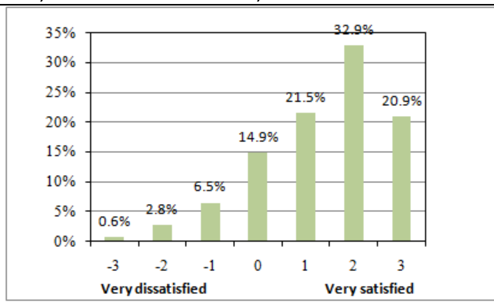
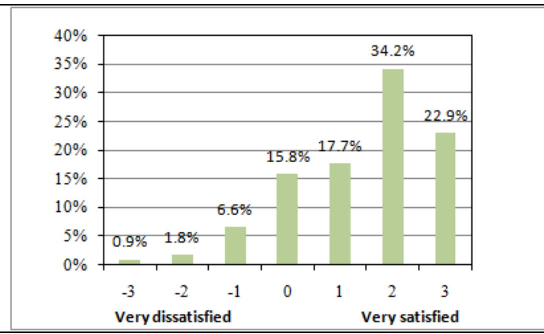
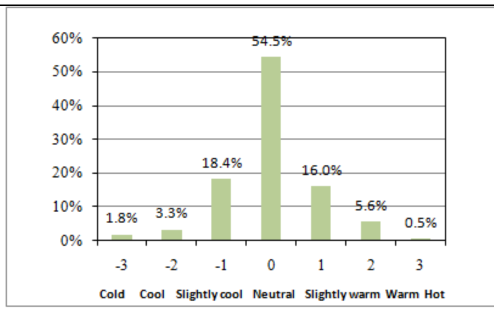
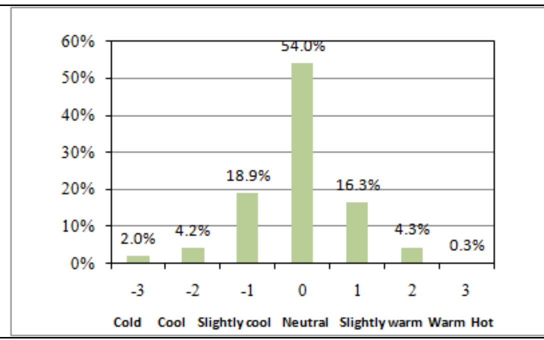
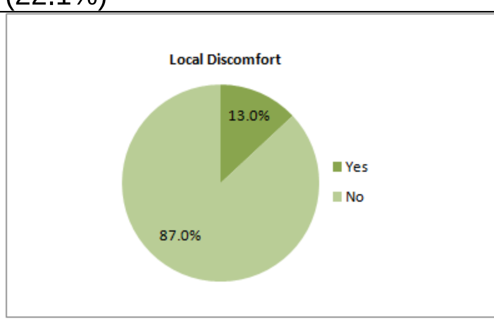
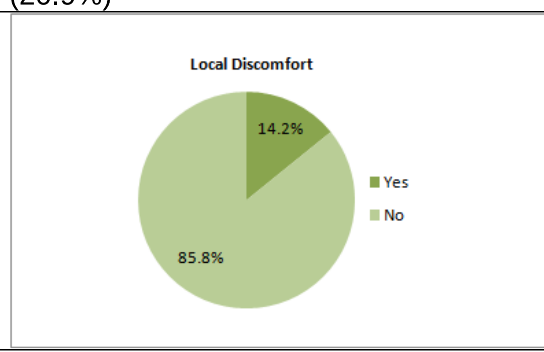

Figure 3.2.1. Daily distribution of thermal comfort dissatisfied votes. N represents the total number of votes for each day. As the survey period approached the Christmas vacation, the number of votes became smaller; only 12 people did the survey in the last day, Dec. 23.

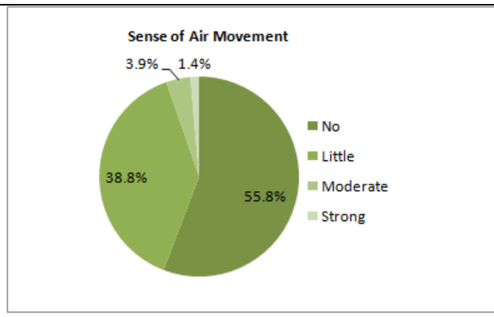
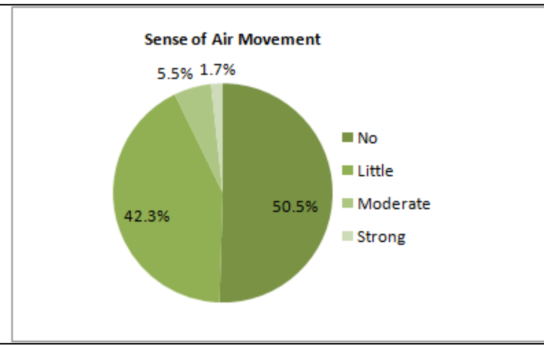
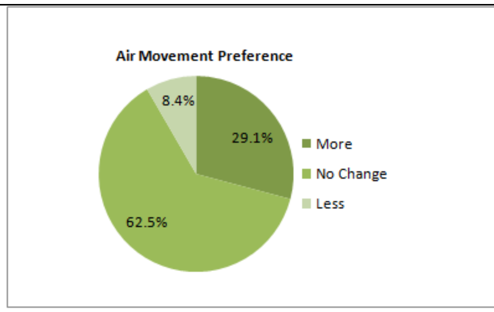
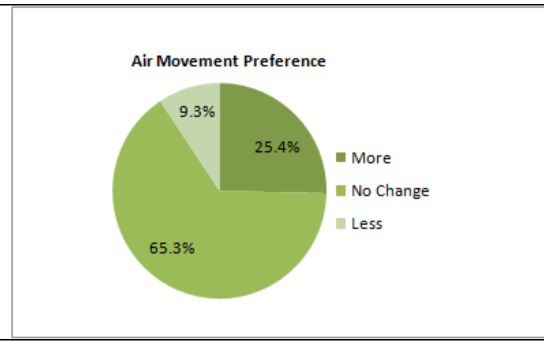
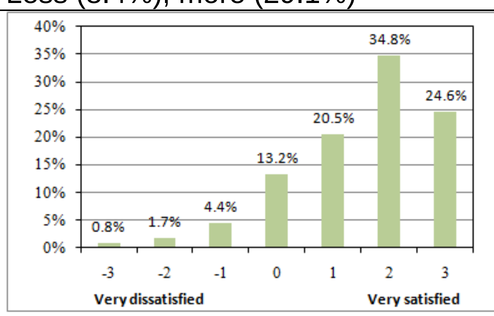
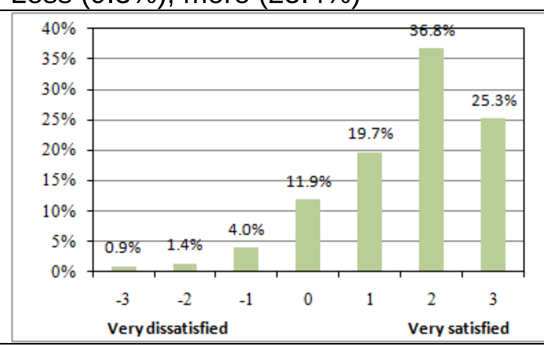
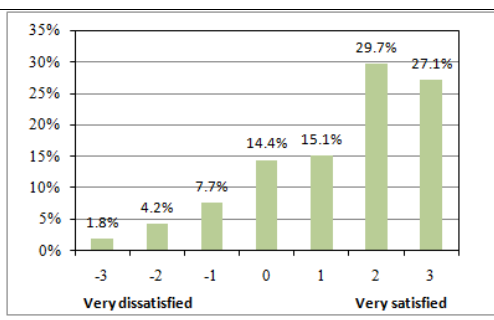
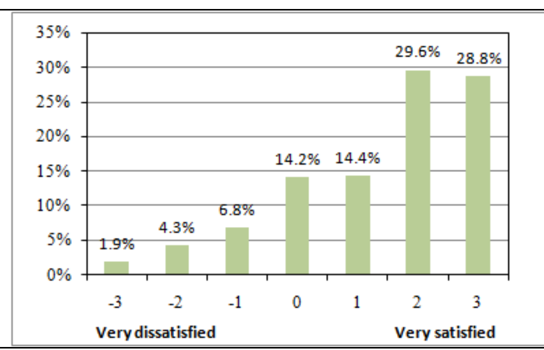
The survey stabilized 4 – 5 days after it started. We here compare the survey responses 3 days before and 3 days after the change of minimum flow rate from 10% to 30%. Right after the switch (Dec. 13 after 2 PM), there was a jump in dissatisfaction, which was probably due to an abrupt change in the minimum flow rate from 10% to 30%. The comments indicate that people noticed the difference in airflow and the dissatisfied votes increased. The votes in the afternoon following the changeover are therefore not included in the analysis. However, the votes on Dec. 13$^{th}$ before 2 PM should not be excluded. In the end, we have 3.5 days of survey votes (Dec. 8, 9, 10, 13 before 2 PM) before the switch under 10% minimum flow and 3 day votes (Dec. 14, 15, 16) under the 30% minimum flow rate. The comparisons are presented in Table 3.3.1, together with figures to show distributions.

Although there is about 0.5% increase in dissatisfaction of thermal comfort, perceived air quality, and acoustical quality for the 10% minimum comparing to 30% minimum (Table 3.2.2), there is no practical significance to the small differences. The small differences could be caused by issues other than the minimum flow rate.

There is a 2% shift in thermal sensation from warm to cool when the minimum flow rate was switched from 10% to 30%. People felt cooler under 30% minimum operation. There is also a 1% increase in local discomfort, 2% increase in sensing of air movement, and 1% more people prefer less air movement and a 4% reduction in preferring more air movement under 30% minimum flow rate operation. Again, these differences are small and there is no practical meaning. We basically conclude that the occupants' responses are similar under both minimum flow rates, although in general they felt slightly cooler under 30% operation.

Table 3.2.1 Comparison of occupants' votes 3 days before (1917 votes) and 3 days after (1499 votes) the switch of minimum flow rate from 10% to 30%.

| | Low min flow rate (~10%), Dec. 8 , 9, 10, 13 before 2 PM, N=1917 | 30% min flow rate, Dec. 14 – Dec. 16, N=1499 |
|---|---|---|
| Temp satisfaction |  |  |
| Dissatisfaction (%) | 9.86% | 9.34% |
| Thermal sensation |  |  |
| Sensation distribution | Cool (23.4%), neutral (54.5%), warm (22.1%) | Cool (25.1%), neutral (54.0%), warm (20.9%) |
| Local discomfort |  |  |
| Local discomfort (%) | 13.0 % | 14.2 % |

| | | |
|---|---|---|
| Sense of air |  |  |
| Moderate and strong | 5.3% | 7.2% |
| Air movement preference |  |  |
| preference | Less (8.4%), more (29.1%) | Less (9.3%), more (25.4%) |
| Perceived air quality |  |  |
| Dissatisfaction (%) | 6.9% | 6.3% |
| Noise level |  |  |
| Dissatisfaction (%) | 13.7% | 13.0% |

The continuous drop towards the end of the survey shown in Figure 3.2.1 is probably due to the fact that it was close to the Christmas. These data are not included in the analysis.

## Task #4 – Measurements of air temperature and velocity profiles in an office before and after the intervention

This task will be mainly conducted this summer. We will conduct detailed temperature and velocity measurements in Price industries for various types of diffusers under 10% and 30% minimum flow rates in August 2011. We will also measure the temperature and velocity profiles in two typical offices in Yahoo buildings for high and low partitions in the summer when the internal loads are high.

Currently we will only present 10 days temperature measurements in two offices of Building A, one high and two low partition. We put three sensors in each workstation. We will compare the temperature differences between them to examine whether closer or far away from a diffuser causes temperature differences. The measurements were conducted Jan 6 – Jan 16 (check). The setting of the low minimum flow rate was 30%.

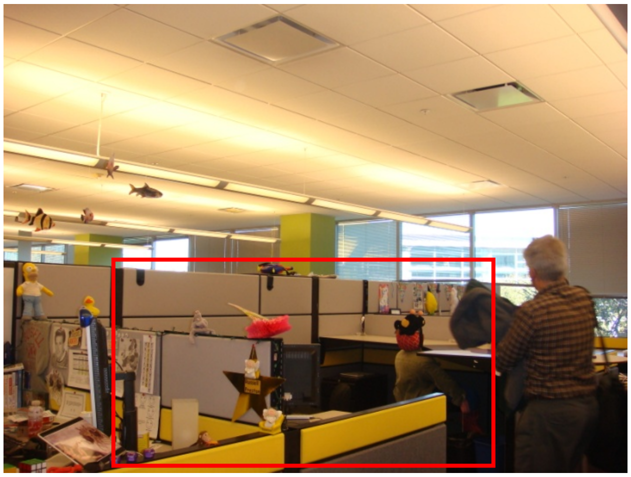
### Objective

The objective of this task is to:

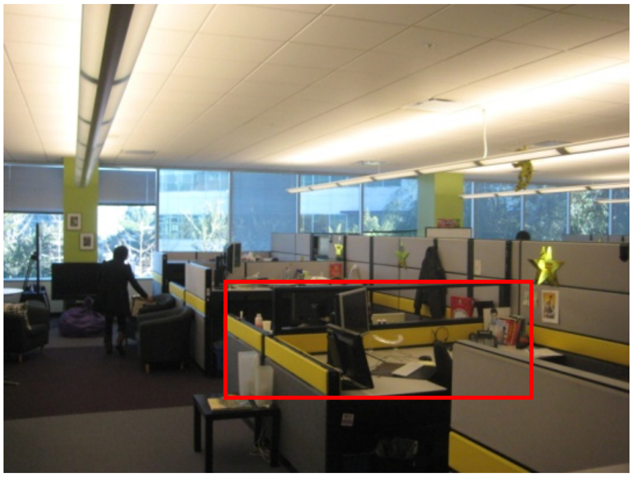
- Compare the temperatures in three different places which are close or far away from a supply diffuser in two typical workstations with high and low partition

### Deliverables: Measured temperature by hobos

Eight hobo thermisters were places in 3 typical workstations in Building A for 10 days since Jan. 6, 2011. The workstations were vacant. The hobo sensors were placed at the two corners of each workstation and one in the middle for two of the workstations. The two corners represent locations near or far away from the air supply diffusers in the three workstations.



High and low partition



Low partition

Figure 4.1 Workspaces with high and low partitions where we located 3 hobo temperature sensors in each workstation.

We will do the analysis later in summer after we finish the summer measurement. We will do the analysis together with the detailed workspace air temperature and velocity profiles that we plan to do in the summer as well.

## Conclusion

From both the background survey and the right-now survey results analysis, we see that satisfaction levels for the indoor environment under both 10% and 30% minimum flow rates are very similar. There is no evidence that the 10% minimum flow rate causes thermal discomfort and reduced perceived air quality.

The energy savings (from electricity and gas meters) by lowing the minimum flow rate from 30% to 10% are substantial, between 24 – 30% for cooling, and near 40% in heating.

## Next step

Under the ASHRAE funding, we will continue to examine the occupants' satisfaction and energy savings for low minimum diffuser flow rate. Specifically we will conduct the following tasks.

1) Continue collect data for the electricity and gas under 10% and 30% minimum flow rates in the spring and in the summer. Redo the regression analysis when the measured energy happen covering high outdoor air temperatures, and redo the energy saving analysis
2) Break out the AC-unit energy savings into "cooling energy" and "fan energy" separately.
3) Analyze the measured energy data and the trend reports of system operation to summarize the variability so that the future simulations of energy savings from reducing low minimum flow can be more accurate based on the measured variability rather than guessing as currently been doing.
4) Summarize the actual flow rate for Building A, B as well
5) Do energy analysis for Building G
6) Match the votes showing "draft" discomfort with the diffuser flow rate and find the conditions when the "draft" sensation is likely happen, under 10% or 30% minimum flow rate, or under high flow rate.
7) Group the occupants into two groups (closer and far way from diffusers) to compare their subjective responses.
8) Finish the analysis of open comments of the Yahoo building background and right-now surveys to further understand the sources of dissatisfaction.
9) Minimum flow setpoints will be changed to the low-minimum setpoint and 30% setpoints again in the summer season to measure the energy and comfort impacts in hot weather.
10) Conduct right-now survey in Yahoo buildings in summer season under both 10% and 30% minimum flow rates. We plan to do it in August. During that survey, we will switch the order to survey occupants' responses first under 30% then 10% of the minimum flow rates.
11) Together with the winter and summer survey responses, we will compare occupants responses for two groups of people, closer and far away from diffusers to examine whether cool air "dumping" could cause thermal discomfort
12) We will measure the temperature and velocity profiles of two typical workspaces (high and low partitions) in the Yahoo buildings under both 10% and 30% minimum flow rates
13) Price Industries will perform detailed temperature and velocity profiles for 10% and 30% diffuser flow rates and for different types of diffusers.
14) We will measure the acoustical levels in typical yahoo offices for both the 10% and 30% minimum flow rates
15) We will conduct the CBE background survey in 10 buildings which are operated under low (lower than 30% the conventional level) minimum flow rate.

16) Data analysis and write a report and an paper.
17) Although in the proposal, we proposed to do the intervention study only in one building, fortunately there is another building which allows us to do a similar study as we did in Yahoo buildings. We have installed the energy meters and re-programmed the control in 800 Ferry Building. We will change the minimum flow rate between 30% and 10% and measure the energy uses, and do the right-now surveys as well.

## References

Huizenga, C., S. Abbaszadeh, L. Zagreus and E. Arens 2006, "Air Quality and Thermal Comfort in Office Buildings: Results of a Large Indoor Environmental Quality Survey". Healthy Buildings 2006, Lisbon

## Appendix A

1. Detailed control re-programming and energy metering diagram
2. Right-now survey screen shot file


# Yahoo CX Project Buildings A, B, E & G

701 First Avenue

Sunnyvale, California

As Prepared By

## ACCO Engineered Systems

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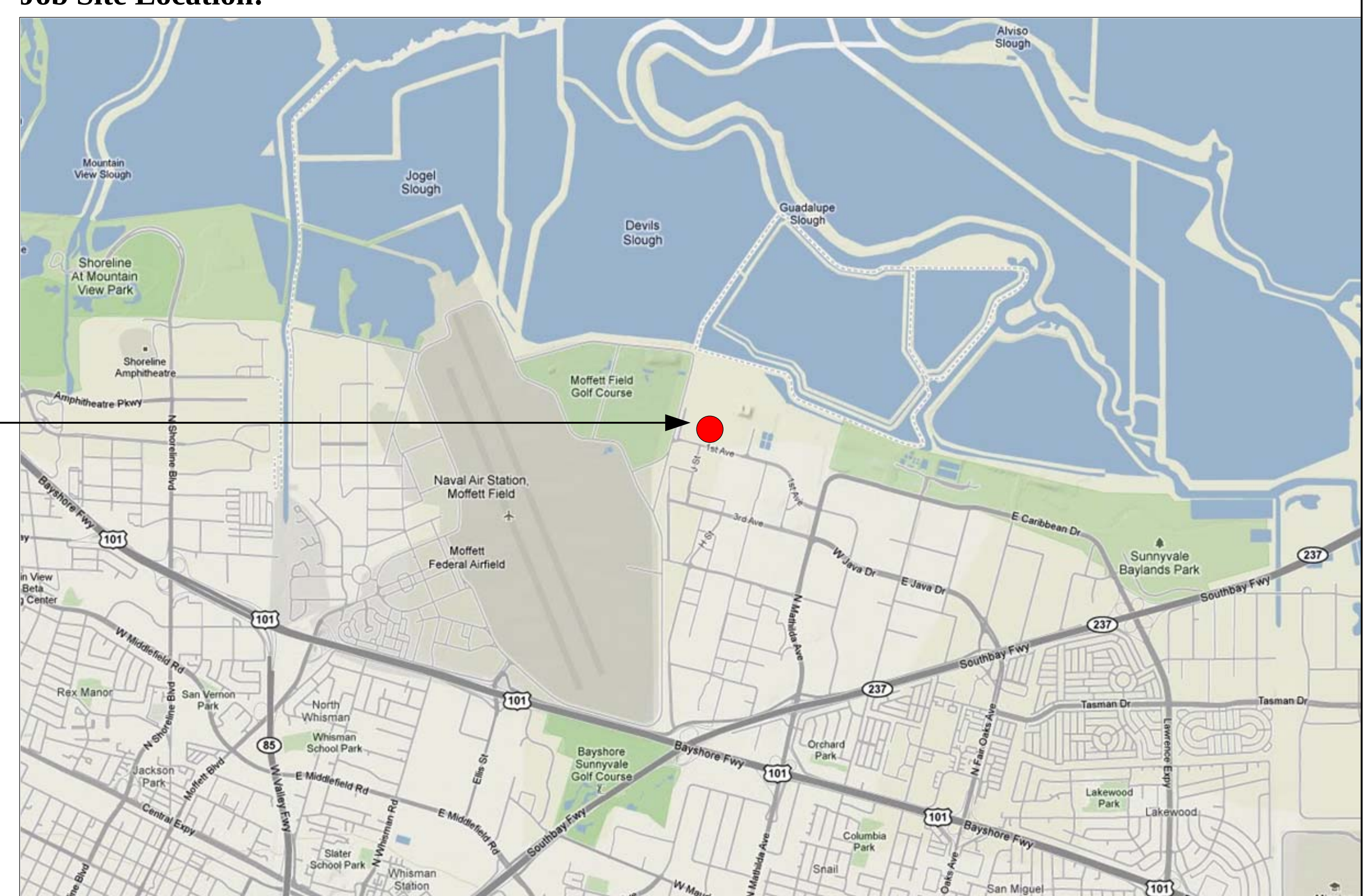
AUTOMATEDLOGIC
CORPORATION

**Job Site Location:**

701 First Avenue




acco engineered systems

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**Mechanical:**

ACCO Engineered Systems

**AUTOMATED LOGIC BUILDING AUTOMATION SYSTEM**

REVISION DATA

| No | Date | Description | By |
|---|---|---|---|
| ⚠ | 6/19/10 | Submittal | WS |

**FILENAME:** Yahoo CX Buildings A, B, E & G Rev 1.vsd

PROJECT

**Yahoo CX Project Buildings A, B, E & G**

701 First Avenue

Sunnyvale, California

| EE | CLT | 90693 |
|---|---|---|
| Project Manager | Project Engineer | Job Number |

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3: Symbol Legend
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10: Veris 8036 Modbus Register
11: Chiller Reset Wiring Detail


| | | | |
|---|---|---|---|
| Yahoo CX Project Buildings A, B, E & G<br>Sunnyvale, California | | | |
| ACCO Engineered Systems | | | |
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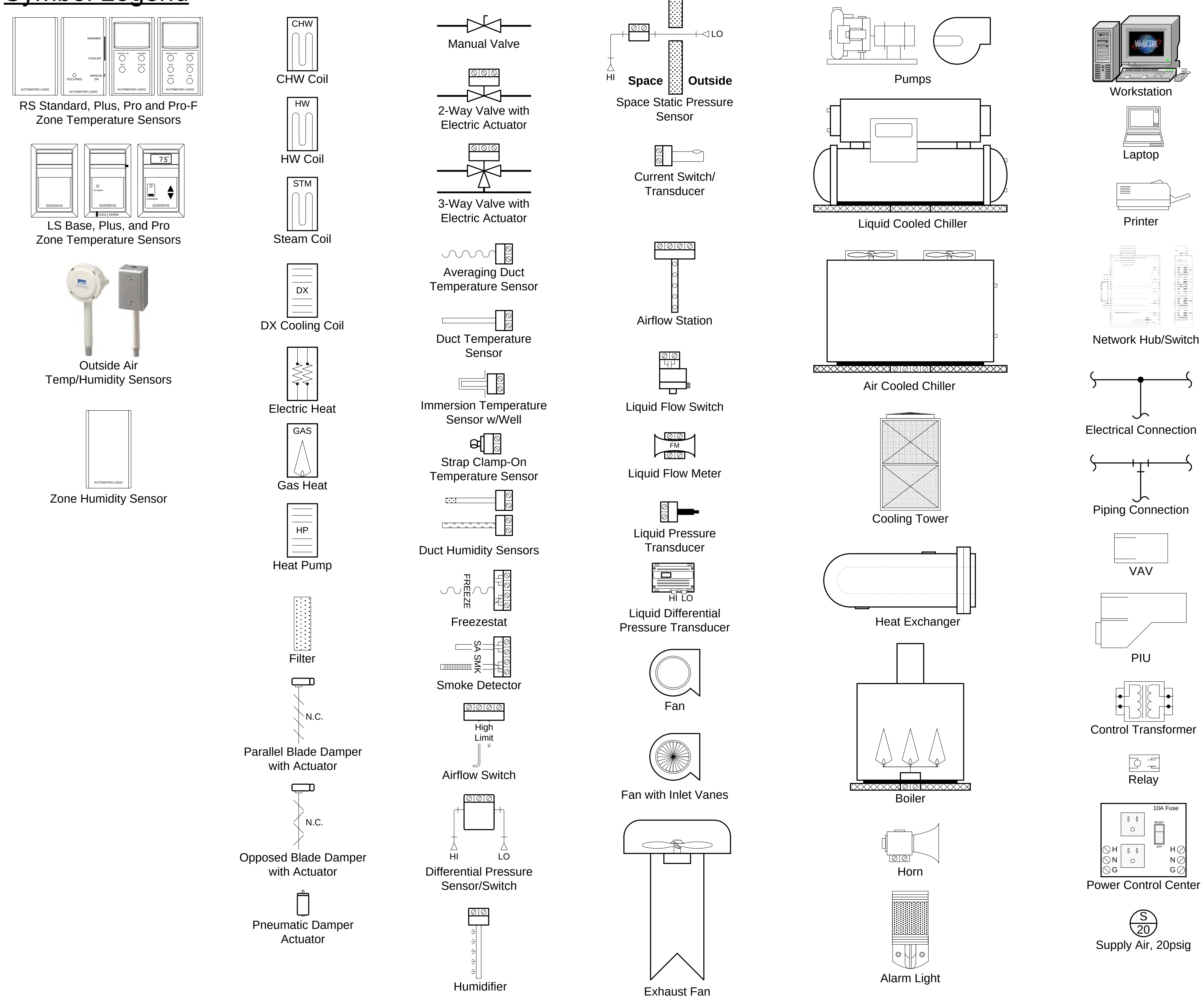
| | | | CORE NO: 90693 |

# Symbol Legend




## Symbol Notes

| | |
|---|---|
| 120 VAC | 120 VAC POWER TO TEMP CONTROL PANELS (TCPs) AND CONDUIT BY DIV. 16. POWER SUPPLY DEDICATED PER PANEL. |
| 120 VAC UPS-1 | 120 VAC UPS POWER AND CONDUIT TO TEMP CONTROL PANELS (TCPs) BY CONTROLS INSTALLATION SUBCONTRACTOR. POWER SUPPLY DEDICATED PER PANEL. |
| 120 VAC UPS-2 | 120 VAC UPS POWER AND CONDUIT TO TEMP CONTROL PANELS (TCPs) BY DIV. 16. ONE DEDICATED UPS CIRCUIT PER FMP. THESE CIRCUITS ARE INTENDED FOR MISSION CRITICAL OPERATIONS. |
| T | TERM485 120 OHM TERMINATING RESISTOR |
| P | PROT485 NETWORK BOARD |
| D | DIAG485 NETWORK BOARD |
| F | FIBER485 FIBER OPTIC CONVERTER |
| R | REP485 NETWORK REPEATER |
| B | BT485 120 OHM TERMINTATOR |
| E | ETHERNET CONNECTION JACK |
| H | ETHERNET HUB/SWITCH |
| | EQUIPMENT CONTROLLED / MONITORED BY ALC BUILDING AUTOMATION SYSTEM |
| | ALCS CONTROL PANEL (FMP) |
| H | ZONE HUMIDITY SENSOR |
| T | ZONE TEMPERATURE SENSOR |
| T/H | COMBINATION ZONE TEMPERATURE/HUMIDITY SENSOR |
| H2 | ZONE HYDROGEN SENSOR |
| DP | DIFFERENTIAL PRESSURE TRANSDUCER |
| SP | STATIC PRESSURE TRANSDUCER |
| U | UNITARY CONTROLLER |
| WT | WIRELESS ZONE TEMP/HUMIDITY SENSOR |
| Wire Type and Number | CABLE/WIRE TYPE MARKER |
| TCP-#-# | PANEL NOMENCLATURE |

PANEL NAME
PANEL LOCATION

Controlled Equipment

HH" x WW"
Panel Size

Notes:
1. Detailed part design and schematics may be used in place of symbols listed above.

| | | | |
|---|---|---|---|
| Yahoo CX Project Buildings A, B, E & G<br>Sunnyvale, California | | | |
| ACCO Engineered Systems | | | |
| Symbol Legend | | | |
| REV: 1 | Submittal | 6/19/2010 | JOB NO: XXX |
| acco engineered systems | | | CHECK BY: MWS |
| | | | CORE NO: 90693 |
| | | | 3 of 11 |

# Abbreviation/Installation Notes

| | |
|---|---|
| ARCNET - | Network Comm 156K |
| A/C - | Alternating Current |
| ACU - | Air Conditioning Unit |
| ADA - | Americans with Disabilities Act |
| AFF - | Above Finished Floor |
| AHU - | Air Handling Unit |
| AI - | Analog Input |
| ALM - | Alarm |
| AMP - | Ampere |
| AO - | Analog Output |
| AUTO - | Automatic |
| AUX - | Auxiliary |
| AWG - | American Wire Gauge |
| BAI - | BACnet Analog Input |
| BAO - | BACnet Analog Output |
| BAS - | Building Automation System |
| BBI - | BACnet Binary Input |
| BBO - | BACnet Binary Output |
| BFF - | Below Finished Floor |
| BH - | Basin Heater |
| BKUP - | Backup |
| BLR - | Boiler |
| BOM - | Bill Of Materials |
| BTU - | British Thermal Units |
| C - | Celsius |
| CAV - | Constant Air Volume |
| CCW - | Counter Clockwise |
| CD - | Cooling Deck |
| CFM - | Cubic Feet Per Minute |
| CHIV - | Chiller Isolation Valve |
| CHLR - | Chiller |
| CHW - | Chilled Water |
| CHWP - | Chilled Water Pump |
| CHWR - | Chilled Water Return |
| CHWS - | Chilled Water Supply |
| CHWV - | Chilled Water Valve |
| CM - | Control Module |
| COND - | Condenser |
| CRAC - | Computer Room Air Conditioner |
| CRAH - | Computer Room Air Handler |
| CRU - | Computer Room Unit |
| CS - | Current Switch |
| CT - | Current Transducer |
| CTM - | Current Transmitter |
| CTRL - | Control |
| CTX - | Current Transformer |
| CU - | Condensing Unit |
| CUH - | Cabinet Unit Heater |
| CW - | Clockwise |
| CNDW - | Condenser Water |
| CWBV - | Condenser Water Bypass Valve |
| CWIV - | Condenser Water Isolation Valve |
| CWP - | Condenser Water Pump |
| CWR - | Condenser Water Return |
| CWS - | Condenser Water Supply |
| D/C - | Direct Current |
| DA - | Discharge Air |
| DAT - | Discharge Air Temperature |
| DD - | Double Duct |
| DDC - | Direct Digital Controls |
| DEV - | Device |
| DH - | Duct Heater |
| DI - | Digital Input |
| DMPR - | Damper |
| DO - | Digital Output |
| DP - | Differential Pressure |
| DPDT - | Double Pole Double Throw |
| DPS - | Differential Pressure Switch |
| DPST - | Double Pole Single Throw |
| DPT - | Differential Pressure Transducer |
| DSP - | Duct Static Pressure |
| DWG - | Drawing |
| DX - | Direct Expansion |
| E - | Existing |
| EA - | Exhaust Air |
| EAD - | Exhaust Air Damper |
| ECON - | Economizer |
| EDH - | Electric Duct Heater |
| EF - | Exhaust Fan |
| EPO - | Emergency Power Off |
| EVAP - | Evaporator |
| F - | Fahrenheit |
| FBO - | Furnished by Others |
| FCU - | Fan Coil Unit |
| FM-200 - | Chemical Fire Suppression |
| FMP - | Field Module Panel |
| FO - | Fuel Oil |
| FOP - | Fuel Oil Pump |
| FS - | Flow Switch |
| G or GND- | Ground |
| GEN - | Generator |
| GPM - | Gallons Per Minute |
| H - | Hot (AC Voltage) |
| H2 - | Hydrogen |
| HD - | Heating Deck |
| HGB - | Hot Gas Bypass |
| HOA - | Hand/Off/Auto |
| HP - | Heat Pump |
| HRU - | Heat Recovery Unit |
| HTX - | Heat Exchanger |
| HU - | Humidifier |
| HW - | Hot Water |
| HWP - | Hot Water Pump |
| HWR - | Hot Water Return |
| HWS - | Hot Water Supply |
| ID - | Inside Diameter |
| I/O - | Input/Output |
| IAQ - | Indoor Air Quality |
| IP - | Internet Protocol |
| ISO - | Isolation |
| L - | Line Voltage |
| LL - | Liquid Level |
| LS - | LogiStat |
| LVL - | Level |
| mA - | Milliamp |
| MAD - | Mixed Air Damper |
| MAT - | Mixed Air Temperature |
| MAU - | Makeup Air Unit |
| MAX - | Maximum |
| MGR - | Manager |
| MIN - | Minimum |
| MISC - | Miscellaneous |
| N - | Neutral |
| NC - | Normally Closed |
| NEC - | National Electric Code |
| NO - | Normally Open |
| NTS - | Not To Scale |
| OA - | Outdoor Air |
| OAD - | Outdoor Air Damper |
| OAH - | Outdoor Air Humidity |
| OAT - | Outdoor Air Temperature |
| OAT/H - | Outdoor Air Temperature / Humidity |
| OBD - | Opposed Blade Damper |
| OD - | Outside Diameter |
| OPS - | Oil Pressure Switch |
| PAC - | Packaged Air Conditioning Unit |
| PBD - | Parallel Blade Damper |
| PCHWP - | Primary Chilled Water Pump |
| PCWP - | Primary Condenser Water Pump |
| PDU - | Power Distribution Unit |
| PIU - | Power Induction Unit |
| PMP - | Pump |
| PNL - | Panel |
| POS - | Position |
| PPM - | Parts Per Million |
| PS - | Power Switch |
| PSI - | Pounds Per Square Inch |
| PWR - | Power |
| R - | Relay |
| RA - | Return Air |
| RAD - | Return Air Damper |
| RET - | Return |
| REV - | Revision |
| RF - | Return Fan |
| RH - | Relative Humidity |
| RM - | Room |
| RTU - | Rooftop Unit |
| S - | Shield |
| S/S - | Start / Stop |
| SA - | Supply Air |
| SAT - | Supply Air Temperature |
| SCHWP - | Secondary Chilled Water Pump |
| SCHWR - | Secondary Chilled Water Return |
| SCHWS - | Secondary Chilled Water Supply |
| SCWP - | Secondary Condenser Water Pump |
| SD - | Smoke Detector |
| SF - | Supply Fan |
| SP - | Static Pressure |
| SPDT - | Single Pole Double Throw |
| SPST - | Single Pole Single Throw |
| SSP - | Systems & Service Provider |
| ST - | Status |
| STP - | Setpoint |
| STS - | Static Transfer Switch |
| SUP - | Supply |
| SW - | Switch |
| T/S - | Twisted Shielded |
| TB - | Terminal Block |
| TD - | Time Delay |
| TEMP - | Temperature |
| TP - | Total Pressure |
| TPI - | Third Party Interface |
| TWR - | Cooling Tower |
| TX - | Transformer |
| UH - | Unit Heater |
| UL - | Underwriters Laboratories |
| UNET - | U-Card Comm Network |
| UPS - | Uninterrupted Power Supply |
| UST - | Underground Storage Tank |
| UV - | Unit Ventilator |
| VA - | Apparent Power (Voltage * Amperage) |
| VAC - | AC Voltage |
| VAV - | Variable Air Volume |
| VD - | Volume Damper |
| VDC - | DC Voltage |
| VESDA - | Very Early Smoke Detecting Apparatus |
| VFD - | Variable Frequency Drive |
| VLV - | Valve |
| VP - | Velocity Pressure |
| VVTU - | Variable Volume Terminal Unit |
| "WC - | Inches of Water Column |
| W - | Watt |
| W/ - | With |
| WB - | Wet Bulb |
| W/O - | Without |
| WSHP - | Water Source Heat Pump |
| XFMR - | Transformer |
| ZD - | Zone Damper |

# Cable Identification/Wire Labels

**M & S-Line Point Notation**

OPC — TAB LABEL TEXT - SPARE — BN-DR-DA-EN-PL

BN - BACNET NETWORK NUMBER (OPTIONAL)
DR - DEVICE ROUTER NUMBER (OPTIONAL)
DA - DEVICE ADDRESS
EN - EXPANDER NUMBER
PL - POINT LOCATION
OPC - OFF PAGE CONNECTOR

**U-Line Point Notation**

OPC — TAB LABEL TEXT - SPARE — BN-DR-DA-FB-PL

BN - BACNET NETWORK NUMBER
DR - DEVICE ROUTER NUMBER
DA - DEVICE ADDRESS
FB - FUNCTION BLOCK NUMBER
PL - POINT LOCATION
OPC - OFF PAGE CONNECTOR

Monitoring and control points for remote equipment are identified by the Module Point representation shown above. The electrical contractor or installer must label both ends of each control or monitoring point cable using the following format : (BN-DR-DA-EN-PL) or (BN-DR-DA-FB-PL). Adherence to this identification system is mandatory and must be followed using an approved tagging system comparable to the Brady I.D. Pro Plus electronic labeling system or equivalent.

These tags are intended for the wiring for all Analog Inputs (AI's), Digital Inputs (DI's), Analog Outputs (AO's), and Digital Outputs (DO's) except VAV's and terminal equipment where the wire runs are short and the field termination point is seen, or is easily identified. Points using pneumatic tubing follow the same convention.

All communication cable, terminations "in" an "out" of a field module panel, terminal equipment or VAV's must be labeled with "from (equipment name)" and "to (equipment name)" locations. **See Figure 1 below.**

All ARC156 or UNet communication, serial interface, control, and monitoring wiring must be terminated at the locations designated and must be free of splices.

When stripping multi-conductor cables, use only strippers specifically designed for removal of outer sheath insulation so as not to damage the shielding or insulation of the conductors. Use Ideal Catalog #45-514 or #45-165 data cable strippers or equivalent.

When shielded cable is used, do not strip back sheath more than 1" in order to keep twisted pair from separating. Do not ground shield to the panel or chassis ground. The shield should only be connected to the 'Optional Shield' connection at a module. Ungrounded shields must be cut back and taped to prevent contact with with metal surfaces (heat shrink is preferred). **See figure 2 below.**

Multi-conductor cabling other than specified or pre-approved by the electrical contractor is unacceptable.

Electrical installation shall be in accordance with the project specifications, national, state, and local electrical codes along with ALC standards as outlined in this and other documents.

LogiStat Plus and LogiStat Pro room temperature sensors shall be mounted 48 inches above the finished floor per the Americans with Disabilities Act.

All pneumatic tubing that exceeds ten feet in length must be rigid copper or poly tubing installed in conduit. All poly tubing in exposed areas must be installed in conduit. Use plenum rated poly tubing for runs made in hung ceilings. Short lengths of less than 16 inches are permitted to be exposed for connection to field devices.

All field module panels (FMPs) will have a dedicated 120vac circuit.

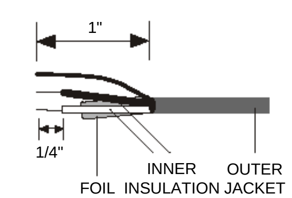



FIGURE 2

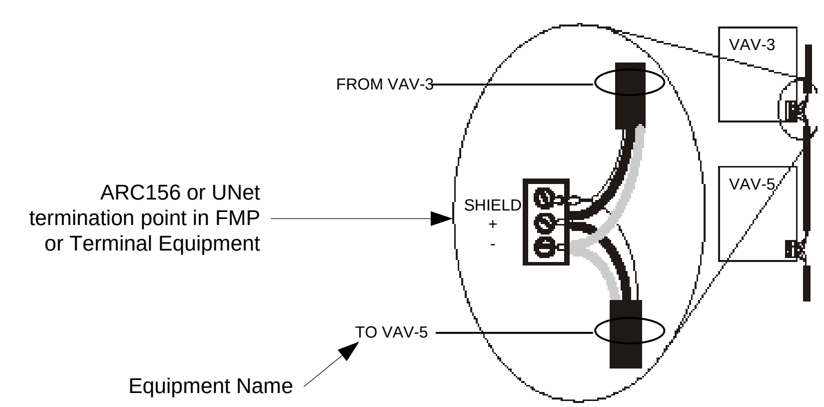



FIGURE 1

| | | | |
|---|---|---|---|
| Yahoo CX Project Buildings A, B, E & G<br>Sunnyvale, California | | | |
| ACCO Engineered Systems | | | |
| Abbreviation/Installation Notes | | | |
| REV: 1 | Submittal | 6/19/2010 | JOB NO: XXX |
| | | | CHECK BY: MWS |
| | | | CORE NO: 90693 |
| | | | 4 of 11 |

# Cable Specification Chart

| ALC STANDARD CABLE SPECIFICATIONS AND ABBREVIATIONS | | | | | |
|---|---|---|---|---|---|
| **Part Number** | **Wire Type** | **Manufacturer** | **Typical Application** | **Circuit Type** | **Color** |
| - CONNECT AIR INTERNATIONAL W224C-2020ACCO | 22/4 AWG TWISTED, SHIELDED. PLENUM RATED | - CONNECT AIR INTERNATIONAL 866.730.5599 | T-STAT: RS | +12V<br>Rnet-<br>Rnet+<br>Gnd | RED<br>BLACK<br>WHITE<br>GREEN<br>WITH WHITE JACKET |
| - CONNECT AIR INTERNATIONAL W221P-2227B | 22/2 AWG, LOW-CAPACITANCE, TWISTED, STRANDED, SHIELDED COPPER WIRE. PLENUM RATED | - CONNECT AIR INTERNATIONAL 866.730.5599 | ARC156 (ARCNET) OR UNET COMMUNICATION (NO POWER WIRE) | NET+<br>NET- | WHITE<br>BLACK<br>WITH GREEN JACKET |
| - CONNECT AIR INTERNATIONAL W184C-2099B | 18/4 AWG TWISTED, UNSHIELDED. PLENUM RATED. | - CONNECT AIR INTERNATIONAL 866.730.5599 | I/O WIRING - DIGITAL | CLASS 2 WIRING ONLY | BLACK, WHITE, RED<br>GREEN<br>WITH WHITE JACKET |
| - CONNECT AIR INTERNATIONAL W183C-2052ACCO | 18/3 AWG TWISTED, PLENUM RATED, UNSHIELDED | - CONNECT AIR INTERNATIONAL 866.730.5599 | I/O WIRING – DIGITAL, VALVES | CLASS 2 WIRING ONLY | BLACK, WHITE, RED<br>WITH WHITE JACKET |
| - CONNECT AIR INTERNATIONAL W181P-2051ACCO | 18/2 AWG TWISTED/SHIELDED PLENUM RATED | - CONNECT AIR INTERNATIONAL 866.730.5599 | COMMUNICATION RS-485 2-WIRE, SITELINK, MODBUS, OR I/O WIRING REQUIRING A SHIELD | NET+ OR TX OR +<br>NET- OR RX OR - | RED<br>BLACK<br>WHITE JACKET W/ PURPLE STRIPE |
| - CONNECT AIR INTERNATIONAL W181P-2040BB/R | 14/2 AWG TWISTED PAIR, PLENUM RATED, UNSHIELDED | - CONNECT AIR INTERNATIONAL 866.730.5599 | I/O WIRING, 24VAC POWER WIRING | INA<br>INB<br>CLASS 2 WIRING ONLY | RED<br>BLACK<br>WITH WHITE JACKET |
| - CONNECT AIR INTERNATIONAL W244P-2175BLUB | 24/8 AWG CAT 5 ENHANCED, PLENUM RATED 100MHz | - CONNECT AIR INTERNATIONAL 866.730.5599 | ETHERNET | NETWORK COMMUNICATIONS | PR.1 WHITE/BLUE & BLUE<br>PR.2 WHITE/ORANGE & ORANGE<br>PR.3 WHITE/GREEN & GREEN<br>PR.4 WHITE/BROWN & BROWN<br>WITH BLUE JACKET |
| - CONNECT AIR INTERNATIONAL W181P-2051ACCO | 18/2 AWG, LOW-CAPACITANCE, TWISTED/SHIELDED PLENUM RATED | - CONNECT AIR INTERNATIONAL 866.730.5599 | TRANE BCU WIRING | TRANE COMMUNICATIONS | WHITE<br>BLACK<br>WITH PURPLE JACKET |

## Abbreviations

| | | |
|---|---|---|
| AWG | - | American Wire Gauge |
| CAT-5 | - | Ethernet Cable |
| DCD/CTS | - | Serial Hardware Handshaking |
| DTR/RTS | - | Serial Hardware Handshaking |
| EIA-232 | - | Communications Protocol |
| EIA-485 | - | Communications Protocol |
| G or GND | - | Ground |
| I/O | - | Input/Output |
| INA | - | Input A |
| INB | - | Input B |
| LS5V | - | +5vdc Logistat |
| NET- | - | ARCnet comm. - |
| NET+ | - | ARCnet comm. + |
| RX- | - | Receive - |
| RX+ | - | Receive + |
| ST | - | Fiber Optic Connector |
| *SW | - | TLO/Setpoint Adjust |
| TEMP | - | Temperature |
| THHN | - | A thermoplastic-insulated, nylon-jacketed conductor designed for use in dry locations and an operating temperature of up to 90 degrees Celsius. |
| TX- | - | Transmit - |
| TX+ | - | Transmit + |
| VAC | - | Voltage Alternating Current |

*Abbreviation is specific for the Logistat device. Do not confuse with the switch (SW) abbreviation on the Abbreviation/Installation Notes page.

Notes:
1. Consult Project ALC Authorized Dealer for approval if a wire substitution is desired.

Yahoo CX Project Buildings A, B, E & G
Sunnyvale, California

ACCO Engineered Systems

Cable Specification Chart

| | | | |
|---|---|---|---|
| REV: 1 | Submittal | 6/19/2010 | JOB NO: XXX |

acco engineered systems

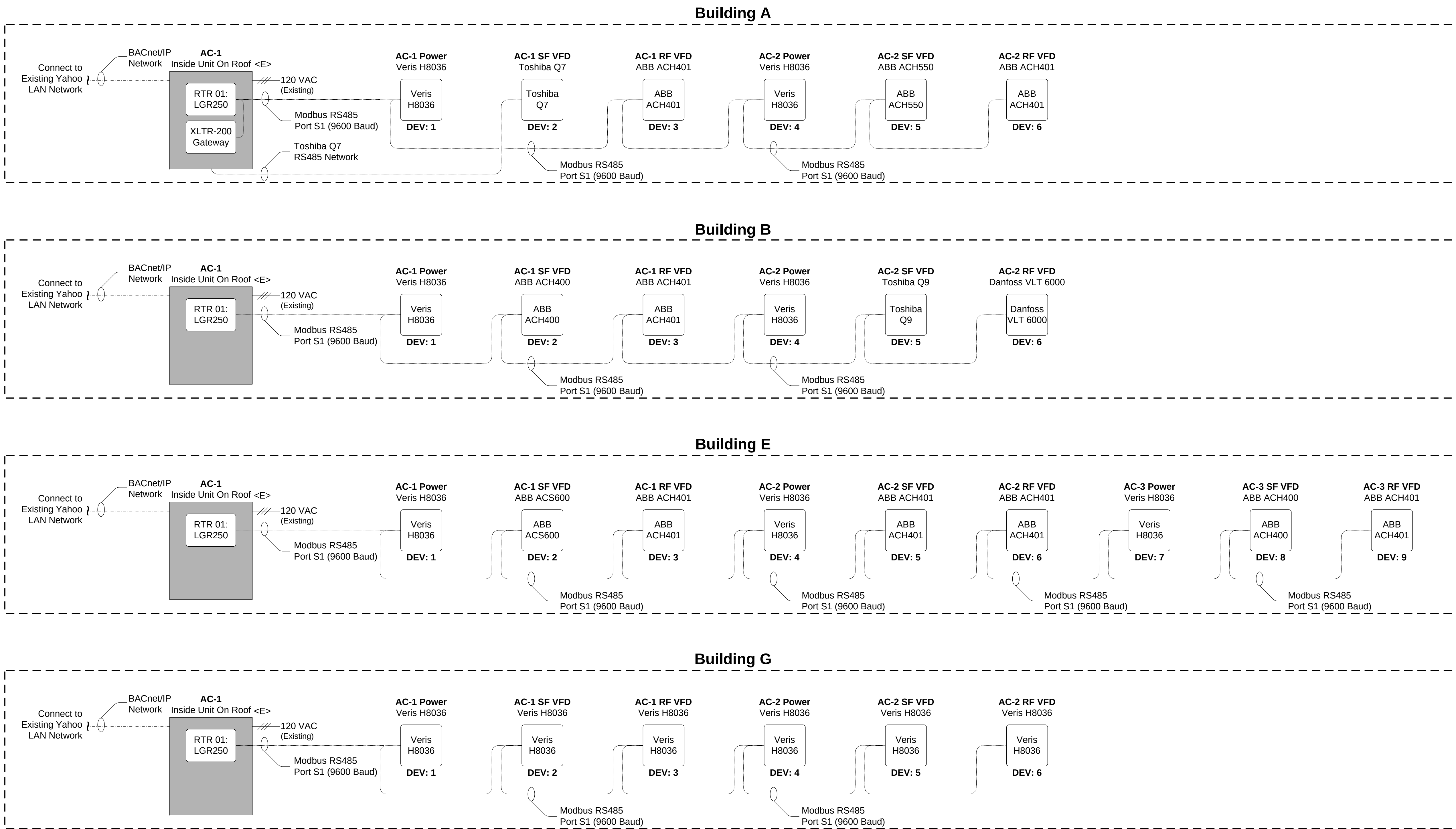
CHECK BY: MWS

CORE NO: 90693

# Summary Bill of Materials

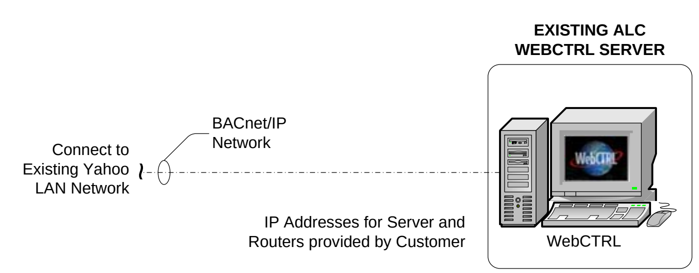
| Summary Bill of Materials | | | | |
|---|---|---|---|---|
| DID | DESCRIPTION | MANUFACTURER | PART NUMBER | QTY |
| H8036-01 | 100 AMP 208VAC-480VAC POWER TRANSDUCER | VERIS | H8036-0100-2 | 4 ea |
| H8036-03 | 300 AMP 208VAC-480VAC POWER TRANSDUCER | VERIS | H8036-0300-2 | 4 ea |
| H8036-08 | 800 AMP 208VAC-480VAC POWER TRANSDUCER | VERIS | H8036-0800-3 | 5 ea |
| LGR250 | LGR250 | AUTOMATED LOGIC | LGR250 | 4 ea |
| PNL-P100A | ENCLOSED 100VA POWER SUPPLY 120 TO 24VAC | FUNCTIONAL DEVICES | PSH100A | 4 ea |
| PNL-PRK | PANEL RECEPTACLE ASSEMBLY | KELE | PRK | 1 ea |
| PWR | 9VDC POWER SUPPLY | ICC | 10456 | 1 ea |
| XLTR-200 | MULTIPROTOCOL NETWORK GATEWAY | ICC | XLTR-200 | 1 ea |

# Network Diagram




General Notes:

1. Wire Types:
   All ARC156, Unet, Rnet, and zone sensor wiring shall be plenum rated cable.
2. ARC156 Wiring/Routing:
   Each segment must be wired in a 'daisy chain' fashion. Branching requires the use of a REP485.
   Segment 'ends' must be terminated with TERM485/BT485 terminating resistors.
   Each segment must have at least one (1) DIAG485 installed on the network to supply bias.
3. WebCTRL Server:
   Coordinate location of server/workstation with owner. Ethernet connections by others.
4. Device Wiring is a recommendation only. All devices should be wired based on equipment proximity and accessibility.
   All Wiring will follow ARC156 Wiring Specifications. TERM485/BT485, PROT485, DIAG485, AND REP485's should be used in accordance with ARC156 wiring guidelines.




Yahoo CX Project Buildings A, B, E & G
Sunnyvale, California

ACCO Engineered Systems

Network Diagram

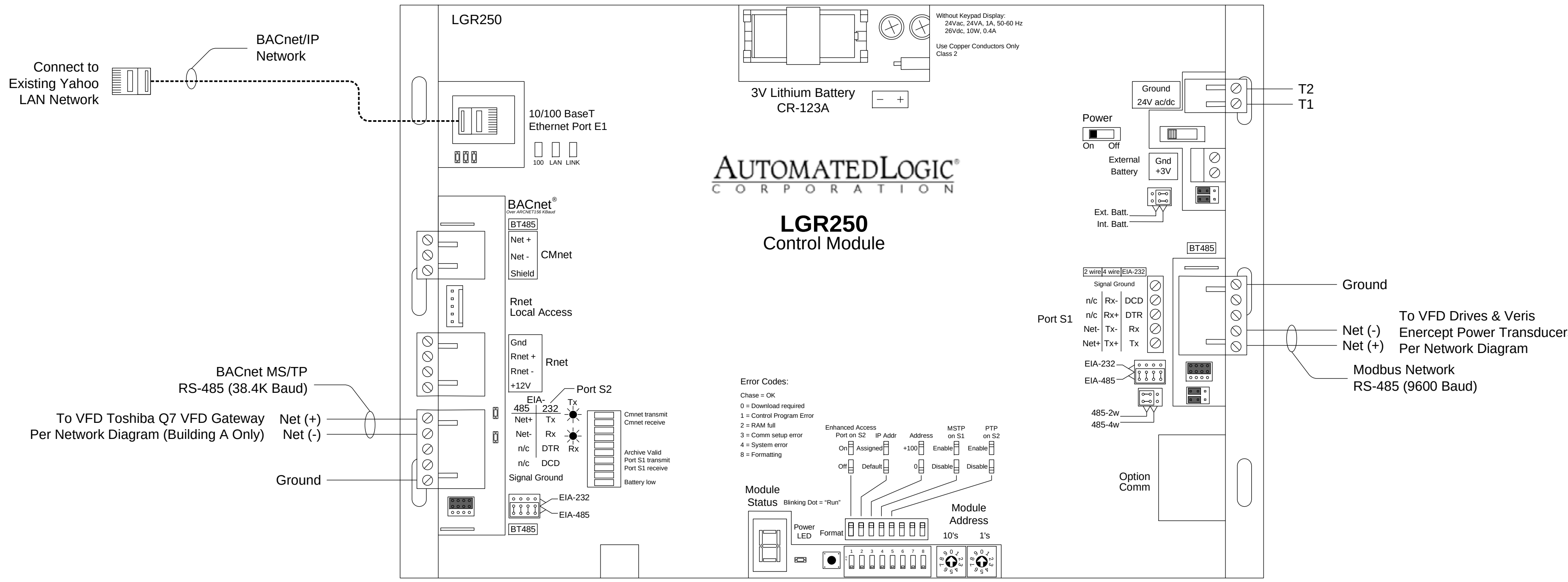
| | | | |
|---|---|---|---|
| REV: 1 | Submittal | 6/19/2010 | JOB NO: XXX |
| acco engineered systems | | | CHECK BY: MWS |
| | | | CORE NO: 90693 |
| | | | 7 of 11 |

# Typical Router Detail

## Bill of Materials

| DID | DESCRIPTION | MANUFACTURER | PART NUMBER | QTY |
|---|---|---|---|---|
| LGR250 | LGR250 | AUTOMATED LOGIC | LGR250 | 4 ea |
| PNL-P100A | ENCLOSED 100VA POWER SUPPLY 120 TO 24VAC | FUNCTIONAL DEVICES | PSH100A | 4 ea |
| PNL-PRK | PANEL RECEPTACLE ASSEMBLY | KELE | PRK | 1 ea |
| PWR | 9VDC POWER SUPPLY | ICC | 10456 | 1 ea |
| XLTR-200 | MULTIPROTOCOL NETWORK GATEWAY | ICC | XLTR-200 | 1 ea |

## Locate in Existing AC Unit Factory Panel




## Fan VFD Schedule

| Location | Unit | Model | Baud Rate | Address |
|---|---|---|---|---|
| Building A | AC-1 SF | Toshiba Q7 | 38.4 | 2 |
| | AC-1 RF | ABB ACH401 | 9600 | 3 |
| | AC-2 SF | ABB ACH550 | 9600* | 5 |
| | AC-2 RF | ABB ACH401 | 9600 | 6 |
| Building B | AC-1 SF | ABB ACH400 | 9600 | 2 |
| | AC-1 RF | ABB ACH401 | 9600 | 3 |
| | AC-2 SF | Toshiba Q9 | 9600* | 5 |
| | AC-2 RF | Danfoss VLT 6000 | 9600 | 6 |
| Building E | AC-1 SF | ABB ACS600 | 9600 | 2 |
| | AC-1 RF | ABB ACH401 | 9600 | 3 |
| | AC-2 SF | ABB ACH401 | 9600 | 5 |
| | AC-2 RF | ABB ACH401 | 9600 | 6 |
| | AC-3 SF | ABB ACH400 | 9600 | 8 |
| | AC-3 RF | ABB ACH401 | 9600 | 9 |

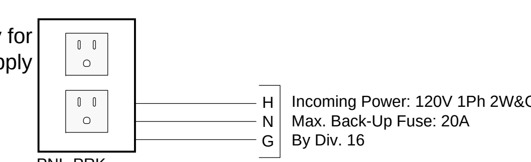
* Note: Devices capable of higher Baud Rates (38.4K), but not on the same Modbus Network

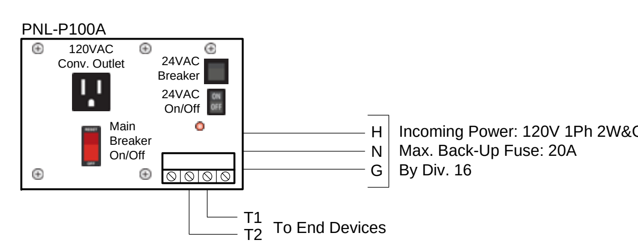
## AC Unit #1- Building A Only

Note: See XLTR-200 Installation Guide for wiring and programming details.


XLTR-200 Gateway
(Required for communications with Toshiba Q7 VFD)

Note: Panel receptacle assembly for 9VDC XLTR-200 Power Supply



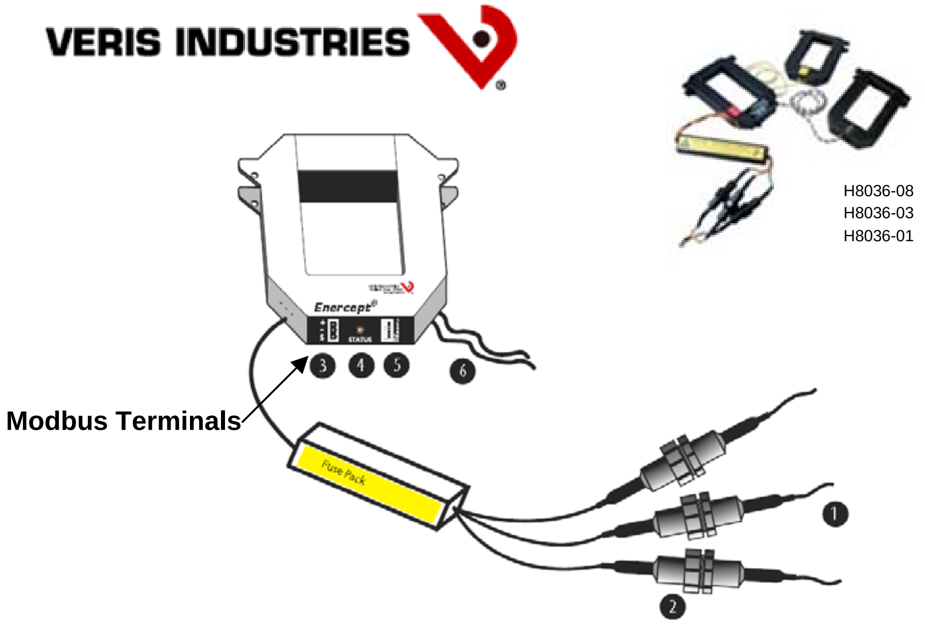




General Notes:
1. Refer to cable specification chart for wire types.
2. Refer to ALC Technical Documentation for specifications on control module setup, wiring, and driver configuration.
3. Refer to ALC Arcnet Wiring Instructions for locations of TERM485, PROT485, REP485, and DIAG485

| | | | |
|---|---|---|---|
| Yahoo CX Project Buildings A, B, E & G<br>Sunnyvale, California | | | |
| ACCO Engineered Systems | | | |
| Typical Router Detail | | | |
| REV: 1 | Submittal | 6/19/2010 | JOB NO: XXX |
| acco engineered systems | | | CHECK BY: MWS |
| | | | CORE NO: 90693 |

# Veris 8036 Energy Monitoring

| Bill of Materials | | | | |
|---|---|---|---|---|
| DID | DESCRIPTION | MANUFACTURER | PART NUMBER | QTY |
| H8036-01 | 100 AMP 208VAC-480VAC POWER TRANSDUCER | VERIS | H8036-0100-2 | 4 ea |
| H8036-03 | 300 AMP 208VAC-480VAC POWER TRANSDUCER | VERIS | H8036-0300-2 | 4 ea |
| H8036-08 | 800 AMP 208VAC-480VAC POWER TRANSDUCER | VERIS | H8036-0800-3 | 5 ea |




1. *Voltage Leads:* Input range is 208 to 480V.
2. *Fuses:* Maximum current draw 60mA. Fuses provided by the factory are rated ½A, 600VAC, 200 KAIC. Replace only with fuses of the same type and rating.
3. *Pulse Output connector*
4. *Status LED:* Blink codes: slow green for normal operation; slow red for incorrect wiring or low power factor (less than 0.5); fast red for maximum current exceedance.
5. *Pulse Rate Switches:* Used to set the pulse output rate.
6. *External CTs:* Permanently attached; do not disconnect or use with other power meters.

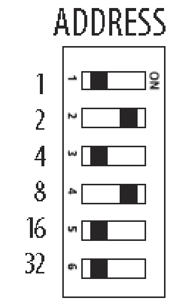
| Power Monitoring Schedule | | | | | |
|---|---|---|---|---|---|
| Location | Unit | Amps | Model Number | Baud Rate | Address |
| Building A | AC-1 | 515 (Full Load) | H8036-0800-3 | 9600 | 1 |
| | AC-2 | 515 (Full Load) | H8036-0800-3 | 9600 | 4 |
| Building B | AC-1 | 515 (Full Load) | H8036-0800-3 | 9600 | 1 |
| | AC-2 | 515 (Full Load) | H8036-0800-3 | 9600 | 4 |
| Building E | AC-1 | 528 (Full Load) | H8036-0800-3 | 9600 | 1 |
| | AC-2 | 150 (Full Load) | H8036-0300-2 | 9600 | 4 |
| | AC-3 | 286 (Full Load) | H8036-0300-2 | 9600 | 7 |
| Building G | AC-1 | 272 (Full Load) | H8036-0300-2 | 9600 | 1 |
| | AC-1 SF | 78 (Full Load) | H8036-0100-2 | 9600 | 2 |
| | AC-1 RF | 30 (Full Load) | H8036-0100-2 | 9600 | 3 |
| | AC-2 | 272 (Full Load) | H8036-0300-2 | 9600 | 4 |
| | AC-2 SF | 78 (Full Load) | H8036-0100-2 | 9600 | 5 |
| | AC-2 RF | 30 (Full Load) | H8036-0100-2 | 9600 | 6 |

Note: 800 AMP Power Monitoring Device model number as shown have medium CT size. Large CT size available as model number # H8036-0800-4

General Notes:
1. Relays as required due to different operating voltages, power sources, or loads.
2. Locate Control Relays in starter enclosures or unit control panels where possible.
3. Coordinate with Electrical Contractor for 120 volt power for panels.
4. Refer to ALC Technical documentation for specifications on Modules and wiring.

**Installation:**

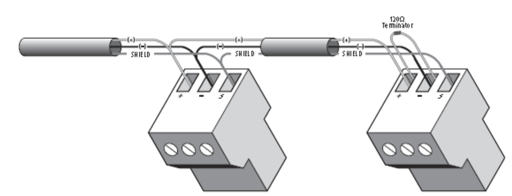
1. Choose a unique address and set the switches for that address as shown in the Address Selection Switches. Only address 1 to 63 can be used.




2. Connect the voltage leads to the phase conductors, at a location that is not normally turned off. Connect voltage leads on the Line side of the conductor to ensure constant power to the meter. For a 3-phase system, connect the red lead to phase A, black to phase B, and yellow to phase C.

3. Snap the CT onto the conductor. Connect CTs to the correspondingly colored voltage lead. If the application can exceed 20 times the rated CT current, use wire ties to secure the I-bar to the CT housing. This CT automatically detects phase reversal, so CT load orientation is not important.

4. Remove the terminal block and attach the RS-485 wires. Observe (+), (-), and Shield polarity. Insulate any exposed wiring.



**Terminals Located on Main CT**

5. Check Power Readings

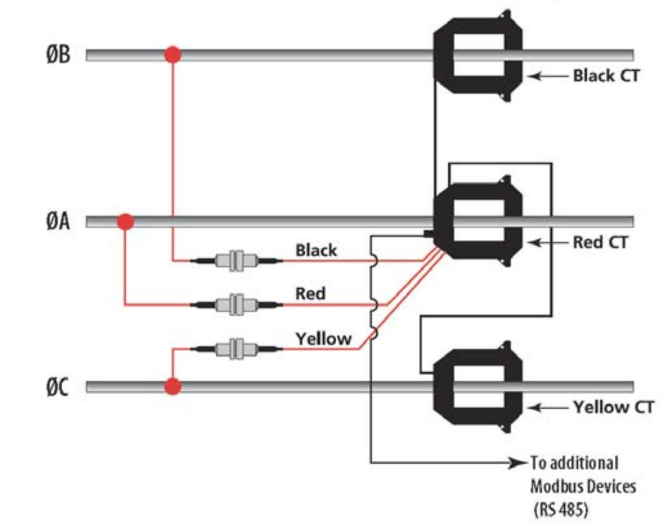
**Entercept Power Transducer Specifications:**

| | |
|---|---|
| **Input Primary Voltage** | 208 to 480VAC RMS†† |
| **Number of Phases Monitored** | One to Three |
| **Frequency** | 50/60Hz |
| **Primary Current** | Up to 2400 amps cont. per phase†† |
| **Internal Isolation** | 2000VAC RMS |
| **Insulation Class** | 600VAC RMS††† |
| **Temperature Range** | 0° to 60°C (32° F to 140°F), 50°C (122°F) for 2400A |
| **Humidity Range** | 0 - 95% non-condensing |
| **Systems Accuracy** | ±1% of reading from 10% to 100% of the rated current of the CTs...accomplished by matching the CTs with electronics and calibrating them as a system |
| **Output Physical Characteristics** | RS-485, 2 wire + shield |
| **Baud Rate** | 9600, 8N1 format |
| **Protocol** | Modbus RTU**(*) |

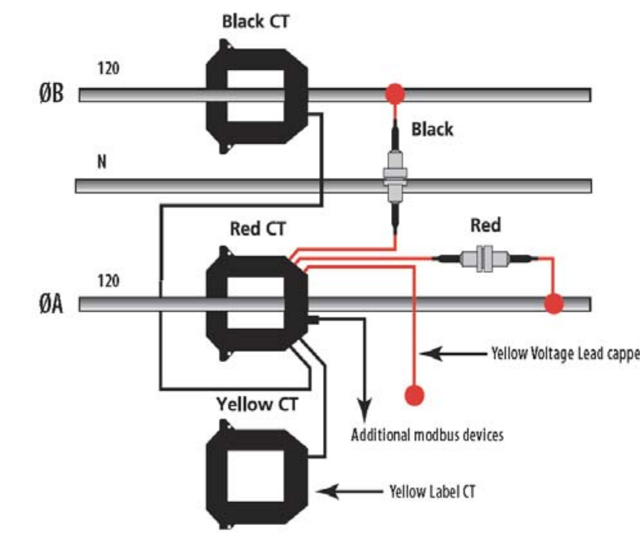
**Data Outputs:**

kWh, Consumption
kW, Real Power
kVAR, Reactive power
kVA, Apparent power
Power factor
Average Real power
Minimum Real power
Maximum Real power
Voltage, line to line
Voltage, line to neutral†
Amps, Average current
kW, Real power ØA†
kW, Real power ØB†
kW, Real power ØC†

*208 or 480VAC 3Ø, Installation*




*240VAC 1Ø, 3-Wire Installation*




| Yahoo CX Project Buildings A, B, E & G<br>Sunnyvale, California | | | |
|---|---|---|---|
| ACCO Engineered Systems | | | |
| Veris 8036 Energy Monitoring | | | |
| REV: 1 | Submittal | 6/19/2010 | JOB NO: XXX |
| acco engineered systems | | | CHECK BY: MWS |
| | | | CORE NO: 90693 |
| | | | 9 of 11 |

## Veris 8036 Modbus Register

| Modbus Address | Units | Description |
|---|---|---|
| 40001 | KWH | Energy Consumption, LSW |
| 40002 | KWH | Energy Consumption, MSW |
| 40003 | KW | Demand (power) |
| 40004 | VAR | Reactive Power |
| 40005 | VAR | Apparent Power |
| 40006 | | Power Factor |
| 40007 | Volts | Voltage, line to line |
| 40008 | Volts | Voltage, line to neutral |
| 40009 | Amps | Current |
| 40010 | KW | Demand (power), Phase A |
| 40011 | KW | Demand (power), Phase B |
| 40012 | KW | Demand (power), Phase C |
| 40013 | | Power Factor, Phase A |
| 40014 | | Power Factor, Phase B |
| 40015 | | Power Factor, Phase C |
| 40016 | Volts | Voltage, Phase A-B |
| 40017 | Volts | Voltage, Phase B-C |
| 40018 | Volts | Voltage, Phase A-C |
| 40019 | Volts | Voltage, Phase A-N |
| 40020 | Volts | Voltage, Phase B-N |
| 40021 | Volts | Voltage, Phase C-N |
| 40022 | Amps | Current, Phase A |
| 40023 | Amps | Current, Phase B |
| 40024 | Amps | Current, Phase C |
| 40025 | KW | Average Demand |
| 40026 | KW | Minimum Demand |
| 40027 | KW | Maximum Demand |
| 40257 | KWH | Energy Consumption |
| 40258 | KWH | Energy Consumption |
| 40259 | KWH | Energy Consumption |
| 40260 | KWH | Energy Consumption |
| 40261 | KW | Demand (power) |
| 40262 | KW | Demand (power) |
| 40263 | VAR | Reactive Power |
| 40264 | VAR | Reactive Power |
| 40265 | VA | Apparent Power |
| 40266 | VA | Apparent Power |
| 40267 | | Power Factor |
| 40268 | | Power Factor |
| 40269 | Volts | Voltage, Line to Line |
| 40270 | Volts | Voltage, Line to Line |

| Modbus Address | Units | Description |
|---|---|---|
| 40271 | Volts | Voltage, Line to Neutral |
| 40272 | Volts | Voltage, Line to Neutral |
| 40273 | Amps | Current |
| 40274 | Amps | Current |
| 40275 | KW | Demand (power, Phase A |
| 40276 | KW | Demand (power, Phase A |
| 40277 | KW | Demand (power, Phase B |
| 40278 | KW | Demand (power, Phase B |
| 40279 | KW | Demand (power, Phase C |
| 40280 | KW | Demand (power, Phase C |
| 40281 | | Power Factor, Phase A |
| 40282 | | Power Factor, Phase A |
| 40283 | | Power Factor, Phase B |
| 40284 | | Power Factor, Phase B |
| 40285 | | Power Factor, Phase C |
| 40286 | | Power Factor, Phase C |
| 40287 | Volts | Voltage, Phase A-B |
| 40288 | Volts | Voltage, Phase A-B |
| 40289 | Volts | Voltage, Phase B-C |
| 40290 | Volts | Voltage, Phase B-C |
| 40291 | Volts | Voltage, Phase A-C |
| 40292 | Volts | Voltage, Phase A-C |
| 40293 | Volts | Voltage, Phase A-N |
| 40294 | Volts | Voltage, Phase A-N |
| 40295 | Volts | Voltage, Phase B-N |
| 40296 | Volts | Voltage, Phase B-N |
| 40297 | Volts | Voltage, Phase C-N |
| 40298 | Volts | Voltage, Phase C-N |
| 40299 | Amps | Current, Phase A |
| 40300 | Amps | Current, Phase A |
| 40301 | Amps | Current, Phase B |
| 40302 | Amps | Current, Phase B |
| 40303 | Amps | Current, Phase C |
| 40304 | Amps | Current, Phase C |
| 40305 | KW | Average Demand |
| 40306 | KW | Average Demand |
| 40307 | KW | Minimum Demand |
| 40308 | KW | Minimum Demand |
| 40309 | KW | Maximum Demand |
| 40310 | KW | Maximum Demand |

# Chiller Reset Wiring Detail

Place Analog Output for CHW Reset on next available address on CHW Control Module.  Point to be added to CHW Module in Buildings A, B, C, D, E, F, & G.

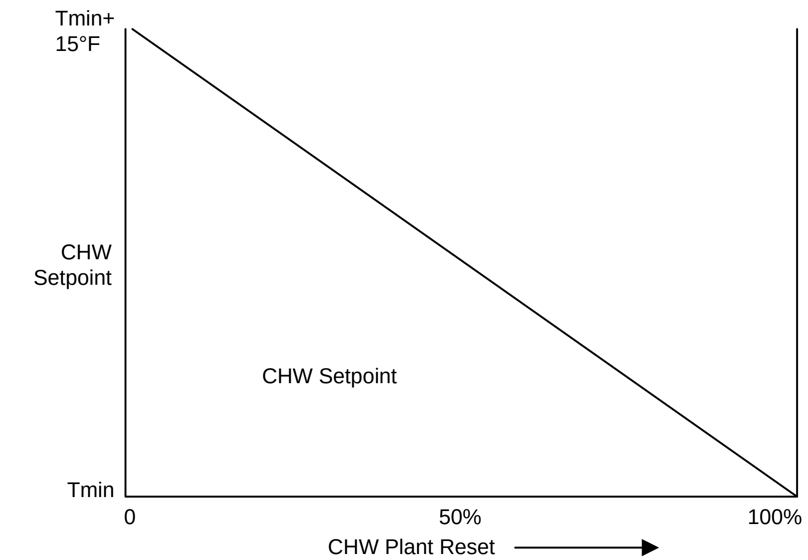

General Notes:
1. Refer to cable specification chart for wire types.
2. Refer to ALC Technical Documentation for specifications on control module setup, wiring, and driver configuration.
3. Refer to ALC Arcnet Wiring Instructions for locations of TERM485, PROT485, REP485, and DIAG485

**Sequence of Operation**

*CHW Reset*

Run Conditions:  Existing Chiller plant logic is to remain with the addition of the CHW reset logic.

Setpoint Control:  Chilled water supply temperature setpoint shall be reset based on the figure below and the value CHW Plant Reset determined as described below. Tmin is the design chilled water temperature as scheduled.




CHW Plant Reset shall be reset using Trim & Respond logic based on chilled water pump status with the following parameters:

| Variable | Value |
|---|---|
| $SP_0$ | 0% |
| $SP_{min}$ | 0% |
| $Sp_{max}$ | 100% |
| $T_d$ | 15 minutes |
| T | 5 minutes |
| I | 2 |
| R | Cooling CHWST Reset Requests |
| $SP_{trim}$ | -2% |
| $SP_{res}$ | +2% |
| $SP_{res-max}$ | +6% |

Trim & Respond logic shall reset setpoint within the range $SP_{min}$ to $SP_{max}$. When the associated device (e.g. fan, pump) is off, the setpoint shall be $SP_0$. The reset logic shall be active while the associated device is proven on, starting $T_d$ after initial device start command. When active, every time step T, increase the setpoint by $SP_{trim}$. If there are more than I Requests, respond by increasing the setpoint by $SP_{res}$ times (R – I), i.e. (the number of Requests minus the number of Ignored requests), but no more than $SP_{res-max}$. The sign of $SP_{trim}$ must be the opposite of $SP_{res}$ and $SP_{res-max}$. For example, if $SP_{trim}$ = -0.1, $SP_{res}$ = +0.1, $SP_{res-max}$ = 0.4, R = 3, I = 2, then each time step, the setpoint change = -0.1 + (3-2)*0.1 = 0.

CHW Plant Reset logic shall be disabled and value fixed at its last value for 15 minutes after the plant stages up or down.

Alarms: Alarms will be generated by the DDC system for Chiller Runtime, High CHW Leaving Temp (>5°F above setpoint) for more than 15 minutes when chiller has been enabled for longer than 15 minutes, Pump Failure, Pump In Hand, and CHW System low pressure (0.9 times the scheduled expansion tank pre-charge pressure for 1 minute).

Yahoo CX Project Buildings A, B, E & G
Sunnyvale, California

ACCO Engineered Systems

Chiller Reset Wiring Detail

| | | | |
|---|---|---|---|
| REV:  1 | Submittal | 6/19/2010 | JOB NO:  XXX |
| | | | CHECK BY:  MWS |
| | | | CORE NO:  90693 |

CENTER FOR THE BUILT ENVIRONMENT

CBE

## Consent Form --- Thermal Comfort Study

We are Ed Arens and Hui Zhang from the Center for the Built Environment at University of California Berkeley. We invite you to participate in a study of how office workers are sensing the thermal environment in their buildings.

If you agree to participate, you will be asked to take a short web-based survey about your thermal sensations and comfort 2 – 3 times a day, over the course of three weeks. Each survey takes between one and two minutes to complete. We will suggest times of day that we would like you to take the survey and you will have freedom to fit it into your schedule as best you can. The survey questions should cause you no physical risks or discomfort.

**Benefits**
There is no direct benefit to you anticipated from participating in this study. However, the results will be used to refine the techniques by which buildings are operated, and to update industry standards for designing future buildings with greater comfort and energy efficiency. Studies such as this have been instrumental to recent progress in making buildings more sustainable.

**Compensation**
Each week during the three week survey, we will raffle off an iPad worth $500 (or equivalent gift certificate if winner so wishes), for all participants who do more than 10 surveys the previous week.

**Confidentiality**
We will use your workstation number to locate you relative to the building heating and cooling system, and to find you to deliver the prizes. Individual survey responses or workstation number will not be discussed with or shown to building management. The workstation numbers and individual survey results will be kept completely confidential and be analyzed only by our study team at UC Berkeley.

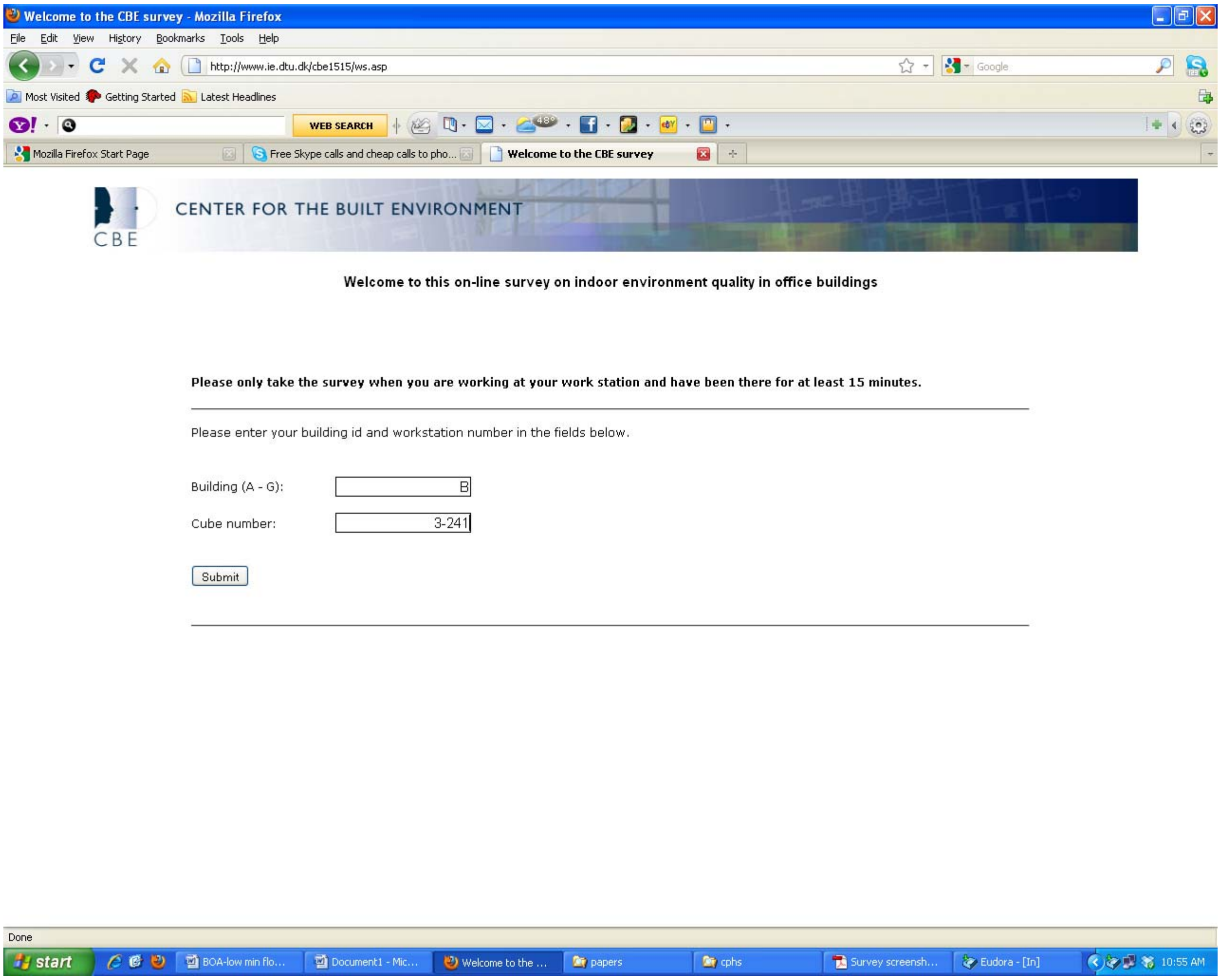
**Risk**
As with all research, there is a chance that confidentiality could be compromised; however, we are taking precautions to minimize this risk.

**Rights**
You are free to decline to take part in the project. You can decline to answer any questions and are free to stop taking part in the project at any time. Whether or not you choose to participate, to answer any particular question, or continue participating in the project, there will be no penalty to you.

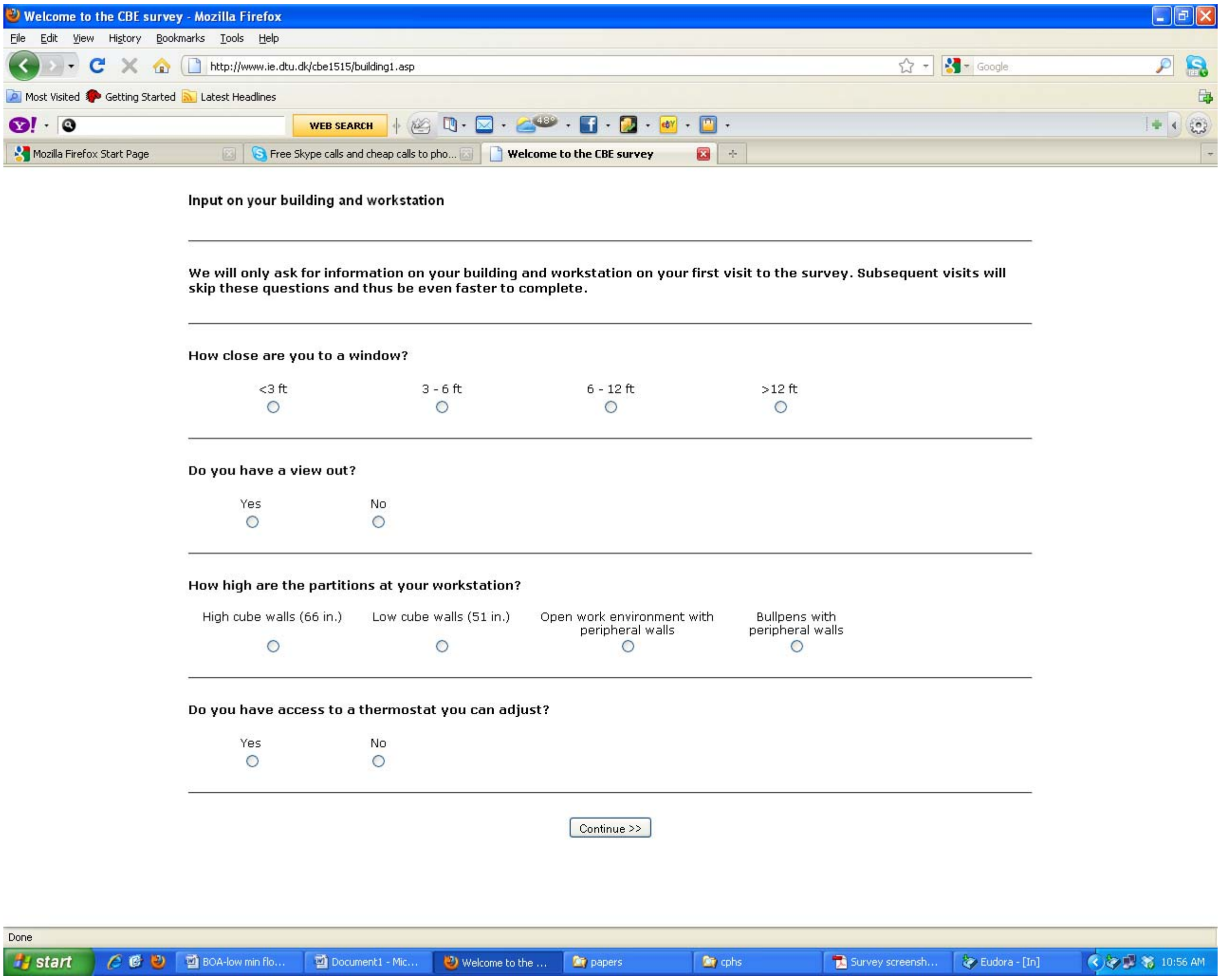
**Questions**
If you have any questions about this research, you may call Zhang at 510-642-6918. If you have any questions about your rights as a research participant in this study, please contact UC Berkeley's Committee for the Protection of Human Subjects at (510) 642-7461, or e-mail: subjects@berkeley.edu.

☑ **If you agree to take part in the research**, please print a copy of this page to keep for future reference. Then check the checkbox to the left and press the "I agree" button.

[I agree] [I do not want to take part]



Welcome to the CBE survey - Mozilla Firefox
http://www.ie.dtu.dk/cbe1515/ws.asp
CBE
CENTER FOR THE BUILT ENVIRONMENT
Welcome to this on-line survey on indoor environment quality in office buildings
Please only take the survey when you are working at your work station and have been there for at least 15 minutes.
Please enter your building id and workstation number in the fields below.
Building (A - G):
B
Cube number:
3-241
Submit
Done



Welcome to the CBE survey - Mozilla Firefox

http://www.ie.dtu.dk/cbe1515/building1.asp

**Input on your building and workstation**

---

**We will only ask for information on your building and workstation on your first visit to the survey. Subsequent visits will skip these questions and thus be even faster to complete.**

---

**How close are you to a window?**

○ <3 ft ○ 3 - 6 ft ○ 6 - 12 ft ○ >12 ft

---

**Do you have a view out?**

○ Yes ○ No

---

**How high are the partitions at your workstation?**

○ High cube walls (66 in.) ○ Low cube walls (51 in.) ○ Open work environment with peripheral walls ○ Bullpens with peripheral walls

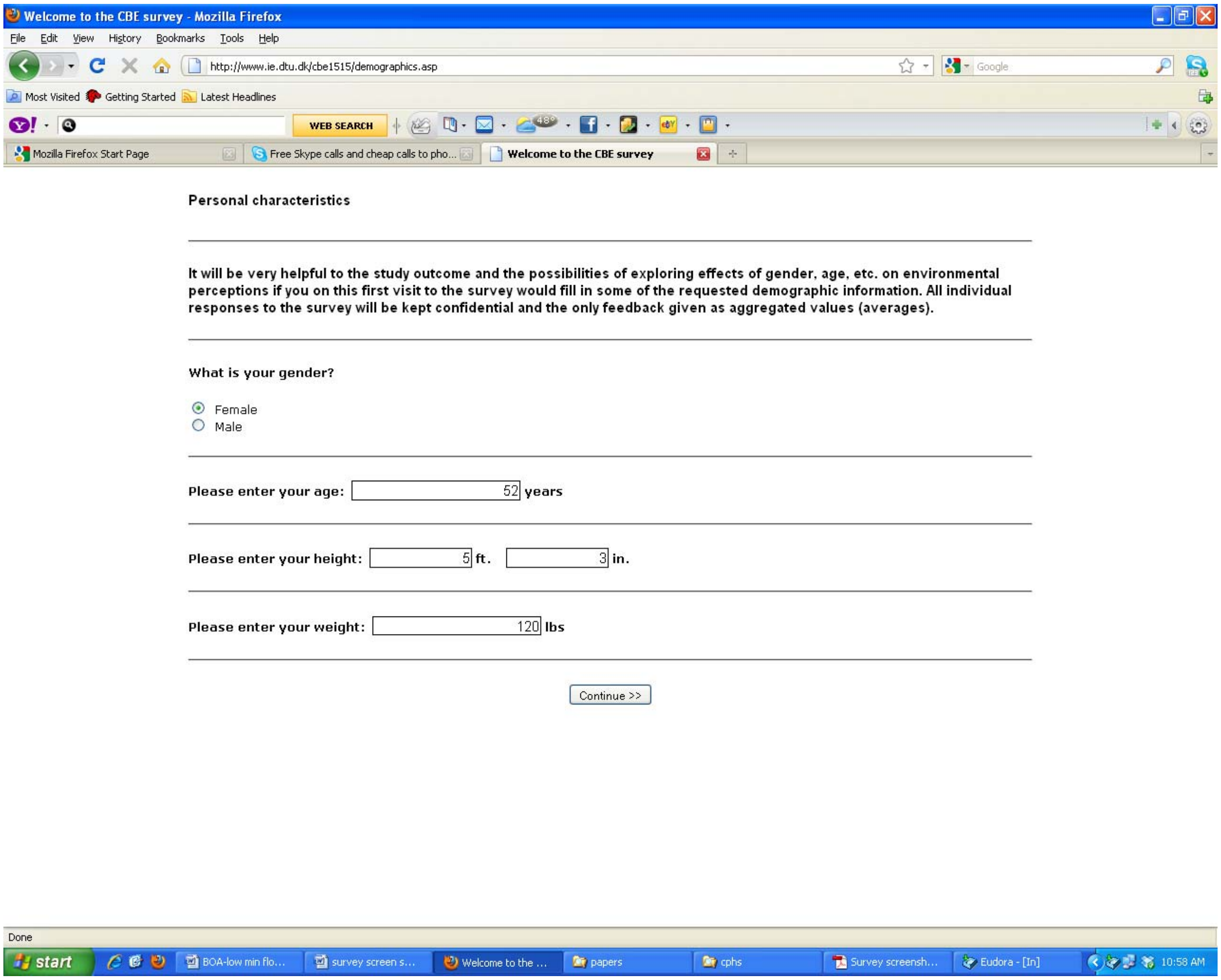
---

**Do you have access to a thermostat you can adjust?**

○ Yes ○ No

---

Continue >>



Welcome to the CBE survey - Mozilla Firefox

http://www.ie.dtu.dk/cbe1515/demographics.asp

**Personal characteristics**

---

**It will be very helpful to the study outcome and the possibilities of exploring effects of gender, age, etc. on environmental perceptions if you on this first visit to the survey would fill in some of the requested demographic information. All individual responses to the survey will be kept confidential and the only feedback given as aggregated values (averages).**

---

**What is your gender?**

- (•) Female
- ( ) Male

---

**Please enter your age:** [52] **years**

---

**Please enter your height:** [5] **ft.** [3] **in.**

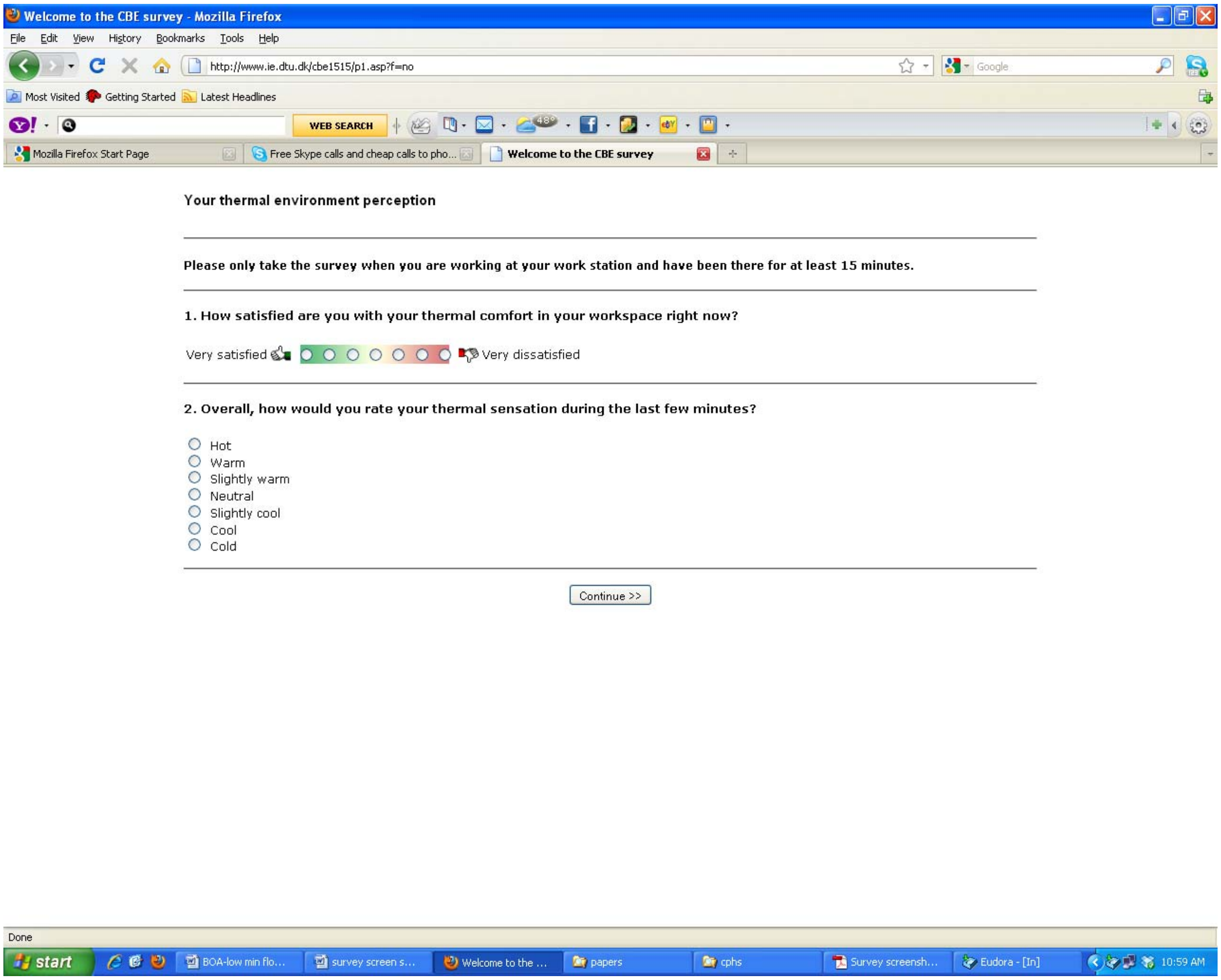
---

**Please enter your weight:** [120] **lbs**

---

Continue >>

Done



Welcome to the CBE survey - Mozilla Firefox

http://www.ie.dtu.dk/cbe1515/p1.asp?f=no

**Your thermal environment perception**

**Please only take the survey when you are working at your work station and have been there for at least 15 minutes.**

**1. How satisfied are you with your thermal comfort in your workspace right now?**

Very satisfied ○ ○ ○ ○ ○ ○ ○ Very dissatisfied

**2. Overall, how would you rate your thermal sensation during the last few minutes?**

- ○ Hot
- ○ Warm
- ○ Slightly warm
- ○ Neutral
- ○ Slightly cool
- ○ Cool
- ○ Cold

Continue >>

Welcome to the CBE survey - Mozilla Firefox

http://www.ie.dtu.dk/cbe1515/p2.asp

**Your thermal environment perception**

---

**3. On any part of your body, do you feel uncomfortable?**

- (•) Yes
- ( ) No

---

**4. Please try to identify the source of the discomfort you feel (check all that apply)**

- [ ] Strong solar radiation
- [ ] Cold surface (e.g. window)
- [ ] Too much air movement
- [ ] Too little air movement
- [ ] Space is cool
- [ ] Space is warm

Other, please describe: ______

---

**5. Please identify the body parts that are uncomfortably warm (check all that apply)**

- [ ] Head/Neck
- [ ] Torso
- [ ] Hands
- [ ] Feet
- [ ] None of my body parts feel warm

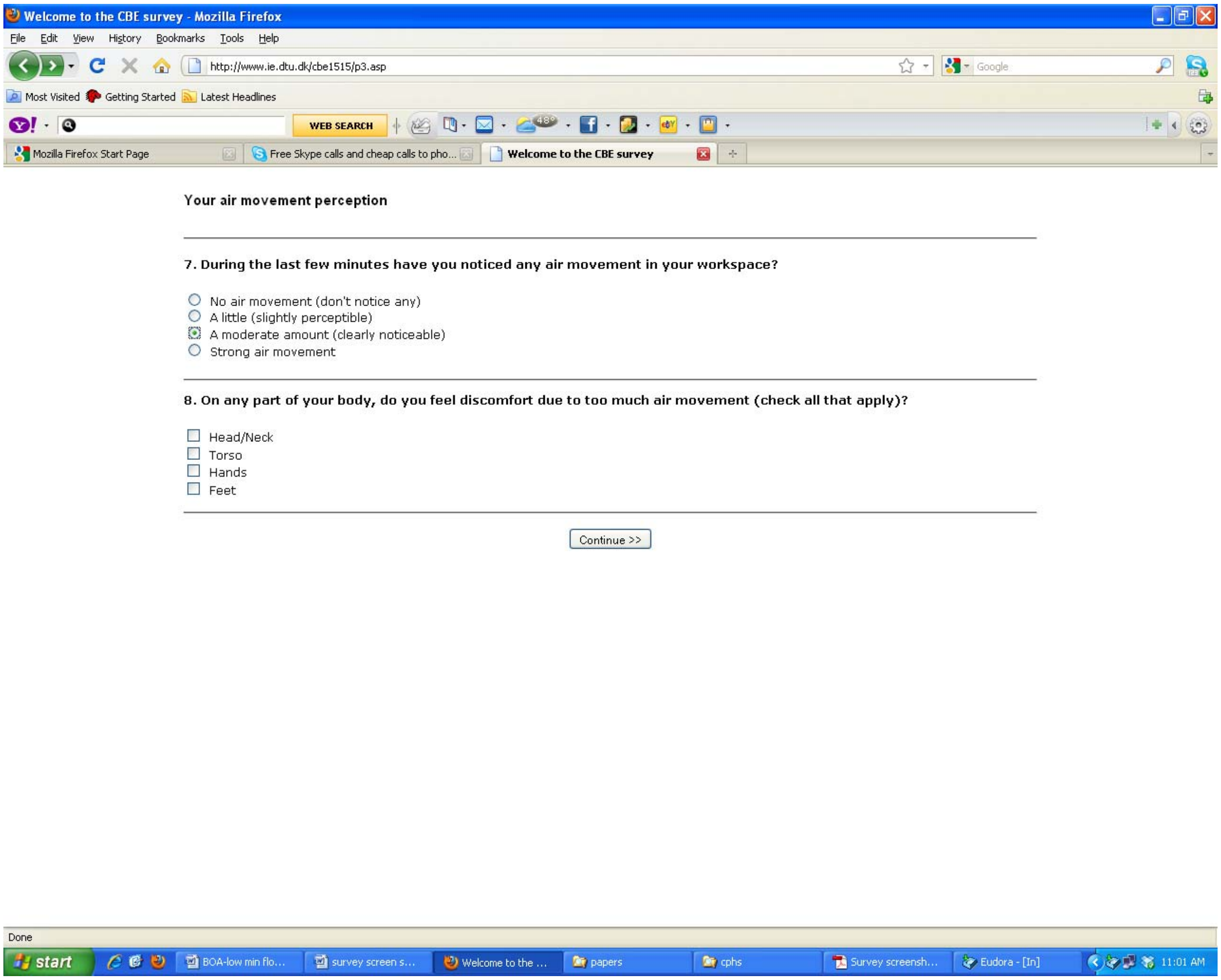
---

**6. Please identify the body parts that are uncomfortably cool (check all that apply)**

- [ ] Head/Neck
- [ ] Torso
- [ ] Hands
- [ ] Feet
- [ ] None of my body parts feel cool

---

Continue >>



Your air movement perception

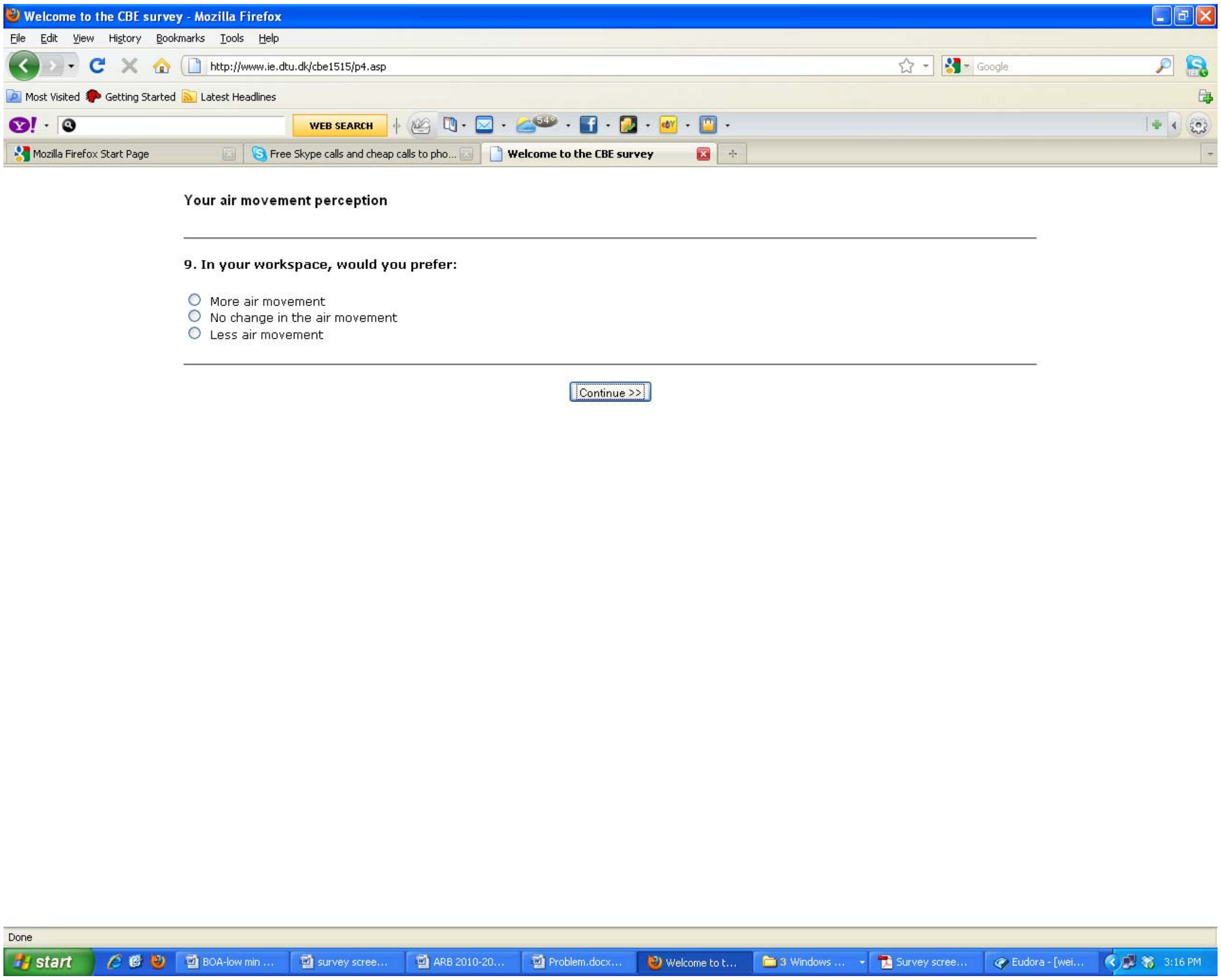
7. During the last few minutes have you noticed any air movement in your workspace?

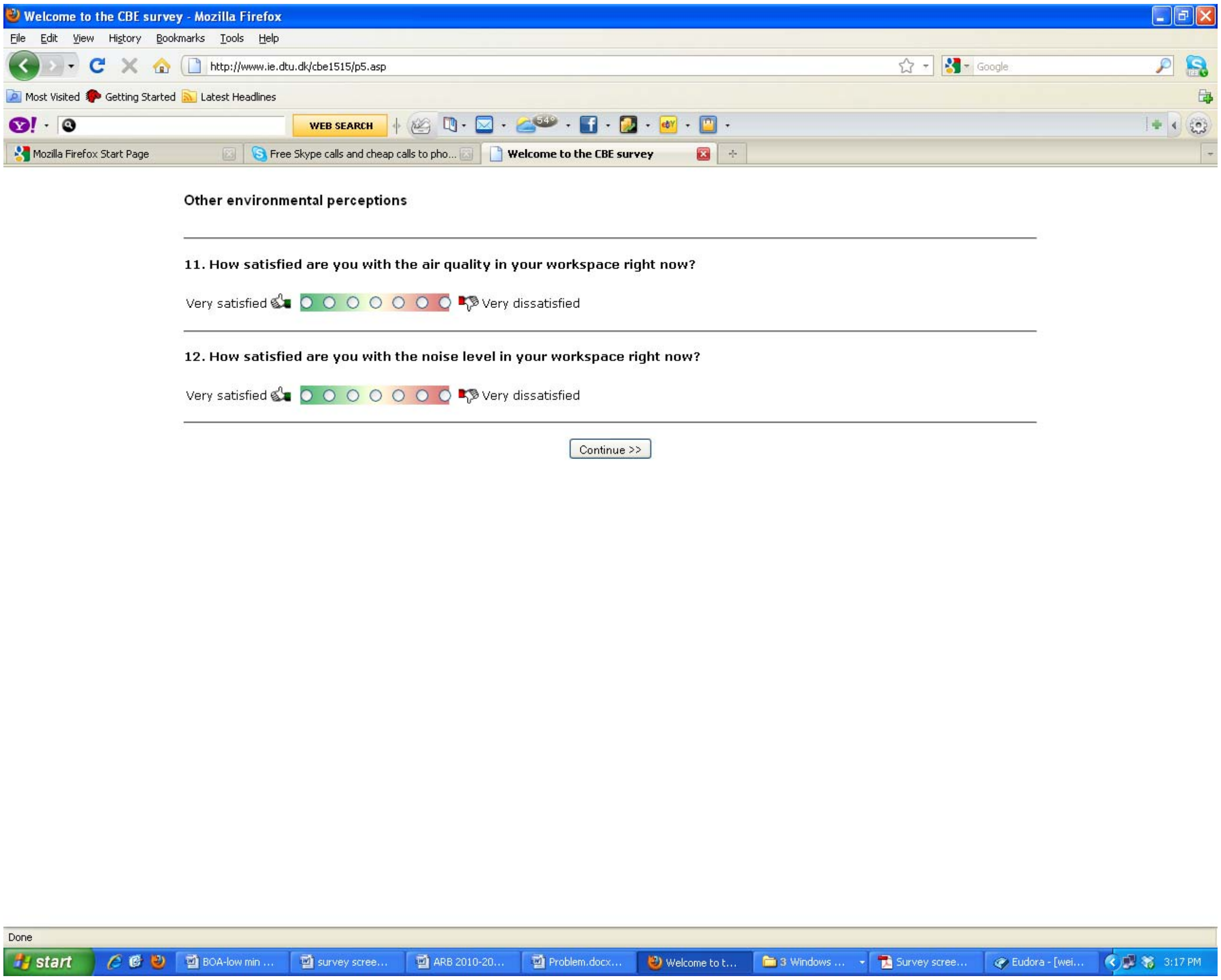
- ○ No air movement (don't notice any)
- ○ A little (slightly perceptible)
- ◉ A moderate amount (clearly noticeable)
- ○ Strong air movement

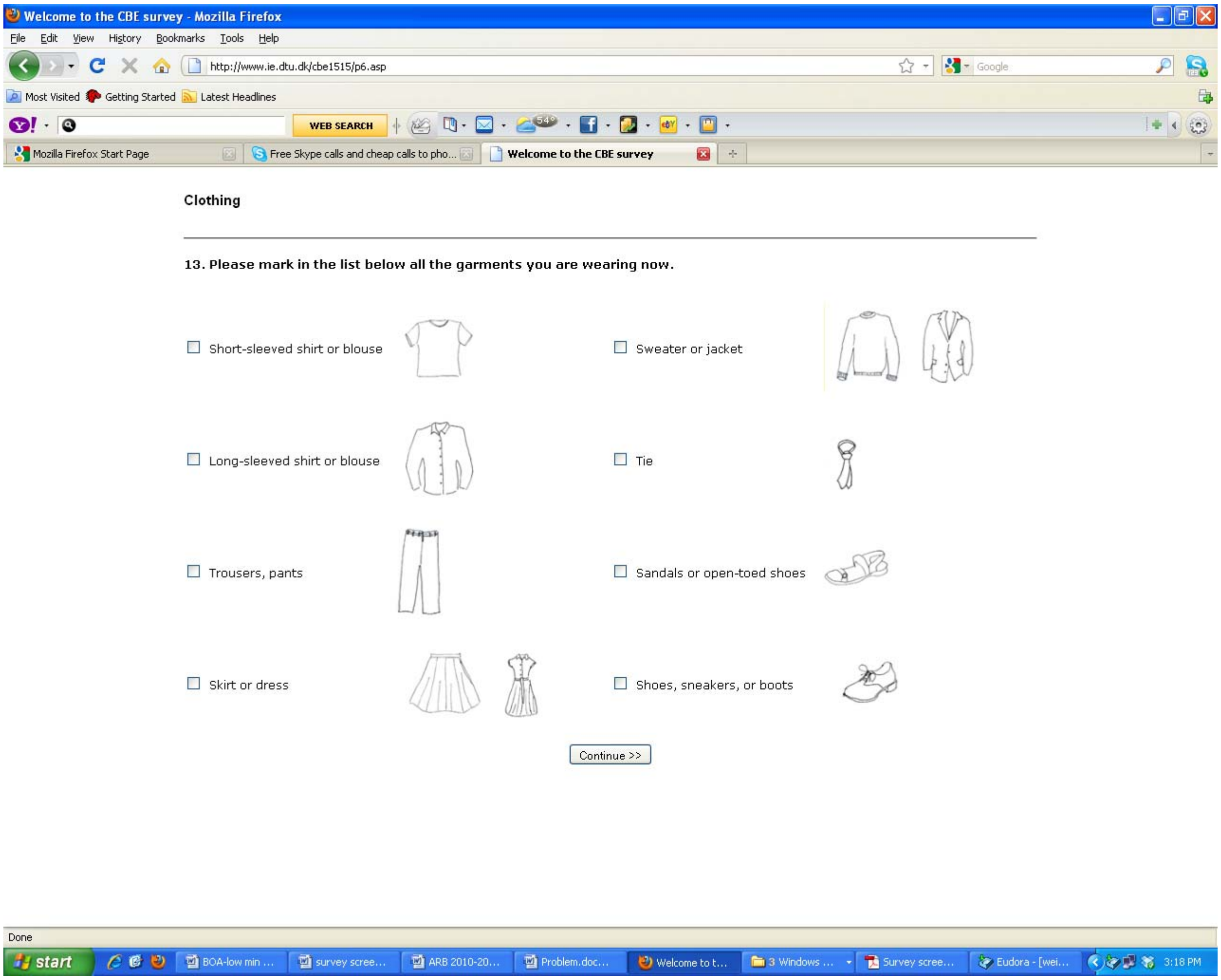
8. On any part of your body, do you feel discomfort due to too much air movement (check all that apply)?

- ☐ Head/Neck
- ☐ Torso
- ☐ Hands
- ☐ Feet

Continue >>


Welcome to the CBE survey - Mozilla Firefox
http://www.ie.dtu.dk/cbe1515/p4.asp
Your air movement perception
9. In your workspace, would you prefer:
More air movement
No change in the air movement
Less air movement
Continue >>
Done


Welcome to the CBE survey - Mozilla Firefox
http://www.ie.dtu.dk/cbe1515/p5.asp
Other environmental perceptions
11. How satisfied are you with the air quality in your workspace right now?
Very satisfied
Very dissatisfied
12. How satisfied are you with the noise level in your workspace right now?
Very satisfied
Very dissatisfied
Continue >>
Done
3:17 PM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Clothing
13. Please mark in the list below all the garments you are wearing now.
Short-sleeved shirt or blouse
Sweater or jacket
Long-sleeved shirt or blouse
Tie
Trousers, pants
Sandals or open-toed shoes
Skirt or dress
Shoes, sneakers, or boots
Continue >>
Done
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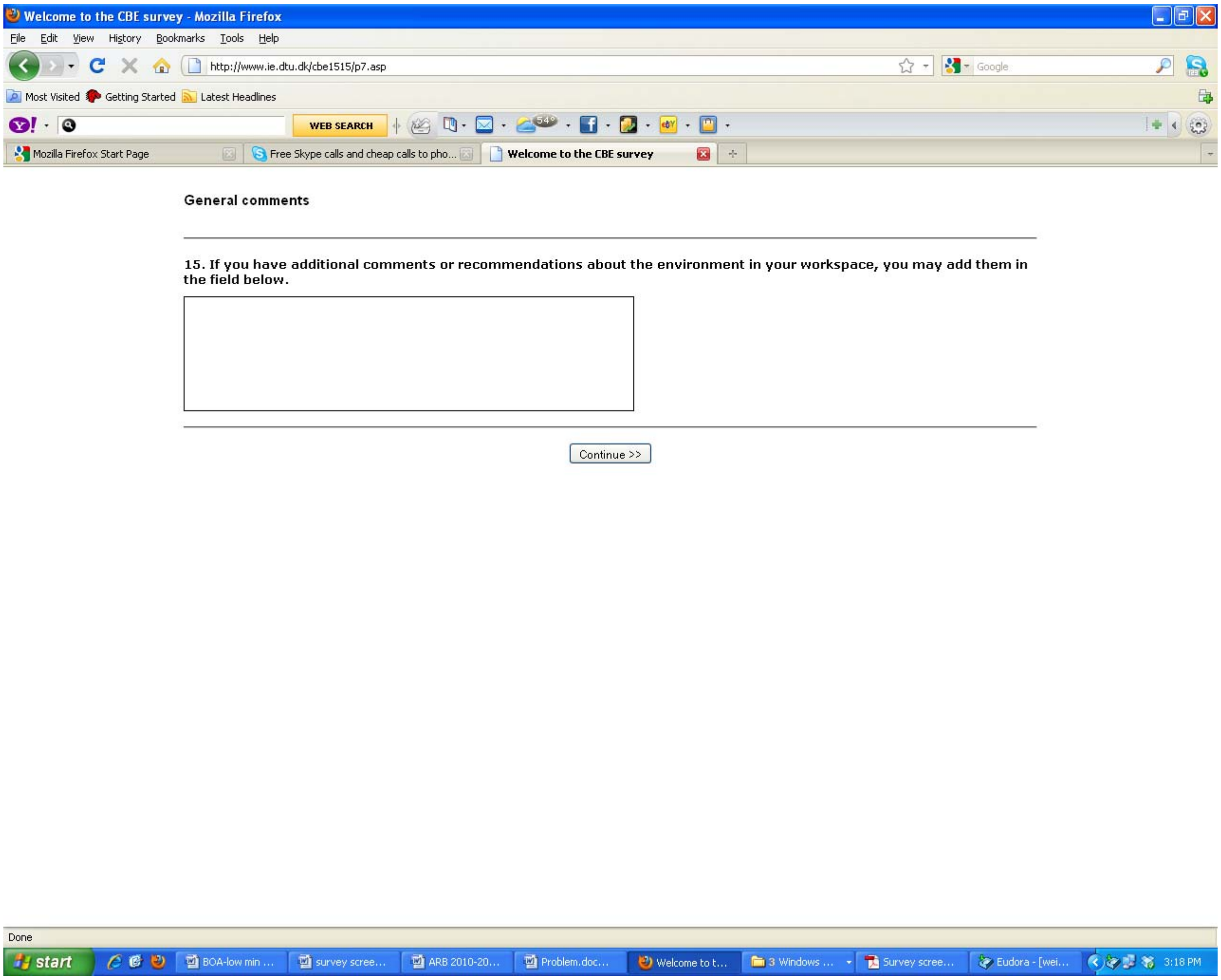
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General comments
15. If you have additional comments or recommendations about the environment in your workspace, you may add them in the field below.
Continue >>
Done
start
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Welcome to t...
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Survey scree...
Eudora - [wei...
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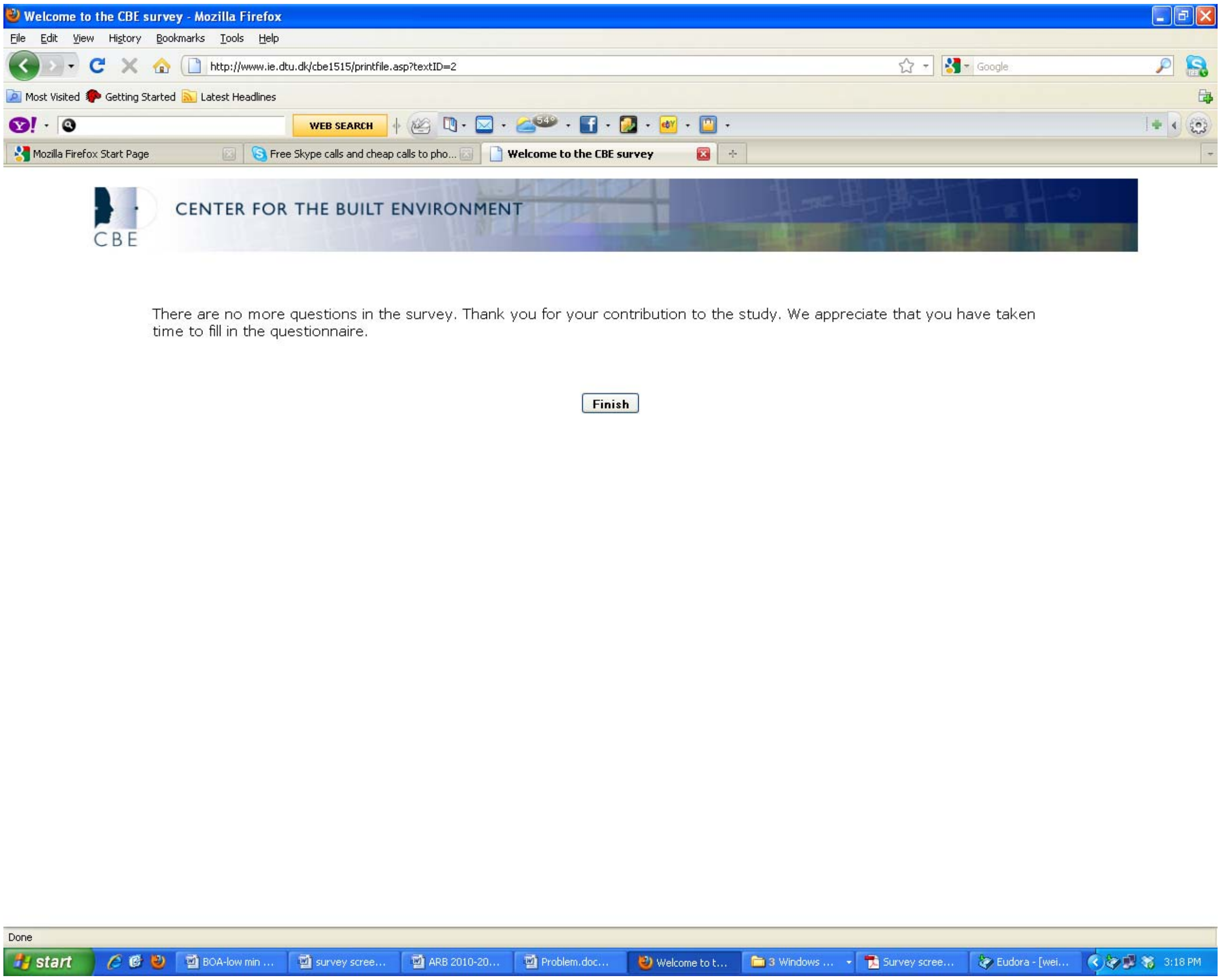
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http://www.ie.dtu.dk/cbe1515/printfile.asp?textID=2
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CBE
CENTER FOR THE BUILT ENVIRONMENT
There are no more questions in the survey. Thank you for your contribution to the study. We appreciate that you have taken time to fill in the questionnaire.
Finish
Done
start
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Welcome to t...
3 Windows ...
Survey scree...
Eudora - [wei...
3:18 PM