Section Three

ENERGY AUDIT REPORT

ABQ INTERNATIONAL SUNPORT

Sustainable Airport Master Plan

Albuquerque International Sunport

Energy Audit Report

Provided by

Quest energy group

Contents

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Executive Summary

Quest Energy Group, LLC (Quest) was engaged to perform an energy audit for the Albuquerque International Airport (Sunport) located in Albuquerque, New Mexico as part of Sunport's new sustainability master plan. The energy audit is intended to assist in identifying, prioritizing, and / or quantifying potential energy efficiency measures (EEMs) as well as renewable energy opportunities.

Through the energy audit process the following EEMs were evaluated. The recently completed or active energy projects that are not reflected in 2014 utility usage are included for reference. Key findings:

- The new condensing boilers should contribute an estimated $20,000 in annual utility savings.
- There are is an abundance of lighting retrofit opportunities that are recommended for both short-term retrofit projects, or as long-term strategies when fixtures are due for replacement or spaces undergo a major renovation. Over $86,000 in annual savings would be achieved when finished.
- There is an opportunity to optimize the operation of the main terminal's HVAC system with improved control logic. This project could save almost $45,000 annually.
- The current air handling unit (AHU) filtration could be upgraded in such a way that would drastically improve the energy performance, as well as save on operations cost through filter replacement maintenance tasks and disposal fees.
- The small data center at Sunport's main terminal is configured so that future temperature issues could develop on server equipment as the space fills up. There a number of low-cost updates that could be made to allow the equipment to run more efficiently and reliably.

Table 1 – Energy Efficiency Measure Results

EEM Number	EEM Description	Estimated Investment ($)	Annual Operational Cost Savings ($)	Utility Cost Savings ($)	Potential Incentive ($)	Simple Payback (Years)
1.1	Current Projects: Condensing Boiler	N/A	N/A	$20,600	$0	N/A
2.1	Planned Projects: Tarmac LED Lights	Unknown	$200	$14,300	$16,100	Unknown
3.1	Lighting & Control Opportunities	$419,345	$7,000	$86,400	$59,300	4.1
3.2	Controls Optimization	215,600	$0	$44,800	$43,200	3.8
3.3	High Efficiency HVAC Filters	20,000	$10,000	$17,900	$17,000	Immediate
3.4	Data Center Improvements	10,000	$0	$1,500	$1,600	5.6
3.5	Window Film	2,300	$200	$300	$500	5.3
	Totals:	**$667,245**	**$17,200**	**$150,900**	**$121,600**	**3.6**

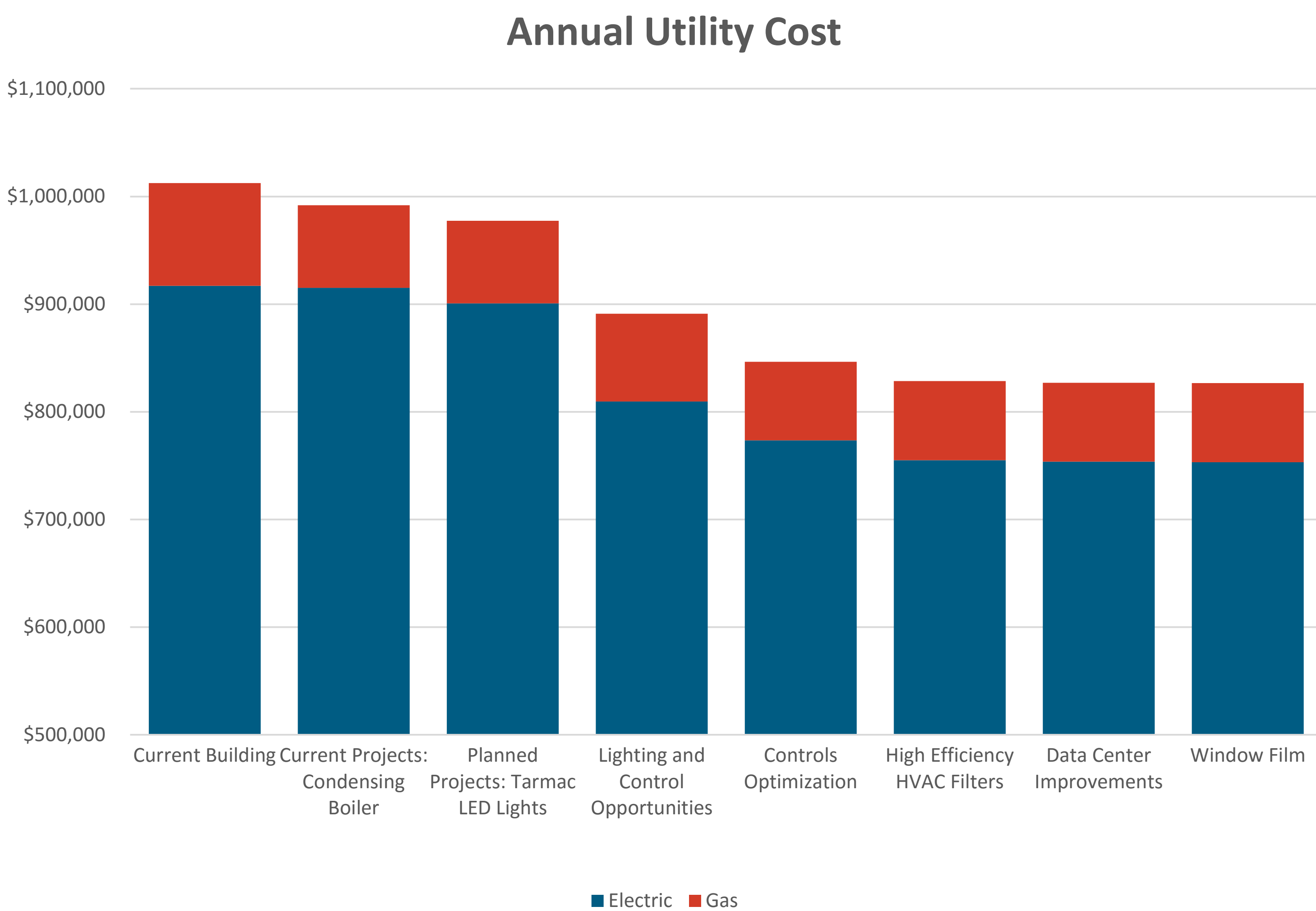


Figure 1 – Energy Efficiency Measure Annual Savings

As part of the audit's scope, Quest also evaluated potential renewable energy opportunities. The table below shows the current renewable energy production relative to Sunport's total energy, describes the revised renewable energy percentage after implementation of energy efficiency measures, and details the potential energy production numbers from the evaluation solar opportunities.

Table 2 – Solar Energy Results

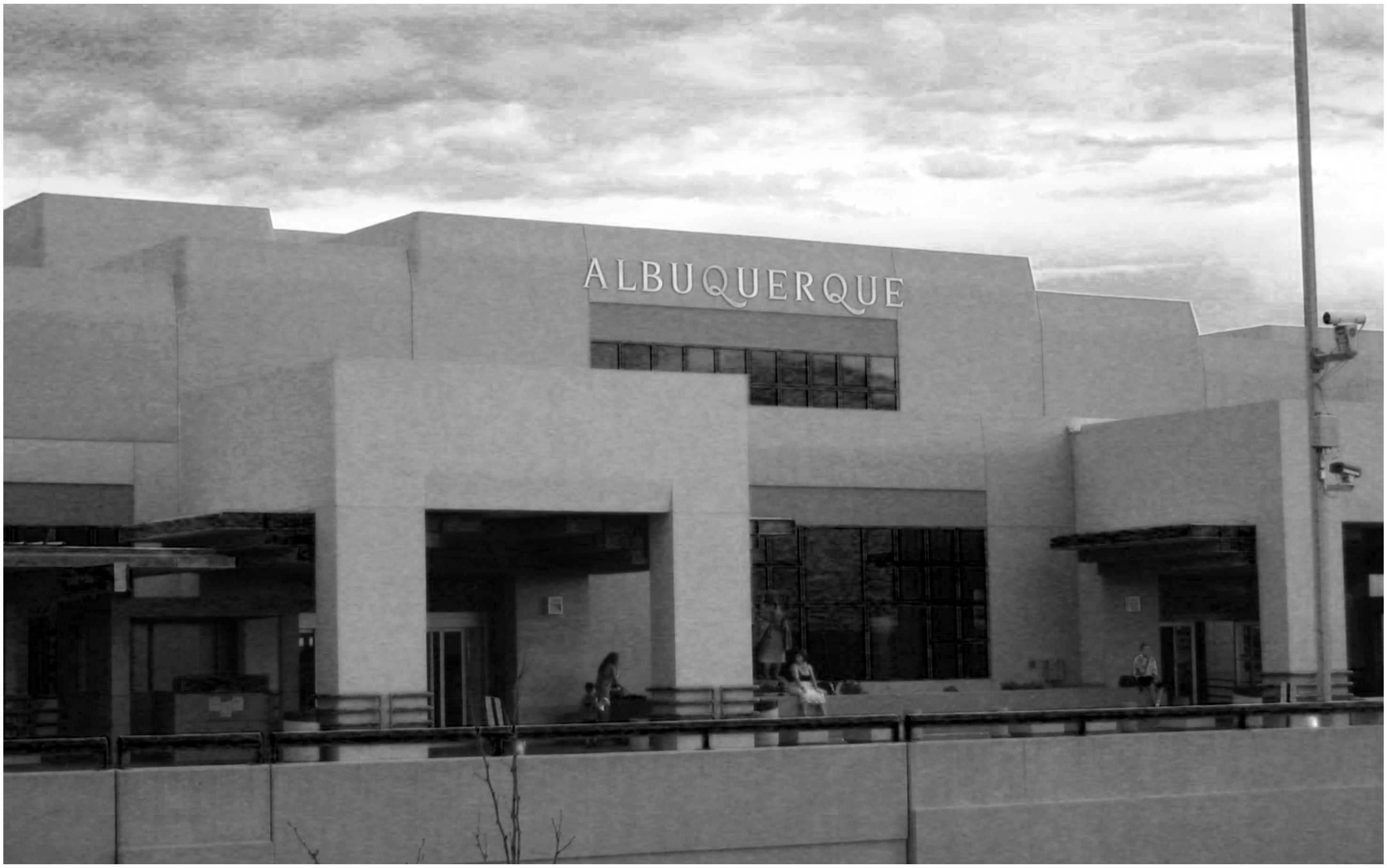
EEM Number	Solar Project Description	Sunport Energy Use kWh	Project Solar Production kWh	Total Solar Production kWh	% Renewable
0.0	Current PV System	14,855,071	N/A	2,480,000	17%
3.5	After Recommended ECMs	12,906,650	N/A	2,480,000	19%
4.1	Rental Car PV Retrofit	12,906,650	294,800	2,774,800	21%
4.2	Credit Card Lot Expansion	12,906,650	1,865,600	4,640,400	36%
4.3	4MW Expansion - Sunport & University	12,906,650	8,479,000	13,119,400	100%

Introduction

The Sunport's grounds are composed of a number of buildings; such as the main terminal, the original terminal, hangars, operation centers, maintenance buildings, and parking garages. The main targets for the energy audit include the main terminal, original terminal, and car rental center, as these buildings have both the majority of the energy use and opportunities for energy reduction.

In determining the opportunities for energy reduction, steps in Quest's energy audit process included the following:

- Research building, history, operation.
- Collect building drawings and energy bills.
- Develop potential list of energy efficiency and renewable energy measures based on building type, function, climate, client, and existing equipment.
- Conduct kick-off, introductory meeting with facility personnel. Review building operation and equipment inventory during detailed staff interviews.
- Compile and organize building information; prepare for site visit.
- Conduct site visit; take notes, record data, conduct further interviews, extract system information.
- Develop baseline energy model and calibrate to utility bills, using information collected.
- Develop and simulate proposed measures and analyze results. Perform QC process to ensure accuracy.
- Perform further review with industry experts and confirm existing facility requirements.
- Perform economic analysis. Contact supplier for costing.
- Document results, methodology. Provide all collected information for Client review and decision making.



Main Terminal

The main terminal building is nearly 700,000 square feet of conditioned space across four (4) stories, and was originally constructed in 1965. The current terminal layout was added during a major addition between 1985 and 1989. Further additions from the late 90's through 2014 added additional gates and renovated spaces.

Level 1 consists of baggage claim, circulation, escalators, and building maintenance and receiving areas. A "basement area", featuring a lower level vestibule and access to lower street arrival/departures can also be found on this level.

Level 2 features the Great Hall; the common holding area during original terminal operation, along with airline ticketing, airport operations, retail, US Customs and Border Patrol, and Aviation Police.

Level 3 contains security checkpoints, TSA operation space, retail, and the A and B Concourses with their individual gate holding areas for departing passengers.

Level 4 consists of the mechanical penthouses, which are structures that contain the majority of the air-handling HVAC equipment at the Sunport. These are discussed in further detail in the following sections.

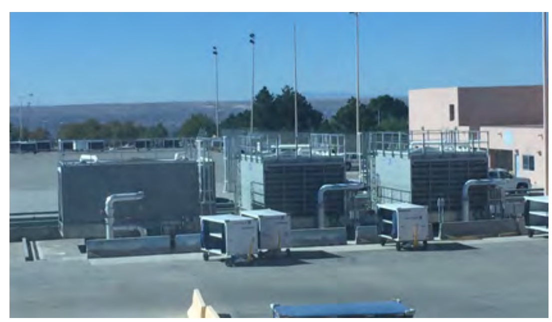
Operation

The main terminal is occupied 24/7, although there is essentially no passenger activity between 1am-4am. Many of the departmental offices found in the perimeter of the building have a reduced operational schedule, some of which are not occupied on the weekends.

The building is maintained between 70-72°F year round. Though the main air-handling units' (AHUs) fans shut off between 1am-4am, the main terminal has a large amount of thermal inertia, and in turn indoor temperatures do not appear to drift from setpoint significantly. Indoor lighting in the main circulation and passenger sections is on 24 hrs/day, while the retail, departmental offices, and other back-of-house spaces that have switch lighting control do turn off during unoccupied periods. Outdoor lighting runs dusk-to-dawn.

HVAC

Coinciding with the additions to the main terminal, the terminal's HVAC system has also been updated several times throughout the Sunport's history. Currently, the vast majority of the area is conditioned with dual-duct, variable air volume (VAV) AHUs. Overall, there are forty-two (42) AHUs located in nineteen (19) penthouses located on the roof of the main terminal building. Each dual-duct AHU consists of a variable speed supply fan, separate variable-speed return fan unit, and an outside air and relief air damper. There are a few single-duct VAV AHUs serving a small percentage of main terminal, as well as some standalone unitary (DX) air-conditioning units. The supply fan motors for most AHUs are between fifteen (15) and forty (40) horsepower (HP), while the majority of return fan motors are slightly smaller: between ten (10) and twenty (20) HP. The AHUs employ three (3) stages of filtration to keep airport odors minimal: a pleated pre-filter; an intermediate bag-filter, and a final stage carbon filter.



The AHUs are provided chilled and hot water by a central chiller plant and a central boiler plant, respectively. The chiller plant consists of three (3) York 700 variable speed centrifugal chillers; three (3) BAC cooling towers with thirty (30) HP variable speed cooling tower fans; three (3) variable speed seventy-five (75) HP chilled water loop pumps; three (3), forty (40) HP condenser water pumps; and three (3), fifteen (15) HP primary chilled water pumps. Yaskawa variable frequency drives (VFDs) are used for all variable speed equipment, including AHU fans. Additionally, an Alfa Laval flat plate heat exchanger (HX) is present to provide "free" cooling when ambient conditions will allow. Free cooling is utilized almost exclusively from October through March. Two of the chillers are older, with Chiller 1 due to be replaced soon.

The central boiler plant consists of two (2), 12 million BTU (MBTU) Unilux boilers; two (2), six (6) MBTU 94% efficient Aerco condensing boilers; two (2), five (5) HP primary hot water pumps; and three (3), forty (40) HP loop hot water pumps. The Aerco boilers were installed in the summer of 2015, and are expected to be able to provide Sunport's hot water demand the majority of heating season, which was determined to be mid-October to mid-April.

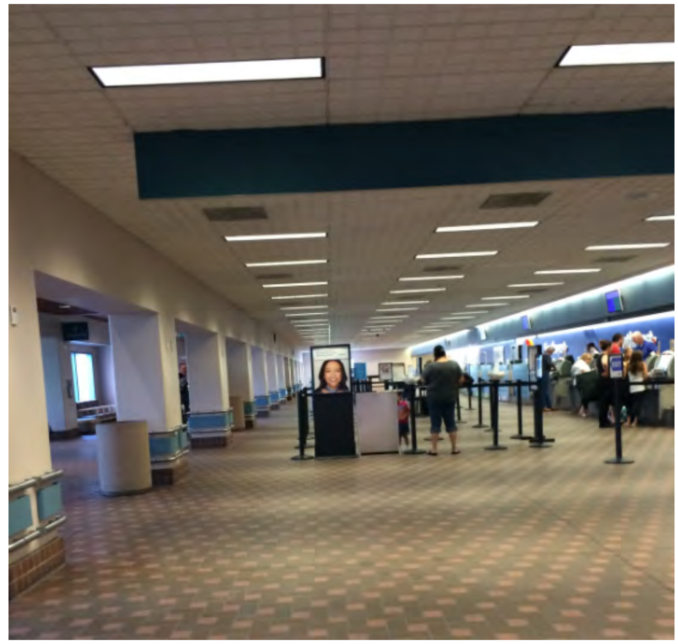
The HVAC and lighting system are controlled through a robust building automation system (BAS) by automated logic. The BAS and all related control hardware appeared to be well-maintained and fairly modern. In some cases, the BAS control sequences were found to be efficient and/or appropriate for the function on the equipment. However, in other cases control strategies were either pre-set or overridden to an inefficient strategy of operation. In most cases, this occurs as a result of occupant feedback of space conditions, which apparently is a common occurrence per facility personnel via the town comment number of 311.

Data Center

A small data center operates within the building. Two (2) Stulz computer room air conditioners (CRAC) provide cooling to an under-floor air distribution plenum to cool approximately eight (8) partially full aisles of server racks. The cold air exits the under-floor plenum through perforated tiles that are currently located directly under each row of server racks. There is no return-air plenum; the mixed room air enters the CRAC units directly. Due to the open concept rack layout, the room is kept cold: at approximately 70°F and 50% humidity.

There is also a tremendous amount of lighting in the space: 27 two-lamp T8 troffer fixtures (~2.5 W/ft^2) connected to a single toggle light switch. As with most data centers, the room is only occasionally occupied, though facility personnel said that the lighting is never turned off.

Lighting



The lighting in the building has a mixture of modern and efficient fixtures as well as older, less efficient lighting technology. As one of the earliest adopters of LED lighting technology, the Sunport has several uses of LED lighting throughout the main terminal, notably the high can-lights used in circulation spaces.

T8 fluorescent lighting is another common lighting fixture found throughout the main terminal. These lamps are located in surface mount linear fixtures, cove lighting, and "troffer" or recessed fluorescent fixtures in either a U-Tube or linear lamp. The vast majority of linear lamps are 32 watts (W).

Inefficient T12 fluorescent lighting was found in large quantities in the arrival and departure covered lighting structures. Metal halide fixtures were also noted in this area. The remaining lighting fixtures in the building consisted of decorative fluorescent, incandescent, or halogen fixtures. The lighting survey conducted in the building can be found in Appendix C.

Information gathered during the audit indicated somewhat functional daylight harvesting lighting controls, which dim or shut off fixtures based on ambient lighting levels. Very few motion controlled lighting (motion) sensors were noted, and facility personnel mentioned that several areas which previously had motion sensors had their sensors removed due to occupant complaints.

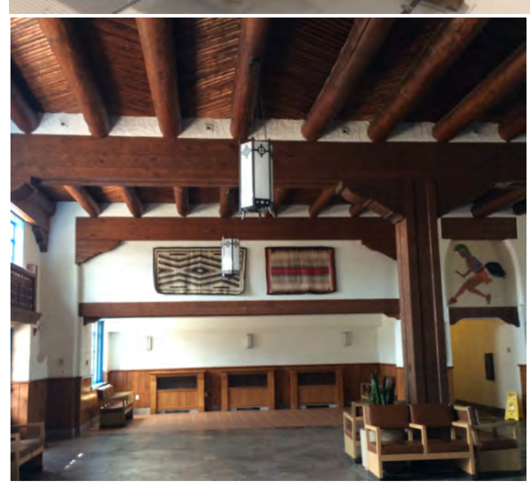
Equipment and Plug Loads

Other significant energy using systems include escalators, baggage claim equipment, and pre-conditioned air (PCA) systems, which condition the airplanes while they're stationed at the terminal building and connected to the jet way bridges.

Original Terminal

The original terminal building was built in 1939 and renovated in 1999. It consists of approximately 28,900 ft^2 of conditioned space. Currently, it now serves only as historic tourist attraction and a location for community and airport personnel meetings. Therefore, the majority of the building is lightly operated.

The HVAC system serving the building consists of York and Trane packaged roof-top units, along with a small hot and chilled water system. The lighting system has been modernized to a certain extent, with fluorescent T8 fixtures throughout the building, along with vintage light fixtures representative of the era and style of the building. Relative to the main terminal, only nominal energy saving opportunities exist.



Rental Car Terminal

The rental car terminal building consists of approximately 22,100 ft^2 of conditioned space, and serves as the primary facility for visitors to pick up and drop off rental cars.

The HVAC system serving the building consists of a small chiller and boiler system which serve a few AHUs. There is a non-functioning absorption chiller system that is connected to a tracking solar thermal system. Per facility personnel, due to the lack of available parts and with the fact that the absorption chiller company is out of business.

The lighting system has been modernized to a certain extent, with fluorescent T8 fixtures throughout the building. However, there are some inefficient metal halide fixtures. The building operates from approximately 4am-2am, 7 days per week

Other Buildings

There are 70+ buildings on Sunport's property in Albuquerque, most of which were out of the scope of the energy audit. The buildings that remained in the scope consisted of smaller maintenance, administration, and airplane hangar buildings. The building systems are much simpler in comparison to the previously mentioned buildings, consisting of basic HVAC & lighting systems, and the building function's equipment loads. Compared to the other buildings, the opportunity for energy savings is minimal.

Renewable Energy

Sunport's existing PV systems were installed between 2010-2013 at Parking I, Parking II, Power Center III, Power Center IV, and the Landside Operations Division. All told, there is over one (1) megawatt (MW) of solar capacity installed at the airport, which in 2014 produced approximately 2.5 million kWh of energy, which accounted for about 16% of the electric usage associated with the Aviation department. This level of solar energy production makes the Sunport a leader in renewable energy use among airports.

The only issue noted from Quest's study was a metering issue with the local electric company, PNM. Specifically, some of the solar energy produced exceeds local energy consumption attached to relevant electric meter. In these situations, the utility will buy the excess energy back at a reduced rate. Because Sunport has much more energy usage that could be displaced, but instead Sunport is purchasing this energy at the retail rate, effectively making this energy use cost partially discounted instead of free. This situation negatively impacts the economics and cash flow of the PV systems. Ideally a resolution of this issue could be reached such that the produced solar energy truly displaced used energy, either through an arrangement with PNM or further modifications to Sunport's electric infrastructure. This issue should be considered as any new PV systems are being planned.

Utility Rates

Local utility information was provided by Sunport and Coffman Associates. In total, there are eighty-five (85) different electric accounts for Sunport and the surrounding buildings. There isn't one uniform rate plan used for all accounts, so the for the purpose of the analysis, the main account type affecting the majority of the main terminal's energy use was used.

There were twenty (20) natural gas accounts provided. Because natural gas rates are not as sensitive to time of day or seasonal issues, the gas rate was determined through an average of the most recent use and costs. Both electric and gas rate information used in the energy analysis is summarized below:

Public Service Company of New Mexico (PNM) Electricity Rate (3B – General Power Service)

Monthly Charge per Account: $873.50 (June-August), $655.00 other months
Off-Peak: $0.039304/kWh
Winter: $0.069938/kWh
Summer: $0.084423/kWh

Summer Rate: 8am-8pm, June-August
Winter Rate: 8am-8pm, September-May
Off-Peak Rate: 8pm-8am, year-round

PNM Natural Gas Rate - Averaged

Average Rate: $0.44 / therm

Energy Use

The current building energy use was examined and analyzed for the purposes of establishing a benchmark for which to compare energy simulation results and other conclusions. Key figures from this analysis are shown below.

Overall, the utility costs are over $1,460,000 annually. The majority of the energy cost is electric, and the majority of the energy consumption is based out of the main terminal's accounts. There has been a net decrease of energy use the last few years due to energy efficiency projects and the hard work of the facilities staff improving upon building operation and maintenance.

Currently, the airport gets over 16% of the Aviation Department's annual electric energy use from on-site photovoltaic (PV) panels, making it one of the leading airports in renewable energy production.

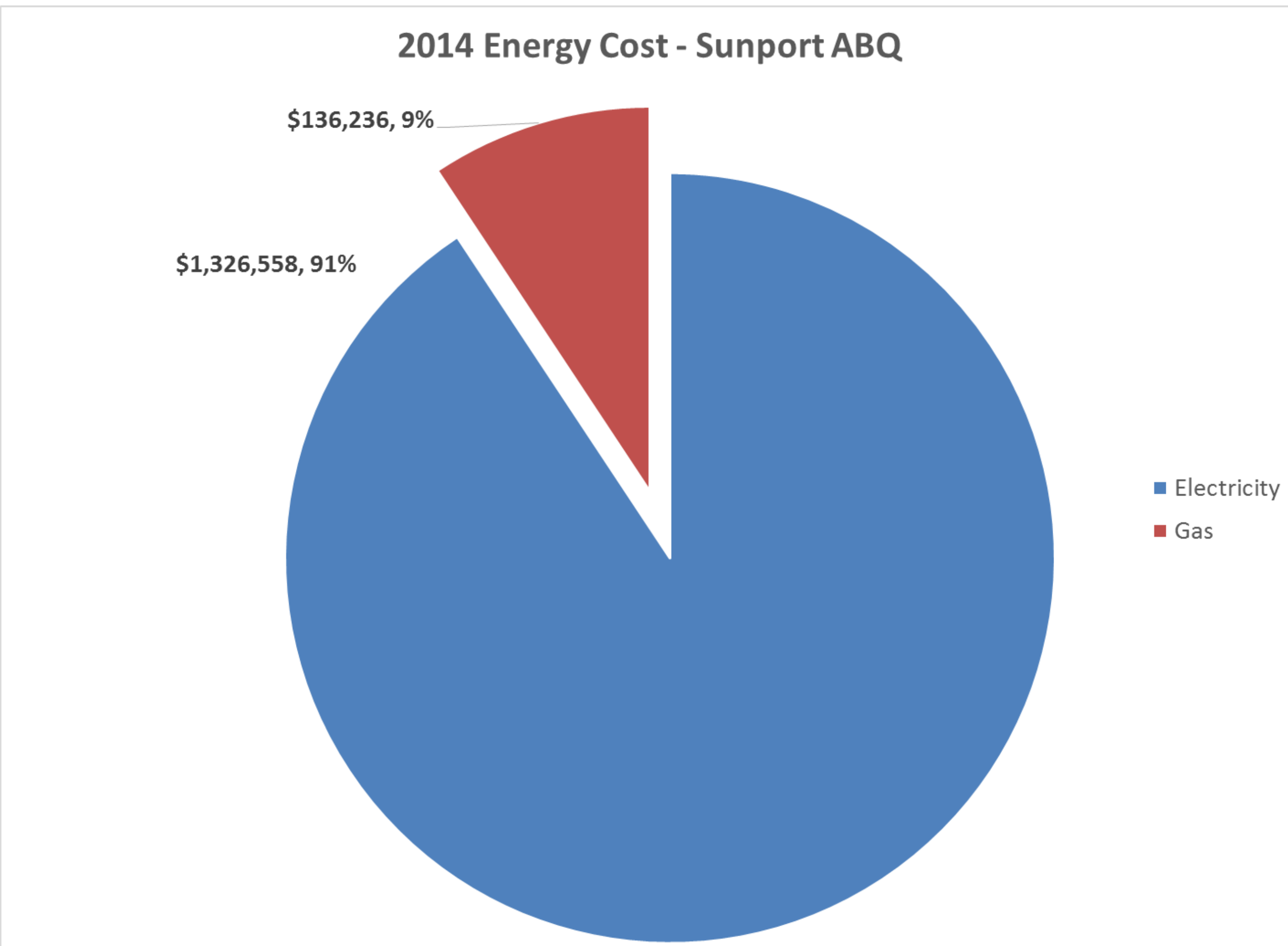


Figure 2: 2014 ABQ Sunport Annual Utility Cost Summary

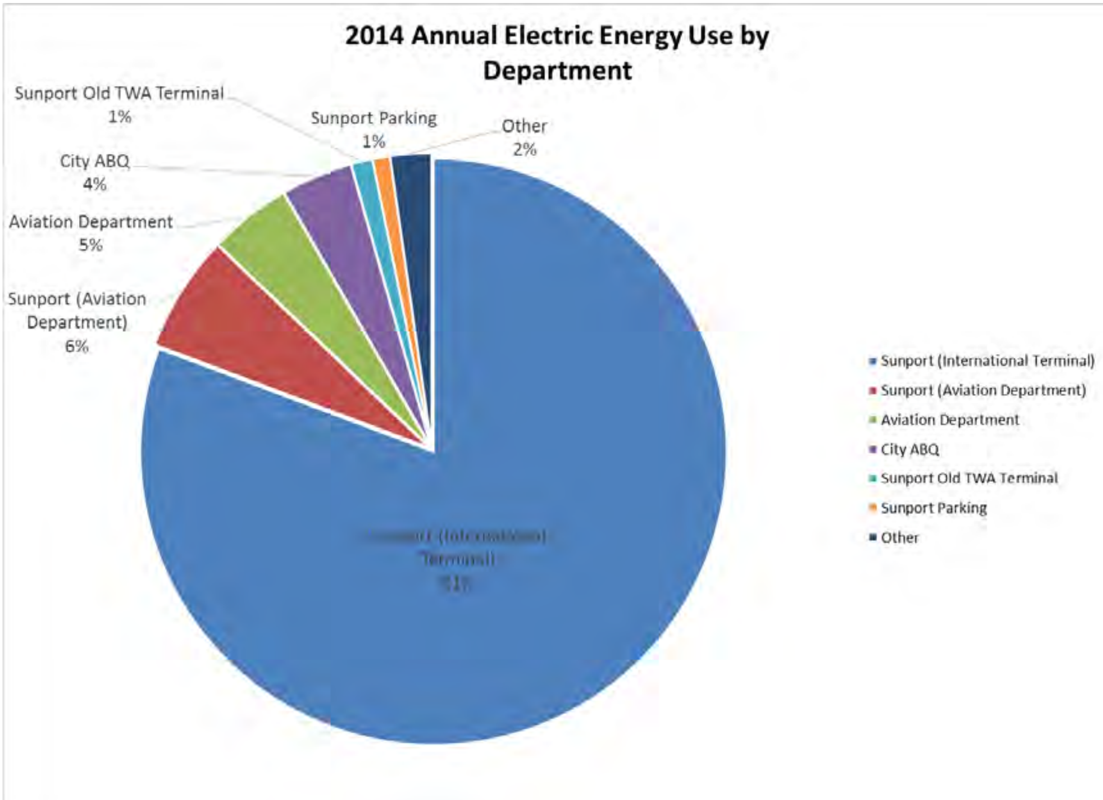


Figure 3: 2014 Electric Energy By Account Breakdown

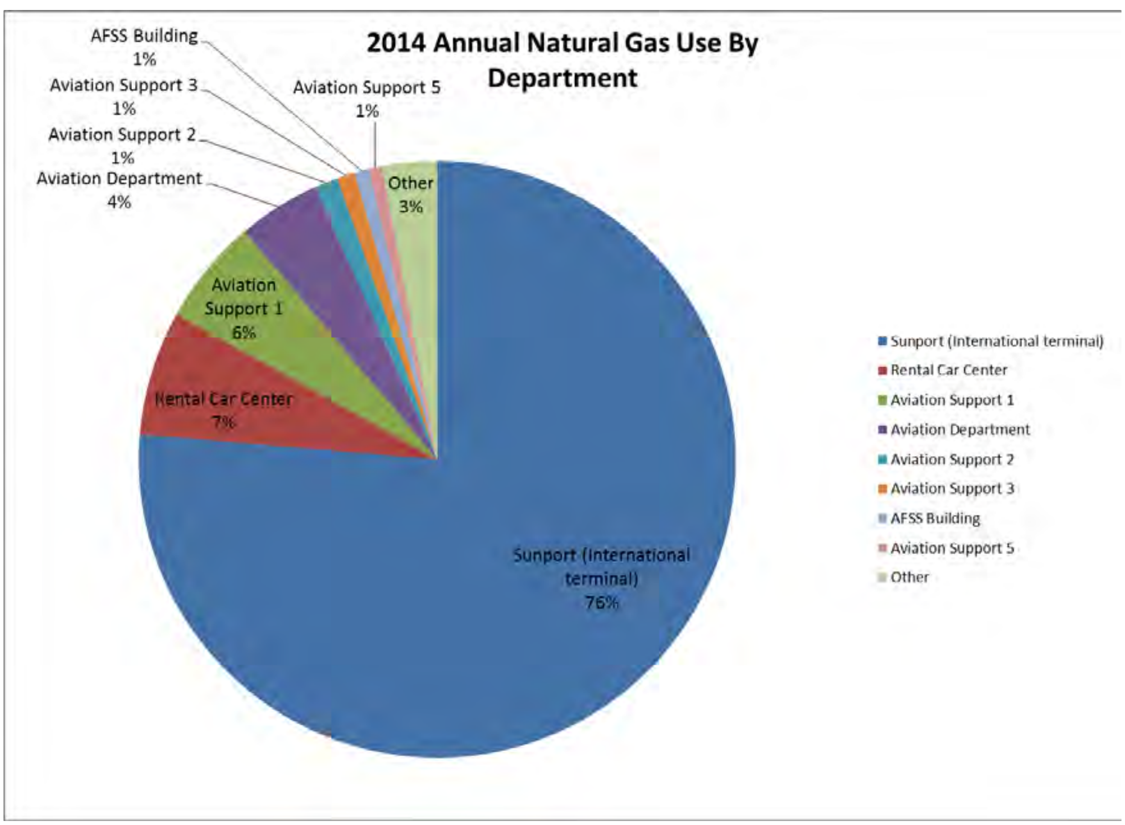


Figure 4: 2014 Natural Gas By Account Breakdown

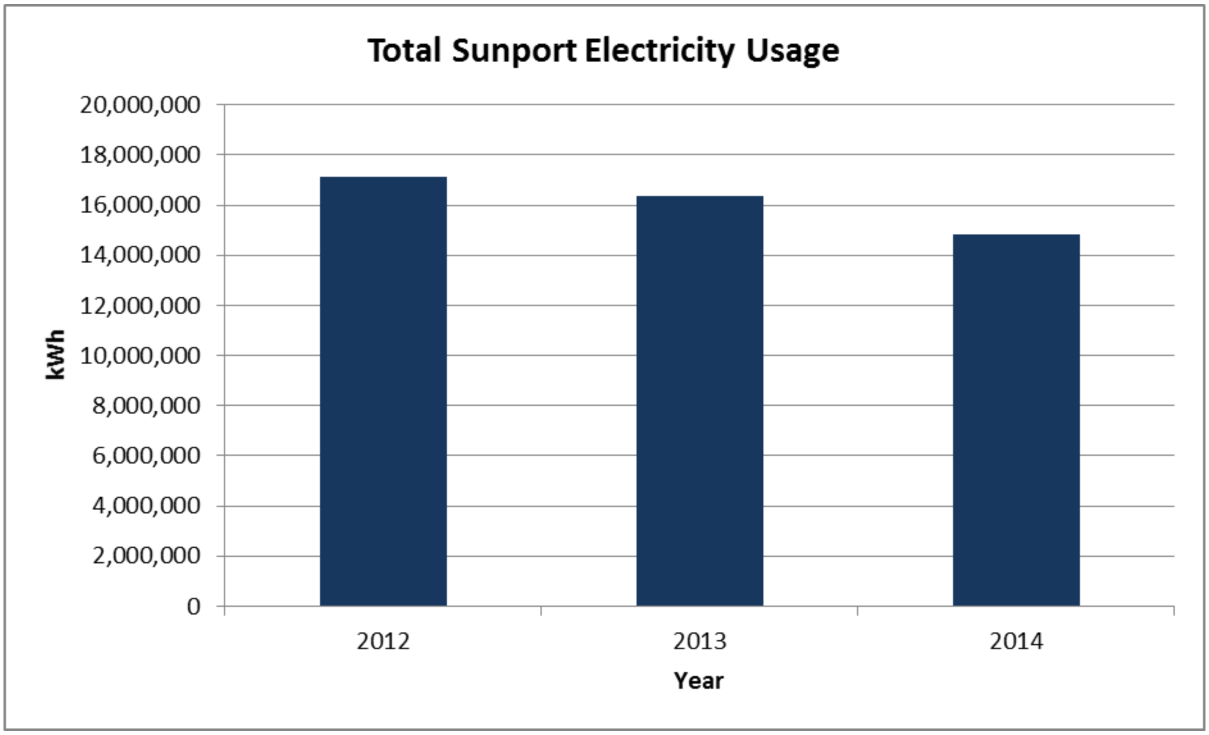


Figure 5: Annual Electric Energy Use (2012-2014)

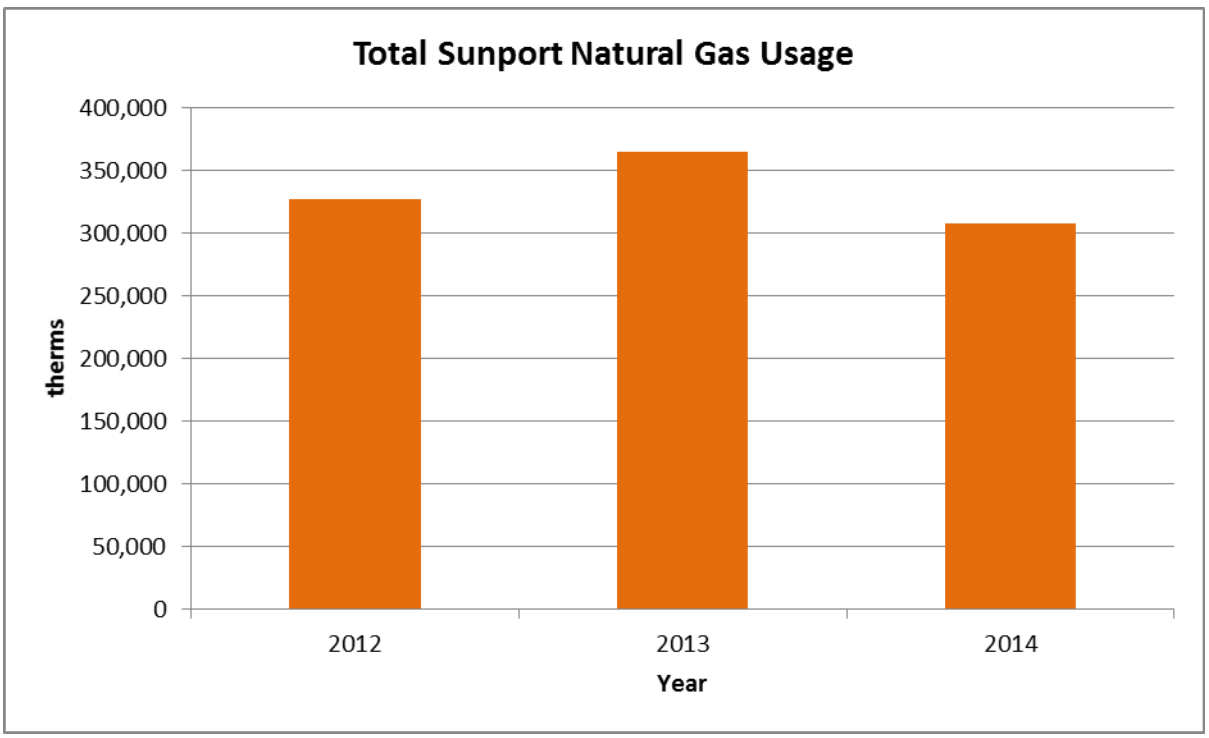
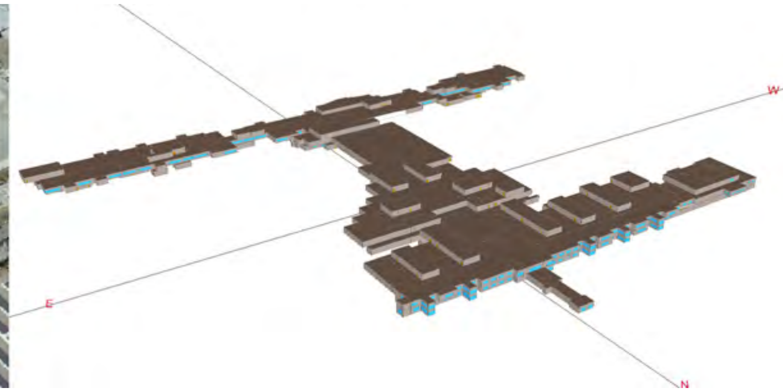


Figure 6: Annual Gas Energy Use (2012-2014)

Methodology

The analysis of the EEMs was done primarily using eQUEST, a front end for DOE 2.2. This is a robust program that allows one to perform an hourly simulation model of the building's energy use based on local weather data, geometry and envelope characteristics, internal gains, system size and performances, schedules, and utility rates. A rendering of the eQUEST model is shown below.



The information used to assemble this model is based on information gathered from the inspection via historical construction documents, trend data, screenshots, equipment nameplates, or operator information. In certain cases, engineering judgement was used for inputs with consideration given to the age, vintage, and industry standards.

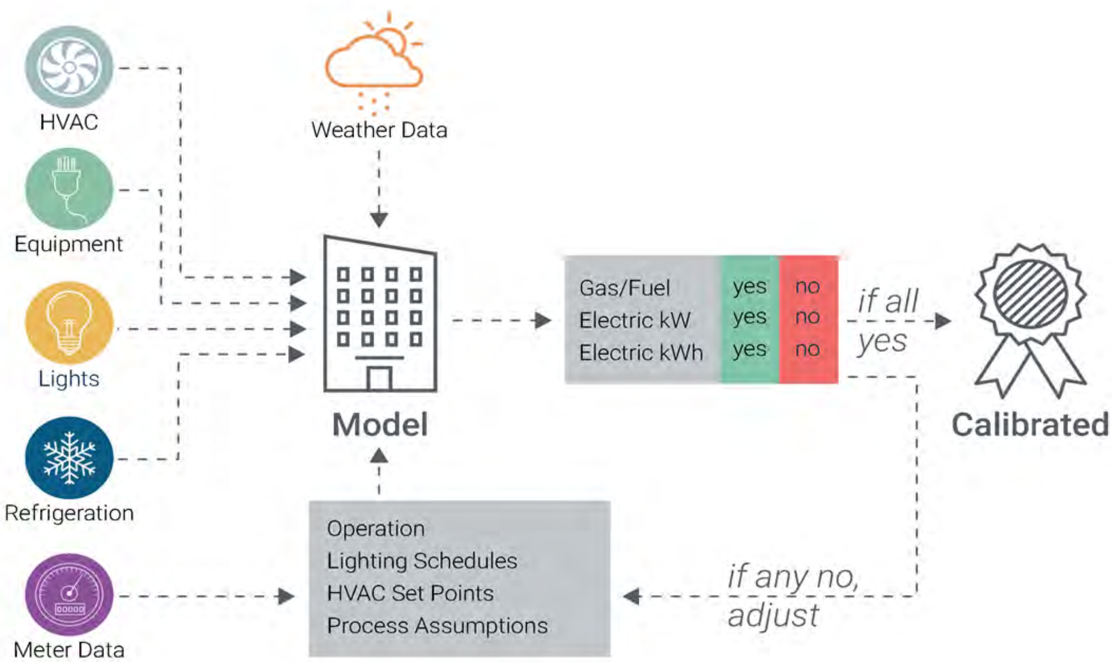


Figure 7: Calibration Process Flow Chart

The model was then iterated with IPMVP compliant baseline calibration in order to validate energy saving estimates and to ensure the model is providing accurate depictions of the actual building operation. The model uses TMY3 weather data for simulations and for projecting accurate savings values, an average of 30 recent years of weather activity of the local climate collected by calibrated weather stations. The calibration validation graphs are shown in the following figures.

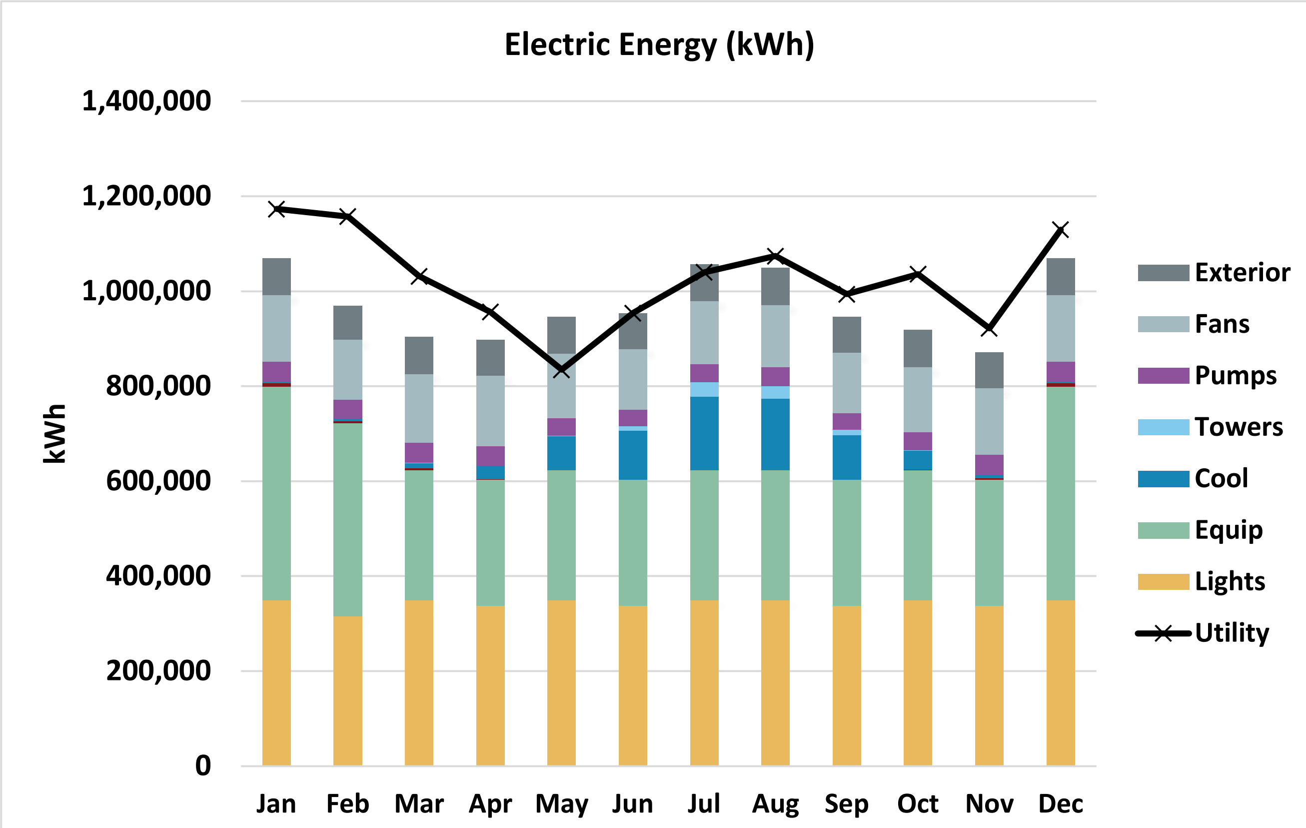


Figure 8: Electric Energy Calibration Results

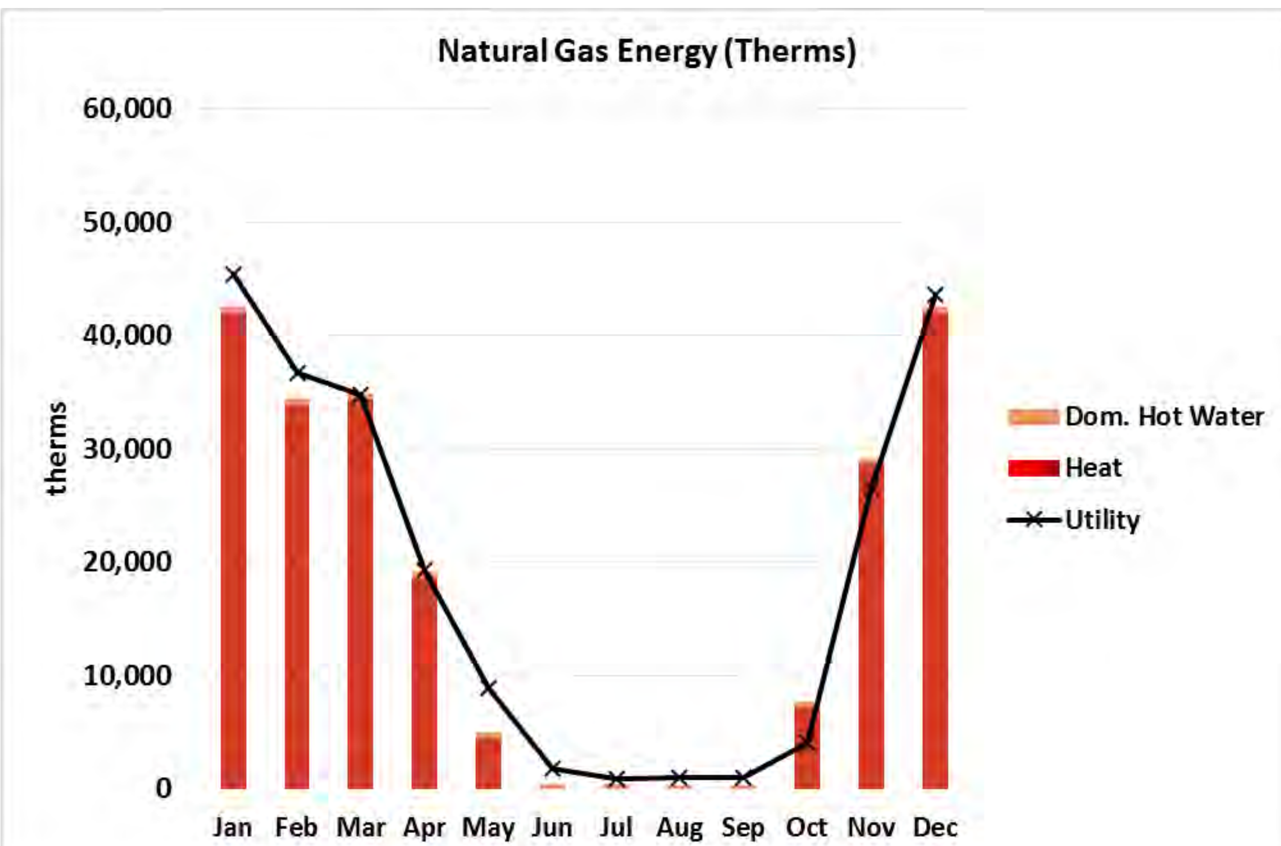


Figure 9: Natural Gas Energy Calibration Results

Energy Efficiency Measures

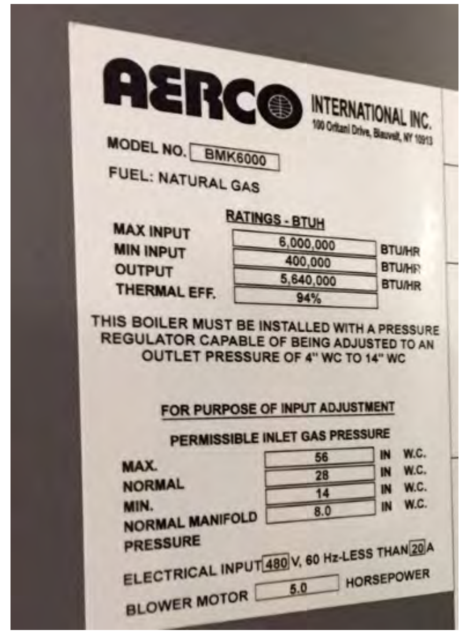
Based off the findings from the audit and Quest Energy's considerable experience with energy efficiency projects, energy efficiency measures (EEMs; labeled 3.X) were identified, analyzed, evaluated, and if determined practical and cost effective, listed below for consideration. Where noted, some EEMs are ideal for inclusion in future renovation projects and should be considered an upgrade over standard specified equipment. The other EEMs are recommended for implementation as standalone projects, as their economic returns (utility cost, maintenance, disposal, and/or utility incentives) and other benefits provide sufficient merits to warrant funding. Additionally, ongoing (labeled 1.X) and future planned (labeled 2.X) projects that will have energy impacts are shown for information purposes to give Sunport staff a clear idea where the energy performance of the airport is headed.

Table 3: Detailed Energy Efficiency Measure Savings Results

EEM Number	EEM Description	Estimated Investment ($)	Estimated Operational Cost Savings ($/year)	Utility Cost Savings ($/year)	Potential Incentive ($)	Simple Payback (Years)
1.1	Current Projects: Condensing Boiler	N/A	N/A	$20,600	$0	N/A
2.1	Planned Projects: Tarmac LED Lights	Unknown	$200	$14,300	$16,100	Unknown
3.1.1	Car Rental Metal Halide Retrofit	$34,000	$1,000	$10,200	$5,400	2.7
3.1.2	Arrival & Departure Lighting Retrofit	$138,150	$2,000	$17,100	$20,600	6.8
3.1.3	Occupancy Sensors	$20,000	$0	$8,800	$14,900	0.6
3.1.4	Baggage Claim & L1 Concourse Strategy	$82,025	$1,000	$20,600	$5,900	3.6
3.1.5	Gates A & B Holding Zone Strategy	$63,270	$1,000	$14,400	$6,700	3.9
3.1.6	LED Troffer Retrofits	$81,900	$2,000	$15,300	$5,800	4.8
3.2	Controls Optimization	$215,600	$0	$44,800	$43,200	3.8
3.3	High Efficiency HVAC Filters	$20,000	$10,000	$17,900	$17,000	Immediate
3.4	Data Center Improvements	$10,000	$0	$1,500	$1,600	5.6
3.5	Window Film	$2,300	$200	$300	$500	5.3
	Totals:	**$667,245**	**$17,200**	**$150,900**	**$121,600**	**3.6**

1. Current Projects:

1.1. New Condensing Boilers



Installed in the summer of 2015, Sunport added two (2) new 94% efficient 6,000,000 BTU Aerco condensing boilers. Condensing boilers are one the most efficient hot water heating options available on the market, and since they replaced the previous non-condensing boilers, Sunport should see strong gas savings from the project.

However, proper control to enable wide temperature differentials between supply and return water temperatures and return water temperatures below 130°F is required to maximize the efficiency of a condensing boiler. The energy audit did not take place when the boilers were operational to confirm that the efficiency is or is not being maximized. EEM 3.2 would address this issue.

The below shows typical condensing boiler performance curve[1] that demonstrates the importance of low return (entering) water temperature.

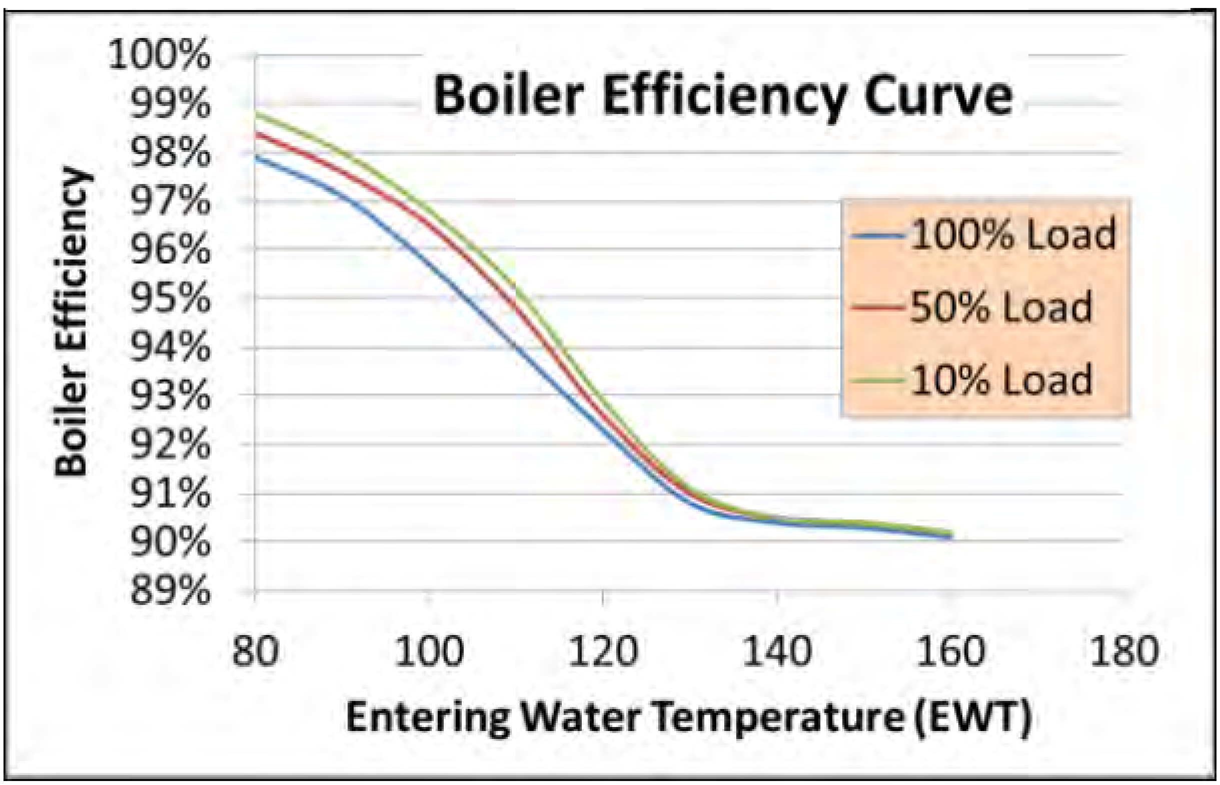


Figure 10: Typical Condensing Boiler Efficiency Curve

2. Planned Projects:

2.1. LED Tarmac Lights

Sunport is currently in the evaluation process of replacing their existing metal halide Tarmac lights, which are believed to be 1000W fixtures, with 580W LED fixtures. LED technology, is at this point, very established in the marketplace, even with high-powered display and theatrical lighting. In fact, the 2015 Super Bowl was played using LED stadium lights.

This implies that airport Tarmac LED lighting should be acceptably reliable and bright. However, Quest still recommends Sunport conducts a thorough due diligence via a trial period (which is being done) and selects a reputable manufacturer and contractor that can provide a strong warranty on the product. Once this measure is implemented, it should save approximately $13,000 annually, as well as be eligible for a similar magnitude incentive from PNM.

[1]Jones , Dennis. "Principals of Condensing Boiler System Design." ASHRAE (2014)

3. Energy Conservation Measures

3.1. Lighting & Lighting Control Opportunities

In the current marketplace, lighting technology is continuing to evolve, with more and more energy efficient options coming out. At Sunport, there are thousands of light fixtures of various vintages, functions, and types. As such, there is a plethora of opportunities to improve lighting efficiency and control and Sunport.

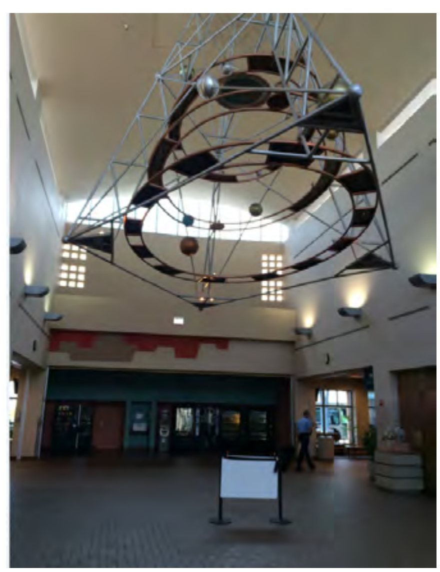
To evaluate the opportunities, Quest conducted a full lighting audit of the main terminal, car rental facility, and original terminal building, as well as the surrounding area of these buildings. Once the existing lighting technology was inventoried, potential retrofit opportunities were reviewed with industry experts for feasibility and pricing. The following sections represent the lighting retrofit opportunities that Quest recommends for consideration. These potential measures encompass like-for-like retrofit projects with quick paybacks, as well as technology that should be considered as upgrade during the upcoming space renovations planned at the airport.

3.1.1. Car Rental Metal Halide Retrofit

The Sunport Car Rental Center has many examples of modern lighting technology in use. This includes T8 troffer fixtures as well as LED can lights, pole lights, and up-lights. However there two particular light fixture types, that, if retrofitted with LED equipment would provide immediate energy savings and quick payback.

3.1.1.1. Indoor Up-Lights

The following photos shows examples of the metal halide up-lights at the Car Rental Center. These could easily be replaced, like-for-like with an LED option for immediate lighting and cooling energy savings. It’s estimated that an LED replacement would save 40% on lighting energy, which would translate to $9,000 in annual utility savings, a potential utility incentive of $5,000, and a simple payback under 3 years.



3.1.1.2. Outdoor Wall-Packs

The photo at right shows examples of the metal halide wall-packs at the Car Rental Center. These could easily be replaced, like-for-like with an LED option for immediate lighting energy savings. It's estimated that an LED replacement would save 40% on lighting energy, which would translate to $1,200 in annual utility savings, a potential utility incentive of $400, and a simple payback under 3 years. Inclusive of these savings are some run-hour savings, as it was noted that several of the fixtures were on during the daytime, which is unnecessary.

3.1.2. Arrival & Departure Lighting Retrofit

The arrival & departure area is another location in the airport that still uses outdated, inefficient lighting equipment. In this area, there are over 1800, T12 fluorescent lamps, estimated at 48 W per lamp with ballast losses. Additionally, there a handful of metal halide fixtures. Please see photographs from the lighting audit below.

These fixtures could & should be replaced with vapor-tight, outdoor rated LED fixtures. Doing so would save $17,100 in annual utility savings, provide a potential utility incentive of $20,600, and offer a simple payback of under 7 years. There should also be some maintenance savings, as LED lights will burn times longer than the current lighting equipment. The T12 lamps are also in the process of being phased out of production, so some form of retrofit should be inevitable.

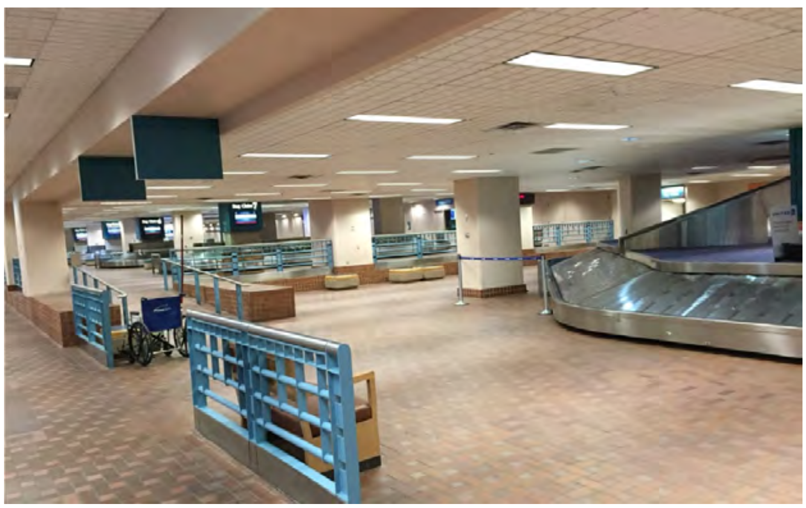
3.1.3. Add occupancy sensors within offices, conference rooms

Many times it was noted the lack of occupancy sensors as the primary form of lighting control in much of the back-of-house spaces that sees sporadic occupancy. Regardless of how much saving energy is part of a company's culture (which it seemed to be at Sunport), human error is inevitable. Installing occupancy sensor is a cost effective (most sensors cost under $50) and easy project to complete.

Predicting energy savings on occupancy controlled technology is an inexact science. In an effort to be conservative, Quest estimated only 5% lighting energy savings in the back-of-house spaces that would have switched-controlled lighting fixtures. These savings would amount to approximately $8,800 in annual utility savings, provide a potential utility incentive of $14,900, and offer a simple payback of under 1 years.

3.1.4. Baggage Claim & L1 Concourse Strategy

The baggage claim and Level 1 concourse is unique area; the main walkway (shown at left in the picture below) along with the escalator and center circulation area receive a fairly constant stream of people the entire day, while the baggage claim area (seen at right), particularly the west side, which sees less flights, is sporadically occupied.



Any space that is sporadically occupied makes it an ideal candidate for occupancy sensing control, particularly areas with as much lighting as the baggage claim areas have. In fact, Sunport personnel informed Quest that at one point, the baggage claim area was in fact controlled with baggage claim operation, which is usually directly related to occupancy. However, because all lights in a baggage claim area are on one circuit (as opposed to have 30-50% lights perpetually on for emergency lighting), this form of control was discontinued with guest complaints centering on the dark environment it was creating, particularly at night.

Quest investigated various options of lighting retrofits and control upgrades, though due to the semi-efficient lighting and limitations of the circuitry, it was deemed too cost prohibitive to consider for a retrofit project. However, per Sunport personnel, this area will undergo a major renovation in coming year or two. This would be an ideal time to update the lighting and control of these spaces to high efficiency equipment. Specifically, Quest makes the following recommendations for consideration to the future renovation of Level 1 and Baggage Claim space:

- Utilize established LED technology, including troffers, recessed can-lighting, and other applications.
- Utilize dimmable ballasts in all baggage claim space as well as any other space likely to see sporadic occupancy.
- Equip fixtures with occupancy sensor sensors with a 5 minute or smaller timer that would dim fixtures to 50% of lower reduced lighting levels when unoccupied.

These modifications to the space would save approximately $20,600 in annual utility savings provide a potential utility incentive of $5,900, and provide a simple payback (with respect to the *incremental* cost of the LED equipment of under 4 years).

3.1.5. Gates A & B Holding Zones Strategy

The holding zones of Gates A and B consist mostly of T8 troffer fixtures. The spaces are also feature plentiful ambient lighting from the large windows in these spaces. Based on the high levels of natural light, these spaces are ideal for daylighting controls, which is a control strategy that automatically adjusts lighting fixture output via dimming, ON/OFF, or stepped controls to maintain an indoor lighting brightness setpoint.

Quest was informed that daylighting controls were installed on the fixtures in the holding areas, but received mixed reports as to how effective the controls were working. Some Sunport personnel had said they're working fine, whereas other reports indicated an incorrect wiring installation are preventing the control scheme from working correctly. While on site, Quest could not confirm proper operation. As part of the next EEM described in this report, which recommends that all controls be systematically tested as part of a control optimization, Quest would recommend that the daylighting controls be examined, and if needed, repaired.

Quest also learned that these areas were once equipped with occupancy sensors, but because the sensors connected *all* lighting fixtures in the area, as opposed to 30-50% as is standard practice, the spaces would become too dark, particularly at night leading to guest complaints and the ultimate discontinuation of that strategy.

However, the long-term recommendation for this space (when the lighting system needs to be replaced) would include the following components:

- Utilize established LED technology to replace T8 fixtures
- Utilize dimmable ballasts in holding area space as well as any other space likely to see sporadic occupancy.

Equip fixtures with occupancy sensor sensors with a 5 minute or smaller timer that would dim fixtures to 50% of lower reduced lighting levels when unoccupied.

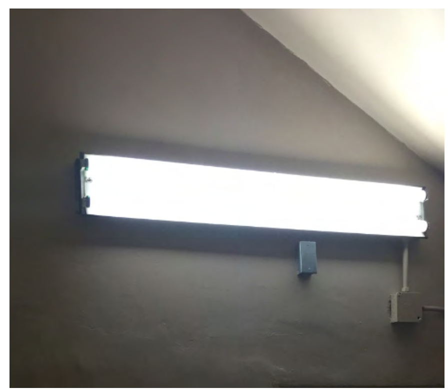
These modifications to the space would save approximately $14,400 in annual utility savings provide a potential utility incentive of $6,700, and provide a simple payback (with respect to the *incremental* cost of the LED equipment of under 4 years).

3.1.6. LED Troffer Retrofits

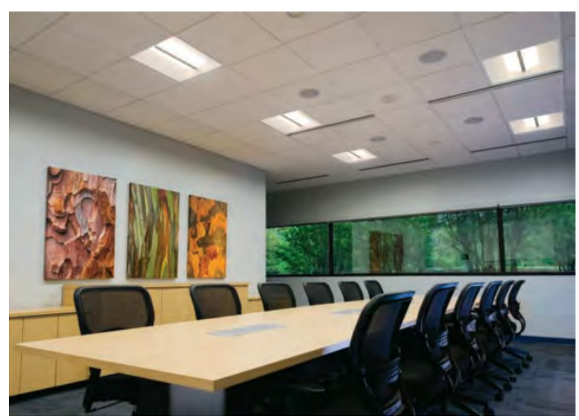
The following spaces were equipped with various forms for T8 Fluorescent tube lighting:

- Car rental offices & lobby
- Original terminal building (various spaces)
- Main terminal stairwells
- Main terminal circulation, TSA screening, concourses, and back-of-house areas

Quest recommends that the T8 fixtures be replaced with new LED fixtures when the fixture are due for complete replacement. The economics of an immediate retrofit were considered. On an energy basis alone, a new LED fixture is not very cost effective when retrofitting a T8 fixture, as a 2-lamp, 32W T8 fixture retrofit to a 40W LED troffer would save, at most $15/year (compared to a ~$100-150 install cost, assuming $0.07/kWh). There are maintenance and disposal/recycling cost savings as well, but these usually aren't significant enough to improve the economics enough.



Additionally, Sunport would have the option of retrofitting the fixtures with an LED retrofit 'kit', which uses the existing housing and other components, but replaces the bulb, ballast, and/or the reflector and lens of the fixture at a lower overall cost that a total fixture replacement. Quest's clients have provided mixed reviews on this type of project, and given the long-term outlook of Sunport, it was deemed that a new fixture, when the time was appropriate, was a better fit for Sunport's principles.



[2] Lower photo: "CREE CR24-40L - 2x4 LED Troffer." EarthLED.com. N.p., n.d. Web. 20 Oct. 2015.

3.2. HVAC Control Optimization

Given the efficient, well-maintained HVAC equipment and robust AutomatedLogic® BAS at Sunport there is a significant opportunity to optimize the control sequences of the equipment on the BAS to maximize the efficiency of the HVAC equipment. While many companies offer "canned" optimization software (which can be very expensive), these can often have limited value long-term, due to the optimization logic being overridden to account for space complaints and the propriety algorithms difficult to obtain support.

Rather, this EEM is being recommended for implementation in such a way that it will be transparent as well long lasting. There are three (3) phases of this EEM: retrocommissioning (RCx), implementation, and measurement & verification.

3.2.1. Retrocommissioning Phase

Generally speaking, retrocommissioning, or existing building commissioning, applies a systematic investigation process for improving and optimizing a building's operation and maintenance. It is typically provided by an experience commissioning company focusing on the building's energy using equipment such as the HVAC and other mechanical equipment, lighting equipment, and related controls. It may or may not emphasize bringing the building back to its original intended design specifications. In fact, via the process, the retrocommissioning team may find that the original specifications no longer apply. The primary focus is to optimize the existing building systems via tune-up activities, improved operation and maintenance (O&M), and diagnostic testing.

The reasoning for RCx at Sunport to first ensure that all equipment whose control sequences would be optimized is systematically tested to ensure things are good working order, and "problem spaces" are identified and addressed. Problem spaces are areas in a building that struggle to maintain typical indoor conditions with ordinary modes of operation. These can be caused by mal-functioning HVAC equipment, improper design of the equipment, or when equipment loads have changed beyond original design conditions. Problem spaces require building operators to tweak normal control sequences until the equipment is able to maintain the required conditions.

However, such corrective actions can have a ripple-effect. In Sunport's case, there are spaces that were determined to require 48-50°F cooling supply air temperatures year round. As a result, the central chiller plant has to provide 42°F chilled water to these AHUs, which then has to provide to every other AHU. *If* corrective actions can be made to the problems spaces and/or their AHUs where 48-50°F supply air is not needed <u>all</u> the time, then the central plant can supply warmer chilled water temperatures. For every 1°F increase in chilled water temperature, chillers use about 1.5% less energy[3]. If a 700 ton, average centrifugal chiller operates 4000 hours per year at an average of 75% load, a 6% savings would be approximately $6,000 annually. (assuming $0.095/kWh)

[3]"TABLE 6.8.1J Minimum Efficiencies for Centrifugal Chillers ≥300 Tons." ASHRAE 90.1. 2007 ed. 52. Print.

Additionally, if the problem space is limited to only a portion of the overall area the AHU serves, each dual-duct mixing box in non-problem spaces may need to compensate for the colder air by mixing neutral or hot air into the space, which will use more fan energy and/or heating energy.

The specific problem areas at Sunport seemed to center around excessive heat loads from retail/restaurant spaces or cold air infiltration in Level 1 spaces. These can potentially be corrected with fixing non-functioning parts, adding supplemental or increasing capacity, and/or reducing infiltration issues. The infiltration issues on Level 1 could likely be addressed with changes to building pressurization controls and/or adding air curtains to vestibules and better baggage claim outdoor-separation devices. However, all problem spaces will need further evaluation under the RCx process.

The systematic testing of building systems that comes with RCx almost always reveals a number of issues within the HVAC that facility operators are unaware of. Facility personnel, especially those at Sunport, do an excellent job within their job description: keeping spaces comfortable, fixing issues on failed critical equipment, performing preventative maintenance activities, and planning and executing capital projects. However, there isn't time within their job responsibilities to do the systematic testing that a commissioning agent would do for a new building, and that usually isn't done until a major renovation. These issues usually keep equipment from operating to their efficiency potential, but once identified they can be repaired or corrected to get the equipment back performing as intended. The repaired issues' energy savings are quite cost effective relative to their implementation price. It is for this reason that utility companies, such as PNM, provide incentives to fund RCx studies. Information on this PNM's program can be found in Appendix G.

3.2.2. Implementation Phase

The implementation phase of the controls optimization EEM will include the following components:

- Retrocommissioning issue repairs
- Problem space corrective actions or repairs
- Add efficient programming sequences to BAS
- Dial-in schedules and setpoints (correct operator over-rides)

3.2.2.1. Programming Sequences

Once the issue repair and problem space issues finished as part of the Implementation Phase, the efficient programming sequences can be added. The following information summarizes the current observed sequences at Sunport, as well as the proposed sequences that are being proposed to improve the efficiency of the HVAC system. Note that these sequences would be need to be customized for the needs of the equipment, vetted with manufacturer's data (which has not been readily available), and thoroughly tested before implementation. Not every sequence may need to be changed; and those unaffected were not listed. There may be other advantageous sequences not listed that could also be added.

A. Dual Duct Terminal Unit (Zone Box) Control
    a. Current Control Sequence:
        i. Modulate heating and cooling airflow dampers to maintain zone temperature setpoint.
    b. Inefficient Elements:
        i. None, though the hierarchy supply air control strategies at the AHUs inherently cause mixing of hot deck and cold deck air flows, which is inefficient.
    c. Proposed Control Sequence:
        i. Modify existing sequence as needed to avoid simultaneous heating and cooling, where possible. The Snap Acting control strategy described ASHRAE RP-1455[4] and shown in the figure below demonstrates the ideal objective.

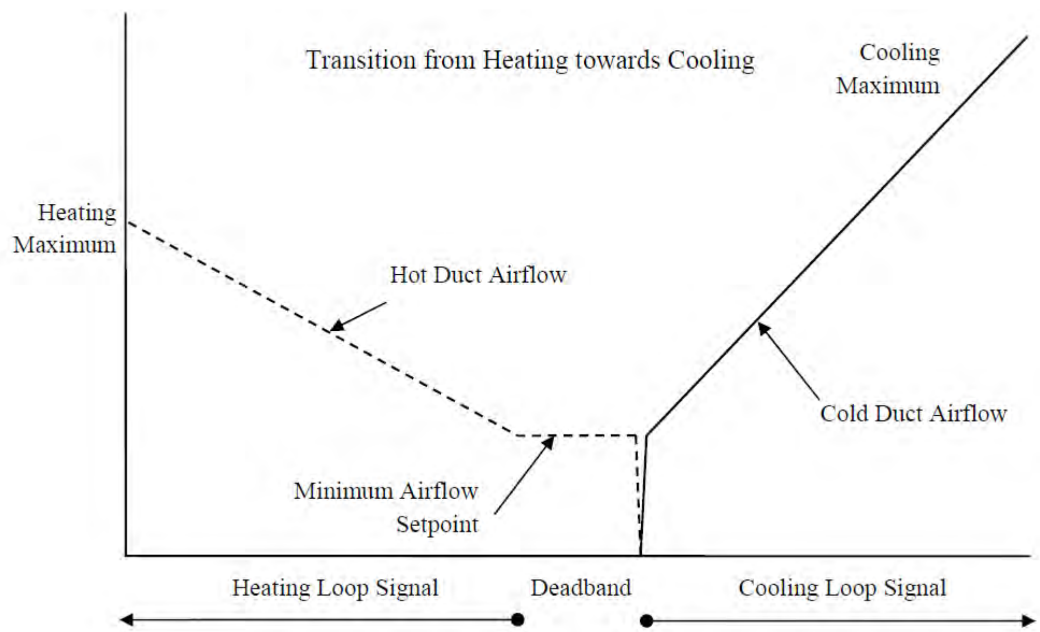


Figure 11: Snap Acting Zone Box Temperature Control Signal

    d. Notes & Considerations:
        i. Careful attention should be made during programming and tuning to ensure this strategy works effectively.
B. Cold Deck (CD) Supply Temperature Control
    a. Current Control Sequence:

Fixed at 48-55°F (depending on the AHU) in the summer, fixed at 48-65°F (depending on the AHU) in the winter.

[4]Taylor Engineering. "Advanced Control Sequences for HVAC Systems Phase I, Air Distribution and Terminal Systems." ASHRAE RP-1455 (2014): 1-105. Print.

b. Inefficient Elements:
    i. This sequence relies on the operator knowledge of the space and the availability of heat in the hot duct and/or ability of the zone mixing boxes to mix air to the proper set-point for the zone. Since there is no logic to zone demands, the system will provide more airflow and/or heating energy than needed to overcome the colder air temperatures.
    ii. The AHUs with the extremely cold supply air temperatures force the central plant to run at a low chilled water supply temperature, which causes an energy penalty.
c. Proposed Control Sequence:
    i. CD Supply air temperature should be reset using a Trim and Respond (TR) logic[4] based on feedback from zone boxes with an overall range between 65 and 55°F (T_{min}) with T_{min} allowed to vary seasonally and tuned per AHU.
    ii. This control strategy will extend economizer hours and allow for higher chilled water temperatures.
d. Notes & Considerations:
    i. This control strategy is intended to be used in coincidence with a TR based static pressure reset control strategy[4] a TR based HD reset strategy[4] and a snap acting zone mixing box strategy[4].

C. Hot Deck (HD) Supply Temperature Control
a. Current Control Sequence:
    i. Reset HD supply temperature setpoint based on OA temperature:
        - No heating at OAT > 75°F
        - at 60°F and higher, 90° HW setpoint
        - at 32°F and lower, 140° HW setpoint
        - Reset proportionally between 90-140°F between 32-60°F OAT
b. Inefficient Elements:
    i. This control is likely in place to accommodate infiltration issues on L1, where space temperatures can get quite cold and as a result, the AHU must provide very warm air.
    ii. Since this sequence is applied to all AHUs, even those without the same infiltration issues, the system likely has to mix in cold air to accommodate for high hot deck temperatures, resulting in excess airflow and/or heating.
    iii. This may also force the boilers to provide hotter than necessary temperature and/or high return water temperatures, which causes an energy penalty on condensing boiler operations.
c. Proposed Control Sequence:
    i. HD supply air temperature should be reset using a Trim and Respond TR based on feedback from zone boxes with an overall range between 75 (neutral air) and 140°F (T_{max}) with T_{max} allowed to vary seasonally and tuned per AHU.
    ii. This control strategy will extend economizer hours and allow for

higher chilled water temperatures.

d. Notes & Considerations:
   i. This control strategy is intended to be used in coincidence with a TR based static pressure reset control strategy[4], a TR based CD reset strategy[4], and a snap acting zone mixing box strategy[4].

D. Duct Static Pressure Setpoint Control
a. Current Control Sequence:
   i. Fan speeds modulate to maintain a fixed duct static pressure setpoint(s)
b. Inefficient Elements:
   i. During part load conditions, when many of the mixing boxes may have closed off dampers, the fans still work to maintain duct pressure designed for design load conditions.
   ii. When duct static pressure is lowered, the fans will use less energy. This strategy works by considering damper positions at the mixing boxes and adjusting accordingly.
c. Proposed Control Sequence:
   i. Duct static pressure should be reset using a TR logic based on feedback from zone boxes such that 1-2 boxes have fully open dampers. As more requests for airflow are received, the control sequence will gradually raise the duct setpoint until the requests decrease.
   ii. This control strategy will save fan energy and work with the proposed supply reset control strategies.
d. Notes & Considerations:
   i. Careful attention should be made during programming and tuning to ensure this strategy works effectively.

E. Hot Water (HW) Supply Temperature Control
a. Current Control Sequence:
   i. Reset HW supply temperature setpoint based on OA temperature:
      - at 60°F and higher, 140° HW setpoint
      - at 30°F and lower, 170° HW setpoint
      - Reset proportionally between 140-170°F between 30-60°F OAT
b. Inefficient Elements:
   i. This control strategy *isn't* the *most* inefficient strategy out there (fixed control strategies are worse), provided that the parameters were well thought out. However, it may be providing warmer water than needed at times because it's not considering AHU needs.
   ii. It's also not considering return water temperature, which is critical to ensure high efficiency condensing boiler operation.
c. Proposed Control Sequence:
   i. Reset temperature incrementally lower based on return water temperature and AHU valve commands such that the worst case valve is fully open and the return water temperature is

100°F or lower.

d. Notes & Considerations:
    i. This control strategy may increase HW pumping energy, but the natural gas cost savings will far outweigh this penalty.

F. Chilled Water Temperature Control
    a. Current Control Sequence:
        i. Fixed at 42°F during chiller operation
        ii. Allowed to drift higher if Flat Plate Heat Exchanger (FPHX) mode is enabled
    b. Inefficient Elements:
        i. Chillers operate less efficiently at lower chilled water supply temperatures
    c. Proposed Control Sequence:
        i. Reset chilled water supply temperature incrementally based on AHU coil valve position. Modulate temperature setpoint such that the worst case valve is 100% open, while allowing time delays to ensure it doesn't stay at full open for too long.
    d. Notes & Considerations:
        i. The chillers run at this low supply water condition due to the low supply air requirements of some of the AHUs. This would need to be reconciled during the RCx process.
        ii. This strategy will result in some increase in pumping energy on the secondary chilled water pumps, but it will be outweighed by cooling energy savings. Improving supply air temperature controls will maximize air-side economizer times, which will in-turn save pumping and chiller energy.

G. Chiller / Flat Plate Heat Exchanger (FPHX) Control
    a. Current Control Sequence:
        i. Chilled water system runs when there is a call for cooling by AHUs
        ii. The FPHX is enabled below 50°F outside air temperature (OAT) and below 69°F wet-bulb (WB) temperature
            - The very unusual wet-bulb enable point was changed during the audit process to 45°F
        iii. The chillers are on when the OAT is above 55°F *and* there are sufficient cooling requests from AHUs.
        iv. The first chiller in the sequence will handle the AHU cooling until it reaches 90% loaded. Then the 2nd chiller will stage on and share the load evenly until the two (2) chillers are below the minimum threshold (40%) for a timed sequence
        v. One cooling tower, one primary chilled water pump, and condenser water pumps will run for each chiller/FPHX enabled
    b. Inefficient Elements:
        i. Shown in the figure below, the York variable speed chillers have a "sweet spot" between 35-60% loading. Allowing one chiller to handle the load at higher loading percentage is less efficient than two chillers running at part load

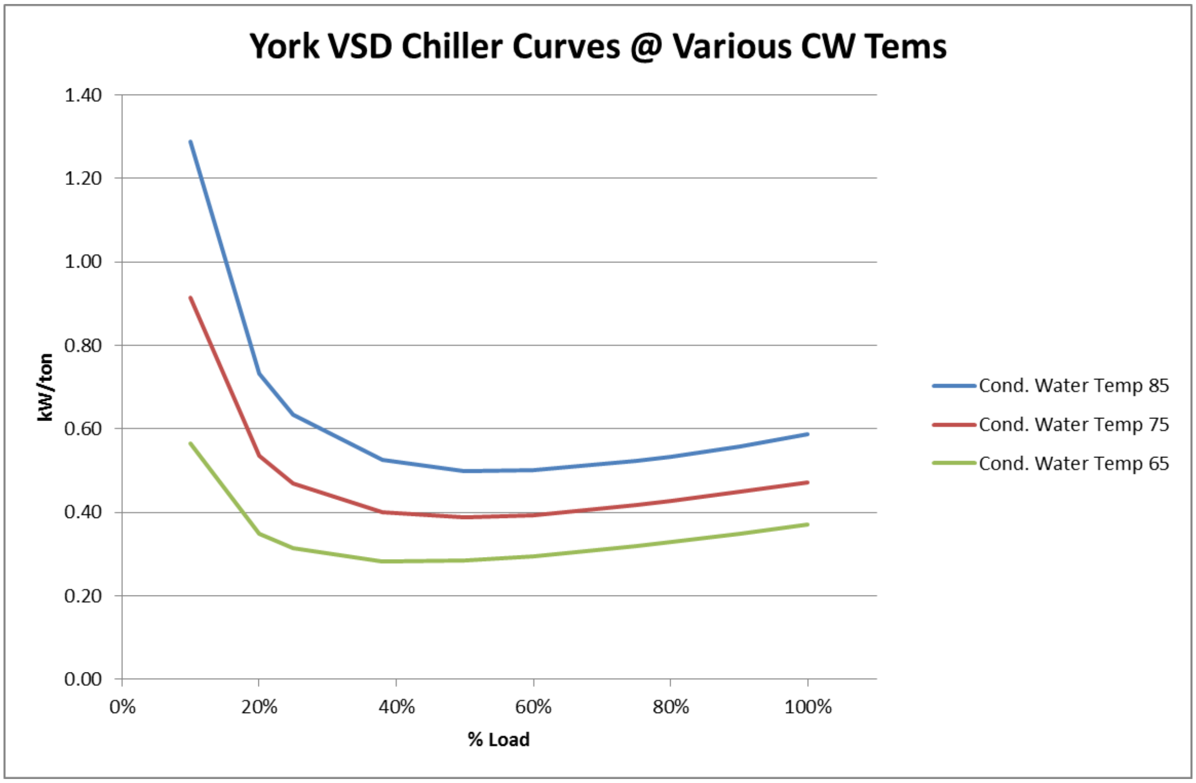


Figure 12: York Centrifugal Chiller Efficiency at Varying Condenser Water Temperature

ii. Once the supply air temperature controls at the AHUs are optimized, and the chilled water reset sequence is based on AHU demand, the enable settings of the FPHX and chillers can be modified to extend FPHX operation

c. Proposed Control Sequence:
   i. Turn on 2nd chiller at 75% load on lead chiller. Thurn off at 60% combined load.
   ii. Allow FPHX to handle cooling load until it can't. Use a timed sequence on supply water temperature not being met to enable the chillers.

d. Notes & Considerations:
   i. With the chillers being older, it may be advantageous to wait until Chiller 1 is replaced until updating chiller sequencing as there seemed to be some concerns with reliability of some of the existing chillers
   ii. The revised chiller sequencing strategy will put more run hours on the chillers, which may increase the frequency of preventative maintenance activities. However, the increased hours of the FPHX should offset this.

H. Chiller Water Secondary (Loop) Pump Control
   a. Current Control Sequence:
      i. Modulate pump speed to maintain fixed differential pressure (DP) of chilled water at 8 psig

b. Inefficient Elements:
   i. The chilled water pump may not need to maintain as much pressure as currently provided when there are multiple valves throttle down. Reducing DP will lower pump speed, which will save on pumping energy.
c. Proposed Control Sequence:
   i. Reset DP incrementally *after* chilled water temperature has been reset until timing sequencing of worst case valve is at 100%
d. Notes & Considerations:
   i. This sequence will help mitigate increased pumping energy that comes with chilled water reset strategies.
   ii. Care should be taken to make sure DP measurements are accounting for the furthest and/or highest coil.

l. Condenser Water Temperature Control
   a. Current Control Sequence:
      i. Fixed at 60°F during chiller operation
      ii. Controlled colder as needed to maintain chilled water temperature during FPHX operation
   b. Inefficient Elements:
      i. There is a physical limit to the water temperature an evaporative cooling tower can produce. It is usually a few (5-10°F) degrees higher than the ambient wet-bulb temperature.
      ii. Therefore, whenever the ambient wet-bulb temperature is 55°F or higher, the tower will never achieve setpoint, but then fan will run at 100% speed at all times.
      iii. A smarter control strategy that would allow the fan to modulate to lower speeds without significantly sacrificing chiller efficiency that comes with low condenser water temperatures would save fan energy and cooling tower water.
   c. Proposed Control Sequence:
      i. Better case: implement a condenser water reset control strategy that resets temperature based on ambient wet-bulb conditions.
      ii. Best case: implement a smart control sequence that adjusts with chiller plant part load ratio and chiller lift[5].
   d. Notes & Considerations:
      i. This strategy will take advantage of the exponential part load characteristics of a variable speed fan, in which drastic power reductions can be realized through small reductions in speed. See figure below[6].

[5] Taylor, Steven T., PE. "Optimizing Design & Control Of Chilled Water Plants Part 5: Optimized Control Sequences." ASHRAE Journal June (2012): 56-75. Print.

[6] http://engineering.electrical-equipment.org/wp-content/uploads/2009/08/pump-curve1.jpg

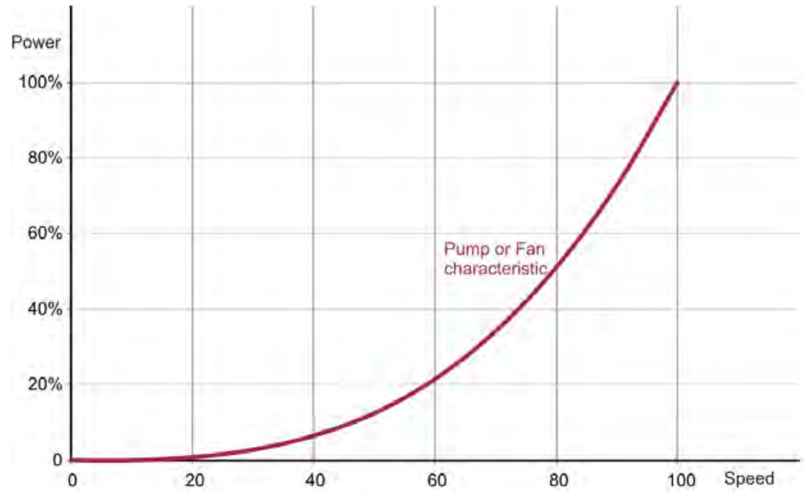


Figure 13: Typical Variable Speed Fan Curve

3.2.3. Measurement & Verification Phase

Although the project is expected to be cost effective and have a relatively short return-on-investment for Sunport, the cost for implementation on the Controls Optimization project will be significant, as a great deal of time will be required to properly test the equipment, fix problem issues, and add and tune the new control sequences. Therefore, in order to maximize the value of the project, Quest recommends that the following steps as part of the projects closeout, as to ensure the energy savings will be persisting:

3.2.3.1. Operator Training

Once the control sequences of the BAS have been updated and the setpoints and schedules dialed in, a critical step in ensuring long-lasting results from the project will to make sure the whole facilities team receives training on the changes made, why they were made, and what to do if there's an issue in a building that would demand input or changes to the BAS programming or setpoints.

3.2.3.2. Documentation

A key part of the controls optimization project will be project documentation. This documentation will fulfill the following objectives through its various forms:

- Document the issues log and repair statuses of the items found during the RCx testing process.
- Provide the control sequences in their final form so that they can be re-instated should future changes negatively alter their performance.
- Demonstrate the energy savings benefits of the final project. In addition to supporting the basis of Sunport's investment for the project, proper documentation and post optimization analysis would likely be needed to support the case for utility incentives, which is described further in Appendix G.

3.2.3.3. Override Tracking

A key part for Sunport's facilities management team in ensuring the continued success of the controls optimization project will be to control any changes to the BAS sequences. Ideally, any operator overrides, such as setpoint and scheduling changes, unless authorized explicitly by management, would be set-up on a temporary basis (e.g. 1 day) to address the occupant complaint for resorting back to the original settings.

This type of functionality may not be possible within AutomatedLogic, however, there is a function to monitor activity through an audit log. This log records the instance, time, date, and type of change within the BAS. At a minimum, it would be recommended that Sunport's facilities management team review the audit log weekly to review changes to the system following the implementation of the controls optimization project.

3.2.3.4. Improved Analytics

A final key to success for the optimization project will be establishing performance metrics and ongoing validation data to compare the actual energy performance to a targeted performance level.

http://www.energymanagementcontrol.co/Performance-dashboards-for-energy-management.htm

It's recommended that all HVAC motors, chillers, and other major energy consumers in the HVAC system be tracked using current transducers (CTs) and mapped into the BAS. Trend logs of the power data can then be compared to an established benchmark developed by controls optimization team for ongoing comparison, diagnosis, and reporting.

The current AutomatedLogic platform may not be able to provide this type of feedback. However, upgraded packages such as Eco-Screen® and EnergyReports® should be able to provide this type of analytics. Information on these packages can be found in Appendix A. There are likely a full suite of other analytical packages from other companies, though they can be quite expensive and maintaining the same company for technical support issues can be advantageous. For this reason Quest did not pursue costs from other providers.

3.2.4. EEM Pricing

In order to provide Sunport with accurate pricing this very involved EEM, Quest collected cost estimates from Integrated Control Systems (for the improved analytics) and previous project experience for other expenses. Additionally, as an experienced RCx firm, Quest developed a detailed cost estimate for the cost of the RCx, programming, project management, and documentation services. All related costs for the EEM are shown in the Table 4 on page 36.

Table 4: Controls Optimization Pricing

RCx / Programming Costs:	$ 79,550
Repair Costs:	$ 40,000
Infiltration Reduction:	$ 40,000
Analytic Software:	$ 56,050
Total:	**$ 215,600**

3.3. High Efficiency HVAC Filters

The AHUs at Sunport, for the most part, use three (3) stages of filtration to treat supply air entering the airport. These stages are: a Merv 8 pleated pre-filter, a Merv 13 bag filter, and a carbon filter for odor removal. Air filtration of all forms is inherently temporary; filters eventually foul, become clogged or broken and must be replaced to ensure ongoing indoor air quality. The energy impact is that as filters become dirtier, the air does not pass through them as easily, creating increased pressure drop. As a result, the fans have to work harder to move the air the spaces need to cool/heat/ventilate, which causes increased energy use. The Sunport facilities staff appears to keep filter changes on a regular schedule, which helps maintain the efficiency of the system. The frequency of changes are: every three (3) months on pleated filters, every one (1) year on the bag filters, and every one (1) years on the carbon filters.

However, there are excellent filtration products available from reputable companies such as 3M and Camfil that can provide the same current levels of filtration, but last longer and/or provide a lower overall pressure drop. These benefits would substantially lower energy costs and reduce the frequency of change outs (maintenance savings, disposal savings). These companies normally fully guarantee their products. Sample filter information can be found in Appendix D.

Specifically, Quest recommends Sunport consider going to a high efficiency bag filter that would replace current bag filters 1:1 *and* would enable the complete removal of the pleated filters. It's estimated that up an average 0.5" water column (w.c.) of static pressure could be reduced, which would save significant fan energy!

The net incremental cost ($15,000 annually) of the high efficiency filters is, as expected, higher than standard air filters. However, the life cycle cost savings of the high efficiency option with pleated filter removal is significant versus the current method of filtration products.

3.4. Data Center Improvements

The Data Center Improvements EEM is both an energy efficiency recommendation as well as a suggestion for improved system and equipment reliability. The current rack air distribution set-up is far from any recommended set-up. With the racks sitting directly on the perforated tiles, the intent of a rack-aisle configuration is gone; the current set-up is forcing the cold air into the bottom servers only, while the upper servers do not see cold air at all. If a thermal image was taken, it would probably look like the figure below[7], where surface temperatures would not be uniform.

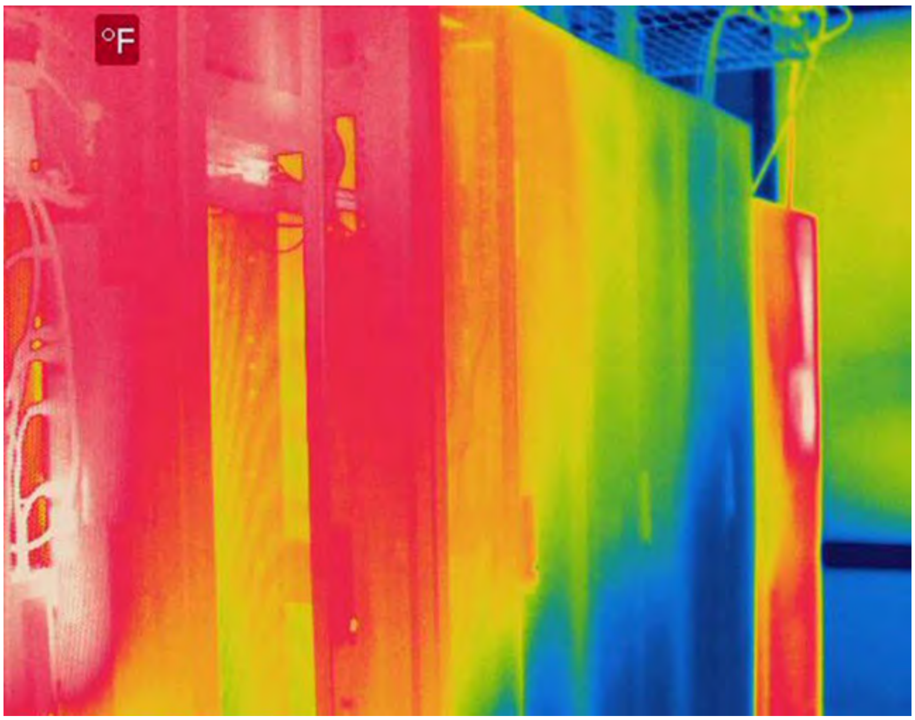


Figure 14: Thermal Imaging of Server Rack with Wide Temp. Variance

To compensate, the CRAC units and control settings are set to maintain the room at a fairly low temperature (70°F, 50% RH), which enables the upper servers to cool off using warmer room air. It's likely that "hot spots", or high temperature areas exist or, with further IT equipment additions, would be created, among the upper servers. An example of hot spots is shown in the figure at right. Recent data center standards by ASHRAE Technical Committee 9.9 recommend that data centers be kept as high as 80°F, 60% RH[8]. As described earlier, there is also excess illumination in the data center space due to the high number of light fixtures, along with excessive lighting burn-hours.

[7] http://www.infraredimagingservices.com/commerc

[8] Technical Committee 9.9. "2008 ASHRAE Environmental Guidelines for Datacom Equipment." ASHRAE 2008: 1-11.

3.4.1. Low-Cost Improvements

The Data Center Improvements EEM can therefore be broken down into three (3) distinct tasks, described in the following sections.

Sunport could see immediate energy savings and improved server conditioning by making the following low cost changes to the data center environment:

- Move racks and/or perforated tiles to create a cold/hot aisle arrangement such that the front of the server racks is adjacent to the perforated tile and the servers' internal fan can blow the cold air across the server and out into the hot aisle shown at below[9].
    - Make sure to provide sufficient tiles across the whole aisle to ensure the cabinets will all get sufficient airflow.
    - Double check airflow distribution using a thermal imaging camera to ensure no significant hot spots
- Block off empty server spaces in cabinets to prevent cold airflow from passing through
- Gradually increase space temperature to near ASHRAE recommended settings.
    - Double check thermal imaging and monitor equipment carefully to ensure no IT equipment issues are created.
- Install a wall-mounted ultra-sonic motion sensor in place of the current toggle light switch.
    - Make sure device has override capability (e.g. button) and set for a 30-minute delay. This should provide sufficient lighting time for periods where people enter the space
    - Using a light-meter to measure brightness, gradually de-lamp fixtures and/or re-arrange fixture locations to provide appropriate, though not over-lit lighting levels.

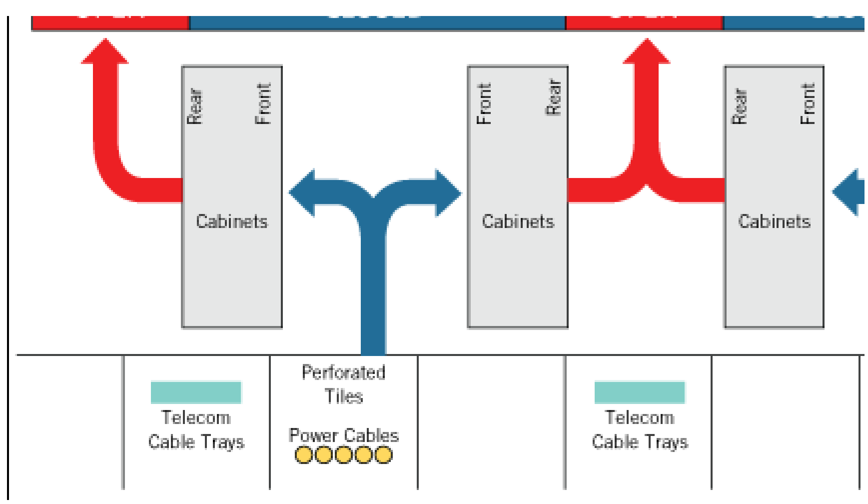


Figure 15: Data Center Aisle Arrangement Concept

[9] http://fibertown.com/data-center/cooling

3.4.2. Cold-aisle Enclosure

Further CRAC energy savings, CRAC redundancy, and server environment benefits could be achieved by installing physical cold aisle containment devices, such as those shown in the below figures[10].

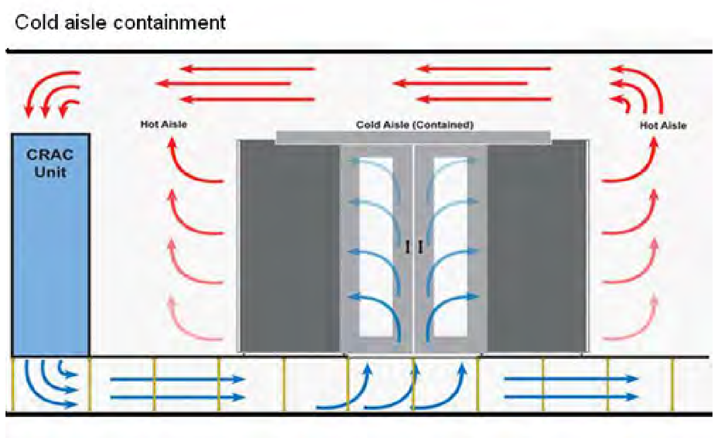


Figure 16, 17: Data Center Cold Aisle Enclosure Concept

This will ensure that servers see only cold supply air. It will also increase the temperature difference of the supply and return air, which will allow the CRAC unit(s) to run more efficiently. The CRAC units can also provide warmer supply air temperatures, which will increase CRAC efficiency. Unfortunately, a variable speed fan application was not feasible.

Information on aisle containment systems can be found in Appendix B. Through conversations with Critical System mechanical contractors, Quest was told that there a variety of solutions available in the marketplace that customers are doing with various price points. An estimated price of $10,000 was included in the economic analysis for this EEM. At that price the total savings for 3.4.1 and 3.4.2 would be $1,500 annually with an estimated utility rebate of $1,600.

3.4.3. High efficiency CRAC unit replacement

With the current Stulz CRAC units being only 5-6 years old (per conversation with manufacturer's rep – Johnston Co.), the units still have several more good years in them before they'll be due for replacement.

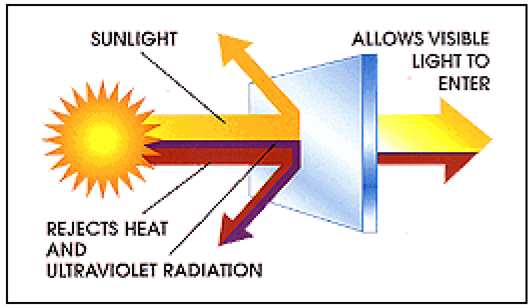
When that eventually comes, Quest recommends Sunport consider the following high efficiency upgrades that come as options on CRAC units from the various CRAC manufacturers (Liebert, Stulz, Data-Aire, etc.).

- Electrically commutated motor plug fans (for load matching and flow balancing)
- Hot gas reheat for dehumidification
- Free-cooling / economizer option

[10]http://www.ait-pg.co.uk/data-centre-services/hot-cold-aisle-containment/

3.5. Window Film

Many of the windows on the main terminal have southern and western exposure, making them susceptible to high solar gains and uncomfortably warm indoor temperatures near the glass. Adding to this is the vintage of the windows themselves, which are representative of the era they were installed (1985-89) and not nearly as efficient as current options. The options to save energy and improve thermal comfort are to either replace the windows, add external shading devices, or add a window film.



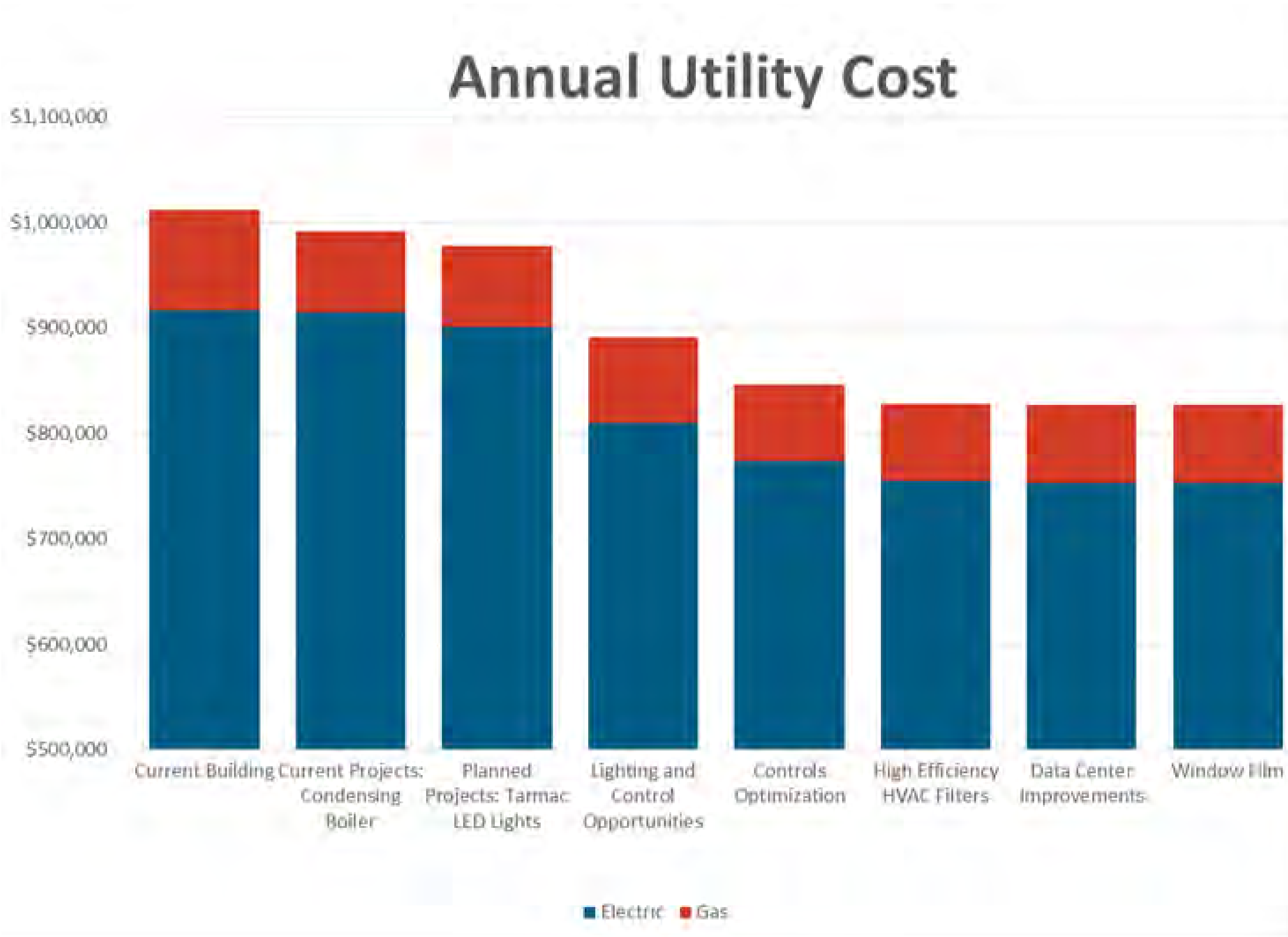
Window replacements are never cost effective from an energy standpoint, and the projects can be disruptive in occupied spaces. External shading devices offer good performances from an energy perspective and can be cost-effective, but impact the view ability of guests; a concept that is not ideal at an airport. The remaining option is window film, which usually involves the application of a highly engineering film that reduces solar gain to the inside face of the glass. The film will reduce the amount of solar radiation entering the glass, as well as improve the glare.

Good window film products are designed for use in commercial buildings and have an extended warranty. The current glass is estimated to have a solar heat gain coefficient (SHGC) of 0.50. A window film that would lower the SHGC to 0.32 would save approximately $300 year in annual savings, and would potentially qualify for a $X incentive from PNM. Other benefits include improved occupant comfort and less UV damage to furniture and interior components. The estimated cost for install is approximately $0.60/sf is typical for the example window film. Window film information from 3M can be found in Appendix H.

Analysis Results

Results of the analysis are summarized in the table and figure below. Sunport has the potential to reduce the energy use of the main terminal, rental car center, and original terminal by 18% combined through strategic investment in the EEMs described. These EEMs are a combination of short-term and long-term capital projects and operation/maintenance related work.

EEM Number	EEM Description	Estimated Investment ($)	Annual Operational Cost Savings ($)	Utility Cost Savings ($)	Potential Incentive ($)	Simple Payback (Years)
1.1	Current Projects: Condensing Boiler	N/A	N/A	$20,600	$0	N/A
2.1	Planned Projects: Tarmac LED Lights	Unknown	$200	$14,300	$16,100	Unknown
3.1	Lighting & Control Opportunities	$419,345	$7,000	$86,400	$59,300	4.1
3.2	Controls Optimization	215,600	$0	$44,800	$43,200	3.8
3.3	High Efficiency HVAC Filters	20,000	$10,000	$17,900	$17,000	Immediate
3.4	Data Center Improvements	10,000	$0	$1,500	$1,600	5.6
3.5	Window Film	2,300	$200	$300	$500	5.3
	Totals:	**$667,245**	**$17,200**	**$150,900**	**$121,600**	**3.6**



Renewable Energy

In addition to the EEMs, Quest Energy examined Sunport's site for renewable energy opportunities. There are two categories of projects that were examined and quantified:

ECM Number	Solar Project Description	Sunport Energy Use kWh	Project Solar Production kWh	Total Solar Production kWh	% Renewable
0.0	Current PV System	14,855,071	N/A	2,480,000	17%
3.4	After Recommended ECMs	12,906,650	N/A	2,480,000	19%
4.1	Rental Car PV Retrofit	12,906,650	294,800	2,774,800	21%
4.2	Credit Card Lot Expansion	12,906,650	1,865,600	4,640,400	36%
4.3	4MW Expansion - Sunport & University	12,906,650	8,479,000	13,119,400	100%

1. Expanding the existing fixed-tilt PV concept to other available parking and empty land. The two areas that were examined closely are:
   a) The NE corner of Sunport and University Blvd (Figure 18).
   b) The credit card parking lot (Figure 19)
2. Converting the rental car facility's tracking solar thermal system (on the non-functioning absorption chiller) to a tracking PV system.

Figure 18: Potential solar site at NE corner of Sunport and University

Figure 19: Potential solar expansion at credit card lot

4. Expansion of PV Infrastructure

As described earlier, Albuquerque has an outstanding climate for solar PV systems and Sunport's existing ~1MW solar infrastructure is a prime example of the airport taking advantage of the plentiful regional solar energy. While Sunport has several parcels of available land that could hypothetically support PV equipment, there are several site-specific constraints that would need to be cleared for the project to be feasible. Some of these constraints include the following:

- Federal Aviation Administration (FAA) regulations for glare and other flight impact issues.
- Taxpayer / public approval of funding
- Other land development options
- Utility connectivity and / or production arrangements
- Other airport operational constraints

Assuming these issues were addressed, Quest conducted analysis into the energy potential and basic feasibility for two sites that Sunport personnel and/or other consultants mentioned existing interest in developing solar projects.

4.1. NE corner of Sunport and University Blvd

This approximately twenty-two (22) acre parcel is a former landfill site that has limited future use for land development. Sunport personnel communicated that the first preference for this site would be a solar field. Solar fields typically can house about 1 kW per 200 ft^2 of solar capacity. This site would then have almost 4.7 MW of solar power potential, which would translate to 8,177,800 kWh per year or about $572,400 per year in utility production (at $0.07/kWh). This would be almost five (5) times the current amount of solar capacity, and would give Sunport almost enough renewable energy to become the first major net-zero airport in the world[11]. Solar calculations as well as economic analysis for this site can be found in Appendix E.

This site would likely have to undergo FAA studies for glare and other factors to get approval from that agency, however, perhaps the most formidable challenge would be the utilities connection agreements. Sunport personnel indicated some potential issues in bringing a large scale solar production site online. These issues include, but may not be limited to PNM connection agreements as well as Sunport's limitations to become a "utility".

Such issues may be mitigated if the project can form a power-purchase agreement (PPA) with a third-party developer. This would theoretically enable Sunport to lease the land to the developer (solar services provider), who would build, own, and maintain the solar equipment. The solar services provider would then sell the produced energy back to Sunport at a set rate. The advantage of this approach is that the solar services provider could take advantage of tax credits lowering the net cost of the project[12], while potentially side-stepping some of the utility issues Sunport would encounter if the site was developed as a Sunport-owned facility.

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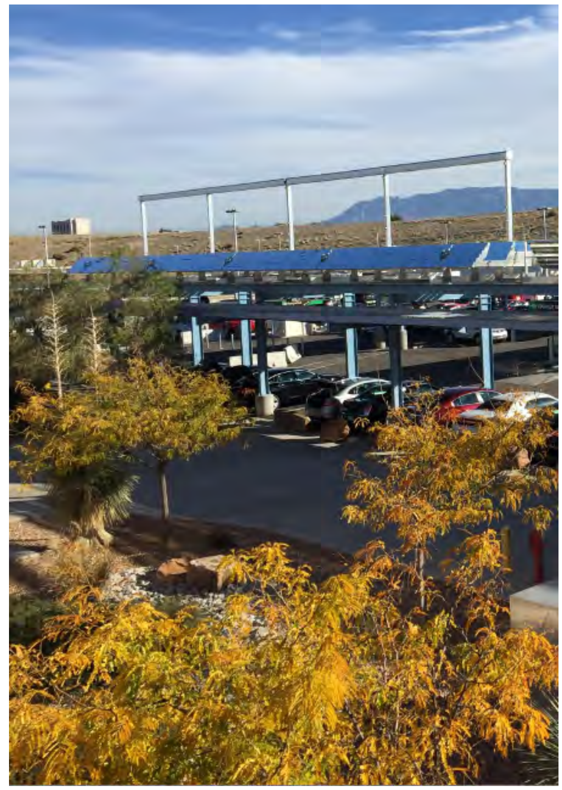
[11] Yu, Alan. "Net Zero Energy Plans at Airports Ready for Takeoff." Net Zero Energy Plans at Airports Ready for Takeoff. Northwestern University, 8 Nov. 2012. Web. 20 Oct. 2015.

[12] "Solar Power Purchase Agreements." Solar Power Purchase Agreements. United States Environmental Protection Agency, n.d. Web. 20 Oct. 2015.

Note the solar calculations found in the Appendix currently assume a cash purchase, rather than a PPA for simplicity. Further analysis into the feasibility of the PPA is out of Quest's scope for the audit, but Quest does recommend this concept be investigated further by Sunport's team.

4.2. Credit card parking lot



This measure evaluates the potential of building a fixed tilt solar system at the credit card parking lot as a form of covered parking. This is similar in concept to what has been done at other ABQ parking lots, as shown in the photo on right.

These systems are spaced to accommodate the flow of traffic and parking spaces, so the solar density is less than the earlier mentioned solar field option, and would be approximately 1kW per 365 ft^2.

Therefore, at the 9.75 acre credit card parking lot, it's assumed that 1.166 MW of solar capacity could be installed. Such as system could potentially produce approximately 2,000,000 kWh/year or about $140,000/year (at $0.07/kWh).

Arrangements for a PPA, as may be necessary in the larger solar field project previously mentioned, may not be required for a smaller parking lot system. However, arrangements on the metering side would need to be made with PNM to ensure the produced solar energy is counted against the large energy use meters found in the main terminal's several Power Centers. If this is not accounted for and the solar energy is bought back by the utility, the economics of the project can be ruined, as the utility buy-back rate is usually several magnitudes below the retail rate. The full energy and economic analysis for this project can be found in Appendix E.

4.3. Rental Car Tracking System Conversion

This project involves retrofitting the existing solar thermal tracking system that was built to use with the non-functioning absorption chiller system to a tracking PV solar system. Per Sunport personnel, the absorption chiller system is from a company that's no longer in business and therefore, the equipment, parts, and operation has no available support for technical issues. Additionally, because the company and/or design had European principals, the sizing of the parts in the system use metric measurements so off-the-shelf parts are not feasible. Altogether, per Sunport personnel, this system does not currently have a future of any further use as the repair and maintenance are too time and cost intensive for the system's value.

For these reasons, Quest recommends converting the tracking system to a tracking solar PV system. A tracking solar system has north-south axis alignment, instead of the traditional east-west of a south-facing fixed tilt system. The PV modules on a tracking system will follow the sun's position over the course of the day using a "tracker" or gearbox driven system that rotates the axis with the solar position, maximizing the optimum solar angle (angle of incidence) needed for maximum solar production. A tracking system in Albuquerque is estimated to produce approximately 30% more energy than a fixed-tilt system.

Normally, tracking PV systems are not cost effective for small systems due to their high initial cost and are usually only reserved for larger utility scale projects. Since the tracking infrastructure is already there, and apparently in good working order, a tracking PV system could equipped much more cost effectively. This system will likely still be more expensive (up to 25% estimated) than a normal fixed-tilt PV system, due to potentially trickier working conditions and more mechanical work. The increased solar production from the tracking system should offset this added cost.

Overall, it's estimated that a tracking PV system on this system would have a total capacity of approximately 134 kW_{DC}, which would produce approximately 300,000 kWh/yr or $21,000 in utility cost savings (at $0.07/kWh). Such an innovative and unique system should also be show-cased as a symbol of Sunport's commitment and progress toward sustainability, which may carry public relation and other positive benefits. The economic and energy analysis can be found in Appendix E.

Appendix A – Building Controls Documentation

See attached.

Appendix B – Data Center Equipment Information

See attached.

Appendix C – Lighting Audit Results

See attached.

Appendix D –Efficient HVAC Filters Documentation

See attached.

Appendix E –Solar Documentation

See attached.

Appendix F –BAS Screenshots & Trend Logs

See attached.

Appendix G –Utility Incentive Information

See attached.

Appendix H –Window Film Product Information

See attached.

Appendix A – Building Controls Documentation

Eco-Screen® Sustainability Kiosk

A Simple, Powerful Way to Promote Your Sustainability Measures

The Eco-Screen® sustainability kiosk is a powerful tool that enables building owners to showcase their properties' energy conservation and sustainability measures. By hosting Eco-Screen on a large touch screen kiosk in your facility's lobby or common area, you'll introduce visitors to your building's sophisticated operating systems, providing the public with an interactive and dynamic presentation of its most innovative green building features.

Key Features and Benefits

- Connects to WebCTRL® building automation system to monitor energy data.
- Dynamic color graphics bring the building to life, making its behind the scenes workings engaging and interactive.
- Displays data including current energy and water usage, reductions in CO2 emissions, outdoor air conditions (temperature, humidity, wind direction/speed).
- Provides historical data for energy consumption and outdoor air temperatures by hour, day, week, month or year. Also features historical highs and lows, total precipitation and weather trends.
- Informs users and visitors about your organization, its history, programs, goals and objectives to increase understanding about its environmental impact.
- Provides important information about your organization or facility including company and building directories, room schedules, virtual tours, local resources and amenities, and more.
- Builds awareness of LEED® certification requirements, ENERGY STAR® criteria and your sustainability goals.
- Compares the energy savings of your energy efficient building, using measurement gauges and graphs with a conventional building that has not received energy upgrades.
- Easily customized, allowing you to change content as needed to keep information current and relevant.
- Educates building occupants about the mechanical systems in the facility.
- Included with the Eco-Screen Sustainability Kiosk version is a web version that can be optionally enabled and accessed on web browsers.

AUTOMATEDLOGIC
United Technologies

1150 Roberts Boulevard
Kennesaw, Georgia 30144
770/429-3000
Fax 770/429-3001

www.automatedlogic.com

Eco-Screen® Sustainability Kiosk

A Simple, Powerful Way to Promote Your Sustainability Measures

With a simple touch of the interactive screen, visitors gain immediate access to the building systems and the energy-efficient operations you'll want to showcase. The Eco-Screen sustainability kiosk launches with a Home screen slide show that can be easily customized to communicate the unique story of the green technologies employed in your facility. Your sustainability and renewable energy message is conveyed throughout with images, animated graphics in a touch-based interface that educate the viewer on activities such as solar power generation, rainwater and daylight harvesting plus other initiatives taken to ensure a positive impact on nature and the environment.

You've made an investment by building or retrofitting a more energy-efficient facility. Now is your opportunity to educate visitors about the integrated systems in your building and the effects they have on the environment and your community.

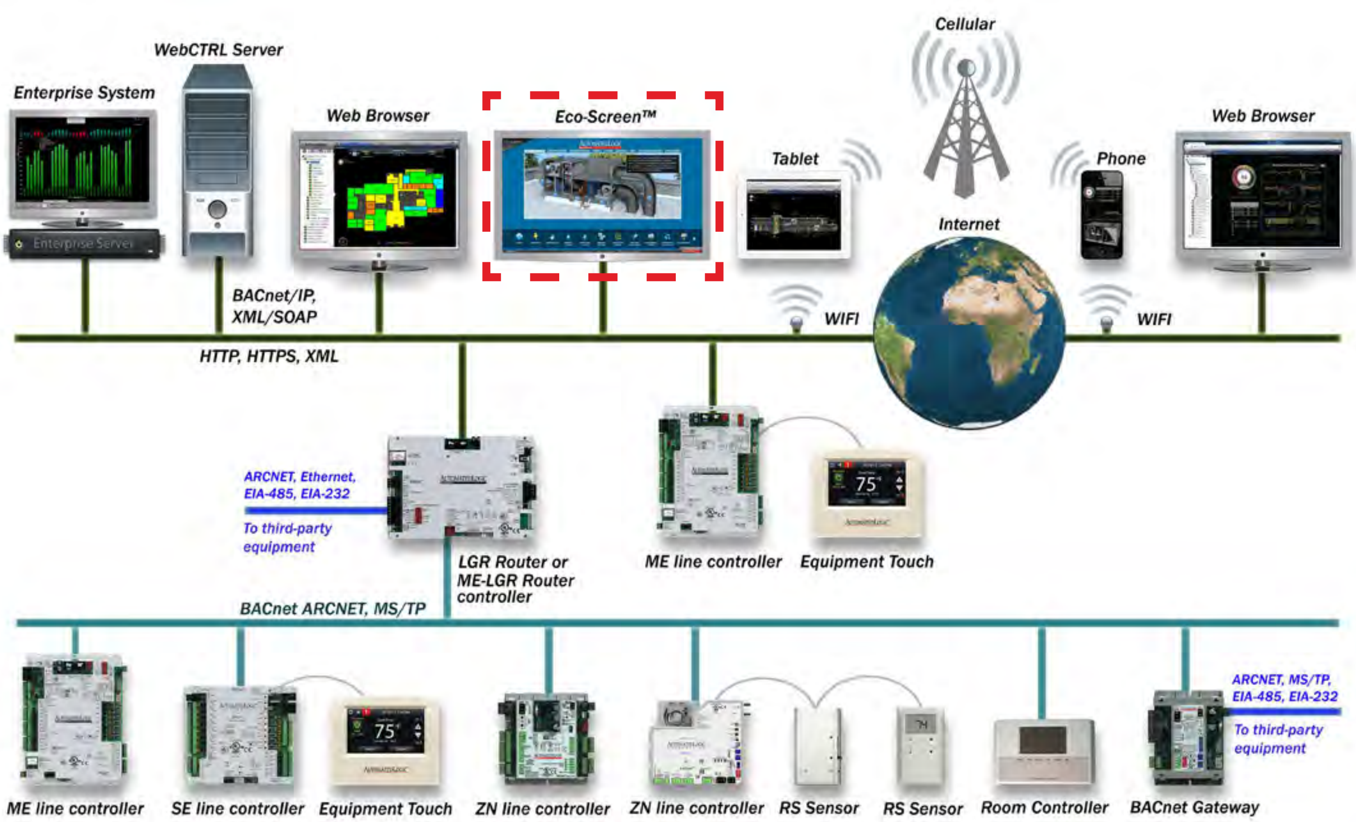
Application Information:

Requirements:

Kiosk Version - WebCTRL® Enterprise; one or more 1080P touch screen monitors

Web Version - WebCTRL® Enterprise; and an intranet or internet connection

- Browsers Supported: Internet Explorer®; Chrome™; Firefox®



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ECO_CS_r2

EnergyReports™ Web Application

A Tool for Sustainable Building Operations

Facility and energy managers now have a powerful tool in their arsenal to minimize energy consumption, maximize comfort, and achieve sustainable building operations.

Automated Logic's EnergyReports web application is an incredibly flexible and easy-to-use reporting tool that uses the WebCTRL system's extensive trending capabilities for metering energy consumption and our Environmental Index™ feature for measuring comfort.

Key Features and Benefits

- Animated energy consumption or demand reports available in 3D bar, line, pie chart, or tabular data
- Easy and convenient access using multiple Internet browsers
- Attractive and intuitive user interface with system tree display designed for simplicity of use
- Energy consumption can be normalized by area or converted to other engineering units (ex. CO_2)
- Includes occupied/unoccupied usage, Cooling Degree Days (CDD) and Heating Degree Days (HDD), low-median-high data, and benchmark data for comparison
- Integrates the Environmental Index feature into energy reports, enabling you to intelligently compare efficiency with comfort
- Adobe Acrobat and Microsoft Excel reports generated on both client and server archive
- JAVA application design to easily integrate with the WebCTRL system's energy data
- Easily installs on existing WebCTRL system server – no additional server or integration with third-party software required
- Integrated Report Manager for scheduling reports on a monthly, quarterly or yearly basis
- Supports energy and water sub-metering
- Existing utility data can easily be imported via MS Excel spreadsheet

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EnergyReports™ Web Application

A Tool for Sustainable Building Operations

EnergyReports is a JAVA webapp that runs concurrently with the WebCTRL system, offering access to key environmental reports through Internet Explorer or Firefox browsers. All consumption and demand data for electricity, gas, oil, steam, or chilled water is stored in a dedicated industry standard database. Metered energy sources are easily configured and assigned to building or area levels in the EnergyReports webapp user tree. Designed for use in single- or multiple-building campuses, the EnergyReports webapp plugs directly into existing WebCTRL systems with minimal setup, and it is ideal for WebCTRL system retrofit or new construction projects. Animated graphical icons make selection of energy types, meters for different energy types and sub-metered sources easy.

The EnergyReports webapp enables users to compare energy consumption or demand over different periods with drop-down menus or to create custom periods using the calendar control. Dynamic and animated three-dimensional color graphs are quickly rendered in bar, line, pie, or tabular data format. A single mouse click enables the user to normalize consumption data, convert to cost in terms of currency or carbon dioxide emissions or change engineering units on the fly! Energy consumption can be benchmarked and compared to validated data or to similar buildings in your area using a simple animated toolbar. Similarly, occupied vs. unoccupied building energy usage can be differentiated visually. Cooling Degree Days and/or Heating Degree Days are calculated automatically and displayed graphically over the review period with a single mouse click.

Soaring energy prices and a growing environmental consciousness have renewed everyone's focus on minimizing building energy consumption and maximizing energy efficiency. Facility managers know too well that sacrificing human comfort costs even more in terms of lost productivity and revenue. Our Environmental Index feature provides a simple and effective solution for measuring comfort in a building or space because energy efficiency must be balanced with comfort.

The EnergyReports webapp can display energy consumption with the Environmental Index feature, enabling a direct comparison of energy efficiency to comfort. Achieving sustainable building operation becomes much easier with the EnergyReports webapp.

And to make operations even easier, the EnergyReports webapp includes a Report Manager so that recurring monthly, quarterly or yearly reports can be scheduled and automatically sent to designated personnel via email in Adobe PDF and/or Microsoft Excel format. Archived reports can be custom labeled, sorted by author and easily retrieved using the integrated Report Manager.

Application Information:

WebCTRL software v5 with the Java API and Enterprise license

EnergyReports webapp Java applications run concurrently with WebCTRL software

Databases supported: MySQL 5.0, PostgreSQL 7.4, Oracle 10g or SQL Server 2008 or later version

Browsers supported: Internet Explorer 9.x and Firefox 7.x. User Access: Concurrent sign-on via privileges in WebCTRL sofware

Automated Logic Corporation . 1150 Roberts Boulevard . Kennesaw, Georgia 30144 . 770/429-3000 . Fax 770/429-3001 . www.automatedlogic.com

ER_CS_r5

From: aduran@icsicontrols.com [mailto:aduran@icsicontrols.com]
Sent: Tuesday, October 13, 2015 11:28 AM
To: Craig Green <craig@questenergy.com>
Cc: 'Mike Aultman' <maultman@icsicontrols.com>; 'Leroy Lucero' <llucero@icsicontrols.com>
Subject: RE: Automated Logic Upgrade Costs

Hello Craig,

Mike has sent your inquiry my way regarding some Automated Logic (ALC) WebCTRL energy add-on pricing and information. As I am sure you know there are many variables that will need to be investigated and taken into consideration in order to provide accurate pricing per your request.

I am not sure how familiar you are with the Automated Logic products but I have attached two of ALC's energy add-on cut sheets which are the ALC Eco Screen (Lists @ $17,800.00) and then of course ALC Energy Reports (Lists @ $5,750.00) which you previously mentioned. Of course labor for configuration, programming, graphics, and database set-up would be dictated by how many points, programs, or zones that would be utilized for the ALC add-on feature.

In regards to adding power monitoring to fans, pumps, & chillers, etc. This too is has many variables. To give you a ball park estimate for preliminary purposes, based off power monitoring we do for another customer, we typically fall in the $7,500 range to monitor incoming power for a facility (600A CT's) with an existing ALC integration device. Actual pricing will vary based off of CT Amperage sizing and if there is an available ALC device to pull the data into the BAS.

I hope this helps, let me know if there is anything else I can do to assist.

Respectfully,

Alex A. Duran
Service Manager

P: 505.830.5938
M: 505.803.0883
F: 505.883.0130
aduran@icsicontrols.com

4020 Vassar Dr NE, Suite H
Albuquerque, NM 87107

From: Mike Aultman [mailto:maultman@icsicontrols.com]
Sent: Tuesday, October 13, 2015 10:49 AM

To: aduran@icsicontrols.com; Leroy Lucero
Subject: FW: Automated Logic Upgrade Costs

Craig Green who is doing the AIS energy report is asking for these cost. Can you let me know what we would charge for this.

From: Craig Green [mailto:craig@questenergy.com]
Sent: Tuesday, October 13, 2015 10:27 AM
To: Mike Aultman
Subject: Automated Logic Upgrade Costs

Mike –

Approximately how much would it cost to add power monitoring (e.g. CTs) for fans/pumps/chillers and bring them into the BAS? Also, how much would it cost to add in analytic programs like AutomatedLogic's Energy Reports?

Craig Green, PE

Quest Energy Group, LLC
1620 W Fountainhead Pkwy #303
Tempe, AZ 85282
Ph 480.467.2480
Fax 480.336.2291
Cell 928.699.1369
craig@questenergy.com
www.questenergy.com

Staff	Principal	Senior Engineer	Analyst	Admin	Extended
Hourly Rate	$ 150	$ 125	$ 100	$ 50	$
Task 1					
Functional Testing					$ -
Typical AHU FPT (Assume 5)		40			$ 5,000
PTP Testing		80			$ 10,000
Zone Testing and Analysis		32	32		$ 7,200
Central Plant Testing		16			$ 2,000
Additional Diagnosis		16			$ 2,000
Documentation		24	16		$ 4,600
Travel		16			$ 2,000
Site Prep		8	8		$ 1,800
Subtotal	**0**	**232**	**56**	**0**	**$ 34,600**

Expenses	Flight	6	$ 250	$/rnd trip flt	$ 1,500
	Hotel	10	$ 125	$/nite	$ 1,250
	Meals	30	$ 50	$/day	$ 1,500
	TAB Contractor	16	$ 100	$/hr	$ 1,600
	Electrical Contractor				$ 20,000
	Control/HVAC Contractor	30	$ 100	$/hr	$ 3,000
					$ 28,850

Task 2					
Implementation					$ -
Manage Issue Log Repairs		16			$ 2,000
Write Programming	8	32			$ 5,200
Add Programming		48			$ 6,000
Documentation		24	16		$ 4,600
Contigency Fixes / Training		40			$ 5,000
Travel		6			$ 750
Site Prep		4	4		$ 900
Subtotal	**8**	**170**	**20**	**0**	**$ 24,450**

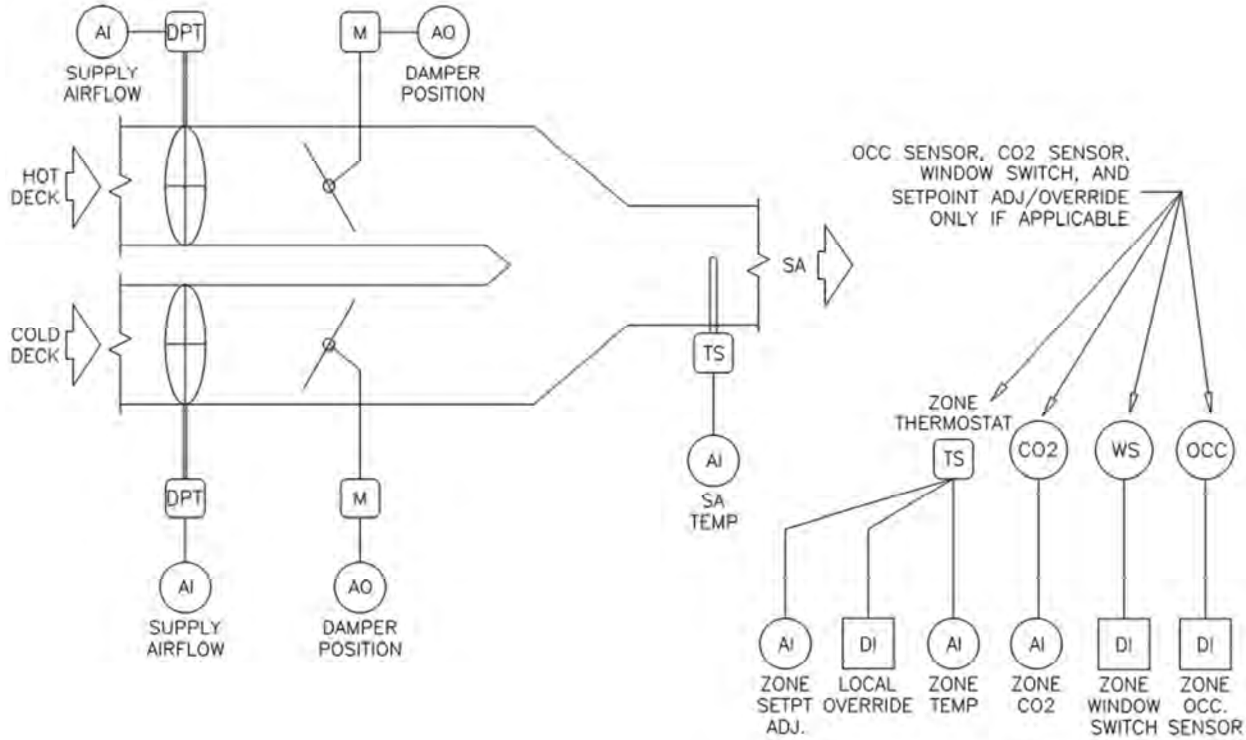
Expenses	Flight	2	$ 250	$/rnd trip flt	$ 500
	Hotel	4	$ 125	$/nite	$ 500
	Meals	6	$ 50	$/day	$ 300
	Control/HVAC Cont	48	$ 100	$/hr	$ 4,800
					$ 6,100

Task 3						
Closeout / Training / Cont's Cx						
Operator Training		16			$	2,000
Documentation		16			$	2,000
Travel		3			$	375
Site Prep		4			$	500
Subtotal	0	39	0	0	$	4,875
Expenses	Flight	1	$ 250	$/rnd trip flt	$	250
	Hotel	1	$ 125	$/nite	$	125
	Meals	6	$ 50	$/day	$	300
					$	**675**
Total Project	8	441	76	0	$	63,925
Expenses	Flight	9	$ 250	$/rnd trip flt	$	2,250
	Hotel	15	$ 125	$/nite	$	1,875
	Meals	42	$ 50	$/day	$	2,100
	Other				$	29,400
					$	35,625
				Grand Total:	**$**	**99,550**

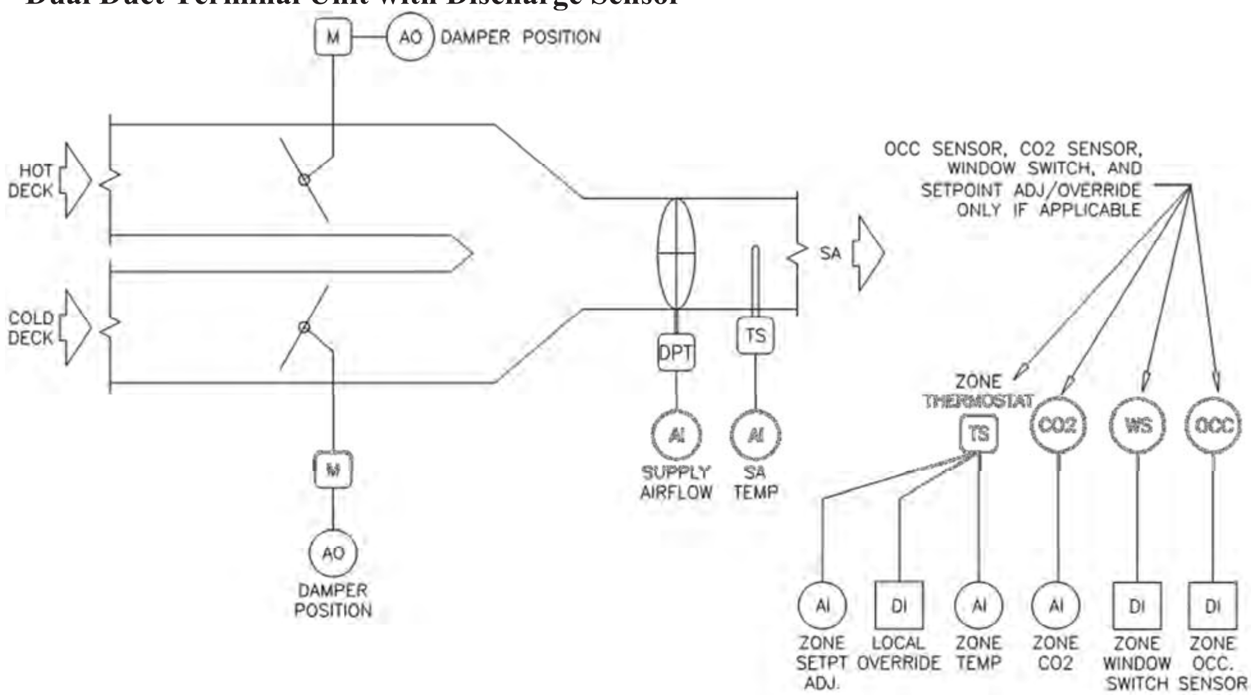
ASHRAE RP-1455: Advanced Control Sequences for HVAC Systems
Phase I, Air Distribution and Terminal Systems

TABLE OF CONTENTS

E. Dual Duct Terminal Unit with Inlet Sensors



F. Dual Duct Terminal Unit with Discharge Sensor



Snap Acting Control logic is the first choice among the various DD control schemes – it is the most efficient and does not require DD boxes with mixing sections which have a high pressure drop. It allows use of dual standard airflow sensors, one at each inlet, with standard pressure independent logic blocks; alternatively, a single discharge airflow sensor may be used.
However, snap acting logic is not ideal for CO_2 control because it can cause the zone to oscillate between Cooling and Heating. This occurs when the CO_2 control pushes the Vmin up to Vcool-max; at that point temperature control is lost and if the space is overcooled, it will be pushed into Heating, where it will be overheated, then back again. If CO_2 demand controlled ventilation is required, the mixing logic described in the next section should be used.*
This logic assumes no ability to mix hot and cold air to prevent overly low supply air temperatures which may occur on systems with high outdoor airflows and no preheat coil. So a preheat coil is likely to be required on such systems if mixed air temperature can fall below 45°F or so in winter.
Note that snap acting logic can also be problematic for zones with high minimums, since the room itself is acting as the mixing box.
Because no cold duct air is supplied during heating mode, the heating system must include ventilation air either with direct outdoor air intake or indirectly via transfer air from over-ventilated spaces on the same system. Refer to Standard 62.1 and the Standard 62.1 User's Manual.

I. Dual Duct VAV Terminal Unit – Snap Acting Control

1. See Generic Thermal Zones for setpoints, loops, control modes, alarms, etc.

2. Design airflow rates shall be as scheduled on plans:

   a. Zone maximum cooling airflow setpoint (Vcool-max)

   b. Zone minimum airflow setpoint (Vmin)

   c. Zone maximum heating airflow setpoint (Vheat-max)

3. See 1.3B.2 for calculation of zone minimum outdoor airflow.

4. The occupied cooling minimum Vmin* shall be equal to Vmin except as follows:

   a. If the zone has an occupancy sensor, Vmin* shall be equal to Varea-min (if ventilation is according to California Title 24) or V_{oz} (if ventilation is according to ASHRAE Standard 62.1) when the room is unpopulated.

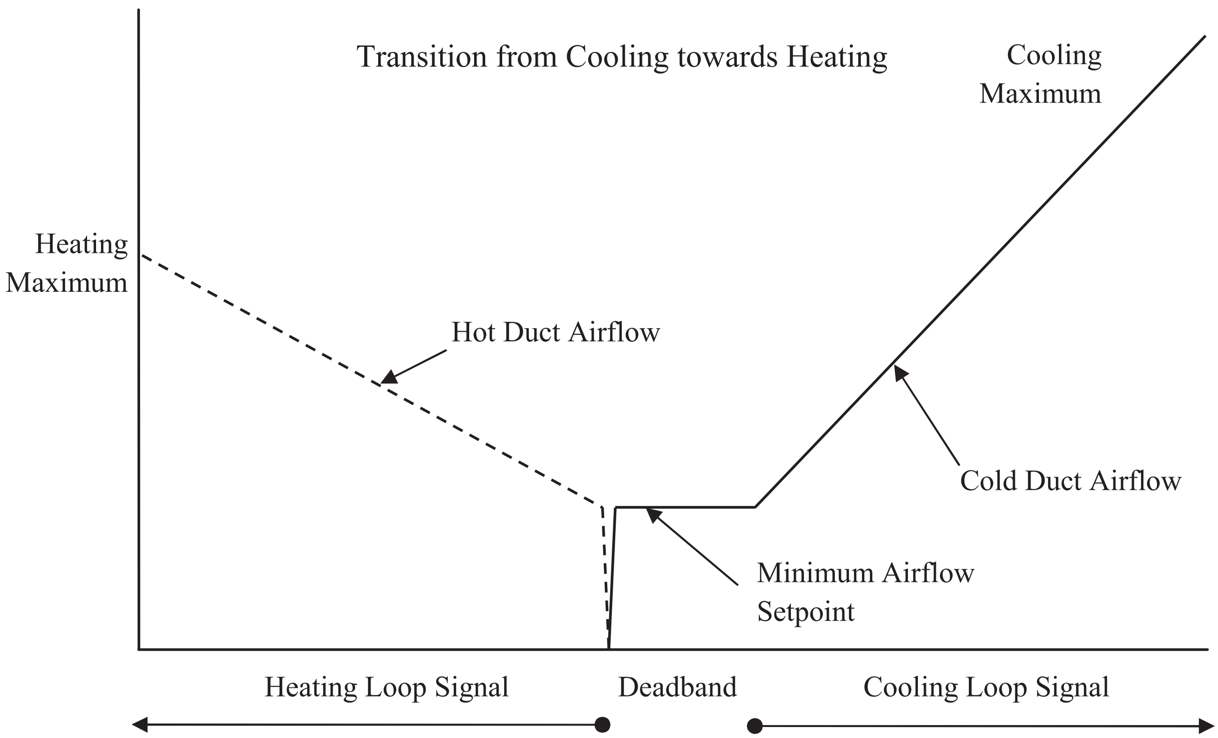
   b. If the zone has a window switch, Vmin* shall be zero when the window is open.

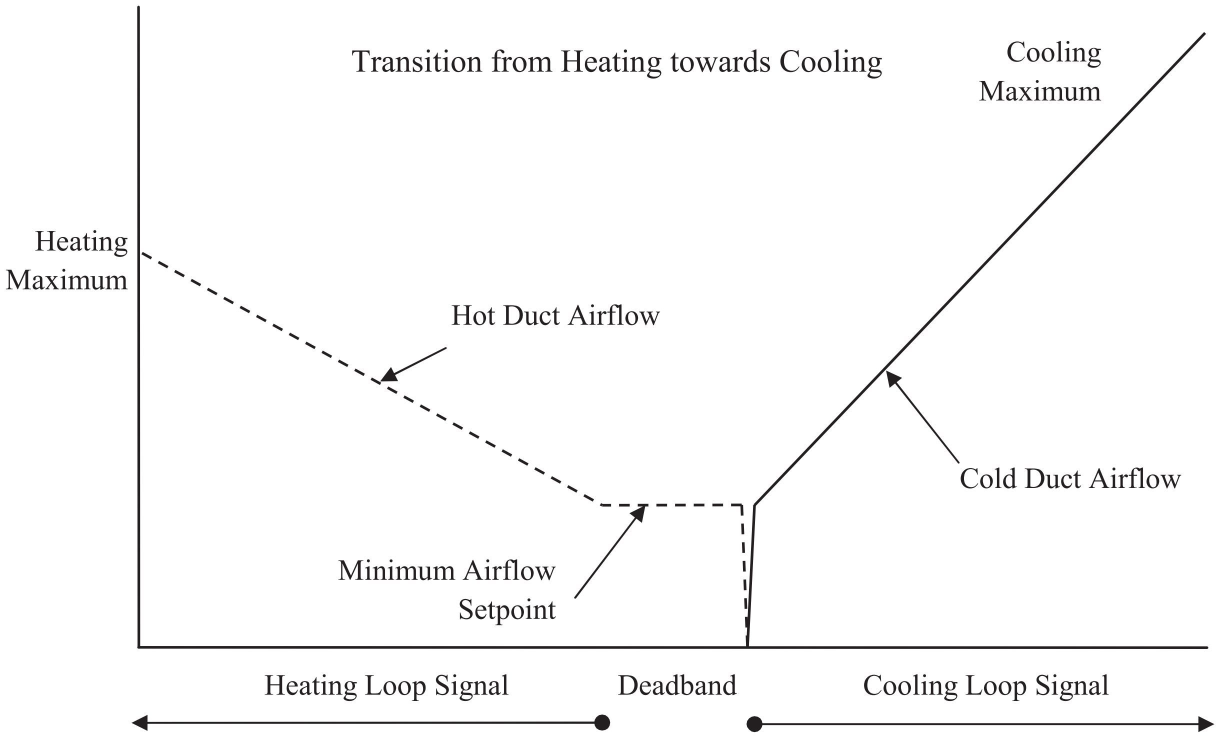
   c. If Vmin is non-zero and less than the lowest possible airflow setpoint allowed by the controls (Vm), Vmin* shall be set equal to Vm. The minimum setpoint Vm shall be determined in accordance with 1.3D.4.c above.

5. Active maximum and minimum setpoints shall vary depending on the Mode of the Zone Group the zone is a part of:

Setpoint	Occupied	Cool-down	Setup	Warm-up	Setback	Unoccupied
Cooling maximum	Vcool-max	Vcool-max	Vcool-max	0	0	0
Minimum	Vmin*	0	0	0	0	0
Heating maximum	Vheat-max	0	0	Vheat-max	Vheat-max	0

6. Control logic is depicted schematically in the figures below and described in the following sections. Relative levels of various setpoints are depicted for Occupied Mode operation.





If the terminal unit is equipped with airflow sensors at both inlets, use paragraph a *and delete paragraph* b.

a. Temperature and Damper Control with dual inlet airflow sensors:

1) When the zone is in Cooling, the Cooling Loop output shall reset the cooling supply airflow setpoint from the minimum to cooling maximum setpoints. The cooling damper shall be modulated by a control loop to maintain the measured cooling airflow at setpoint. The heating damper shall be closed.

a) If cold deck supply air temperature from air handler is greater than room temperature, Cooling shall be locked out.

2) When the zone is in Heating, the Heating Loop output shall reset the heating supply airflow setpoint from the minimum to heating maximum setpoints. The heating damper shall be modulated by a control loop to maintain the measured heating airflow at setpoint. The cooling damper shall be closed.

a) If hot deck supply air temperature from air handler is less than room temperature, Heating shall be locked out.

3) When the zone is in Deadband, the cooling and heating airflow setpoints shall be their last setpoints just before entering Deadband. In other words, when going from Cooling to Deadband, the cooling airflow setpoint is equal to the zone minimum and the heating setpoint is zero. When going from Heating to Deadband, the heating airflow setpoint is equal to the zone minimum and the cooling setpoint is zero. This results in a snap-action switch in the damper setpoint as indicated in the figures above.

If the terminal unit is equipped with airflow sensors at both inlets, use paragraph b *and delete paragraph* a *above.*

b. Temperature and Damper Control with a single discharge airflow sensor:

1) When the zone is in Cooling, the Cooling Loop output shall reset the discharge airflow setpoint from the minimum to cooling maximum setpoints. The cooling damper shall be modulated by a control loop to maintain the measured discharge airflow at setpoint. The heating damper shall be closed.

2) When the zone is in Heating, the Heating Loop output shall reset the discharge airflow setpoint from the minimum to heating maximum setpoints. The heating damper shall be modulated by a control loop to maintain the measured discharge airflow at setpoint. The cooling damper shall be closed.

3) When the zone is in Deadband, the discharge airflow setpoint shall be the zone minimum, maintained by the damper that was operative just before entering Deadband. The other damper shall remain closed. In other words, when going from Cooling to Deadband, the cooling damper shall maintain the discharge airflow at the zone minimum setpoint and the heating damper shall be closed. When going from Heating to Deadband, the heating damper shall maintain the discharge airflow at the zone minimum setpoint and the cooling damper shall be closed. This results in a snap-action switch in the damper setpoint as indicated in the figures above.

7. Alarms

a. Low Airflow

1) If the measured airflow is less than 70% of setpoint for 5 minutes, generate a Level 3 alarm.

2) If the measured airflow is less than 50% of setpoint for 5 minutes, generate a Level 2 alarm.

3) If a zone has an Importance multiplier of 0 [see 1.3A.11.b.1)a)] for its static pressure reset Trim & Respond control loop, low airflow alarms shall be suppressed for that zone.

b. Airflow sensor calibration. If the fan serving the zone has been off for 10 minutes and airflow sensor reading is above 20 CFM, generate a Level 3 alarm.

Per 1.3A.9, all hardware points can be overridden through the EMCS. Each of the following points is interlocked so that they can be overridden together at a Zone Group level, per 1.3C.6.
E.g. The CxA can check for leaking dampers by forcing all VAV boxes in a Zone Group closed and then recording airflow at the AHU.

8. Testing/Commissioning Overrides: Provide software points that interlock to a system level point to

a. Force zone airflow setpoint to zero

b. Force zone airflow setpoint to Vcool-max

c. Force zone airflow setpoint to Vmin

d. Force zone airflow setpoint to Vheat-max

e. Force cooling damper full closed/open

f. Force heating damper full closed/open

g. Reset request-hours accumulator point to zero (provide one point for each reset type listed below)

9. System Requests

a. Cooling SAT Reset Requests

1) If the Cooling Loop is less than 85%, send 0 Requests.

2) If the Cooling Loop is greater than 95%, send 1 Request.

3) If the zone temperature exceeds the zone's cooling setpoint by 3°F for 2 minutes, send 2 Requests.

4) If the zone temperature exceeds the zone's cooling setpoint by 5°F for 2 minutes, send 3 Requests.

b. Cooling Static Pressure Reset Requests

1) If the Damper Loop is less than 85%, send 0 Requests.

2) If the Damper Loop is greater than 95%, send 1 Request.

3) If the measured airflow is less than 70% of setpoint for 1 minute, send 2 Requests.

4) If the measured airflow is less than 50% of setpoint for 1 minute, send 3 Requests.

c. Heating SAT Reset Requests

1) If the Heating Loop is less than 85%, send 0 Requests.

2) If the Heating Loop is greater than 95%, send 1 Request.

3) If the zone temperature falls below the zone's heating setpoint by 3°F for 2 minutes, send 2 Requests.

4) If the zone temperature falls below the zone's heating setpoint by 5°F for 2 minutes, send 3 Requests.

d. Heating Static Pressure Reset Requests

1) If the Damper Loop is less than 85%, send 0 Requests.

2) If the Damper Loop is greater than 95%, send 1 Request.

3) If the measured airflow is less than 70% of setpoint for 1 minute, send 2 Requests.

4) If the measured airflow is less than 50% of setpoint for 1 minute, send 3 Requests.

e. Heating Fan Requests. Send the heating fan that serves the zone a Heating Fan Request as follows:

1) If the zone Heating Loop is less than 1%, send 0 Requests.

2) If the zone Heating Loop is greater than 15%, send 1 Request.

Mixing Control logic is the preferred option for use with demand control ventilation. If the box serves more than one room, it requires a DD box with mixing capability – a pair of single-duct boxes strapped together with a common plenum will not work because the discharge air will stratify rather than mix. However, if only a single room is served – as is typical for a zone using DCV – then the room becomes the mixing box and this issue can be disregarded.
This sequence utilizes two airflow sensors, one at each inlet. This eliminates the need for a restriction at the discharge to facilitate flow measurement (and its associated pressure drop). A discharge restriction may still be required for mixing; see previous paragraph.
When the majority of the airflow is through one duct, the airflow velocity in the other duct may be too low to read and result in hunting at that damper. This is not a problem, because the absolute airflow in that duct will be too low for minor fluctuations to be detectable, while the airflow in the dominant duct is sufficient to provide a clear velocity signal.
Because no cold duct air is supplied during heating mode, the heating system must include ventilation air either with direct outdoor air intake or indirectly via transfer air from over-ventilated spaces on the same system. Refer to Standard 62.1 and the Standard 62.1 User's Manual.

J. Dual Duct VAV Terminal Unit – Mixing Control with Inlet Airflow Sensors

1. See Generic Thermal Zones for setpoints, loops, control modes, alarms, etc.

2. Design airflow rates shall be as scheduled on plans:

   a. Zone maximum cooling airflow setpoint (Vcool-max)

   b. Zone minimum airflow setpoint (Vmin)

   c. Zone maximum heating airflow setpoint (Vheat-max)

3. See 1.3B.2 for calculation of zone minimum outdoor airflow.

4. The occupied cooling minimum Vmin* shall be equal to Vmin except as follows:

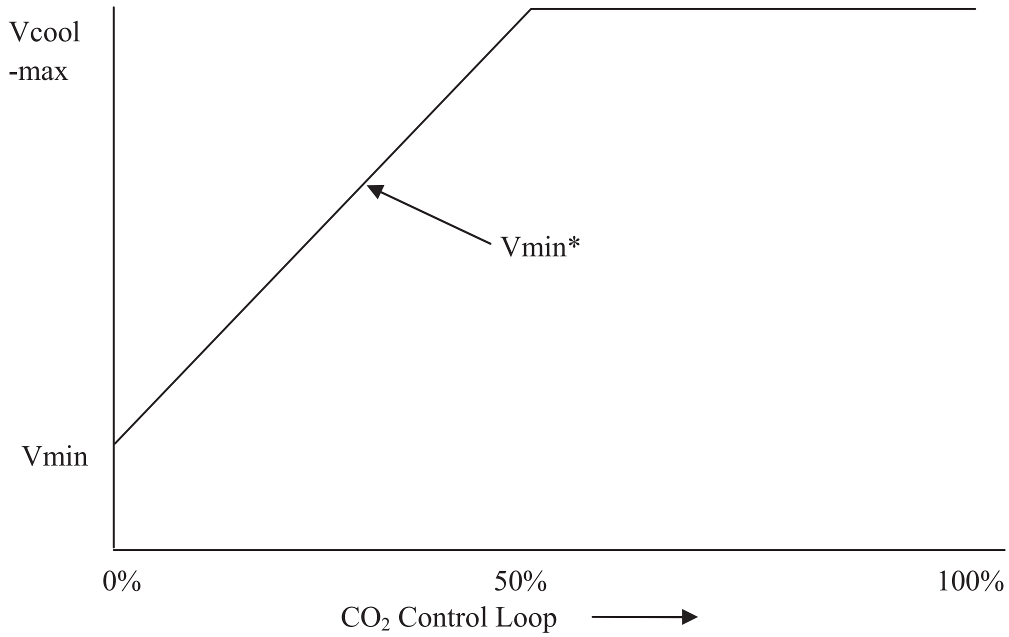
   a. If the zone has an occupancy sensor, Vmin* shall be equal to Varea-min (if ventilation is according to California Title 24) or V_{oz} (if ventilation is according to ASHRAE Standard 62.1) when the room is unpopulated.

   b. If the zone has a window switch, Vmin* shall be zero when the window is open.

   c. If Vmin is non-zero and less than the lowest possible airflow setpoint allowed by the controls (Vm), Vmin* shall be set equal to Vm. The minimum setpoint Vm shall be determined in accordance with 1.3D.4.c above.

   d. If the zone has a CO_2 sensor

      1) During Occupied Mode, a P-only loop shall maintain CO_2 concentration at 1000 PPM; reset 0% at 800 PPM and 100% at 1,000 PPM of CO_2. The loop output from 0 to 50% shall reset the occupied minimum airflow setpoint (Vmin*) from the zone minimum airflow setpoint Vmin up to maximum cooling airflow setpoint Vcool-max, as shown below.



2) If ventilation outdoor airflow is controlled in accordance with California Title 24, the loop output from 50% to 100% will be used at the system level to reset outdoor air minimum; see AHU controls.

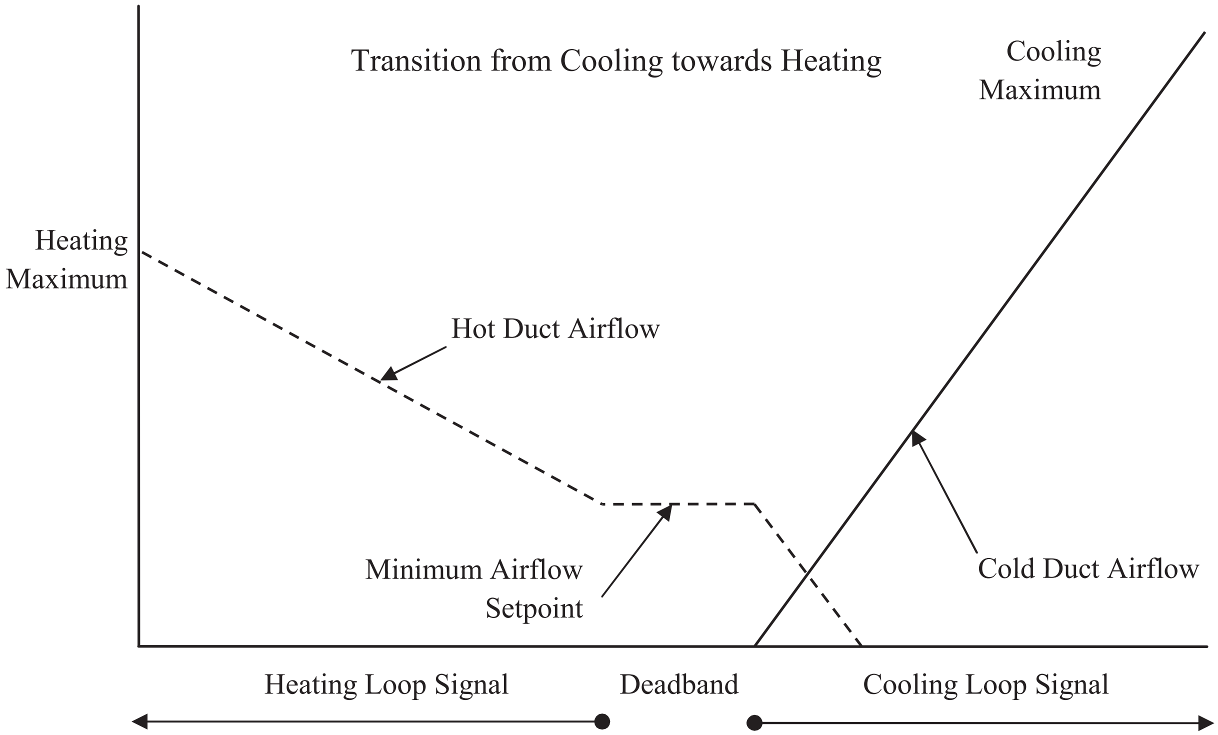
3) If ventilation outdoor airflow is controlled in accordance with ASHRAE Standard 62.1, the loop output from 50% to 100% shall be ignored.

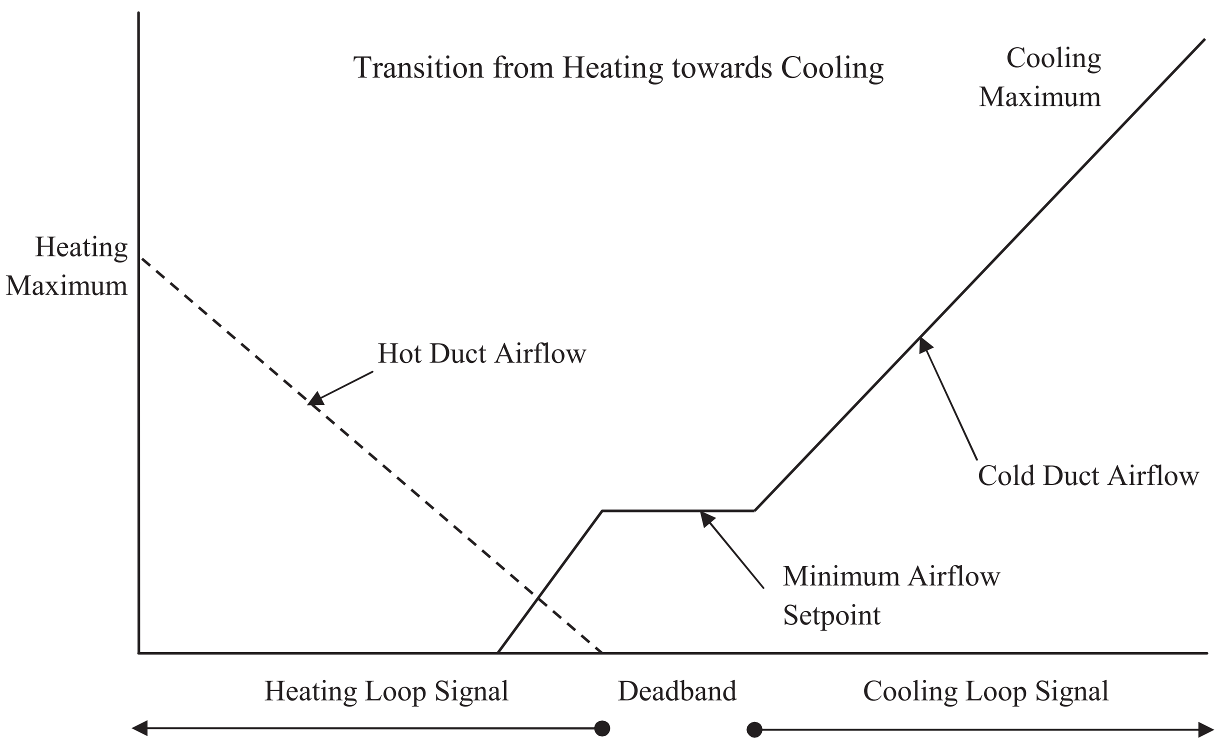
4) Loop is disabled and output set to zero when the zone is not in Occupied Mode.

5. Active maximum and minimum setpoints shall vary depending on the Mode of the Zone Group the zone is a part of:

Setpoint	Occupied	Cool-down	Setup	Warm-up	Setback	Unoccupied
Cooling maximum	Vcool-max	Vcool-max	Vcool-max	0	0	0
Minimum	Vmin*	0	0	0	0	0
Heating maximum	Vheat-max	0	0	Vheat-max	Vheat-max	0

6. Control logic is depicted schematically in the figures below and described in the following sections. Relative levels of various setpoints are depicted for Occupied Mode operation.





a. Temperature Control

1) When the zone is in Heating, the Heating Loop output shall reset the heating supply airflow setpoint from zero to the maximum heating setpoint. The heating damper shall be modulated by a control loop to maintain the measured heating airflow at setpoint. The cooling damper shall be controlled to maintain minimum airflow, as described below.

a) If hot deck supply air temperature from air handler is less than room temperature, Heating shall be locked out.

2) When the zone is in Cooling, the Cooling Loop output shall reset the cooling supply airflow setpoint from zero to the maximum cooling setpoint. The cooling damper shall be modulated by a control loop to maintain the measured cooling airflow at setpoint. The heating damper shall be controlled to maintain minimum airflow, as described below.

a) If cold deck supply air temperature from air handler is greater than room temperature, Cooling shall be locked out.

3) When the zone is in Deadband, the cooling and heating dampers are controlled to maintain minimum airflow, as described below.

b. Minimum Volume Control

1) In Heating, the cooling damper is modulated to maintain the sum of the measured inlet airflows at the minimum airflow setpoint.

2) In Cooling, the heating damper is modulated to maintain the sum of the measured inlet airflows at the minimum airflow setpoint.

3) In Deadband, the last damper that was used to maintain minimum airflow continues to do so (for example in transitioning from Heating into Deadband, the cooling damper would continue to maintain minimum airflow).

7. Alarms

a. Low Airflow

1) If the measured airflow is less than 70% of setpoint for 5 minutes, generate a Level 3 alarm.

2) If the measured airflow is less than 50% of setpoint for 5 minutes, generate a Level 2 alarm.

3) If a zone has an Importance multiplier of 0 [see 1.3A.11.b.1)a)] for its static pressure reset Trim & Respond control loop, low airflow alarms shall be suppressed for that zone.

b. Airflow sensor calibration. If the fan serving the zone has been off for 10 minutes and airflow sensor reading is above 20 CFM, generate a Level 3 alarm.

Per 1.3A.9, all hardware points can be overridden through the EMCS. Each of the following points is interlocked so that they can be overridden together at a Zone Group level, per 1.3C.6.
E.g. The CxA can check for leaking dampers by forcing all VAV boxes in a Zone Group closed and then recording airflow at the AHU.

8. Testing/Commissioning Overrides: Provide software points that interlock to a system level point to

   a. Force zone airflow setpoint to zero

   b. Force zone airflow setpoint to Vcool-max

   c. Force zone airflow setpoint to Vmin

   d. Force zone airflow setpoint to Vheat-max

   e. Force cooling damper full closed/open

   f. Force heating damper full closed/open

   g. Reset request-hours accumulator point to zero (provide one point for each reset type listed below)

9. System Requests

   a. Cooling SAT Reset Requests

      1) If the Cooling Loop is less than 85%, send 0 Requests.

      2) If the Cooling Loop is greater than 95%, send 1 Request.

      3) If the zone temperature exceeds the zone's cooling setpoint by 3°F for 2 minutes, send 2 Requests.

      4) If the zone temperature exceeds the zone's cooling setpoint by 5°F for 2 minutes, send 3 Requests.

   b. Cooling Static Pressure Reset Requests

      1) If the Damper Loop is less than 85%, send 0 Requests.

      2) If the Damper Loop is greater than 95%, send 1 Request.

      3) If the measured airflow is less than 70% of setpoint for 1 minute, send 2 Requests.

      4) If the measured airflow is less than 50% of setpoint for 1 minute, send 3 Requests.

   c. Heating SAT Reset Requests

      1) If the Heating Loop is less than 85%, send 0 Requests.

      2) If the Heating Loop is greater than 95%, send 1 Request.

      3) If the zone temperature falls below the zone's heating setpoint by 3°F for 2 minutes, send 2 Requests.

4) If the zone temperature falls below the zone's heating setpoint by 5°F for 2 minutes, send 3 Requests.

d. Heating Static Pressure Reset Requests

1) If the Damper Loop is less than 85%, send 0 Requests.

2) If the Damper Loop is greater than 95%, send 1 Request.

3) If the measured airflow is less than 70% of setpoint for 1 minute, send 2 Requests.

4) If the measured airflow is less than 50% of setpoint for 1 minute, send 3 Requests.

e. Heating Fan Requests. Send the heating fan that serves the zone a Heating Fan Request as follows:

1) If the zone Heating Loop is less than 1%, send 0 Requests.

2) If the zone Heating Loop is greater than 15%, send 1 Request.

Mixing Control logic is the preferred option for use with demand control ventilation. If the box serves more than one room, it requires a DD box with mixing capability – a pair of single-duct boxes strapped together with a common plenum will not work because the discharge air will stratify rather than mix. However, if only a single room is served – as is typical for a zone using DCV – then the room becomes the mixing box and this issue can be disregarded.
This sequence utilizes a single airflow sensor at the discharge outlet. This requires a restriction at the outlet to ensure that airflow velocity is high enough to measure, which adds extra pressure drop. It is somewhat a legacy approach, from when adding a second airflow sensor was much more expensive. As dual-airflow-sensor controllers are now more common, the next sequence (mixing control with inlet airflow sensors) is generally preferred.
Because no cold duct air is supplied during heating mode, the heating system must include ventilation air either with direct outdoor air intake or indirectly via transfer air from over-ventilated spaces on the same system. Refer to Standard 62.1 and the Standard 62.1 User's Manual.

K. Dual Duct VAV Terminal Unit – Mixing Control with Discharge Airflow Sensor

1. See Generic Thermal Zones for setpoints, loops, control modes, alarms, etc.

2. Design airflow rates shall be as scheduled on plans:

a. Zone maximum cooling airflow setpoint (Vcool-max)

b. Zone minimum airflow setpoint (Vmin)

c. Zone maximum heating airflow setpoint (Vheat-max)

3. See 1.3B.2 for calculation of zone minimum outdoor airflow.

4. The occupied cooling minimum Vmin* shall be equal to Vmin except as follows:

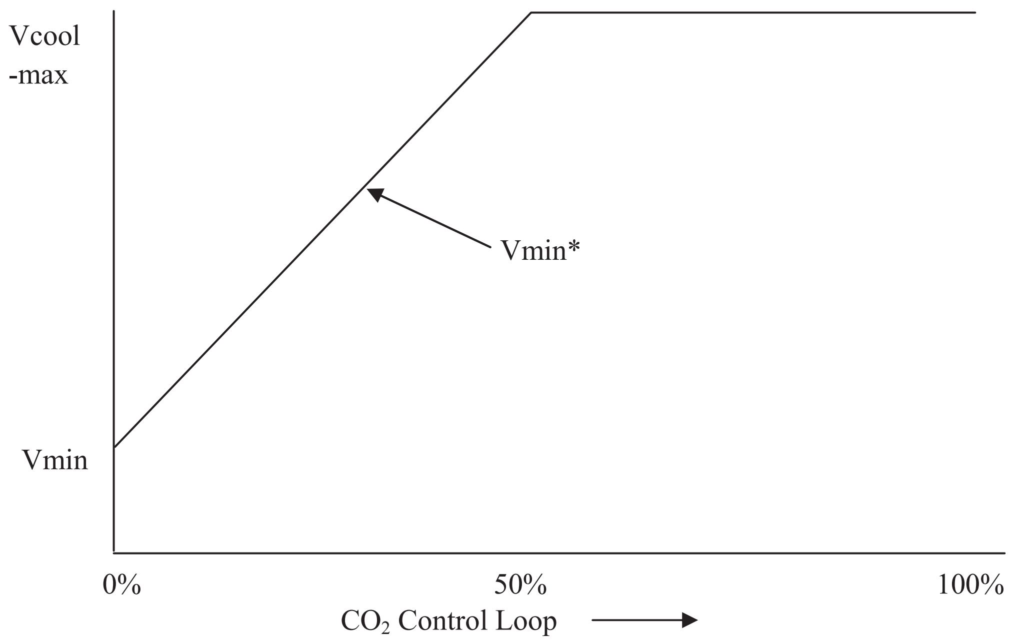
a. If the zone has an occupancy sensor, Vmin* shall be equal to Varea-min (if ventilation is according to California Title 24) or V_{oz} (if ventilation is according to ASHRAE Standard 62.1) when the room is unpopulated.

b. If the zone has a window switch, Vmin* shall be zero when the window is open.

c. If Vmin is non-zero and less than the lowest possible airflow setpoint allowed by the controls (Vm), Vmin* shall be set equal to Vm. The minimum setpoint Vm shall be determined in accordance with 1.3D.4.c above.

d. If the zone has a CO_2 sensor

1) During Occupied Mode, a P-only loop shall maintain CO_2 concentration at 1000 PPM; reset 0% at 800 PPM and 100% at 1,000 PPM of CO_2. The loop output from 0 to 50% shall reset the occupied minimum airflow setpoint (Vmin*) from the zone minimum airflow setpoint Vmin up to maximum cooling airflow setpoint Vcool-max, as shown below.



2) If ventilation outdoor airflow is controlled in accordance with California Title 24, the loop output from 50% to 100% will be used at the system level to reset outdoor air minimum; see AHU controls.

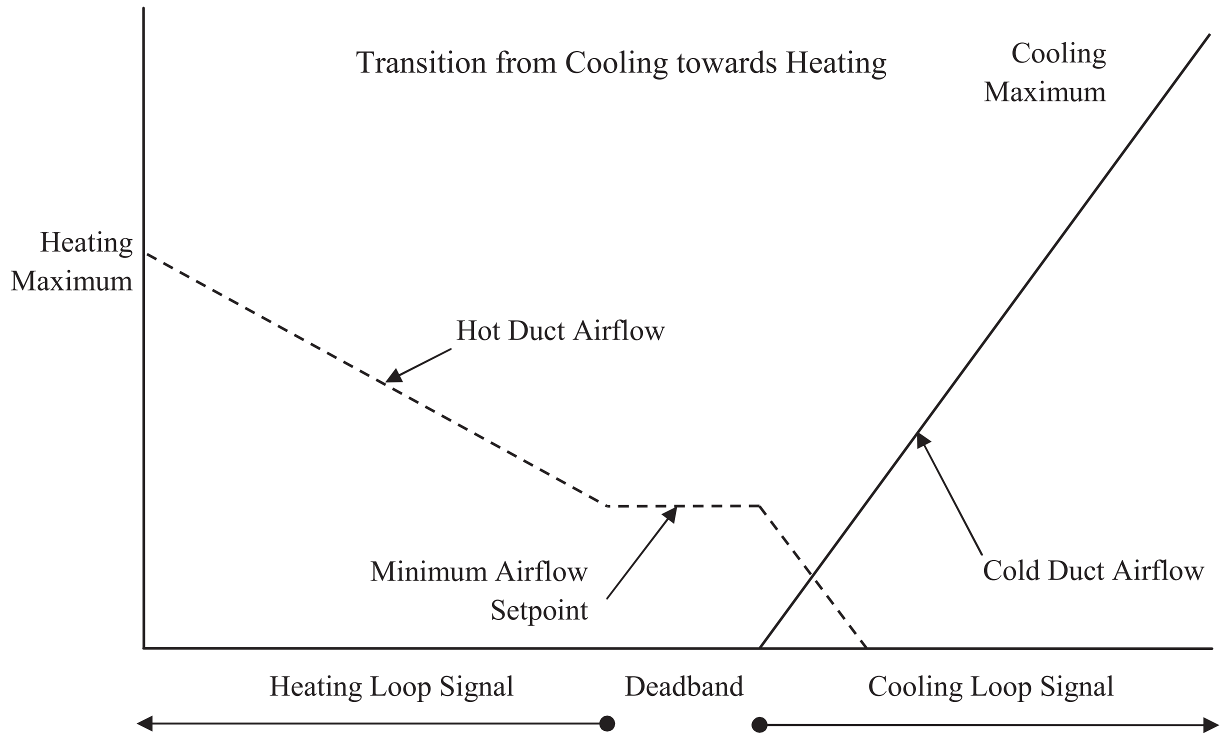
3) If ventilation outdoor airflow is controlled in accordance with ASHRAE Standard 62.1, the loop output from 50% to 100% shall be ignored.

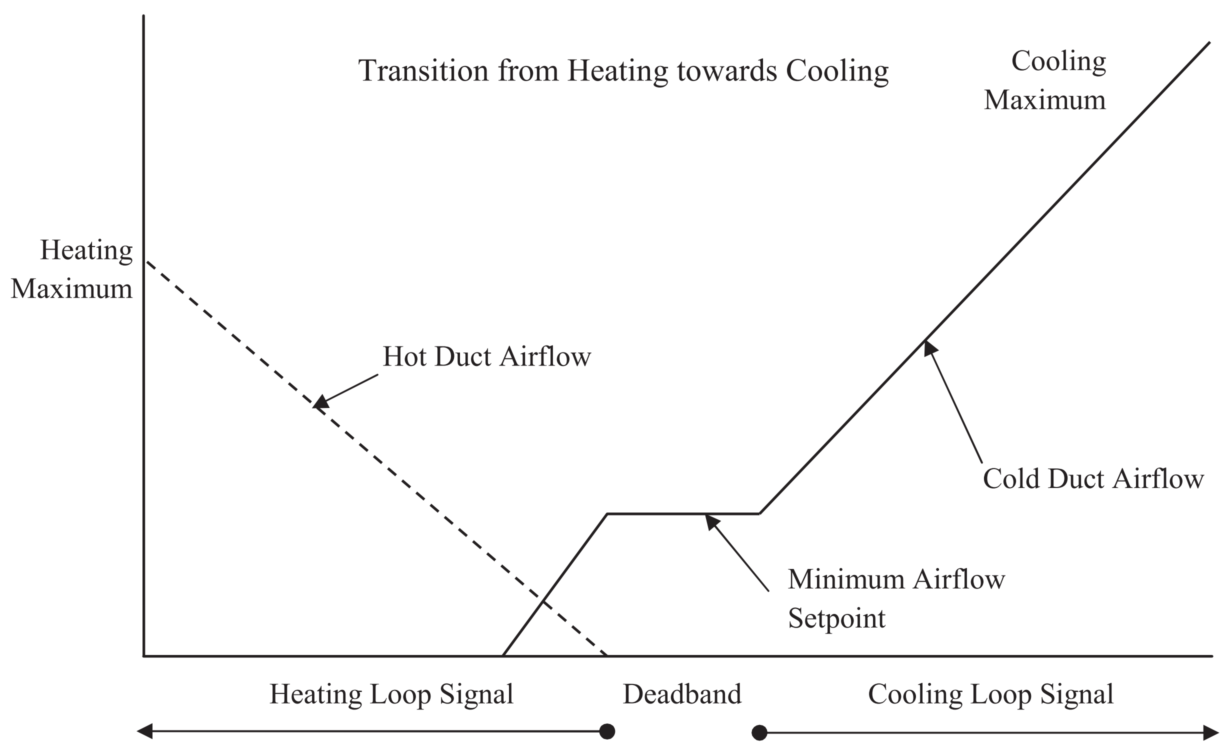
4) Loop is disabled and output set to zero when the zone is not in Occupied Mode.

5. Active maximum and minimum setpoints shall vary depending on the Mode of the Zone Group the zone is a part of:

Setpoint	Occupied	Cool-down	Setup	Warm-up	Setback	Unoccupied
Cooling maximum	Vcool-max	Vcool-max	Vcool-max	0	0	0
Minimum	Vmin*	0	0	0	0	0
Heating maximum	Vheat-max	0	0	Vheat-max	Vheat-max	0

6. Control logic is depicted schematically in the figures below and described in the following sections. Relative levels of various setpoints are depicted for Occupied Mode operation.





Because there is only a single airflow sensor on the combined discharge, typical pressure-independent control will not work. Instead, the active (Heating or Cooling) damper position equals the active loop signal (i.e. pressure dependent control), with additional logic to ensure that minimum and maximum airflow volumes are met.

a. Temperature Control

1) When the zone is in Heating, the Heating Loop output shall be mapped to the heating damper position.

a) If hot deck supply air temperature from air handler is less than room temperature, Heating shall be locked out.

2) When the zone is in Cooling, the Cooling Loop output shall be mapped to the cooling damper position.

a) If cold deck supply air temperature from air handler is greater than room temperature, Cooling shall be locked out.

3) When the zone is in Deadband, the cooling and heating dampers are controlled to maintain minimum airflow, as described below.

b. Minimum Volume Control

1) In Heating, the cooling damper is modulated to maintain measured discharge airflow at the minimum airflow setpoint.

2) In Cooling, the heating damper is modulated to maintain measured discharge airflow at the minimum airflow setpoint.

3) In Deadband, the last damper that was used to maintain minimum airflow continues to do so (for example in transitioning from Heating into Deadband, the cooling damper would continue to maintain minimum airflow).

c. Maximum Volume Control

1) There shall be a Maximum Volume Control loop which is a reverse-acting P-only loop. The loop's setpoint shall be the current maximum airflow volume, i.e. either Vcool-max or Vheat-max depending on whether the zone is in Cooling or Heating.

2) The output of the Maximum Volume Control loop shall be a damper position from 0% to 100%. This value shall be the maximum damper position of the currently-active damper, i.e. the maximum cooling damper position in Cooling; the maximum heating damper position in Heating.

7. Alarms

a. Low Airflow

1) If the measured airflow is less than 70% of setpoint for 5 minutes, generate a Level 3 alarm.

2) If the measured airflow is less than 50% of setpoint for 5 minutes, generate a Level 2 alarm.

3) If a zone has an Importance multiplier of 0 [see 1.3A.11.b.1)a)] for its static pressure reset Trim & Respond control loop, low airflow alarms shall be suppressed for that zone.

b. Airflow sensor calibration. If the fan serving the zone has been off for 10 minutes and airflow sensor reading is above 20 CFM, generate a Level 3 alarm.

Per 1.3A.9, all hardware points can be overridden through the EMCS. Each of the following points is interlocked so that they can be overridden together at a Zone Group level, per 1.3C.6.
E.g. The CxA can check for leaking dampers by forcing all VAV boxes in a Zone Group closed and then recording airflow at the AHU.

8. Testing/Commissioning Overrides: Provide software points that interlock to a system level point to

a. Force zone airflow setpoint to zero

b. Force zone airflow setpoint to Vcool-max

c. Force zone airflow setpoint to Vmin

d. Force zone airflow setpoint to Vheat-max

e. Force cooling damper full closed/open

f. Force heating damper full closed/open

g. Reset request-hours accumulator point to zero (provide one point for each reset type listed below)

9. System Requests

a. Cooling SAT Reset Requests

1) If the Cooling Loop is less than 85%, send 0 Requests.

2) If the Cooling Loop is greater than 95%, send 1 Request.

3) If the zone temperature exceeds the zone's cooling setpoint by 3°F for 2 minutes, send 2 Requests.

4) If the zone temperature exceeds the zone's cooling setpoint by 5°F for 2 minutes, send 3 Requests.

b. Cooling Static Pressure Reset Requests

1) If the Damper Loop is less than 85%, send 0 Requests.

2) If the Damper Loop is greater than 95%, send 1 Request.

3) If the measured airflow is less than 70% of setpoint for 1 minute, send 2 Requests.

4) If the measured airflow is less than 50% of setpoint for 1 minute, send 3 Requests.

c. Heating SAT Reset Requests

1) If the Heating Loop is less than 85%, send 0 Requests.

2) If the Heating Loop is greater than 95%, send 1 Request.

3) If the zone temperature falls below the zone's heating setpoint by 3°F for 2 minutes, send 2 Requests.

4) If the zone temperature falls below the zone's heating setpoint by 5°F for 2 minutes, send 3 Requests.

d. Heating Static Pressure Reset Requests

1) If the Damper Loop is less than 85%, send 0 Requests.

2) If the Damper Loop is greater than 95%, send 1 Request.

3) If the measured airflow is less than 70% of setpoint for 1 minute, send 2 Requests.

4) If the measured airflow is less than 50% of setpoint for 1 minute, send 3 Requests.

e. Heating Fan Requests. Send the heating fan that serves the zone a Heating Fan Request as follows:

1) If the zone Heating Loop is less than 1%, send 0 Requests.

2) If the zone Heating Loop is greater than 15%, send 1 Request.

Cold Duct Minimum Control logic is the most conventional but least efficient dual duct control strategy. It assures ventilation rates without Standard 62.1 "generalized multiple spaces" considerations since only the cold duct has ventilation air with DFDD systems.
This strategy utilizes dual airflow sensors, one at each inlet. It may be used with or without demand control ventilation.
The designer must ensure that the cooling minimum and heating maximum sum to less than the cooling maximum to avoid over-supplying the diffusers.

L. Dual Duct VAV Terminal Unit – Cold Duct Minimum Control

1. See Generic Thermal Zones for setpoints, loops, control modes, alarms, etc.

2. Design airflow rates shall be as scheduled on plans:

   a. Zone maximum cooling airflow setpoint (Vcool-max)

   b. Zone minimum airflow setpoint (Vmin)

   c. Zone maximum heating airflow setpoint (Vheat-max)

3. See 1.3B.2 for calculation of zone minimum outdoor airflow.

4. The occupied cooling minimum Vmin* shall be equal to Vmin except as follows:

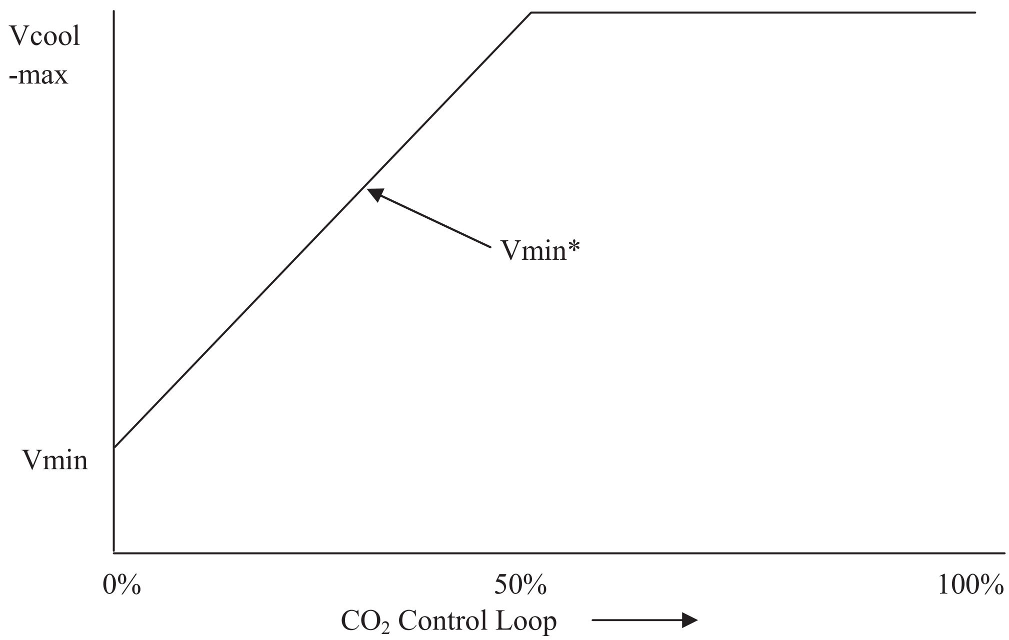
   a. If the zone has an occupancy sensor, Vmin* shall be equal to Varea-min (if ventilation is according to California Title 24) or V_{oz} (if ventilation is according to ASHRAE Standard 62.1) when the room is unpopulated.

b. If the zone has a window switch, Vmin* shall be zero when the window is open.

c. If Vmin is non-zero and less than the lowest possible airflow setpoint allowed by the controls (Vm), Vmin* shall be set equal to Vm. The minimum setpoint Vm shall be determined in accordance with 1.3D.4.c above.

d. If the zone has a CO_2 sensor

1) During Occupied Mode, a P-only loop shall maintain CO_2 concentration at 1000 PPM; reset 0% at 800 PPM and 100% at 1,000 PPM of CO_2. The loop output from 0 to 50% shall reset the occupied minimum airflow setpoint (Vmin*) from the zone minimum airflow setpoint Vmin up to maximum cooling airflow setpoint Vcool-max, as shown below.



2) If ventilation outdoor airflow is controlled in accordance with California Title 24, the loop output from 50% to 100% will be used at the system level to reset outdoor air minimum; see AHU controls.

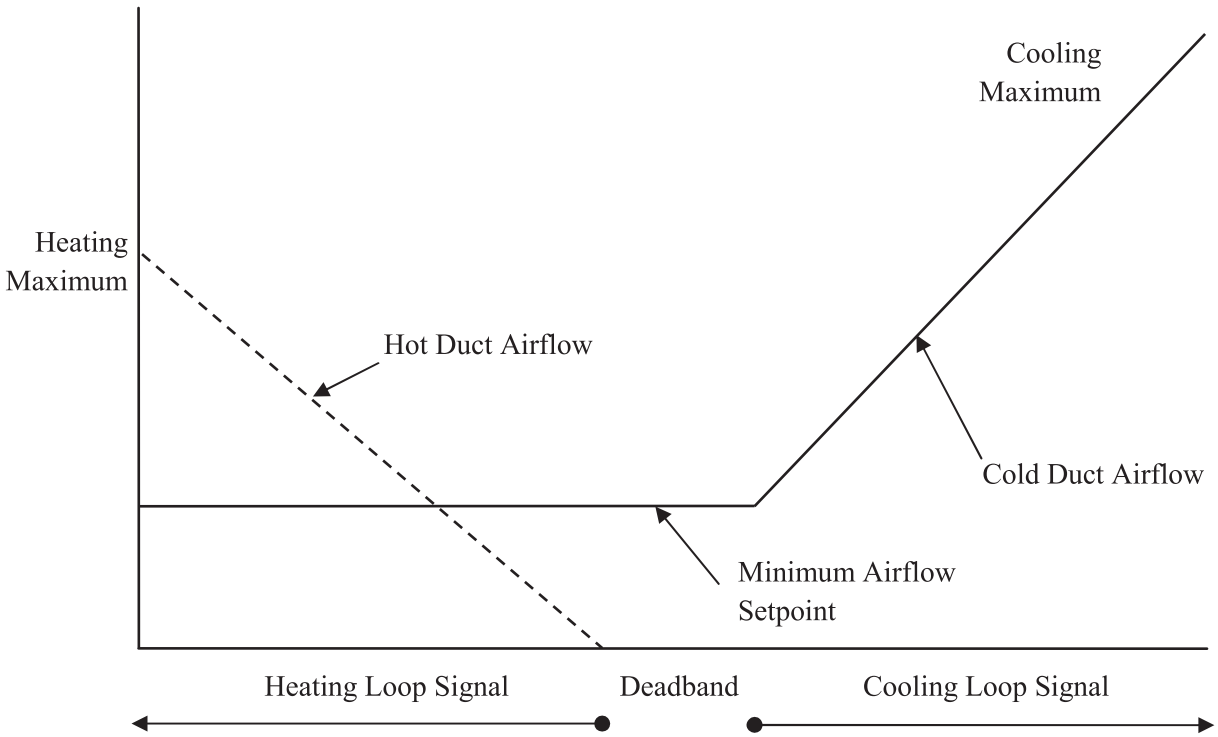
3) If ventilation outdoor airflow is controlled in accordance with ASHRAE Standard 62.1, the loop output from 50% to 100% shall be ignored.

4) Loop is disabled and output set to zero when the zone is not in Occupied Mode.

5. Active maximum and minimum setpoints shall vary depending on the Mode of the Zone Group the zone is a part of:

Setpoint	Occupied	Cool-down	Setup	Warm-up	Setback	Unoccupied
Cooling maximum	Vcool-max	Vcool-max	Vcool-max	0	0	0
Minimum	Vmin*	0	0	0	0	0
Heating maximum	Vheat-max	0	0	Vheat-max	Vheat-max	0

6. Control logic is depicted schematically in the figures below and described in the following sections. Relative levels of various setpoints are depicted for Occupied Mode operation.



a. Temperature and Damper Control:

1) When the zone is in Cooling, the Cooling Loop output shall reset the cooling supply airflow setpoint from the minimum to cooling maximum setpoints. The cooling damper shall be modulated by a control loop to maintain the measured cooling airflow at setpoint. The heating damper shall be closed.

a) If cold deck supply air temperature from air handler is greater than room temperature, Cooling shall be locked out.

2) When the zone is in Deadband, the cooling airflow setpoint shall be the minimum setpoint. The cooling damper shall be modulated by a control loop to maintain the measured cooling airflow at setpoint. The heating damper shall be closed.

3) When the zone is in Heating,

a) The Heating Loop output shall reset the heating supply airflow setpoint from zero to heating maximum setpoint. The heating damper shall be modulated by a control loop to maintain the measured heating airflow at setpoint.

b) The cooling airflow setpoint shall be the minimum setpoint. The cooling damper shall be modulated by a control loop to maintain the measured cooling airflow at setpoint.

c) If hot deck supply air temperature from air handler is less than room temperature, Heating shall be locked out.

7. Alarms

   a. Low Airflow

      1) If the measured airflow is less than 70% of setpoint for 5 minutes, generate a Level 3 alarm.

      2) If the measured airflow is less than 50% of setpoint for 5 minutes, generate a Level 2 alarm.

      3) If a zone has an Importance multiplier of 0 [see 1.3A.11.b.1)a)] for its static pressure reset Trim & Respond control loop, low airflow alarms shall be suppressed for that zone.

   b. Airflow sensor calibration. If the fan serving the zone has been off for 10 minutes and airflow sensor reading is above 20 CFM, generate a Level 3 alarm.

Per 1.3A.9, all hardware points can be overridden through the EMCS. Each of the following points is interlocked so that they can be overridden together at a Zone Group level, per 1.3C.6.
E.g. The CxA can check for leaking dampers by forcing all VAV boxes in a Zone Group closed and then recording airflow at the AHU.

8. Testing/Commissioning Overrides: Provide software points that interlock to a system level point to

   a. Force zone airflow setpoint to zero

   b. Force zone airflow setpoint to Vcool-max

   c. Force zone airflow setpoint to Vmin

   d. Force zone airflow setpoint to Vheat-max

   e. Force cooling damper full closed/open

   f. Force heating damper full closed/open

   g. Reset request-hours accumulator point to zero (provide one point for each reset type listed below)

9. System Requests

   a. Cooling SAT Reset Requests

      1) If the Cooling Loop is less than 85%, send 0 Requests.

      2) If the Cooling Loop is greater than 95%, send 1 Request.

      3) If the zone temperature exceeds the zone's cooling setpoint by 3°F for 2 minutes, send 2 Requests.

      4) If the zone temperature exceeds the zone's cooling setpoint by 5°F for 2 minutes, send 3 Requests.

   b. Cooling Static Pressure Reset Requests

      1) If the Damper Loop is less than 85%, send 0 Requests.

      2) If the Damper Loop is greater than 95%, send 1 Request.

3) If the measured airflow is less than 70% of setpoint for 1 minute, send 2 Requests.

4) If the measured airflow is less than 50% of setpoint for 1 minute, send 3 Requests.

c. Heating SAT Reset Requests

1) If the Heating Loop is less than 85%, send 0 Requests.

2) If the Heating Loop is greater than 95%, send 1 Request.

3) If the zone temperature falls below the zone's heating setpoint by 3°F for 2 minutes, send 2 Requests.

4) If the zone temperature falls below the zone's heating setpoint by 5°F for 2 minutes, send 3 Requests.

d. Heating Static Pressure Reset Requests

1) If the Damper Loop is less than 85%, send 0 Requests.

2) If the Damper Loop is greater than 95%, send 1 Request.

3) If the measured airflow is less than 70% of setpoint for 1 minute, send 2 Requests.

4) If the measured airflow is less than 50% of setpoint for 1 minute, send 3 Requests.

e. Heating Fan Requests. Send the heating fan that serves the zone a Heating Fan Request as follows:

1) If the zone Heating Loop is less than 1%, send 0 Requests.

2) If the zone Heating Loop is greater than 15%, send 1 Request.

M. Multiple Zone VAV Air Handling Unit

1. AHU system Modes are the same as the Mode of the Zone Group served by the system. When Zone Group served by an air handling system are in different modes, the following hierarchy applies (highest one sets AHU mode).

   a. Occupied Mode

   b. Cool-down Mode

   c. Setup Mode

   d. Warm-up Mode

   e. Setback Mode

   f. Unoccupied Mode

2. Supply Fan Control

a. Supply Fan Start/Stop

1) Supply fan shall run when system is in the Cool-down Mode, Setup Mode, or Occupied Mode.

2) If there are any VAV-reheat boxes on perimeter zones, supply fan shall also run when system is in Setback Mode or Warmup Mode (i.e. all Modes except Unoccupied).

3) Totalize current airflow rate from VAV boxes and display on AHU graphic at discharge duct. If the AHU has an airflow measurement station, display the AFMS airflow rate adjacent to the sum-of-zone airflow rate.

b. Static Pressure Setpoint Reset

1) Static pressure setpoint: Setpoint shall be reset using Trim & Respond logic [see 1.3A.11]. The following parameters are suggested as a starting place, but they will require adjustment during the commissioning/tuning phase:

Variable	**Value**
SP_0	0.5 inches
SP_{min}	0.1 inches
SP_{max}	Per TAB report
T_d	10 minutes
T	2 minutes
I	2
R	Zone Static Pressure Reset Requests
SP_{trim}	-0.05 inches
SP_{res}	+0.06 inches
$SP_{res\text{-}max}$	+0.13 inches

c. Static Pressure Control

High pressure trips may occur if all VAV boxes are closed (as in Unoccupied Mode) or if fire/smoke dampers are closed (in some FSD designs, the dampers are interlocked to the fan status rather than being controlled by smoke detectors).

1) Supply fan speed is controlled to maintain duct static pressure at setpoint when the fan is proven on. See 1.3A.10 for minimum speed setpoint. Where the Zone Groups served by the system are small, provide multiple sets of gains that are used in the control loop as a function of a load indicator (such as supply fan airflow rate, the area of the Zone Groups that are occupied, etc.).

Delete the next paragraph if there is only one supply fan or if fan isolation is by barometric dampers.
The delay is to ensure fan is on before damper opens to prevent backflow from the other fan from back-wheeling the fan prior to startup.
Contractor should adjust rate of isolation damper closing and opening to prevent damage to plenum.

2) Loop output shall be mapped to the VFD speed from minimum VFD speed to 100% speed. Start to open isolation damper (inlet cone) when fan reaches minimum speed. Close the damper when the fan status indicates fan is off.

3. Supply Air Temperature Control

a. Control loop is enabled when the supply air fan is proven on, and disabled and output set to Deadband (no heating, minimum economizer) otherwise.

The default range of outdoor air temperatures (70°F – 60°F) used to reset the Occupied Mode SAT setpoint was chosen to maximize economizer hours. It may be preferable to use a lower range of OATs (e.g. 65°F – 55°F) to minimize fan energy if:
- *There is a 24/7 chiller plant that is running anyway*
- *Reheat is minimized, as in a VAV dual-fan, dual-duct system*
- *The climate severely limits the number of available economizer hours*

If using this logic, the engineer should oversize interior zones and rooms with high cooling loads (design them to be satisfied by the warmest SAT) so these zones don't drive the T&R block to the minimum SAT setpoint.

b. Supply Air Temperature Setpoint

1) During Occupied Mode: Setpoint shall be reset from T-min when the outdoor air temperature is 70°F and above, proportionally up to T-max when the outdoor air temperature is 60°F and below.

a) T-min shall be the design cooling coil leaving air temperature per coil schedule.

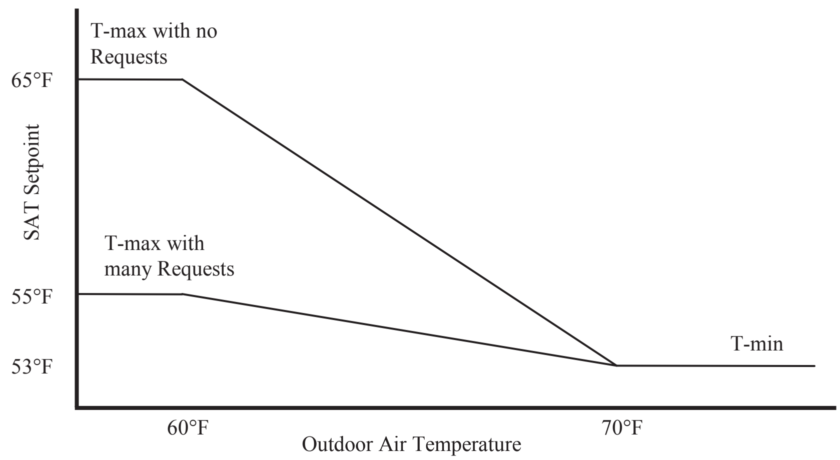
b) T-max shall be reset using Trim & Respond logic [see 1.3A.11] between SP_{min} (the design supply air temperature per the AHU schedule) and SP_{max}. The following parameters are suggested as a starting place, but they will require adjustment during the commissioning/tuning phase:

SPmin should equal the design supply air temperature.
SPmax may need to be less than 65°F for dehumidification in humid climates. It should not normally be greater than 65°F, as this may lead to excessive fan energy use.

Variable	Value
SP_0	SP_{max}
SP_{min}	Design SAT (55ºF typ)
SP_{max}	65ºF (or less for dehumidification)
T_d	10 minutes
T	2 minutes
I	2
R	Zone Cooling SAT Requests

Variable	Value
SP_{trim}	+0.2ºF
SP_{res}	-0.3ºF
$SP_{res-max}$	-1.0ºF

The net result of this SAT reset strategy is depicted in the chart below:



2) During Setup or Cool-Down Modes: Setpoint shall be T-min.

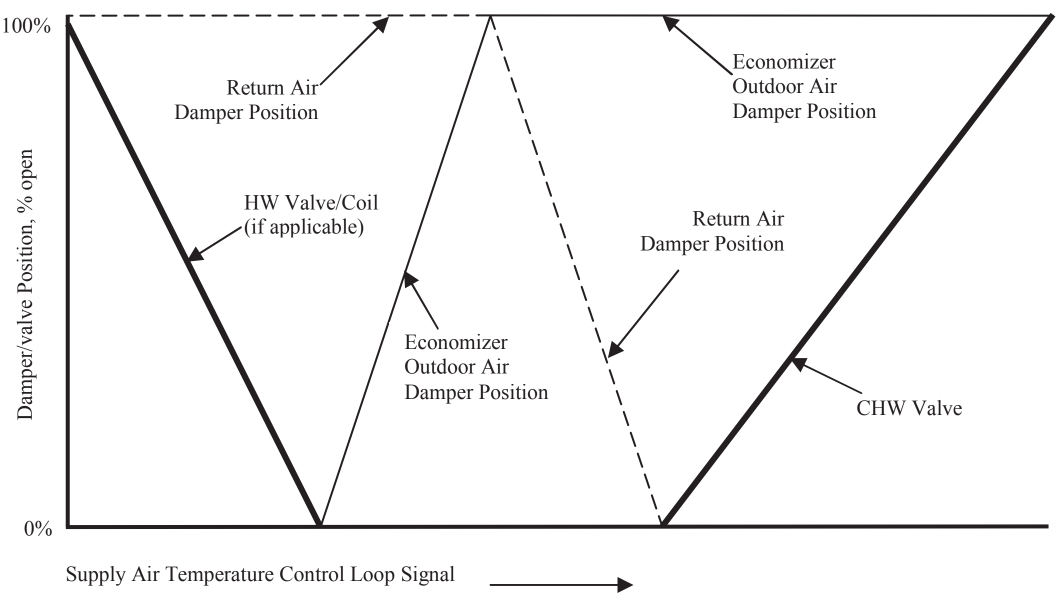
The following will effectively lock out the economizer and cooling coil, which is desirable for warmup even if there is no heating coil at the AHU to meet the higher SAT.
This does not apply in the case of a DFDD AHU, or if all the zones are equipped with fan-powered boxes such that the AHU is off in warmup and setback.

3) During Warm-Up and Setback Modes: Setpoint shall be 95°F.

The following paragraph applies when the unit has a separate minimum outdoor air damper. Outdoor air and return air dampers are sequenced rather than complementary (as per most standard sequences) to reduce fan power at part loads.

c. For units with a separate minimum outdoor air damper: Supply air temperature shall be controlled to setpoint using a control loop whose output is mapped to sequence the hot water valve or modulating electric heating coil (if applicable), economizer outdoor damper, return air damper, and chilled water valve as shown in the diagram below. Outdoor air and return air dampers are sequenced rather than complementary (as per most standard sequences) to reduce fan power at part loads

1) The points of transition along the x-axis shown and described below are representative. Separate gains shall be used for each section of the control map (hot water, economizer, chilled water), which are determined by the Contractor to provide stable control. If this is not possible, Contractor shall adjust the precise value of the x-axis thresholds shown in the figure to provide stable control.



C. Parallel Fan-Powered Terminal Unit, Constant Volume Fan

(in addition to Generic Zone parameters)

Parameter	Units	Description	Hints/Comments	Variable Name in Demo System
Vm	CFM	Minimum airflow allowed by controls		min_CFM
Vmin	CFM	Minimum zone airflow when occupied		occ_min
Vcool-max	CFM	Zone airflow at 100% cooling		vcool_max
CV Fan Flow	CFM	Rated flow of CV fan		fan_flowrate

D. Parallel Fan-Powered Terminal Unit, Variable Volume Fan

(in addition to Generic Zone parameters)

Parameter	Units	Description	Hints/Comments	Variable Name in Demo System
Vm	CFM	Minimum airflow allowed by controls		min_CFM
Vmin	CFM	Minimum zone airflow when occupied		occ_min
Vcool-max	CFM	Zone airflow at 100% cooling		vcool_max
Pfan-z	CFM	Parallel fan airflow at minimum speed		pfanz
Pfan-max	CFM	Parallel fan maximum airflow		pfanmax

E. Series Fan-Powered Terminal Unit, Constant Volume Fan

(in addition to Generic Zone parameters)

Parameter	Units	Description	Hints/Comments	Variable Name in Demo System
Vm	CFM	Minimum airflow allowed by controls		min_CFM
Vmin	CFM	Minimum zone airflow when occupied		occ_min
Vcool-max	CFM	Zone airflow at 100% cooling		vcool_max

F. Dual Duct VAV Terminal Unit, Snap Acting Control, Dual Inlet Sensors

(in addition to Generic Zone parameters)

Parameter	Units	Description	Hints/Comments	Variable Name in Demo System
Vm	CFM	Minimum airflow allowed by controls		min_CFM
Vmin	CFM	Minimum zone airflow when occupied		occ_min
Vcool-max	CFM	Zone airflow at 100% cooling		air_flow – “Cooling Max Airflow”
Vheat-max	CFM	Zone airflow at 100% heating		hd_air_flow – “Heating Max Airflow”

G. Dual Duct VAV Terminal Unit, Snap Acting Control, Discharge Sensor

(in addition to Generic Zone parameters)

Parameter	Units	Description	Hints/Comments	Variable Name in Demo System
Vm	CFM	Minimum airflow allowed by controls		min_CFM
Vmin	CFM	Minimum zone airflow when occupied		occ_min
Vcool-max	CFM	Zone airflow at 100% cooling		air_flow – "Cooling Max Airflow"
Vheat-max	CFM	Zone airflow at 100% heating		air_flow – "Heating Max Airflow"

H. Dual Duct VAV Terminal Unit, Mixing Control, Dual Inlet Sensors

(in addition to Generic Zone parameters)

Parameter	Units	Description	Hints/Comments	Variable Name in Demo System
Vm	CFM	Minimum airflow allowed by controls		min_CFM
Vmin	CFM	Minimum zone airflow when occupied		occ_min
Vcool-max	CFM	Zone airflow at 100% cooling		air_flow – "Cooling Max Airflow"
Vheat-max	CFM	Zone airflow at 100% heating		hd_air_flow – "Heating Max Airflow"

I. Dual Duct VAV Terminal Unit, Mixing Control, Discharge Sensor

(in addition to Generic Zone parameters)

Parameter	Units	Description	Hints/Comments	Variable Name in Demo System
Vm	CFM	Minimum airflow allowed by controls		min_CFM
Vmin	CFM	Minimum zone airflow when occupied		occ_min
Vcool-max	CFM	Zone airflow at 100% cooling		vcool_max
Vheat-max	CFM	Zone airflow at 100% heating		vheat_max

J. Dual Duct VAV Terminal Unit, Cold Duct Minimum Control

(in addition to Generic Zone parameters)

Parameter	Units	Description	Hints/Comments	Variable Name in Demo System
Vm	CFM	Minimum airflow allowed by controls		min_CFM
Vmin	CFM	Minimum zone airflow when occupied		occ_min
Vcool-max	CFM	Zone airflow at 100% cooling		air_flow – "Cooling Max Airflow"
Vheat-max	CFM	Zone airflow at 100% heating		hd_air_flow – "Heating Max Airflow"

Principals of Condensing Boiler System Design

Dennis Jones, P.E.
Member ASHRAE

ABSTRACT

Condensing boilers can provide significant energy savings due to operating efficiencies as high as 98% as compared to a peak efficiency of 80% for a conventional boiler. However, specifying a condensing boiler does not guarantee achieving anticipated savings; careful attention must be paid to the heating water system as a whole. The first principal is that low boiler entering water temperatures (EWT) are required to realize the advertised efficiency and AFUE performance of condensing boilers. ANSI Standard Z21.13 specifies condensing boiler performance testing with 80˚F (27˚C) EWT and a 100˚F (55˚C) temperature rise (delta-T), a condition not generally achieved with standard design practices. Advantages of high delta-T systems include reduced boiler and pump energy use and reduced pipe sizing and distribution heat loss. A condensing boiler is not a compact fluorescent lamp (CFL); you can't simply plug it into a typical system and expect it to save energy. Selecting a condensing boiler is the easiest and least consequential part of designing a condensing boiler system. This paper provides basic principles for designing a heating system utilizing condensing boilers. The remaining design principals are mostly related to how to achieve a low EWT. The paper presents design principles for heat delivery to the space, coil selection, boiler selection, low mass versus high mass boilers, piping system design, pump and control valve selection, use of buffer tanks, and boiler controls. The paper presents a detailed description of each design principal along with recommendations as to how to achieve it.

INTRODUCTION

Experience over several years of commissioning buildings with condensing boilers is that about 90% of the boilers never operate in the condensing range. Traditional design practices include designing and controlling hydronic heating system to not return water cooler than 140˚F (60˚C) in order to prevent condensation of corrosive flue gases within the boilers. Conversely the focus for condensing boiler system design is to return 80˚F (27˚C) water to the boilers to promote maximum boiler efficiency. Little information could be found on recommended design practices for condensing boiler systems and in discussing design issues with commissioning agents, design engineers, and boiler factory representatives; it was clear there was no consensus on how to design these systems. The ASHRAE Handbook was of little help, but it did encourage design of high delta-T hydronic heating water systems. Internet searches failed to locate any design guidelines focused on optimizing efficiency in condensing boiler systems. Condensing boilers can provide significant energy savings due to operating efficiencies as high as 98% as compared to a peak efficiency of 80% for a conventional boiler. However, installing condensing boiler alone does not guarantee achieving anticipated savings; careful attention must be paid to the boiler heating water system as a whole. Condensing boilers require entering water temperature (EWT) in the 100˚F (55˚C) range to actually condense water out of the exiting flue gas. The onset of condensing is with an EWT of about 130˚F (54˚C), but maximum efficiency occurs at an EWT of 80˚F (27˚C) or lower. This EWT requirement varies with altitude, with condensation starting at 125˚F (54˚C) EWT in Denver. The following design principles were developed for condensing water systems.

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DESIGN PRINCIPALS

Principal-1 - Return Water Temperatures to the Boilers must not Exceed 80˚F (27˚C) to Achieve the Advertised Boiler Efficiency

ANSI Standard Z21.13 tests and rates condensing boiler performance with an 80˚F (27˚C) boiler entering water temperature (EWT) and a 100˚F (55˚C) temperature rise (delta-T) to produce a boiler leaving water temperature (LWT) of 180˚F (82˚C). Condensing boiler performance is dominated by the boiler EWT. Figure 1 below shows a typical condensing boiler efficiency curve from a manufacture and a theoretical performance curve.

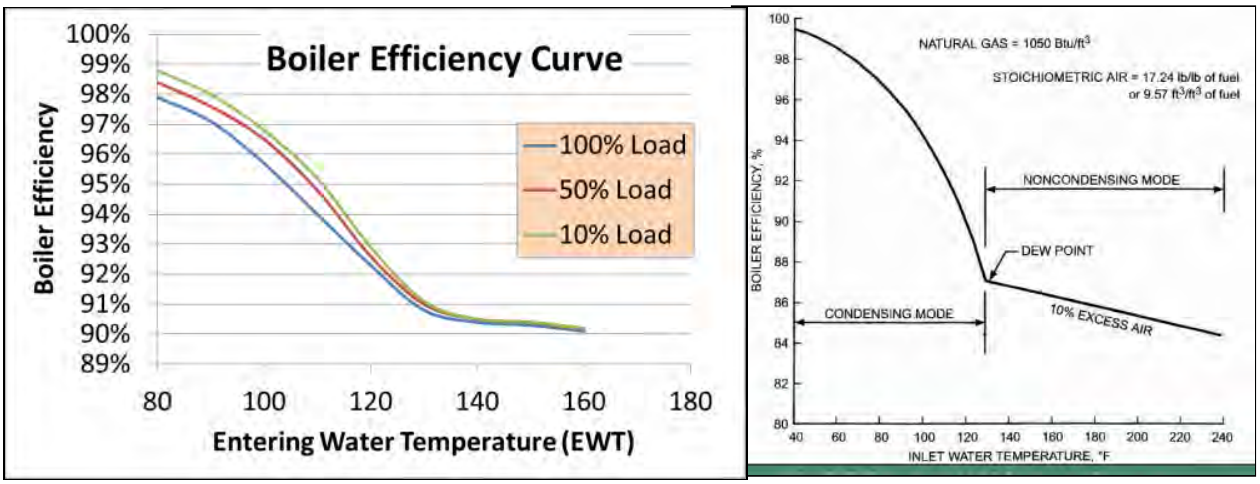

Figure 1 Typical Condensing Boiler Efficiency Curves

The boiler starts to condense water out of the combustion gasses when the dewpoint of the combustion gasses is reached; which, at sea level, is about 130˚F (54˚C). As gas temperatures continue to drop, more water is condensed out and the boiler efficiency increases dramatically down to about 80˚F (27˚C), which is the boiler EWT at which the boiler is rated. If the heating water system cannot deliver 80˚F (27˚C) water back to the boiler; the boiler will not operate at it's rated efficiency.

If the system cannot be designed to return water near 80˚F (27˚C) for a good portion of the heating season, a non-condensing boiler should be considered; which can operate with an efficiency of up to 87% with an EWT of 140˚F (60˚C). Typically non-condensing boilers cost about a third of the cost of a condensing boiler.

Principal-2 – Select Heating Coils for a 80˚F (27˚C) Leaving Water Temperature

Proper heating coil selection is the most important element of designing a high-performance heating water system. Consider the following example, summarized in Table 1.

Table 1. DHW Coil Selection Example

Selection	Load Side GPM (L/M)	Load Side EWT ˚F(˚C)	Load Side LWT ˚F(˚C)	Source Side (GPM)	Source Side EWT ˚F(˚C)	Source Side LWT ˚F(˚C)	LxWxH inches (cm)	Weight lbs (kg)

20˚F (11.1˚C) Delta-T	80 (303)	40 (4.4)	135 (57.2)	195 (90.6)	150 (65.6)	110 (43.3)	38x13x16 (97x33x41)	769 (349)
80˚F (44.4˚C) Delta-T	80 (303)	40 (4.4)	135 (57.2)	125 (51.7)	160 (71.1)	80 (26.7)	20x10x12 (51x25x30)	156 (71)

A heat exchanger is required to heat 80 gpm (303 lpm) of domestic water from 40˚F (4˚C) to 135˚F (57˚C) . The deisgn specified a heat, based on a vendor selection, that used 195 gpm (738 lpm) of 150˚F (66˚C) boiler water with a design LWT of 110˚F. During a design review, the commissioning agent re-selected the heat exchanger assuming EWT=160˚F and LWT=80˚F (27˚C). The resulting LWT back to the boiler was 80˚F (27˚C), increasing boiler efficiency, the heating water flow rate dropped about 40%, allowing for a smaller pump, and the heat exchanger weight and cost dropped to 20% of that of the original selection. This is a typical result from sizing the heat exchanger for an appropriate Delta-T rather than staying with a 20˚F (27˚C) Delta-T dictated by a rule of thumb.

Consider another example, selection of an air heating coil, summarized in **Table** 2. A 20˚F (11˚C) delta-T on the water side is often used to size heating coils. High-performance systems require coil selection at a much higher delta-T, in the 80˚F (45˚C) range. A heating coil is required in an AHU to heat 10,000 cfm (4719 lps) of air from 35˚F (2˚C) to 90˚F (32˚C) . In an attempt to keep coil LWT at 100˚F (38˚C), the engineer uses a 120˚F (49˚C) EWT. He then tries the same selection with a 180˚F (82˚C) EWT. The difference in the results is that 3 coil rows are required for the 20˚F (11˚C) delta-T selection along with a 56.4 GPM (213 lpm) flow rate. The 80˚F (44˚C) delta-T selection results in a 2 coil row and a 14.4 GPM (55 lpm) flow rate.

Table 2. Air Heating Coil Example.

Selection Run	20F (11C) delta	80F (45C) delta
Face Area ft2 (m2)	20 (1.8)	20 (1.8)
Face Velocity fpm (mps)	500 (2.5)	500 (2.5)
Rows – FPI	**3 – 10**	**2 – 10**
CFM (lps)	10,000 (4,719)	10,000 (4,719)
Entering Air Temp ˚F (˚C)	35 (2)	35 (2)
Leaving Air Temp ˚F (˚C)	93.1 (33.9)	94.2 (34.6)
Fluid	Water	Water
Air Pressure Drop in WG (Pa)	0.28 (70)	0.19 (47)
Water Pressure Drop ft (m)	11.56 (3.5)	13.7 (4.2)
Water Velocity ft/s (m/s)	5.2 (1.6)	4.0 (1.2)
Entering Water Temp ˚F (˚C)	**120 (49)**	**180 (82)**
Leaving Water Temp ˚F (˚C)	**100 (38)**	**100 (38)**
GPM (l/m)	**56.4 (213)**	**14.4 (55)**

The only other difference is that the 80˚F (45˚C) delta-T selection has 16 passes of tubing per circuit across the coil face as opposed to 8 passes for the other coil. At lower water flow rates, fewer circuits with longer lengths are required to keep flow in the turbulent range for better heat transfer. The coil selection program used in this example was randomly downloaded from a coil provider web site. The high delta-T coil is very similar to the low delta-T coil, but it provide significant energy savings due to a 75% reduction in pumping energy, lower pressure drop on the air side, and low boiler EWT in a coil that has less rows.

Principal-3 – The Heating Water Design Delta-T for a Heating Coil should equal the Load Design Delta-T

Performance of a hot water heating coil is given by the following equation:

$$Q = \text{Cmin} \times \epsilon \times (\text{EWT} - \text{EAT}) \quad (1)$$

where Q = Rate of heat transfer (Btuh)
Cmin = Minimum fluid capacitance rate (Btuh/°F)
ϵ = Effectiveness
EWT=Entering water temperature
EAT=Entering air temperature

Fluid capacitance rate is the product of the mass flow rate and the fluid specific heat for both the air and water sides of the coil. Capacitance rate is equal to 500 x GPM on the water side and 1.08 x CFM on the air side, expressed in Btuh/F. Selecting a heating coil with matched capacitance rates on the source and load sides will result in equal Delta-Ts on both side of the heat exchanger. Selecting a delta-T on the source side less than the delta-T on the load side will maximize the heating water delta-T; resulting in cooler return water temperatures to the condensing boilers. In addition, good control with a control vlave requires the source side delta-T to be less than or equal to the load delta-T; given the heat exchanger performance equation above in which the minimum capacitance rate dominates the amount of heat transfer. At part load, the delta-T of the heating water will increase as the control valve pinches down to control coil output. With proper coil sizing, control valves can be significantly smaller and provide much more effective control.

Principal-4 – Select Heating Systems Capable of Returning 80˚F (27˚C) Water to the Boiler

Some HVAC heating systems are more compatible with condensing boilers than other systems. **Error! Reference source not found.** Summarizes typical operating temperatures of common HVAC equipment, the approximate heat exchanger effectiveness appropriate for a condensing boiler system, and achievable hot water return temperatures.

Table 3. Typical Coil Design Temperatures.

Equipment	DHW Heater	AHU Heating Coil (Single Zone)	AHU Heating Coil (VAV)	VAV Box Reheat Coil	Radiant Slab Heating System	Hot Water Baseboard	Snow Melt System
Entering Load Temp ˚F (˚C)	50 (10)	60 (16)	40 (22)	60 (16)	80 (27)	70 (21)	30 (-1)
Leaving Load Temp ˚F (˚C)	140 (60)	90 (32)	60 (16)	80 (27)	120 (49)	140 (60)	40 (4)
Load Delta-T	90 (50)	30 (17)	20 (11)	20 (11)	40 (22)	70 (39)	10 (5)
Achievable HTX Effectiveness	0.95	0.50	0.40	0.40	0.90	0.60	1.00
Required HW Supply Temp ˚F (˚C)	145 (63)	120 (49)	90 (32)	110 (43)	120 (49)	180 (82)	40 (4)
HW Return Temp ˚F (˚C)	60 (16)	90 (32)	70 (21)	90 (32)	80 (27)	120 (49)	30 (-1)

Ideally the heating coil serves a low temperature load like DHW heating or snow melting or a pre-heat coil in an AHU; which allows a low return water temperature to the boilers. Problem coils include:

- VAV reheat coils, typically 1 and 2 row coils, which require warmer heating water temperatures. Typically a 3 to 4 row coil is required, which is an added-cost option for most manufactures.
- Hot water baseboard heating should be avoided; they require higher temperatures to drive the airflow over the coils. Hot water baseboard can and should be designed with heating water delta-T of 60˚F (33˚C). The heat output is proportional to the average water temperature for a baseboard circuit.
- Radiant heating slabs work well with condensing boilers, if designed to return water at about the temperature of the slab. The system should include a tertiary pumping loop and optimal tube spacing within the slab.

Table 3 is for typical peak heating load conditions; heating water delta-Ts will increase as flow is throttled down for part loads and the hot water supply temperature can be reset downwards based on decreasing load.

Principal-5 – Use Primary-Only Heating Water Distribution Systems

A problem we've seen the field with condensing water systems is the use of primary-secondary distribution systems, which are designed to provide constant water flow through the boilers and variable flow through the heating coils. This arrangement results in mixing of supply and return water, if boiler and load flow rates are not exactly the same. Mixing will result in either elevated return water temperatures to the boilers or reduced supply water temperatures to the coils; both of which degrade condensing boiler efficiency. The recommended primary-only boiler system is indicated by the Figure 2 and has the following elements:

- A single variable-speed pump sends return water to the boilers and on to the heating coils. The boilers are equipped with isolation valves and the coils with 2-way control valves. Pump speed is controlled to maintain a differential pressure (DP) setpoint between coil supply water and return water piping in the vicinity of the coils. The DP setpoint may be reset based on valve positions.
- A recirculation control (system bypass) valve operates at low load to maintain the required minimum flow rate setpoint through the operating boiler. A flow meter (not shown) is required in the boiler loop. Boiler sequencing is controlled to avoid operation of the recirculation valve.

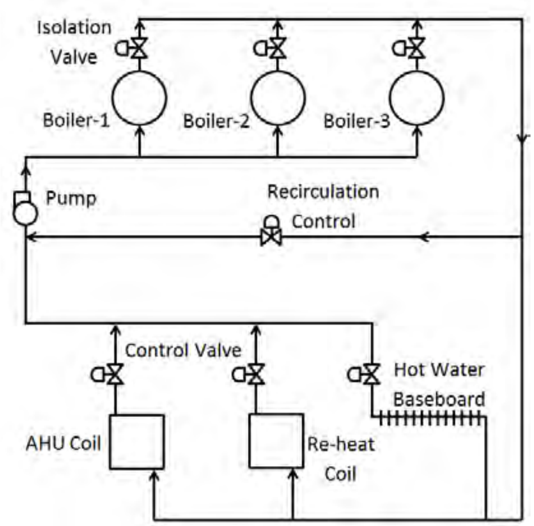

Figure 2 Primary-Only Heating System Schematic.

Principal-6 – Select Boilers with Low Burner Turn-Down Ratios

Condensing boilers are typically designed with a low burner turn-down ratio to 20% or lower. Some of the better boilers have turn-down ratios as low as 5%. If loads drop below the turn-down ratio, the boilers must cycle on and off to meet the load, which can significantly reduce the efficiency of the boiler. When boilers cycle, a pre and post purge of the combustion air in the burner and heat exchanger is required. As a result, every time a boiler is started, cold combustion air is blown through the heat exchanger at the maximum airflow rate for a minute or two; pulling heat out of the boiler and exhausting it. Purge losses are insignificant if boiler cycling is limited to 20 minutes or more, but are significant for fast boiler cycling, like every 5 minutes. We've seen boiler cycling as fast as every 2 minutes with a minute of operation and a minute of purge.

Boiler mass is essentially the amount of water inside the boiler and has a direct impact on boiler cycling at low load. Most condensing boilers are "low-mass" meaning they could have as little as 2 quarts (liters) of water in the boiler. The problem is low-mass boilers are subject to fast cycling at low loads, which aggravates the performance during cycling. External water storage (buffer) tanks can be piped into the system to reduce or eliminate short-cycling. Low-mass boilers are compact and can be wheeled through a doorway and arranged in modular banks; adding a large buffer tank defeats the space-saving advantage of low-mass boilers.

Principal-7 - Select Boilers with Low Minimum Water Flow Requirements

Minimum operating boiler water flow rates are usually more important to system performance than the burner turn-down ratio. Minimum flow turndowns range from zero to as high as 80%, depending on the boiler selected. High-mass condensing boilers generally have low or no minimum flow requirements. Most primary-only distribution systems utilize a system flow meter and bypass valve to maintain the minimum flow rate through the operating boilers. The bypass valve directs boiler exiting supply water directly back into the boiler return, which greatly increase boiler entering water temperatures, generally taking the boiler out of the condensing range. The minimum boiler flow requirement is generally the most critical factor in boiler selection. The minimum allowable boiler flow is often not immediately apparent in boiler design and installation manuals, but it is almost always stated somewhere. Operation below this limit can damage the boiler and void the warranty.

Principal-8 – Vary the Size of Boilers to lower System Turn-Down Ratio and Minimum Water Flow Requirements

For instance, for a total system capacity of 100%, consider two boilers sized at 20% and 80% rather than two boilers both sized at 50%. Assuming the minimum burner turn-down and flow rate is 20% of peak for each boiler, the system minimum of unequally sized boilers is 4% versus 10% for equally sized boilers.

Principal-9 – Select Control Valves Capable of Accurately Controlling less than 1% of Peak Flow

Control valves can negatively affect the ability of the system to maintain a high delta-T at low loads. Restricting water flow with a modulating control valve, results in a higher water delta-T. However, operating a control valve in an open/closed mode, results in a low delta-T. Open/closed control of a modulating valve will occur at low flow through the valve, typically starting at about 5% of design flow for an inexpensive control valve. Characterized valves and multi-port valves can decrease the advent of open/closed cycling down to 1% or less. It is recommended that all high-performance systems be equipped with modern pressure independent control (PIC) valves. PIC valves can provide accurate control down to the range of 0.5% load.

Principal-10 – Optimize Heating Water System Controls

Optimizing hydronic system controls is focused on reducing boiler entering water temperature (EWT) to maximize boiler condensing time and efficiency. Control strategies include system enable control, optimal boiler sequencing, outside air reset, and load reset.

System Enable Control is an important consideration for both condensing and conventional boiler operation. Most systems, we encounter in commissioning, use an outside air temperature (OAT) lockout strategy, which enables the heating water system when temperatures drop below a setpoint, typically 60˚F (15˚C) . This is a very poor strategy, resulting in hundreds of operating hours at no load other than pipe heat loss. A better strategy is a dual boiler enable setpoint strategy. An example of a dual setpoint strategy is to keep the system off when the OAT is above 60˚F (15˚C) and enable the system when OAT is below 40˚F (4˚C). When OAT is between these setpoint limits, the system enables upon a call for heating by one or more coils. During a retro-commissioning effort on two identical buildings, one enabled the hot water system on OAT and the other on coil demand between the two setpoints; the single OAT strategy had double the annual natural gas use as the one with the recommended strategy.

Optimal Boiler Sequencing can be complex given multiple boiler sizes, varying burner and minimum flow turn-down ratios, boiler performance characteristics, and temperature reset strategies. Operating multiple boilers in parallel at low loads is often recommended; condensing boilers are most efficient when operated at middle part load conditions in the 20% to 60% range. However, the minimum boiler flow ratio must be considered to avoid excessive hot water flow through the bypass valve, and subsequent increase in boiler entering water temperature, which is the dominant factor in the boiler efficiency equation.

Outside Air Temperature (OAT) Reset, which reduces boiler LWT in response to OAT, is common boiler control strategy. Traditionally OAT reset is focused on reducing control valve cycling at low flow, but will also reduce boiler EWT and thus increase condensing boiler efficiency.

Load Reset is like OAT reset, except boiler LWT is reset in response to zone temperatures or control valve position. With the feedback from the loads, load reset is much more effective than OAT reset.

Principal-11 – Use a Robust Design Tool to Design Condensing Boiler Systems

There are many variables to consider in designing a high performance condensing boiler system, too many for the human mind to consider simultaneously. A design tool is required to evaluate the result of applying the nine principals of condensing boiler system design. **Error! Reference source not found.** below is from a spreadsheet based tool and shows the results of a particular schematic design. Boiler LWT is automatically reset to meets the loads on two air heating coils, some hot water baseboard, and a radiant slab. At high loads, the hot water baseboard LWT pushes the Boiler EWT up close to 130˚F (54˚C) , the edge of the condensing range. But overall, Boiler EWT is mostly in the 80˚F (27˚C) range at mid and low loads, where the majority of load hours occur.

A design tool must include calculation of several components of the system including:

- The boiler efficiency curve,
- Boiler operating characteristics including the minimum burner turndown ratio, the performance with short cycling boilers, the minimum flow ratio, the sequencing of the boilers, and other control strategies,
- The heat exchange characteristics of several types of heat coils including air heating coils, hot water baseboard, radiant slabs, and DHW heaters,

- The ability to convert coil selection data into a coil performance model,
- The flow characteristics of control valves and their performance when cycling at low load conditions,
- And finally the tool must output results in a meaningful manner.

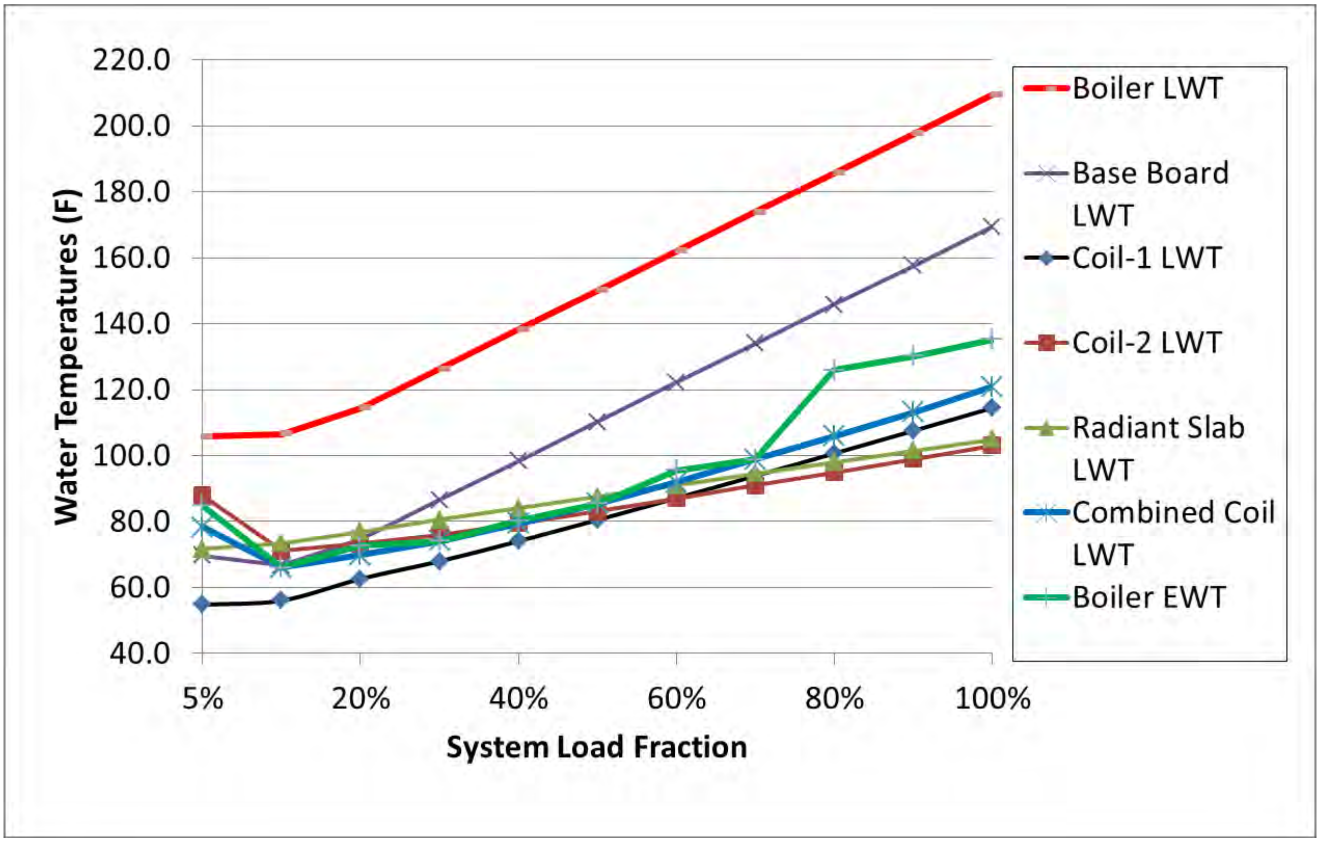

Figure 3 Condensing Boiler System Energy Model Output Graphic.

CONCLUSION

Designing an energy-efficient design for a heating system using condensing boilers is completely different than designing a conventional boiler system. The goal in a conventional system design is to keep the boiler return water temperature above 140˚F (60˚C) . The goal for a condensing boiler system is to return 80˚F (27˚C) to the boilers to maximize efficiency. This difference in the optimal boiler EWT results in significant differences in systems including distribution piping design, operating system delta-T, coil selection, boiler sequencing, and system control. Given the cost premium of a condensing boiler, the designer's goal is to make the system operate as efficiently as possible.

Optimizing Design & Control Of Chilled Water Plants

Part 5: Optimized Control Sequences

By **Steven T. Taylor, P.E.,** Fellow ASHRAE

This is the last of a series of articles discussing how to optimize the design and control of chilled water plants. The series summarizes ASHRAE's Self Directed Learning (SDL) course called *Fundamentals of Design and Control of Central Chilled Water Plants* and the research that was performed to support its development. The articles, and the SDL course upon which it is based, are intended to provide techniques for plant design and control that require little or no added engineering time compared to standard practice but at the same time result in significantly reduced plant life-cycle costs.

A procedure was developed to provide near-optimum plant design for most chiller plants including the following steps:

1. Select chilled water distribution system.
2. Select chilled water temperatures, flow rate, and primary pipe sizes.
3. Select condenser water distribution system.
4. Select condenser water temperatures, flow rate, and primary pipe sizes.
5. Select cooling tower type, speed control option, efficiency, approach temperature, and make cooling tower selection.
6. Select chillers.
7. Finalize piping system design, calculate pump head, and select pumps.
8. Develop and optimize control sequences.

Each of these steps is discussed in this series of five articles. This article discusses step 8.

Typical Chiller Plant

Figure 1 is a typical primary-only variable flow chilled water plant. The plant has two of each major component (chillers, towers, condenser water pumps, and chilled water pumps) each sized for 50% of the load. This plant design is very common and was used as the basis of the simulations and optimization for this series of articles and the SDL course upon which it is based.

Note that the condenser water (CW) pumps in *Figure 1* do not have variable speed drives (VSDs). Sequences for variable speed CW pumps are also addressed in this article but, as discussed in Part 2[1] of this series and in more detail below, VSDs on condenser water

About the Author

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Modeling the Plant

The plant in *Figure 1,* serving a typical office building, was modeled with all permutations of the following design variables:

Weather Oakland, Calif., Albuquerque, N.M., Chicago, Atlanta, Miami, Las Vegas

CHWST Reset by valve position from 42°F to 57°F

Chillers

- ≠# Two styles (two stage and open-drive)
- ≠# Efficiency at 0.35, 0.5, and 0.65 kW/ton at AHRI conditions

Towers

- ≠# Approach: 3°F, 6°F, 9°F, and 12°F
- ≠# Tower Range: 9°F, 12°F, and 15°F
- ≠# Efficiency: 50, 70, and 90 gpm/hp

Condenser water pumps With and without VSDs

The control equation coefficients were determined from each run, then these coefficients were themselves regressed against various design parameters and weather indicators. The results are shown below. The development of these regressions is ongoing to include more weather sites and chiller variations.

1. Condenser water temperature control. Control CW return temperature to the setpoint determined from Equation 1a:

$$CWRT = CHWST + A \times PLR + B \qquad (1a)$$

A = –63 + 0.0053 × CDD65 – 0.0087 × WBDD55 + 1.67 × WB + 0.52 × APPROACH – 0.029 × GPM/HP

B = 18 – 0.0033 × CDD65 + 0.0053 × WBDD55 – 0.26 × WB + 0.15 × APPROACH – 0.014 × GPM/HP

2. Variable speed condenser water pumps. Control CW flow ratio to the setpoint determined from Equation 2:

$$CWFR = C \times PLR + D \qquad (2)$$

C = 1.35 - 1.27E–05 × CDD65 + 1.36 × NPLV – 0.0212 × WB – 0.012 × APPROACH + 0.0765 × RANGE

D = –0.147 + 7.04E–06 × CDD65 – 0.124 × NPLV + 0.0038 × WB + 0.00133 × APPROACH + 0.00217 × RANGE

3. Chiller Staging. Use one chiller when PLR is less than SPLR determined from Equation 3:

$$SPLR = E \times (CWRT - CHWST) + F \qquad (3)$$

E = 0.057 – 0.000569 × WB – 0.0645 × IPLV – 0.000233 × APPROACH – 0.000402 × RANGE + 0.0399 × KW/TON

F = –1.06 + 0.0145 × WB + 2.16 × IPLV + 0.0068 × APPROACH + 0.0117 × RANGE – 1.33 × KW/TON

These control sequences strictly apply to primary-only plants with centrifugal chillers serving air handlers with outdoor air economizers in a typical office building. It is not known how well they apply to other applications.

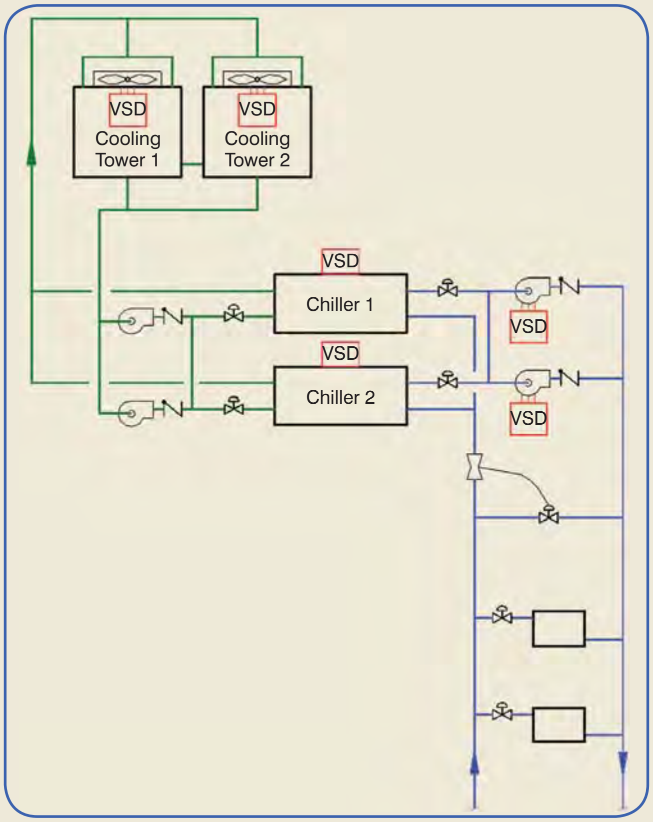

Figure 1: Typical chilled water plant schematic.

Variables

APPROACH	Design tower leaving water temperature minus WB, °F
CHWFR	Chilled water flow ratio, actual flow divided by total plant design flow
CHWST	Chilled water supply temperature (leaving evaporator temperature), °F
CWFR	Condenser water flow ratio, actual flow divided by total plant design flow
CWRT	Condenser water return temperature (leaving condenser water temperature), °F
CDD65	Cooling degree-days base 65°F
DP	Differential pressure, feet H_2O
KW/TON	Chiller efficiency at AHRI conditions, kW/ton
Γ*T*	Temperature difference, °F
GPM/HP	Tower efficiency per ASHRAE Standard 90.1
IPLV	Integrated part load value per AHRI 550/590, kW/ton
NPLV	Non-standard part load value per AHRI 550/590, kW/ton
RANGE	Design tower entering minus leaving water temperature, °F
PLR	Plant part load ratio, current load divided by total plant design capacity
TOPP	Theoretical optimum plant performance
WB	Design wet-bulb temperature, ASHRAE 1%, °F
WBDD55	Wet-bulb cooling degree-days base 55°F

pumps are usually not life-cycle cost effective for plants serving office building type loads.

Also note in *Figure 1* that the cooling towers do not include any isolation valves to shut off flow to allow one tower to operate alone. As discussed in Part 4[2] of this series, towers generally can be selected with nozzles and dams that allow half flow from one CW pump while still providing full coverage of fill and it is always most efficient to run as many tower cells as possible. So whether one or two CW pumps are operating, both tower cells are enabled and fans are controlled to the same speed.

Determining Optimal Control Sequences

Chilled water plants have many characteristics that make each plant unique so that generalized sequences of control that maximize plant efficiency are not readily determined. Equipment and system variables that affect performance include:

Chillers. Each chiller has unique characteristics that affect full-load and part-load efficiency such as compressor design, evaporator and condenser heat transfer characteristics, unloading devices (such as variable speed drives, slide valves, and inlet guide vanes), oil management systems, and internal control logic.

Cooling towers. Tower efficiency (gpm/hp) varies significantly by almost an order of magnitude between a compact centrifugal fan tower to an oversized propeller fan tower. Towers can also be selected for a wide range of approach temperatures.

Chilled and condenser water pumps. Pumps and piping systems can be selected for a broad range of ΔTs and may or may not include variable speed drives. Pump efficiency also varies by pump type and size and pump head varies significantly depending on physical arrangement and pipe sizing standards.

Chilled water distribution systems. Distribution system arrangements, such as primary-secondary vs. primary-only variable flow, significantly affect plant control logic.

Weather. Changes in outdoor air conditions affect loads and the ability of cooling towers to reject energy.

Load profile. The size and consistency of loads will affect optimum sequences. For instance, control sequences that are optimum for an office building served by air-handling systems with airside economizers may not be optimum for a data center served by systems without economizers.

With so many variables, no single control sequence will maximize the plant efficiency of all plants in all climates for all building types.

There are a number of papers[3,4] on techniques to optimize control sequences for chilled water plants. Almost all require some level of computer modeling of the system and system components, and the associated amount of engineering time that most plant designers do not have. In writing this series of articles and the SDL upon which it is based, significant modeling was performed in an effort to determine generalized control sequences that account for most of the variation in plant design parameters summarized above. The technique used to determine optimized performance is described in a June 2007 ASHRAE Journal article.[4]

In brief, the technique involves developing calibrated simulation models of the plant and plant equipment that are run against an annual hourly chilled water load profile with coincident weather data while parametrically modeling virtually all of the potential modes of operation at each hour. The operating mode requiring the least amount of energy for each hour is determined. The minimum hourly energy use summed for the year is called the theoretical optimum plant performance (TOPP). Since all modes of operation were simulated, the plant performance cannot be better than the TOPP within the accuracy of the component models.

TOPP modeling was performed for the chilled water plant shown in *Figure 1* for a wide range of plant design options for tower range, approach, and efficiency; different chiller types and chiller efficiency; and varying climates (see "Modeling the Plant," Page 57). The operating modes (e.g., number of chillers, condenser water flow and pump speed, tower fan speed and related condenser water temperatures) that result in the TOPP for each plant design scenario were studied to see how they relate to independent variables such as plant load and weather (e.g., wet-bulb temperature) to find trends that can be used to control the plant in real applications through the direct digital control (DDC) system.

Ideally, equipment should be controlled as simply as possible; complex sequences are less likely to be sustained since operators are more likely to disable them at the first sign of perceived improper operation. The remainder of this article discusses the TOPP modeling and the generalized sequences that were developed from the analysis for the chilled water plant shown in *Figure 1* serving a typical office building.

CHW Pump Control

Chilled water pump speed is typically controlled to maintain supply-to-return differential pressure (DP) at setpoint. Standard 90.1[5] requires that the DP sensor(s) be located at the most remote coil(s). This is because the lower the DP setpoint, the lower the pump energy, as shown in *Figure 2*.* If the DP setpoint is reset by valve position, as discussed further below, pump energy can be close to the ideal curve in *Figure 2* for "DP setpoint = 0."

Figure 3 shows the optimum number of CHW pumps as a function of CHW flow ratio and as a function of pump speed for the chilled water plant shown in *Figure 1* based on TOPP modeling. Unlike cooling towers, the optimum sequence is not to run as many pumps as possible. This is because the pumps all pump through the same circuit (other than the pipes into and out of the each pump between headers) so there are not "cube-law" energy benefits for each pump individually.

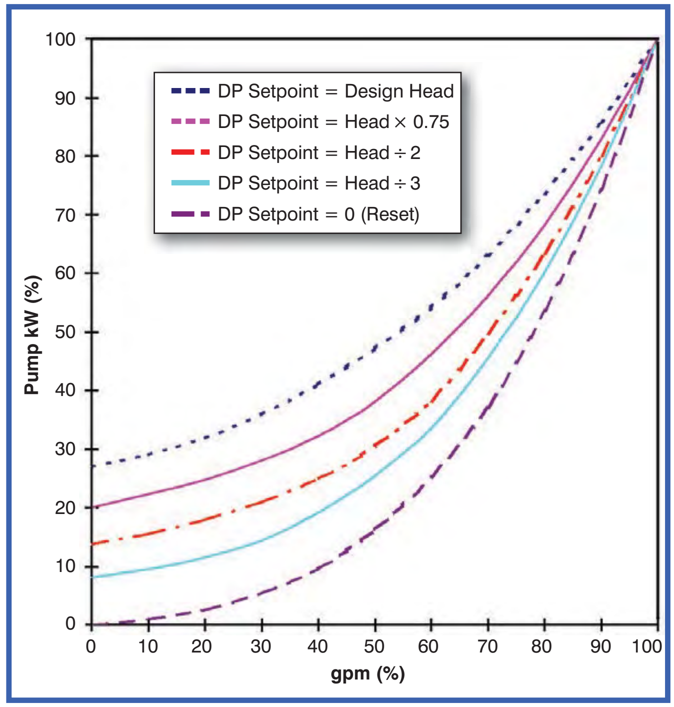

Figure 2: Variable speed performance at varying DP setpoint.

Figure 3 clearly indicates that staging pumps off of flow provides better optimization than staging off of pump speed.

As suggested by *Figure 3*, CHW pumps should be staged as a function of CHW flow ratio (CHWFR = actual flow divided by total plant design flow) at a staging point of 47%, i.e., one pump should operate when the CHWFR is below 47% and two pumps should operate when CHWFR is above 47%, with a time delay to prevent short cycling. The 47% optimum staging point assumes DP setpoint is reset by valve position; it will be somewhat higher at higher DP setpoints.

For very large pumps (>~100 hp [75 kW]), it may be worth the effort to determine the actual pump operating point (flow vs. head) and optimize staging based on pump efficiency determined by flow and pressure drop readings mapped to pump curves duplicated mathematically in the DDC system.[6] This can allow pumps to operate closer to their design efficiency as the system operating curve varies from the ideal parabolic curve due to modulating valves and minimum differential pressure setpoint. But the small potential energy savings is not worth the effort for most chilled water plants.

Chilled Water Temperature and DP Setpoint Reset

Chillers are more efficient at higher leaving water temperatures so, in general, optimum efficiency is achieved when the chilled water supply temperature (CHWST) setpoint is as high as possible. (The impact of CHWST on CHW pump energy is discussed below.) Where all zones are controlled by the DDC system, the best reset strategy is based on valve

* The curves in this figure assume pressure drop varies with flow to the 1.8 power since flow is typically in the transitional region between turbulent and laminar flow. They do not account for the impact of opening and closing control valves, which change system geometry and hence the system flow characteristics. The curves do include reductions to the efficiency of motors and VSDs at low load.

position where the CHWST setpoint is reset upwards until the valve controlling the coil that requires the coldest water is wide open. This strategy ensures that no coil is starved; all are able to maintain their desired supply air or space temperature setpoints.†

Valve position can also be used to reset the DP setpoint used to control pump speed. In fact, this is required by Standard 90.1. The logic is similar to CHWST setpoint reset: the DP setpoint is reset upwards until the valve controlling the coil that requires the highest DP is wide open.

So we have a dilemma: Valve position can be used to reset either CHWST setpoint or DP setpoint, but not both independently; it is not possible to know if the valve is starved for lack of pressure or from lack of cold enough water. We must decide which of the two setpoints to favor.

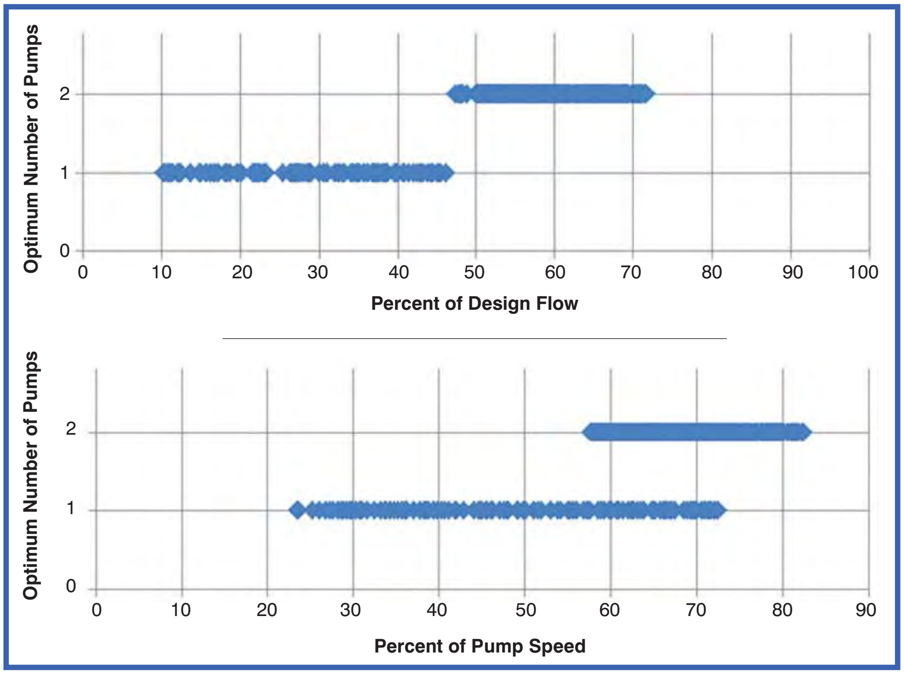

Figure 3: TOPP CHW pump staging vs. CHW flow ratio and pump speed.

While resetting CHWST setpoint upward reduces chiller energy use, it will increase pump energy use in variable flow systems. Higher chilled water temperature will cause coils to require more chilled water for the same load, degrading CHW ΔT and increasing flow and pump energy requirements. Degrading ΔT can also affect optimum chiller staging; however, this is not generally an issue in primary-only plants with variable speed chillers.[7] Furthermore, our simulations have shown that the positive impact of resetting chilled water temperature on chiller efficiency is much greater than the negative impact on pump energy even when distribution losses are high.

Figure 4 shows a DOE2.2 simulation of a primary-only plant with variable speed chillers and CHW pumps with high pump head (150 ft [450 kPa]) using three reset strategies based on valve position: reset of chilled water temperature alone; reset of differential pressure setpoint alone; and a combination of the two that first resets chilled water temperature then resets DP setpoint. The simulations were done in several climate zones (Houston and Oakland results are shown in the figure) and in all cases, resetting chilled water temperature was a more efficient strategy than resetting DP setpoint. Sequencing the two (resetting chilled water temperature first then DP setpoint) was the best approach, although only slightly better than resetting chilled water temperature alone.

† Contrary to conventional wisdom, the impact of reset on the dehumidification capability of air handlers is quite small and should not be a concern. Space humidity is a function of the supply air humidity ratio, which in turn, is a function of the coil leaving dry-bulb temperature setpoint. Regardless of CHWST, the air leaving a wet cooling coil is nearly saturated; lowering CHWST only slightly reduces supply air humidity ratio. As long as the supply air temperature can be maintained at the desired setpoint, resetting CHWST will not impact space humidity.

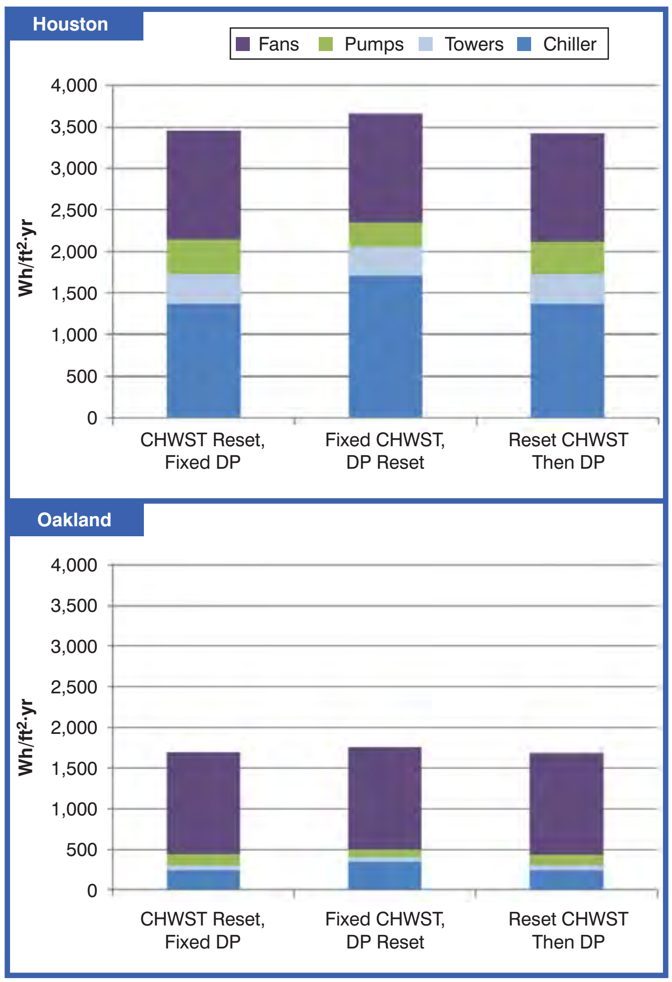

Figure 4: Plant energy with CHWST Setpoint Reset, CW DP Setpoint Reset and a combination of the two.

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Figure 5 shows how this sequenced reset strategy can be implemented. The x-axis is a software point called "CHW Plant Reset" that varies from 0% to 100% using "trim and respond" logic.[8] The coil valve controllers generate "requests" for colder chilled water temperature or higher pump pressure when the valve is full open. When valves are generating "requests," CHW Plant Reset increases; when they are not, CHW Plant Reset steadily decreases.

When CHW Plant Reset is 100%, the CHWST setpoint is at T_{min} (the design chilled water temperature) and the DP setpoint is at DP_{max} (the design DP setpoint). As the load backs off, the trim and respond logic reduces the CHW Plant Reset point. As it does, chilled water temperature is increased first up to a maximum T_{max} (equal to the lowest air handler supply air temperature setpoint less 2°F [1°C]), then DP setpoint is reduced down to a minimum value DP_{min} (such as 3 psi [21 kPa]).

In practice, this logic seldom results in much reset of the DP setpoint—the CHWST reset is aggressive enough to starve the coils first—so it is important to locate the DP sensor(s) at the most remote coil(s) so that DP_{max} can be as low as possible to minimize pump energy (*Figure 2*).

‡ For plants with more consistent loads that do not vary with weather, such as those serving data centers and those located in consistently humid climates such as Miami, correlation of load with CWRT/CHWST temperature difference is poor. For these plants, optimum CWST vs. wet-bulb temperature was found to have better correlation. But for office buildings in general, the correlations in *Figure 7* were more consistent.

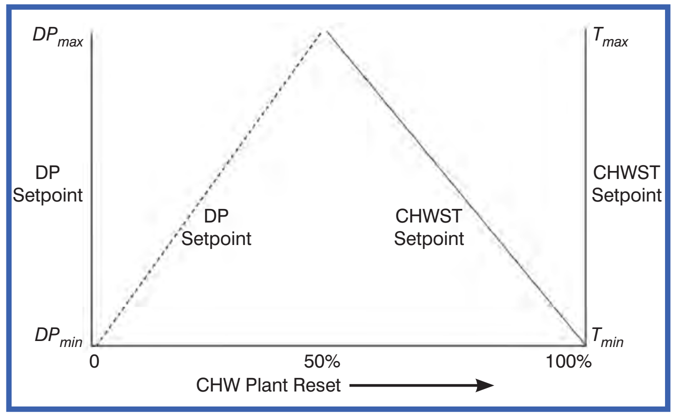

Figure 5: CHWST Setpoint and CW DP Setpoint Reset sequenced off of CHW valves.

Tower Fan Speed Control

A common approach to controlling cooling towers is to reset condenser water supply temperature based on outdoor air wet-bulb temperature. But our simulations seldom indicated a good fit; as shown in *Figure 6*, the correlation was fairly good in Miami but not in Oakland and most other climates.

For plants serving typical office buildings,‡ good correlations were found in all TOPP simulations between plant part load ratio (PLR, actual plant load divided by total plant design

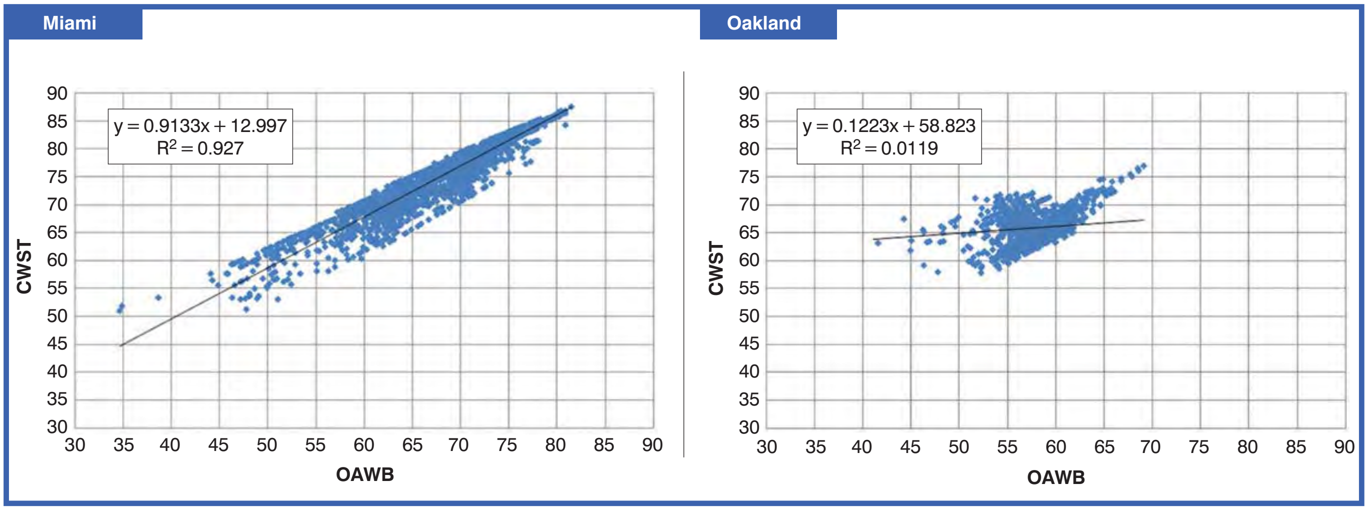

Figure 6: TOPP optimum condenser water supply temperature vs. wet-bulb temperature.

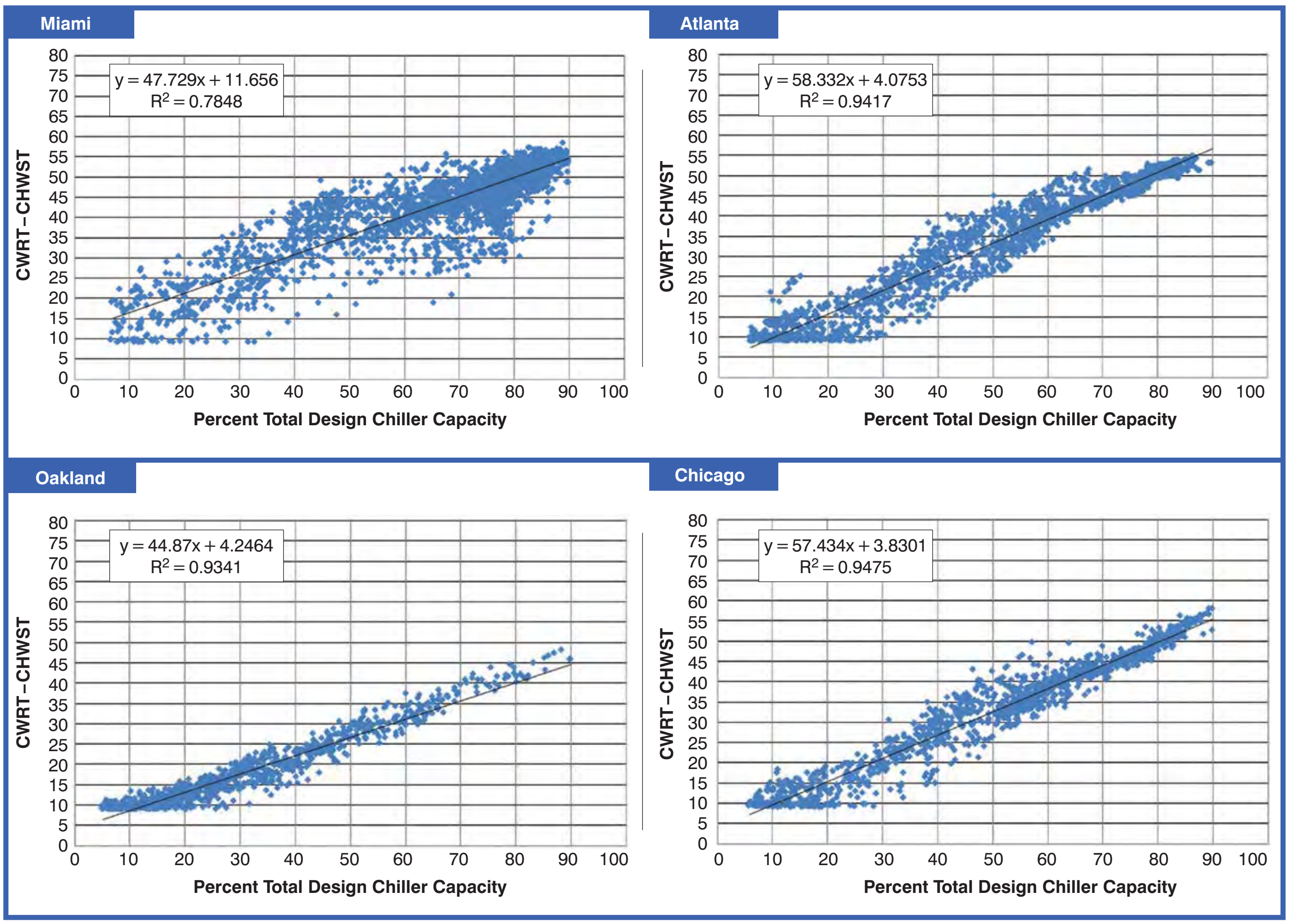

Figure 7: TOPP [CWRT-CHWST] vs. plant load ratio.

capacity) and the difference between the condenser temperature return temperature (CWRT, leaving the condenser) and the CHWST. Examples are shown in *Figure 7*. The CWRT-CHWST difference is a direct indicator of the refrigerant lift (the condenser and evaporator leaving water temperatures are determined by the condenser and evaporator temperatures), which drives chiller efficiency.

The data in *Figure 7* can be fit to a straight line:

$$\text{CWRT} - \text{CHWST} = A \times \text{PLR} + B \quad (1)$$

"Very impressed."

– Ray Fischer, Design Engineer

Bob Stiens of Cincinnati Air Conditioning with Ray Fischer, the project's Design Engineer

Developer Bloomfield/Schon + Partners recently converted the abandoned 180,000 sq. ft. American Can factory in Cincinnati's Northside into a 110-unit apartment complex. Residents enjoy efficient indoor comfort from an HVAC delivery system comprised of ClimateMaster® heat pumps and a Taco LoadMatch® system.

No strangers to LoadMatch

The developer chose Turnbull-Wahlert as its GC; the firms had worked together previously on a 98,000 sq. ft. LoadMatch project in Ithaca, NY. Bob Stiens of Cincinnati Air Conditioning was brought on board, too, bringing his wealth of LoadMatch experience to the job.

HS2 and LoadMatch save time

A very tight construction schedule gave design engineer Ray Fischer just five weeks to design and size the system. Ray was introduced to LoadMatch and to Taco's Hydronic System Solutions® software. "That HSS tool saved me a lot of time," says Ray, "I was very impressed. As for LoadMatch, I'd use it again!"

Taco through and through

The rooftop mechanical room was small, requiring close coordination of mechanical equipment and Taco products. Twin gas-fired condensing boilers were supported by four Taco KV and KS Vertical In-line Pumps, a Taco Plate & Frame Heat Exchanger and a 4900 Series Air Separator. Despite the space limitations, Bob Stiens says it was a "turn-key install."

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A and B are coefficients that vary with climate and plant design (see "Modeling the Plant," Page 57). Equation 1 can be solved for the optimum CWRT setpoint given the current CHWST:

$$\text{CWRT} = \text{CHWST} + A \times \text{PLR} + B \tag{1a}$$

This setpoint must be bounded by the minimum CWRT-CHWST difference at low load prescribed by the chiller manufacturer. This minimum (9°F [5°C] for the chiller in *Figure 7*) is a function primarily of the chiller's oil management design and can range from only a few degrees for oil-free chillers (e.g., those with magnetic or ceramic bearings) to as high as about 20°F [11°C]. The lower this minimum is, the lower annual chiller plant energy will be, particularly in mild climates.

So near-optimum tower performance can be achieved by controlling tower fan speed based on condenser water *return* temperature to the setpoint determined from Equation 1a. Controlling tower fan speed based on return temperature rather than supply temperature is non-conventional but it makes sense because it is the temperature leaving the condenser that determines chiller lift, not the entering (supply) water temperature. Chiller efficiency is not sensitive to entering chilled or condenser water temperature.

Condenser Water Pump Control

No good correlations were found for control of VSDs on condenser water pumps. Optimum condenser water pump speed and flow were plotted against various parameters such as PLR, wet-bulb temperature, chiller percent power, and lift with no consistent relationships. The best correlation was flow vs. PLR as shown in *Figure 8*, but the correlations were seldom strong (R^2 typically less than 0.85 and some as low as 0.5). The correlations were significantly weaker for pump speed than for flow so a condenser water flow meter should be added if one is not already part of the design.

The curve fit can be expressed as follows

$$\text{CWFR} = C \times \text{PLR} + D \tag{2}$$

where CWFR is the ratio of desired CW flow setpoint to the design CW flow. The CW flow setpoint is then calculated as:

$$\text{CWFSP} = \text{CWFR} \times \text{CWDF} \tag{2a}$$

where CWDF is the design CW flow rate for the plant (both pumps). This setpoint must be bounded by the minimum required CW flow rate obtained from the chiller manufacturer. The minimum flow from most manufacturers cor-

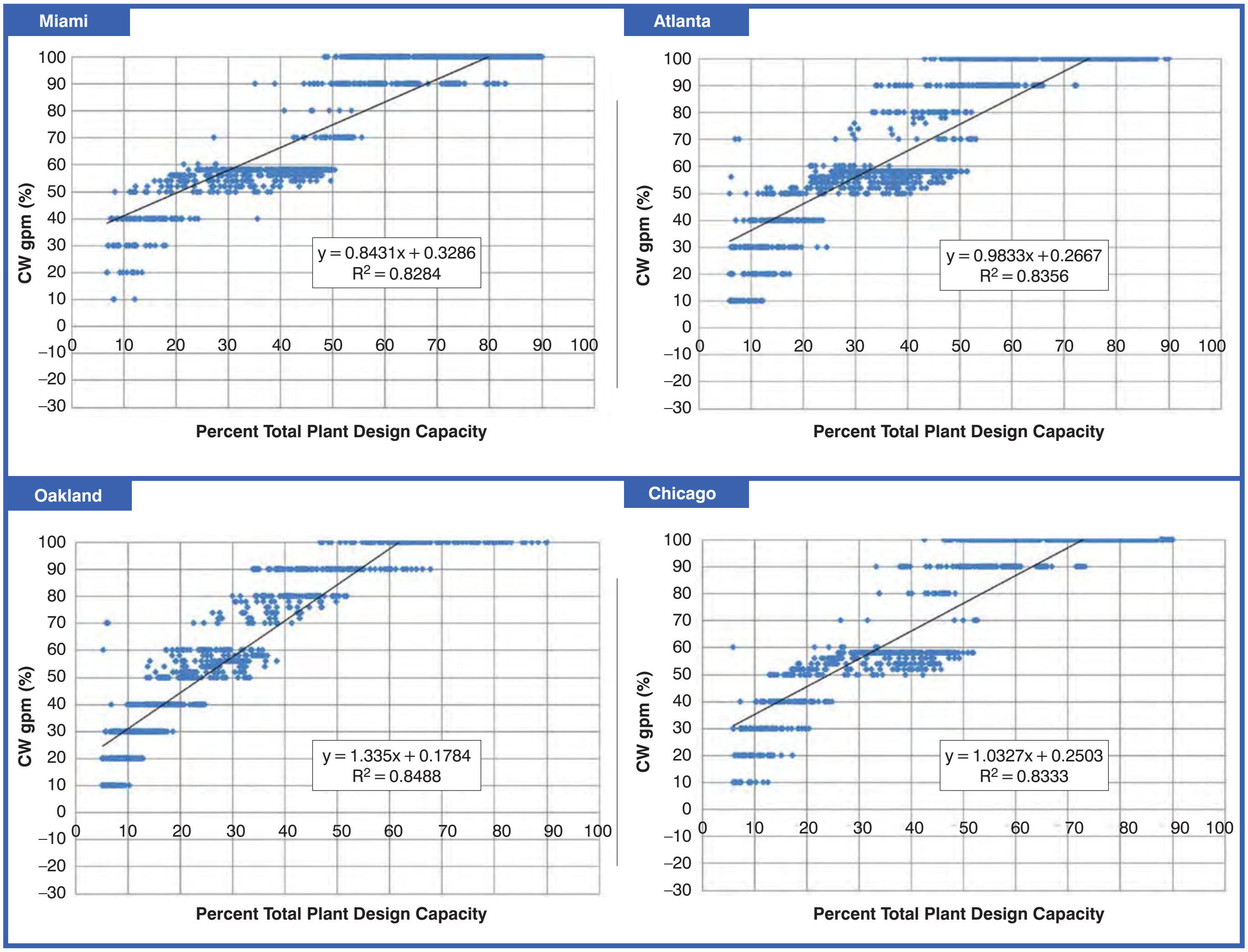

Figure 8: TOPP CW flow vs. plant load ratio.

relates to the onset of laminar flow and will be on the order of 40% to 70% of design flow depending on the number of tubes, number of passes, and tube design (e.g., smooth vs. enhanced). Higher rates are reputed to discourage fouling of condenser tubes but to the author's knowledge, no studies have been done to support that notion.[9] Once the flow rate is determined, CW pump speed is modulated to maintain the CW flow at setpoint.

When C and D coefficients determined for specific plants were fed back into the energy model, actual performance ranged from 101% to 110% of the TOPP. With this less than optimum performance, VSDs were found to be marginally life-cycle cost effective in dry climates (Albuquerque, N.M.) and not cost effective elsewhere. This performance gets worse when C and D are determined from the regression equations based on plant design (see "Modeling the Plant"), rather than from actual plant performance modeling (e.g., *Figure 8*). In some cases, particularly in humid climates, the CW pump control logic caused energy use to *increase* vs. constant speed CW pumps. Therefore, VSDs on CW pumps are recommended only on plants in dry climates and only if

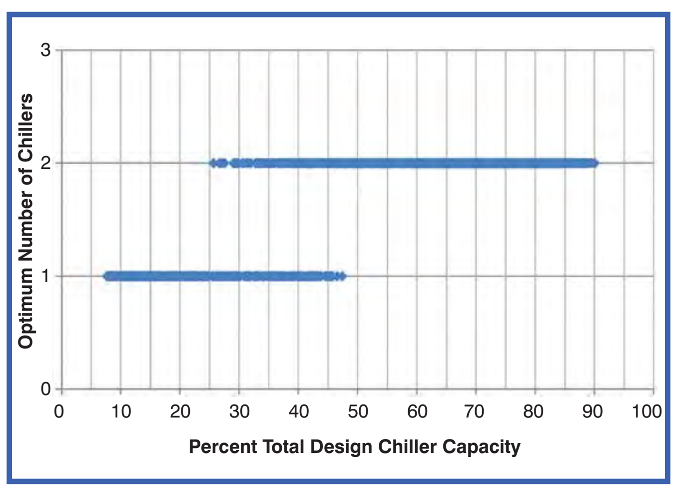

Figure 9: TOPP variable speed chiller staging vs. plant load ratio (Albuquerque).

C and D coefficients are based on TOPP simulations of the actual plant, not from the equations list in "Modeling the Plant."

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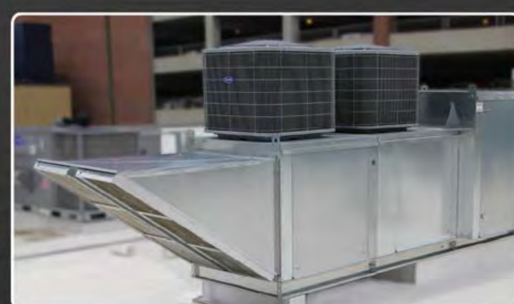

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Optimum staging for variable speed CW pumps was found to correlate very well to CW flow with 60% of the total design flow as the staging point, i.e., one pump should operate when the CWFR is below 60% and two pumps should operate when CWFR is above 60%, with a time delay to prevent short cycling.

Optimum staging for constant speed pumps was found to vary with both CWRT-CHWST difference and with PLR, but with fairly weak correlations and relatively small energy impact regardless of logic. For simplicity, constant speed CW pumps should simply be staged with the chillers.

Chiller Staging

Figure 9 (Page 68) shows the optimum number of chillers that should be run plotted against plant load for variable speed centrifugal chillers. The graph shows that it is often optimum to operate two chillers as low as 25% of overall plant load. This result may seem somewhat counterintuitive; conventional wisdom is to run as few chillers as possible. That is true for fixed speed chillers, but not for variable speed chillers, which are more efficient at low loads when condenser water temperatures are low.

Figure 9 shows that staging chillers based on load alone will not optimize performance since there is a fairly wide range where either one or two chillers should be operated.

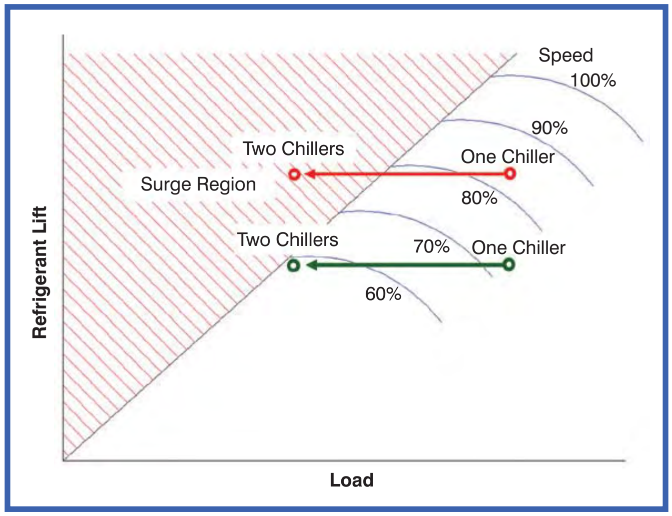

Figure 10: Possible surge problem staging by load only.

There is also another problem with staging based on load alone: it can cause the chillers to operate in surge. This can be seen in *Figure 10*, which schematically shows centrifugal chiller load vs. lift, defined as the difference between condenser and evaporator refrigerant temperature. If two chillers are operated when the refrigerant lift is high (red line), the chillers will operate in the surge region. To avoid surge, the chiller controllers will speed up the compressors and throttle inlet guide vanes to control capacity. This reduces chiller efficiency so that it would then be more efficient to operate one chiller rather than two. But if the lift is low (green line in *Figure 10*), the chillers would not be in surge so operating two chillers would be more efficient than operating one. So in addition to load, chiller staging must take chiller lift into account. (This consideration applies only to centrifugal chillers; surge does not occur with positive displacement chillers such as those with screw compressors.)

Figure 11 shows the optimum number of operating chillers (blue dots indicate one chiller while red dots indicate two chillers) for example TOPP simulations. For all plant design options and for all climate zones, good correlations were found for the optimum staging point described by a straight line:

$$SPLR = E \times (CWRT - CHWST) + F \qquad (3)$$

where SPLR is the staging PLR and E and F are coefficients that vary with climate and plant design (see "Modeling the Plant"). If the actual measured PLR is less than SPLR, one chiller should operate; if the PLR is larger than SPLR then two chillers should operate, with a time delay to prevent short cycling.

Note that the number of operating chilled water pumps and the number of operating chillers may not match. The pumps must respond to the flow and pressure requirements of the system, not to the load, and thus are staged independently from chillers.

Primary-only variable flow plants like this also will require "soft staging" and minimum flow control. These sequences and why they are needed are discussed in more detail in the SDL and in Reference 10.

Example

The TOPP model results for an Oakland plant were plotted per *Figures 7, 8,* and *11* and the following slopes and intercepts were determined from curve-fits:

A = 47, B = 5.2
C = 1.3, D = 0.13
E = 0.009, F = 0.21

Figure 12 shows the theoretical optimum performance for both variable speed (VS) constant speed (CS) CW pumps compared to our proposed "real" sequences using the coefficients listed above. Despite their simplicity, our sequences resulted in only about 1% higher energy use than the TOPP. Variable speed drives on the CW pumps saved 3% vs. constant speed pumps, but this was not enough savings to make them cost effective at a 15 scalar ratio (simple payback period) for this plant. Also shown in the figure for comparison is plant performance using the AHRI 550/590 condenser water relief curve to reset condenser water temperature (4% higher energy use than our sequences) and performance assuming CWST

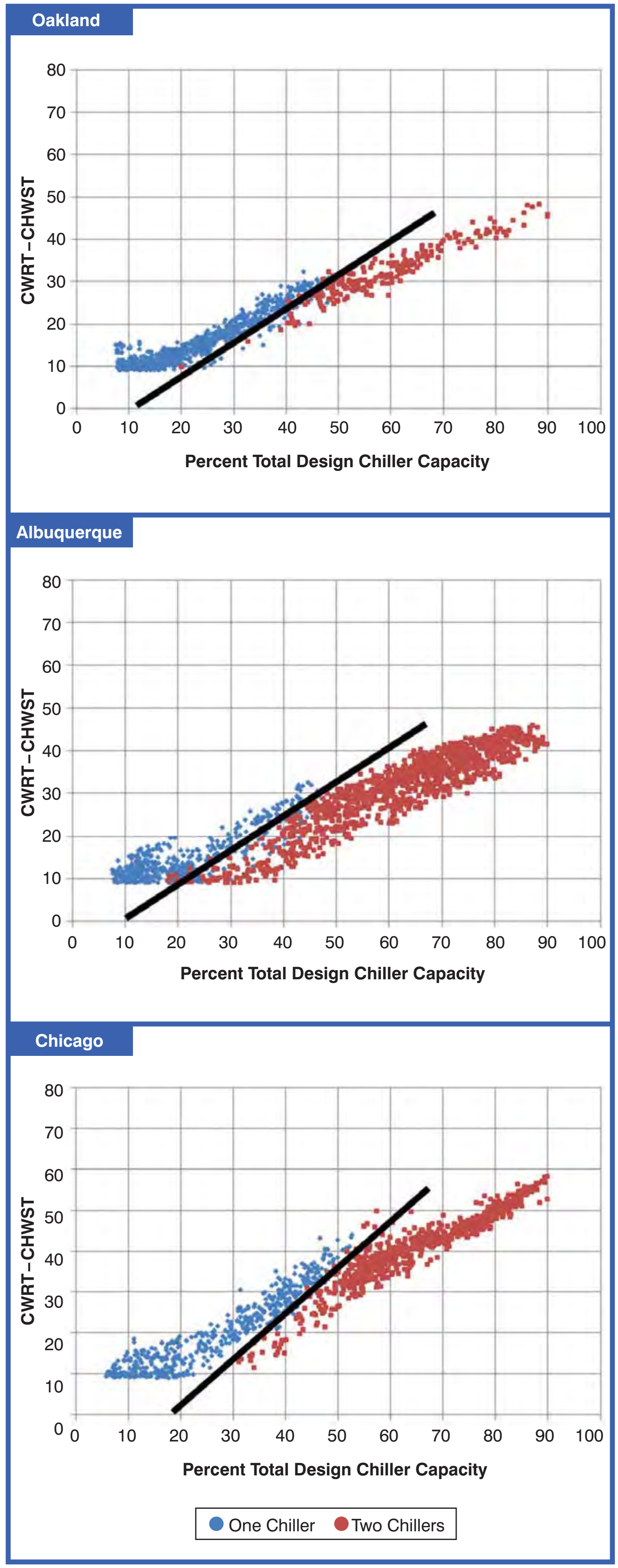

Figure 11: Optimum staging vs. (CWRT-CHWST) and plant part load ratio.

setpoint is fixed at the design temperature (16% higher than our sequences).

Summary

This article is the last in a series of five that summarize chilled water plant design techniques intended to help engineers optimize plant design and control with little or no added engineering effort. In this article, optimized control logic was addressed. The logic is very simple and easily programmed into any DDC system controlling the plant. With these sequences properly implemented, chiller plants can perform within a few percent of their theoretical optimum.

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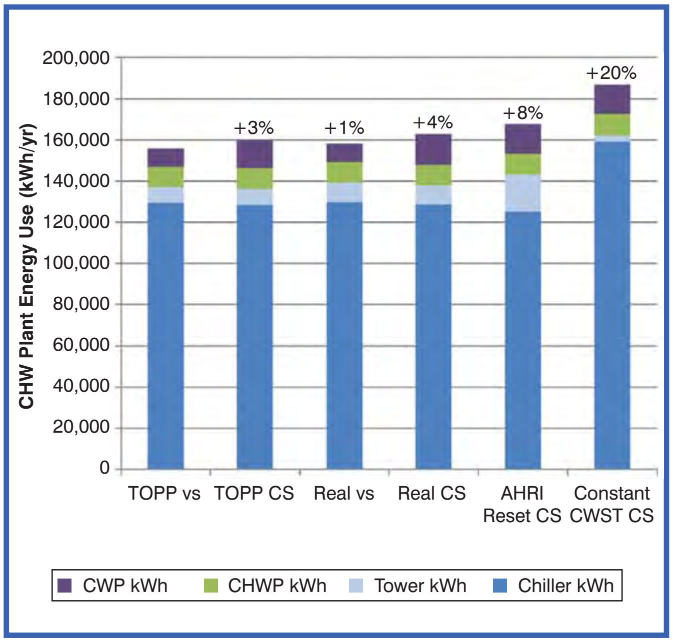

Figure 12: TOPP vs. real sequences for both constant speed and variable speed CW pumps.

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Central Chilled Water Plants Series

This series of articles summarizes the upcoming Self Directed Learning (SDL) course Fundamentals of Design and Control of Central Chilled Water Plants and the research that was performed to support its development. The series includes five segments.

Part 1: "Chilled Water Distribution System Selection" (July 2011), Part 2: "Condenser Water System Design" (September 2011), Part 3: "Pipe Sizing and Optimizing ΓT" (December 2012), and Part 4: "Chiller & Cooling Tower Selection" (March 2012).

Optimized control sequences. The series concluded with a discussion of how to optimally control chilled water plants, focusing on all-variable speed plants.

The intent of the SDL (and these articles) is to provide simple yet accurate advice to help designers and operators of chilled water plants to optimize life-cycle costs without having to perform rigorous and expensive life-cycle cost analyses for every plant.

In preparing the SDL, a significant amount of simulation, cost estimating, and life-cycle cost analysis was performed on the most common water-cooled plant configurations to determine how best to design and control them. The result is a set of improved design parameters and techniques that will provide much higher performing chilled water plants than common rules-of-thumb and standard practice.

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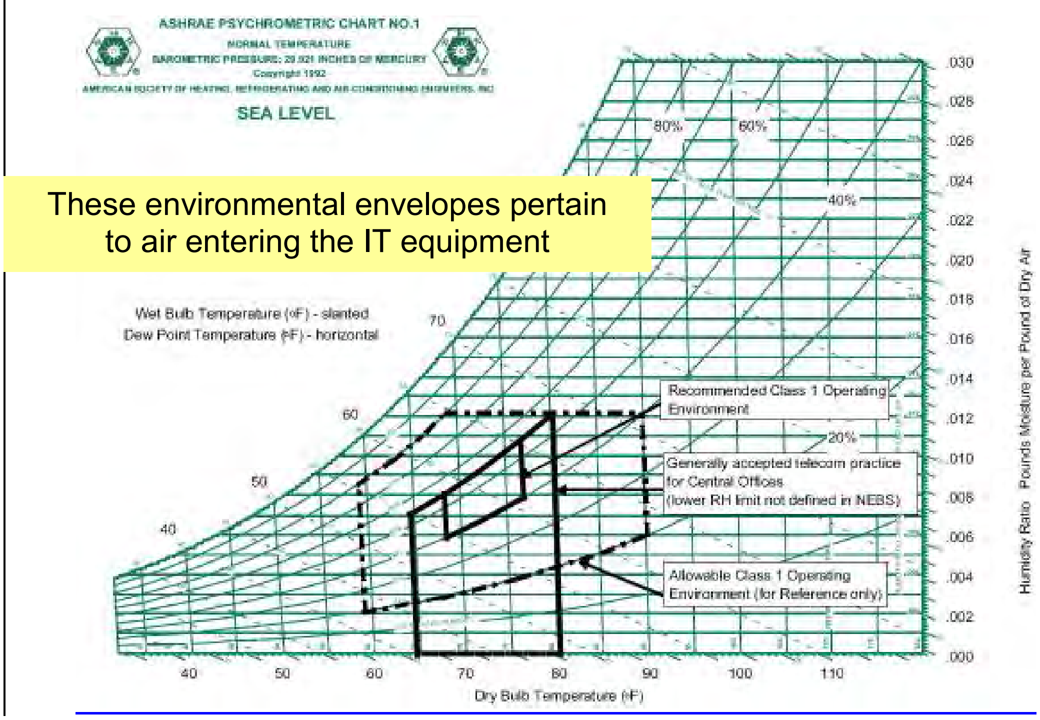
Appendix B – Data Center Equipment Information

2008 ASHRAE Environmental Guidelines for Datacom Equipment
-Expanding the Recommended Environmental Envelope-

Overview:

The current recommended environmental envelope for IT Equipment is listed in Table 2.1 of the 2004 referenced ASHRAE Datacom book [1]. These recommended conditions as well as the allowable conditions refer to the inlet air entering the datacom equipment. Specifically, it lists for data centers in ASHRAE classes 1 and 2 (refer to the referenced ASHRAE book for details on data center type, altitude, recommended vs allowable, etc.) a recommended environment range of 20 to 25 °C (68 to 77 °F) (dry bulb temperature) and a relative humidity (RH) range of 40 to 55%. (See the allowable and recommended envelopes for class 1 in the psychrometric chart below.).



To provide greater flexibility in facility operations, particularly with the goal of reduced energy consumption in data centers, TC 9.9 has undergone an effort to revisit these recommended Equipment Environmental Specifications, specifically the recommended envelope for classes 1 and 2 (the recommended envelope is the same for both of these environmental classes). The result of this effort, detailed below, is to expand the recommended operating environment envelope. The purpose of the recommended envelope is to give guidance to data center operators on maintaining high reliability and also operating their data centers in the most energy efficient manner. The allowable envelope is where IT manufacturers test their equipment in order to verify that the equipment will function within those environmental boundaries. Typically manufacturers will perform a number of tests prior to announcement of a product to verify that their product meets all the functionality requirements within this environmental envelope. This is not a statement of reliability but one of functionality of the IT equipment. However, the recommended envelope is a statement on reliability. For extended periods of time, the IT manufacturers recommend that data center operators maintain their environment within the recommended envelope. Exceeding the recommended limits for short periods of time should not be a problem, but running near the allowable limits for months could result in increased reliability issues. In reviewing the available data from a number of IT manufacturers the 2008 expanded recommended operating envelope is the agreed-upon envelope that is acceptable to all the IT manufacturers, and operation within this envelope will not compromise overall reliability of the IT equipment.

The previous and 2008 recommended envelope data is shown in table 1.

	2004 Version	2008 Version
Low End Temperature	20°C (68 °F)	18°C (64.4 °F)
High End Temperature	25°C (77 °F)	27°C (80.6 °F)
Low End Moisture	40% RH	5.5°C DP (41.9 °F)
High End Moisture	55% RH	60% RH & 15°C DP (59 °F DP)

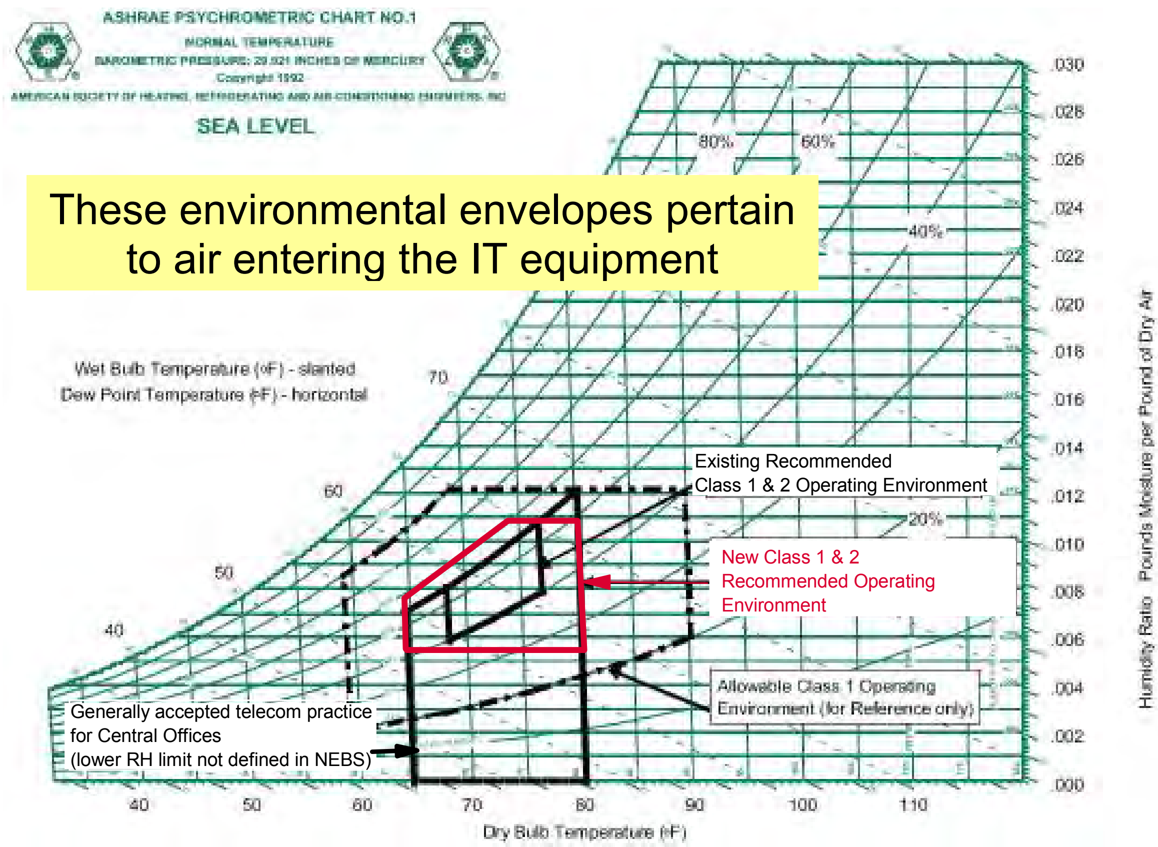
Table 1 Comparison of 2004 and 2008 recommended operating envelope

Neither the 2004 nor the 2008 recommended operating environments ensure that the data center is operating at the optimum energy efficiency. Depending on the cooling system design and outdoor environmental conditions there will be varying degrees of efficiency within the recommended zone. For instance, when the ambient temperature in the data center is raised, the thermal management algorithms within some datacom equipment will increase the speeds of the air moving devices to compensate for the higher inlet air temperatures, potentially offsetting the gains in energy efficiency due to the higher ambient temperature. It is incumbent upon each data center operator to review and determine, with appropriate engineering expertise, the ideal operating point for their system. This will include taking into account the recommended range and their site specific conditions. Using the full recommended envelope is not the most energy efficient environment when a refrigeration cooling process is being used. For example, the high dew point at the upper areas of the envelope will result in latent cooling (condensation) on refrigerated coils, especially in DX (direct expansion) units. Latent cooling decreases the available sensible cooling capacity for the cooling system and in many cases leads to the need to humidify to replace the moisture removed from the air.

The ranges included in this document apply to the inlets of all equipment in the data center (except where IT manufacturers specify other ranges). Attention is needed to make sure the appropriate inlet conditions are achieved for the top portion of IT equipment racks. The inlet air temperature in many data centers tends to be warmer at the top portion of racks, particularly if the warm rack exhaust air does not have a direct return path to the CRACs. This warmer air also affects the relative humidity resulting in lower values at the top portion of the rack. The air temperature generally follows a horizontal line on the psychometric chart where the absolute humidity remains constant but the relative humidity decreases.

Finally, it should be noted that the 2008 change to the recommended upper temperature limit from 25°C to 27°C (77 °F to 80.6 °F) can have detrimental effects on the acoustical noise levels in the data center. See the section on "Acoustical Noise Levels" near the end of this document for a discussion of these effects.

The 2008 recommended environmental envelope is shown in red in the figure below.



The reasoning behind the selection of the boundaries of this envelope are described below:

Dry bulb temperature limits

Part of the rationale in choosing the new low and high temperature limits was based on the generally accepted practice for the telecommunication industry's Central Office, based on NEBS GR-63-CORE, which uses the same dry bulb temperature limits as specified here. In addition, this choice provides a precedence for reliable operation of telecommunication electronic equipment based on a long history of Central Office installations all over the world.

Dry bulb Low side limit:

From an IT point of view, there is no concern in moving the lower recommended limit for dry bulb temperature from 20 °C to 18 °C. (68 °F to 64.4 °F) In equipment with constant speed air moving devices, a facility temperature drop of 2 °C (3.6 °F) will result in about a 2 °C (3.6 °F) drop in all component temperatures. Even if variable speed air moving devices were deployed, typically no change in speed occurs in this temperature range so that component temperatures would again experience a 2 °C (3.6 °F) drop.

One reason for lowering the recommended temperature is to extend the control range of economized systems by not requiring a mixing of hot return air to maintain the previous 20 °C (68 °F) recommended limit. The lower limit should not be interpreted as a recommendation to reduce operating temperatures as this could increase hours of chiller operation and increase energy use. A non-economizer based cooling system running at 18 °C (64.4 °F) will most likely carry an energy penalty. (One reason to do this would be a wide range of inlet rack temperatures due to poor airflow management, however fixing the airflow would likely be a good first step towards reducing energy)

Where the setpoint for the room temperature is taken at the return to cooling units, the recommended range should not be applied directly as this could drive energy costs higher from overcooling the space. The recommended range is intended for the inlet to the IT equipment. If the recommended range is used as a return air set-point, the lower end of the range (18 to 20°C) (64.4 to 68 °F) increases the risk of freezing the coils in a DX cooling system.

Dry Bulb High side limit:

The greatest justification for increasing high side temperature is to increase hours of economizer use per year. For non-economizer systems there may be an energy benefit by increasing the supply air or chilled water temperature set points. However, the move from 25 °C to 27 °C (77 °F to 80.6 °F) can have an impact on the IT equipment's power dissipation. Most IT manufacturers start to increase air moving device speed around 25 °C (77 °F) to improve the cooling of the components and thereby offset the increased ambient air temperature. Therefore care should be taken before operating at the higher inlet conditions.

The concern that increasing the IT inlet air temperatures might have a significant effect on reliability is not well founded. An increase in inlet temperature does not necessarily mean an increase in component temperatures. Consider the following graph showing a typical component temperature relative to an increasing ambient temperature for an IT system with constant speed fans.

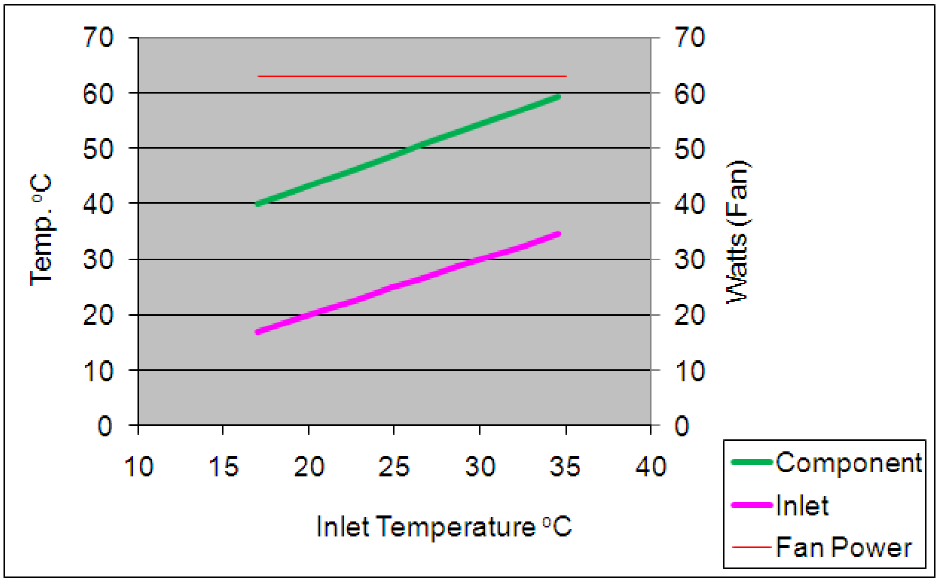
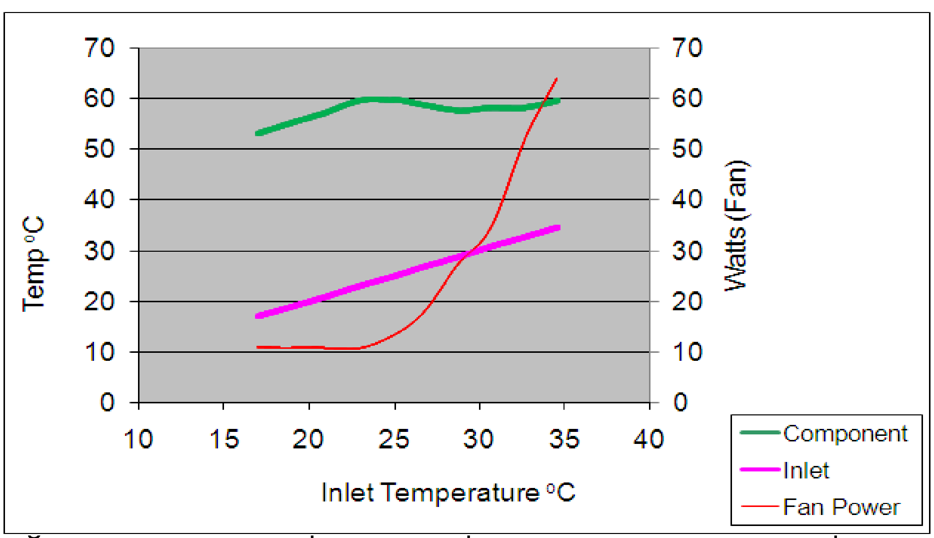


Figure 2: Inlet and Component Temperatures with fixed fan speed

In this example, the component temperature is 21.5 °C above the inlet temperature of 17 °C; it is 23.8 °C above an inlet ambient temperature of 38°C. The component temperature tracks the air inlet ambient temperature very closely.

Now consider the response of a typical component in a system with variable speed fan control as depicted in the figure below. Variable speed fans decrease the fan flow rate at lower temperatures to save energy. Ideal fan control optimizes the reduction in fan power to the point that component temperatures are still within vendor temperature specifications (i.e. the fans are slowed to the point that the component temperature is constant over a wide range of inlet air temperatures).



This particular system has a constant fan flow up to approximately 23°C. Below this inlet air temperature, the component temperature tracks closely to the ambient air temperature. Above this inlet temperature, the fan adjusts flow rate such that the component temperature is maintained at a relatively constant temperature.

This data brings up several important observations:

- Below a certain inlet temperature (23 °C in the case described above), IT systems that employ variable speed air moving devices have constant fan power, and their component temperatures will track fairly closely to ambient temperature changes. Systems that don't employ variable speed air moving devices would track ambient air temperatures over the full range of allowable ambient temperatures.
- Above this air inlet temperature (23 °C in the case described above), the speed of the air moving device increases in speed to maintain fairly constant component temperatures and in this case inlet temperature changes have little-to-no effect on component temperatures and thereby no affect on reliability since component temperatures are not affected by ambient temperature changes
- The introduction of IT equipment that employs variable speed air moving devices has:
    - Minimized the effect on component reliability as a result of changes in ambient temperatures, and
    - Allowed for potential of large increases in energy savings especially in facilities that deploy economizers

As shown in the figure 3 the IT fan power can increase dramatically as it starts ramping up in speed to counter the increased inlet ambient temperature. The graph shows a typical power increase that results in the near constant component temperature. In this case the fan power increased from 11 watts at ~23°C inlet to over 60 watts at 35°C inlet. The inefficiency in the power supply results in an even larger system power increase. The total room power (facilities + IT) may actually go up at warmer temperatures. IT manufacturers should be consulted when considering system ambient temperatures approaching the upper recommended ASHRAE temperature specification. See reference [2] for a technical evaluation of the effect of increased environmental temperature, where it was shown that an increase in temperature can actually increase energy use in a standard data center, but reduce it in a data center with economizers in the cooling system.

Because of the derating of the maximum allowable temperature with altitude for classes 1 and 2, the recommended maximum temperature is derated by 1 °C/300 m (1.8 °F/984.25 ft.) above 1800 m (5905.51 ft.).

Upper moisture limit

Based on extensive reliability testing of Printed Circuit Board (PCB) laminate materials, it has been shown that conductive anodic filament (CAF) growth is strongly related to relative humidity [3]. As humidity increases, time to failure rapidly decreases. Extended periods of relative humidity exceeding 60% can result in failures, especially given the reduced conductor to conductor spacings common in many designs today. The CAF mechanism involves electrolytic migration after a path is created. Path formation could be due to a breakdown of inner laminate bonds driven by moisture which supports the electrolytic migration, explaining why moisture is so key to CAF formation.

The upper moisture region is also important for disk and tape drives. In disk drives, there are head fly-ability and corrosion issues at high humidity. In tape drives, high humidity can increase frictional characteristics of tape, head wear and head corrosion. High relative humidity in combination with common atmospheric contaminants is required for atmospheric corrosion. The humidity forms monolayers of water on surfaces, thereby providing the electrolyte for the corrosion process. 60% RH is associated with adequate monolayer buildup for monolayers to start taking on fluid-like properties. Combined with humidity levels exceeding the critical equilibrium humidity of a contaminant's saturated salt, hygroscopic corrosion product is formed, further enhancing the buildup of acid-electrolyte surface wetness and greatly accelerating the corrosion process. Although disk drives do contain internal means to control and neutralize pollutants, maintaining humidity levels below the critical humidity levels of multiple monolayer formation retards initiation of the corrosion process.

A maximum recommended dew point of 15 °C (59 °F) is specified to provide an adequate guard band between the recommended and allowable envelopes.

Lower moisture limit

The motivation for lowering the moisture limit is to allow a greater number of hours per year where humidification (and its associated energy use) is not required.

The previous recommended lower limit was 40% RH. This correlates on the psychrometric chart to 20 °C (68 °F) dry bulb temperature and a 5.5 °C (41.9 °F) dew point (lower left) and a 25 °C (77 °F) dry bulb and a 10.5 °C (50.9 °F) dew point (lower right). The dryer the air, the greater the risk of electrostatic discharge (ESD). The main concern with decreased humidity is that the intensity of static electricity discharges increases. These higher voltage discharges tend to have a more severe impact on the operation of electronic devices, causing error conditions requiring service calls and, in some cases, physical damage. Static charges of thousands of volts can build up on surfaces in very dry environments. When a discharge path is offered, such as a maintenance activity the electric shock of this magnitude can damage sensitive electronics. If the humidity level is reduced too far, static dissipative materials can lose their ability to dissipate charge and then become insulators.

The mechanism of the static discharge and the impact of moisture in the air are not widely understood. Montoya [4] demonstrates through a parametric study that ESD charge voltage level is a function of dew point or absolute humidity in the air and not relative humidity. Simonic [5] studied ESD events over various temperature and moisture conditions over a period of a year and found significant increases in ESD events (20x) depending on the level of moisture content (winter vs summer months). It was not clear whether the important parameter was absolute humidity or relative humidity. Blinde and Lavioe[6] studied electrostatic charge decay (vs discharge) of several materials and have shown that it is not sufficient to specify environmental ESD protection in terms of absolute humidity; nor is a relative humidity specification sufficient since temperature effects ESD parameters other than atmospheric moisture content.

The 2004 recommended range includes a dew point temperature as low as 5.5 °C (41.9 °F). Discussions with the IT equipment manufacturers indicated that there have been no known reported ESD issues within the current recommended environmental limits. In addition the referenced information on ESD mechanisms [4-6] do not suggest a direct relative humidity correlation with ESD charge creation or discharge, but reference 4 does demonstrate a strong correlation of dewpoint to charge creation, a lower humidity limit based upon a minimum dewpoint(rather than minimum relative humidity) is proposed. Therefore the 2008 recommended lower limit is a line from 18 °C (64.4 °F) dry bulb and 5.5 °C (41.9 °F) dew point temperature to 27 °C (80.6 °F) dry bulb and a 5.5 °C (41.9 °F) dew point temperature. Over this range of dry bulb temperature and a 5.5 °C (41.9 °F) dew point the relative humidity varies from approximately 25% to 45%.

Another practical benefit of this change is that process changes in data centers and their HVAC systems, in this area of the psychrometric chart, are generally sensible only (i.e. horizontal on the psychrometric chart). Having a limit of relative humidity greatly complicates the control and operation of the cooling systems and could require added humidification operation at a cost of increased energy in order to maintain an RH when the space is already above the needed dew point temperature. To avoid these complications, the hours of economizer operation available using the 2004 guidelines were often restricted.

ASHRAE is developing a research project to investigate moisture levels and ESD with the hope of driving the recommended range to a lower moisture level in the future. In addition to ESD, low moisture levels can result in drying out of lubricants which can adversely affect some components. Possible examples include motors, disk drives, and tape drives. While manufacturers have indicated acceptance of the environmental extensions documented here, some have expressed concerns about further extensions. Another concern for tape drives at low moisture content is the increased tendency to collect debris on the tape, around the head, and tape transport mechanism due to static buildup.

Acoustical Noise Levels

The ASHRAE proposal to expand the operating envelope for datacom facilities may have an effect on acoustical noise levels. Noise levels in high-end data centers have steadily increased over the years and have become, or at least will soon become, a serious concern to data center managers and owners. For background and discussion on this, see Chapter 9 "Acoustical Noise Emissions" in the ASHRAE datacom book [7] . The increase in noise levels is the obvious result of the significant increase in cooling requirements of new, high-end datacom equipment. The increase in concern results from noise levels in data centers approaching or exceeding regulatory workplace noise limits, such as those imposed by OSHA in the U.S. or by EC Directives in Europe. Empirical fan laws generally predict that the sound power level of an air moving device increases with the 5th power of rotational speed. This means that a 20% increase in speed (e.g., 3000 to 3600 rpm) equates to a 4 dB increase in noise level. While it is not possible to predict a priori the effect on noise levels of a potential 2°C (3.6 °F) increase in data center temperatures, it is not unreasonable to expect to see increases in the range of 3-5 dB. Data center managers and owners should therefore weigh the trade-offs between the potential energy efficiencies with the proposed new operating environment and the potential increases in noise levels.

With regard to the regulatory workplace noise limits, and concern to protect their employees against potential hearing damage, data center managers should check whether potential changes in the noise levels in their environment will cause them to trip various "action level" thresholds defined in the local, state, or national codes. The actual regulations should be consulted, because these are complex and beyond the scope of this document to explain fully. For instance, when levels exceed 85 dB(A), hearing conservation programs are mandated, which can be quite costly, generally involving baseline audiometric testing, noise level monitoring or dosimetry, noise hazard signage, and education and training. When levels exceed 87 dB(A) (in Europe) or 90 dB(A) (in the US), further action such as mandatory hearing protection, rotation of employees, or engineering controls must be taken. Data center managers should consult with acoustical or industrial hygiene experts to determine whether a noise exposure problem will result from increasing ambient temperatures to the upper recommended limit proposed here.

Data Center Operation scenarios for ASHRAE's new recommended environmental limits

The recommended ASHRAE guideline is meant to give guidance to IT data center operators on the inlet air conditions to the IT equipment for the most reliable operation. Four possible scenarios where data center operators may elect to operate at conditions that lie outside the recommended environmental window are listed as follows:

1. Scenario #1: Expand economizer use for longer periods of the year where hardware fails are not tolerated

For short periods of time it is acceptable to operate outside this recommended envelope and approach the extremes of the allowable envelope. All manufacturers perform tests to verify that the hardware functions at the allowable limits. For example if during the summer months it is desirable to operate for longer periods of time using an economizer rather than turning on the chillers, this should be acceptable as long as this period of warmer inlet air temperatures to the datacom equipment does not exceed several days each year where the long term reliability of the equipment could be affected. Operation near the upper end of the allowable range may result in temperature warnings from the IT equipment.

2. Scenario #2: Expand economizer use for longer periods of the year where limited hardware fails are tolerated

All manufacturers perform tests to verify that the hardware functions at the allowable limits. For example if during the summer months it is desirable to operate for longer periods of time using the economizer rather than turning on the chillers and if your data center operation is such that periodic hardware fails are acceptable then operating for extended periods of time near or at the allowable limits may be acceptable. This, of course, would be a business decision on where to operate within the allowable and recommended envelopes and for what periods of time. Operation near the upper end of the allowable range may result in temperature warnings from the IT equipment.

3. Scenario # 3: Failure of cooling system or servicing cooling equipment

If the system was designed to perform within the recommended environmental limits it should be acceptable to operate outside this recommended envelope and approach the extremes of the allowable envelope during the failure. All manufacturers perform tests to verify that the hardware functions at the allowable limits. For example if a modular CRAC unit fails in the data center and the temperatures of the inlet air of the nearby racks increase beyond the recommended limits but are still within the allowable limits, this is acceptable for short periods of time until the failed component is repaired. As long as the repairs are completed within industry norm times for these type failures this operation should be acceptable. Operation near the upper end of the allowable range may result in temperature warnings from the IT equipment.

4. Scenario # 4: Addition of new servers that push the environment beyond the recommended envelope

For short periods of time it should be acceptable to operate outside this recommended envelope and approach the extremes of the allowable envelope. All manufacturers perform tests to verify that the hardware functions at the allowable limits. For example if additional servers are added to the data center in an area that would increase the inlet air temperatures to the server racks above the recommended limits but adhere to the allowable limits, this should be acceptable for short periods of time until the ventilation can be improved. The length of time operating outside the recommended envelope is somewhat arbitrary but several days would be acceptable. Operation near the upper end of the allowable range may result in temperature warnings from the IT equipment.

References:

1. ASHRAE Publication, “Thermal guidelines for Data Centers and other Data Processing Environments”, Atlanta, 2004

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3. Sauter, Karl, "Electrochemical Migration Testing Results - Evaluating Printed Circuit Board Design, Manufacturing Process and Laminate Material Impacts on CAF Resistance", IPC Printed Circuits Expo Proceedings, March 2001.

4. Montoya, 2002,
http://ismi.sematech.org/meetings/archives/other/20021014/montoya.pdf
from the Sematech Electrostatic Discharge Impact and Control Workshop, Austin Texas, October, 2002.

5. Simonic, R, “ESD Event Rates for metallic Covered Floor Standing Information Processing Machines,” IEEE EMC Symp. 1982, p.191-198.

6. Blinde, D. and Lavoie, L., “Quantitative effects of relative and absolute humidity on ESD generation/suppression,” in Proc. EOS/ESD Symp., vol. EOS-3, Sept. 1981, pp. 9-13.

7. ASHRAE Publication, "Design considerations for Datacom Equipment Centers", Atlanta, 2005.

Model	VFS-072-DAR, DW, DG					VFS-096-DAR, DW, DG					VFS-120-DAR, DW, DG				
	FLA			MCA	MFS	FLA			MCA	MFS	FLA			MCA	MFS
	DAR	DW	DG			DAR	DW	DG			DAR	DW	DG		
Cooling w/ Electric Reheat/Heat & Humidification															
208/3/60	39.0	36.7	40.0	48.3	50	55.2	52.8	55.9	70.4	80	61.3	58.3	62.2	76.7	80
460/3/60	19.7	19.0	19.9	25.6	30	28.0	27.1	28.3	36.8	40	30.9	29.6	31.3	39.6	40
575/3/60	15.9	15.4	16.0	20.8	25	22.3	21.5	22.5	28.6	30	24.7	23.7	25.0	32.4	35
Cooling w/ Electric Reheat /Heat Only (No humidifier)															
208/3/60	38.0	36.7	38.5	48.3	50	55.2	52.8	55.9	70.4	80	61.3	58.3	62.2	76.7	80
460/3/60	19.7	19.0	19.9	25.6	30	28.0	27.1	28.3	36.8	40	30.9	29.6	31.3	39.6	40
575/3/60	15.9	15.4	16.0	20.8	25	22.3	21.5	22.5	28.6	30	24.7	23.7	25.0	32.4	35
Cooling w/ Humidification (No Electric Heat/Reheat)															
208/3/60	39.0	36.4	40.0	45.4	50	49.0	44.2	50.4	58.3	70	58.6	52.6	60.4	67.4	80
460/3/60	17.9	16.5	18.3	21.9	25	21.2	19.4	21.8	27.5	35	25.8	23.2	26.6	31.5	40
575/3/60	14.5	13.5	14.7	18.1	20	17.0	15.4	17.4	20.6	25	20.7	18.7	21.3	26.7	30
Cooling and Electric Heat Only (No Electric Reheat or Humidifier)															
208/3/60	28.4	28.4	28.4	35.5	40	41.4	41.4	41.4	51.7	60	44.4	38.4	46.2	53.2	70
460/3/60	15.3	15.3	15.3	19.1	20	22.3	22.3	22.3	27.9	30	23.5	23.5	23.5	29.4	30
575/3/60	12.4	12.4	12.4	15.5	20	17.7	17.7	17.7	22.1	25	18.8	18.8	18.8	23.5	25
Cooling Only															
208/3/60	24.8	22.2	25.8	31.2	40	34.8	30.0	36.2	44.1	60	44.4	38.4	46.2	53.2	70
460/3/60	11.5	10.1	11.9	15.5	20	14.8	13.0	15.4	21.1	25	19.4	16.8	20.2	25.1	30
575/3/60	9.4	8.4	9.6	13.0	15	11.9	10.3	12.3	15.5	20	15.6	13.6	16.2	21.6	25

Model	VFS-180-DAR, DW, DG					VFS-240-DAR, DW, DG					VFS-312-DAR, DW, DG				
	FLA			MCA	MFS	FLA			MCA	MFS	FLA			MCA	MFS
	DAR	DW	DG			DAR	DW	DG			DAR	DW	DG		
Cooling w/ Electric Reheat/Heat & Humidification															
208/3/60	82.4	74.8	84.8	101.8	125	98.6	90.5	101.8	124.9	150	127.6	118.1	131.8	160.4	200
460/3/60	38.2	36.6	39.0	51.1	60	47.8	45.5	48.5	62.5	70	60.0	57.1	60.8	80.8	90
575/3/60	30.3	29.0	30.9	39.6	45	38.0	36.1	38.6	48.1	50	51.9	49.3	52.7	66.6	80
Cooling w/ Electric Reheat /Heat Only (No humidifier)															
208/3/60	76.0	72.2	77.2	98.3	110	95.5	90.5	97.1	124.9	150	124.8	118.1	126.9	160.4	175
460/3/60	38.2	36.6	38.7	51.1	60	47.8	45.5	48.5	62.5	70	60.0	57.1	60.8	80.8	90
575/3/60	30.3	29.0	30.8	39.6	45	38.0	36.1	38.6	48.1	50	51.9	49.3	52.7	66.6	80
Cooling w/ Humidification (No Electric Heat/Reheat)															
208/3/60	82.4	74.8	84.8	101.8	125	98.6	88.6	101.8	124.1	150	127.6	114.2	131.8	156.8	200
460/3/60	38.0	34.8	39.0	50.3	60	44.6	40.0	46.0	56.6	70	53.3	47.5	54.9	73.0	90
575/3/60	29.9	27.3	30.9	37.9	45	35.3	31.5	36.5	42.0	50	49.4	44.2	51.0	61.0	80
Cooling and Electric Heat Only (No Electric Reheat or Humidifier)															
208/3/60	68.2	60.6	70.6	87.6	110	84.4	74.4	87.6	109.9	150	113.4	100.0	117.6	142.6	175
460/3/60	31.6	28.4	32.6	43.9	60	38.2	33.6	39.6	50.2	60	46.9	41.1	48.5	66.6	90
575/3/60	24.8	22.2	25.8	32.8	40	30.2	26.4	31.4	36.9	50	44.3	39.1	45.9	55.9	70
Cooling Only															
208/3/60	68.2	60.6	70.6	87.6	110	84.4	74.4	87.6	109.9	150	113.4	100.0	117.6	142.6	175
460/3/60	31.6	28.4	32.6	43.9	60	38.2	33.6	39.6	50.2	60	46.9	41.1	48.5	66.6	90
575/3/60	24.8	22.2	25.8	32.8	40	30.2	26.4	31.4	36.9	50	44.3	39.1	45.9	55.9	70

Electrical Data - *DX Compressorized Systems*

Electrical Data - Outdoor Condensers

Remote Propeller Fan(s) Outdoor Air Cooled Condensers

For use with SATS Models - OHS,COS,FCS, CCU/D, VFS & CCH - 95 ° Ambient, - 0 ° and -30° control packages

Model	208/1			208-230/3/60			460/3/60		
	FLA	MCA	MFS	FLA	MCA	MFS	FLA	MCA	MFS
SCS-012-( )AA	1.6	1.8	15	1.2	1.4	15	0.8	0.9	15
SCS-018-( )AA	1.6	1.8	15	1.2	1.4	15	0.8	0.9	15
SCS-024-( )AA	1.6	1.8	15	1.2	1.4	15	0.8	0.9	15
SCS-036-( )AA	4.6	5.6	15	3.8	4.6	15	2.4	2.8	15
SCS-060-( )AA	4.6	5.6	15	3.8	4.6	15	2.4	2.8	15
SCS-096-( )AA	8.6	9.6	15	7.1	7.9	15	4.2	4.7	15
SCS-120-( )AA	8.6	9.6	15	7.1	7.9	15	4.2	4.7	15
SCS-144-( )AA	8.6	9.6	15	7.1	7.9	15	4.2	4.7	15
SCS-192-( )AA	N/A	N/A	N/A	17.5	19.7	25	10.3	11.5	15
SCS-252-( )AA	N/A	N/A	N/A	17.5	19.7	25	10.3	11.5	15
SCS-276-( )AA	N/A	N/A	N/A	17.5	19.7	25	10.3	11.5	15
SCS-312-( )AA	N/A	N/A	N/A	17.5	19.7	25	10.3	11.5	15
SCS-427-( )AA	N/A	N/A	N/A	17.5	19.7	25	10.3	11.5	15
SCS-525-( )AA	N/A	N/A	N/A	26.1	28.2	35	15.2	16.5	20
SCS-597-( )AA	N/A	N/A	N/A	26.1	28.2	35	15.2	16.5	20
SCS-683-( )AA	N/A	N/A	N/A	26.1	28.2	35	15.2	16.5	20

For use with SATS Models - OHS,COS,FCS, CCU/D, VFS & CCH - 95 ° & 105 ° Ambient, - 20 ° control packages

Model	208/1/60			208-230/3/60			460/3/60		
	FLA	MCA	MFS	FLA	MCA	MFS	FLA	MCA	MFS
SCS-012-( )SA	1.1	1.3	15	N/A	N/A	N/A	N/A	N/A	N/A
SCS-018-( )SA	1.1	1.3	15	N/A	N/A	N/A	N/A	N/A	N/A
SCS-024-( )SA	1.1	1.3	15	N/A	N/A	N/A	N/A	N/A	N/A
SCS-036-( )SA	4.1	5.1	15	N/A	N/A	N/A	N/A	N/A	N/A
SCS-060-( )SA	4.1	5.1	15	N/A	N/A	N/A	N/A	N/A	N/A
SCS-096-( )SA	8.6	9.6	15	7.9	8.9	15	N/A	N/A	N/A
SCS-120-( )SA	8.6	9.6	15	7.9	8.9	15	N/A	N/A	N/A
SCS-144-( )SA	8.6	9.6	15	7.9	8.9	15	N/A	N/A	N/A
SCS-192-( )SA	N/A	N/A	N/A	16.1	18.2	25	8.9	10.1	15
SCS-252-( )SA	N/A	N/A	N/A	16.1	18.2	25	8.9	10.1	15
SCS-276-( )SA	N/A	N/A	N/A	16.1	18.2	25	8.9	10.1	15
SCS-312-( )SA	N/A	N/A	N/A	16.1	18.2	25	8.9	10.1	15
SCS-427-( )SA	N/A	N/A	N/A	16.1	18.2	25	8.9	10.1	15
SCS-525-( )SA	N/A	N/A	N/A	24.6	26.7	35	13.8	15.1	15
SCS-597-( )SA	N/A	N/A	N/A	24.6	26.7	35	13.8	15.1	15
SCS-683-( )SA	N/A	N/A	N/A	24.6	26.7	35	13.8	15.1	15

For use with SATS Models - OHS,COS,FCS, CCU/D, VFS & CCH - 95 ° & 105 ° Ambient, - 20 ° control packages w/ EC Fan

Model	208/1/60			208-230/3/60			460/3/60		
	FLA	MCA	MFS	FLA	MCA	MFS	FLA	MCA	MFS
SCS-012-( )EC	2.19	2.61	15	N/A	N/A	N/A	N/A	N/A	N/A
SCS-018-( )EC	2.19	2.61	15	N/A	N/A	N/A	N/A	N/A	N/A
SCS-024-( )EC	2.19	2.61	15	N/A	N/A	N/A	N/A	N/A	N/A
SCS-036-( )EC	N/A	N/A	N/A	3.9	4.7	15	2.7	3.3	15
SCS-060-( )EC	N/A	N/A	N/A	3.9	4.7	15	2.7	3.3	15
SCS-096-( )EC	N/A	N/A	N/A	7.2	8.1	15	4.9	5.5	15
SCS-120-( )EC	N/A	N/A	N/A	7.2	8.1	15	4.9	5.5	15
SCS-144-( )EC	N/A	N/A	N/A	7.2	8.1	15	4.9	5.5	15
SCS-192-( )EC	N/A	N/A	N/A	16.0	18.0	25	7.5	8.4	15
SCS-252-( )EC	N/A	N/A	N/A	16.0	18.0	25	7.5	8.4	15
SCS-276-( )EC	N/A	N/A	N/A	16.0	18.0	25	7.5	8.4	15
SCS-312-( )EC	N/A	N/A	N/A	16.0	18.0	25	7.5	8.4	15
SCS-427-( )EC	N/A	N/A	N/A	16.0	18.0	25	7.5	8.4	15
SCS-525-( )EC	N/A	N/A	N/A	23.8	25.8	30	11.0	11.9	15
SCS-597-( )EC	N/A	N/A	N/A	23.8	25.8	30	11.0	11.9	15
SCS-683-( )EC	N/A	N/A	N/A	23.8	25.8	30	11.0	11.9	15

AIRBLOCK™ DATA CENTER SYSTEMS Product Bulletin on Data Center Curtains

PolySim™ – Our NFPA and ASTM fire-rated material.

See page 3

AirBlock Data Center Curtains:

- Maximize Cooling Efficiency
- Increase Data Center Capacity
- Insure System Stability
- Save Energy Dollars

SIMPLEX™ ISOLATION SYSTEMS

Heat is your enemy in the data center. Hot aisle/cold aisle containment is acknowledged as the most effective and inexpensive way to redirect air flow and lower temperatures. The result is greater computing capacity in your data center, stable, crash-free systems, and the savings of thousands of dollars in excess energy.

Since 1979 Simplex Isolation Systems has been a leader in the business of isolation control and air handling. We are known for innovation and product development. Many of our materials are based on proprietary formulas. We have also developed unique hardware solutions for the data center. It is no wonder that our AirBlock line of data center products offers the best in hot aisle/cold aisle isolation.

AirBlock Data Center Curtains from Simplex were developed with a singular goal--to provide the finest quality products for achieving effective hot aisle/cold aisle isolation in the data center. We achieved this by setting new standards: AirBlock is engineered for performance in the data center. Our modular design allows for easily installation, easy expansion and adherence to all fire and safety standards.

Choose from options that include vinyls with ESD resistance and those that are free from out-gassing. AirBlock's selection of mounting systems offer you solutions to the challenges of existing infrastructure in the legacy data center, and also limitless options for new installations.

Finally, our systems are engineered to help you maintain compliance with local fire codes. AirBlock data center curtains are tested to NFPA and ASTM E-84 Class 1 standards for flame and smoke generation.

Choose AirBlock Data Center Curtains from Simplex. We offer the best engineered materials and hardware to give you maximum performance for your investment.

Simplex Isolation Systems,
Creators of AirBlock™

SIMPLEX™ ISOLATION SYSTEMS

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www.simplexisolationsystems.com

AirBlock™: Getting the Maximum from Hot Aisle/Cold Aisle Isolation

“Hot aisle/cold aisle isolation is an important part of reducing the energy needs of data centers. Simplex is doing this better than anyone out there”
– Eugean Hacopians, ANRE Technologies, LLC

Curtains – *Specify full length ceiling-to-floor curtains. Custom lengths for above-the-rack installations can be specified to accommodate racks of varying heights and widths, and from different manufacturers.*

Overlapping Design – *Vinyl panels are 40 mil thick and 48 inches wide, with four-inch overlaps to prevent leakage.*

Strip Doors – *End-of-aisle access is easy with strip doors. Strips come back together easily to limit air loss from one area to another.*

Molded Corners – *Molded, wraparound corners for superior seals in the data center.*

PolySim™ – Our NFPA and ASTM fire-rated material.

PolySim™– The Clear Choice Among Data Center Curtains

- PolySim, exclusively from Simplex, is a thermal plastic urethane, not a PVC. No outgassing, no blooming, and reduced cleaning requirements.
- PolySim meets and exceeds the new NFPA 76 data center standard. Also meets ASTM E-84 standards and is Class 1 fire rated, with the lowest smoke and flame spread ratings available.
- PolySim helps you meet your sustainability goals. It contains no plasticizers or phthalates and is better for the environment.
- Polysim is an alloy using high molecular weight materials. Its permanent static dissipation properties do not wear off or diminish over time like anti-static vinyls do.

AirBlock curtain materials are made from a proprietary formula. Select from models that offer limited outgassing and resistance to electro-static discharge.

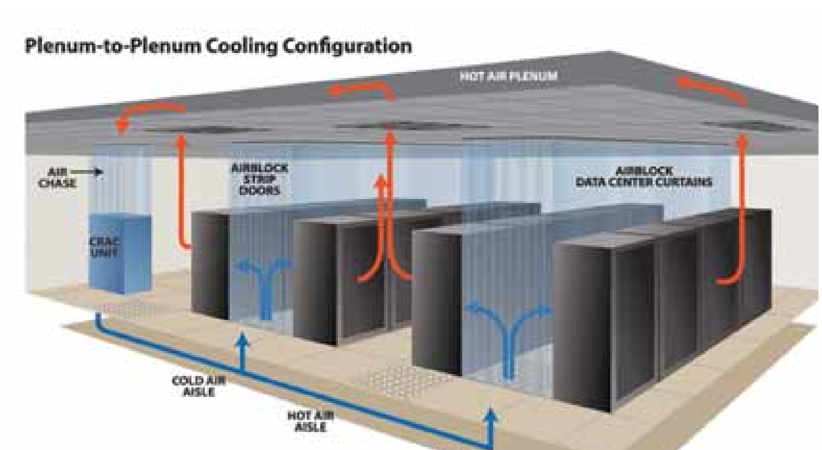
Additional AirBlock Data Center Materials

FlexSim™ FR – FlexSim, another exclusive only from Simplex or our authorized dealers, is a low-outgassing, fire-resistant PVC. It is based on our proprietary formula of non-phthalate plasticizers, thus meeting U.S. and European requirements for an environmentally friendly material. FlexSim also meets and exceeds the standards of NFPA 76, NFPA 701 small scale and ASTME-84 Class 1 fire ratings.

Simplex Standard and Anti-static* Vinyls – These offer excellent clarity and are UV stabilized. These materials meet and exceed the basic ULV-90 standards of the California Fire Marshal. They are the economical choice in areas where the stricter NFPA and ASTM E-84 standards are not needed.

**NOTE: All anti-static vinyls have a blooming effect in which a film develops on the surface. This is a byproduct of the dissipation of the static charge. Anti-static vinyls must be cleaned regularly to keep film from building up and affecting the clarity.*

For complete test results check the specifications chart on the last page of this bulletin, or consult your AirBlock sales representative.



AirBlock curtains can be used for isolating either hot or cold aisles in the data center.

Call 1-800-854-7951 Today for a Quote, Specifications or Free Design Help

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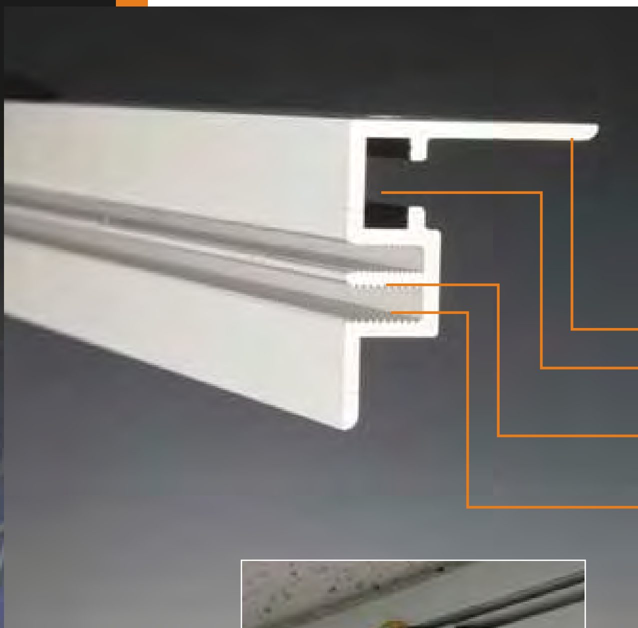
SIMPLEX™ ISOLATION SYSTEMS

What Sets Simplex Apart?

Just about everything we do. We incorporate sound engineering principals into hardware design so that our mountings match up to the performance of our curtains. We understand that the data center manager must be able to count on our product for day-to-day functionality, including both ease of installation and operation, and also the need for the system to behave predictably in the event of a fire or other emergency.



The AirBlock DCT Mounting: Custom Designed for the Data Center

DCT gives you the ability to create a solid base frame for your data center with many more options for installing it to your ceiling. You can even install DCT across T-bar ceiling grids when connections are possible only every 48 inches.

- Extra wide mounting flange allows room for easy installation.
- Built-in splicer channel accepts locking splices for both in-line and corner connections.
- Threaded channels allow for attachment of mounting hardware anywhere along the DCT rail.
- Upper channel accepts #8 machine screws, lower channel accepts #12 machine as well as sheet metal screws.

Use the AirBlock DCT mounting system for quick and easy installation and reconfiguration of data center curtains. Make changes, extend walls, add blanks – all in just a few minutes.

- Continuous threaded channels provide unlimited attachment points and flexibility to configure system.
- Works with fusible links. Curtains fall away in case of fire, allowing sprinklers full operational range.
- Quickly installs to T-bar ceilings, hard decks, or suspended threaded rod. Also can be used to attach curtains or rigid panels to racks or the floor.
- Individual curtain modules are then installed in sections with fuse links. In the event of fire, modules drop easily away.

Ceiling Suspension Systems

Corner modules of DCT tracks come together with internal splicing for a solid connection.

In-line splicing ensures a solid connection and rigid construction.

"The cost of data center curtains includes time spent in installation. AirBlock is an easy install." – Shawn Mills, Green House Data

Mounting Hardware for all Situations

Flatwall Mounting for mounting on walls or vertical frames.

In-jamb ceiling mountings for mounting under headers, frames or horizontal surfaces.

Bi-folding curtain mounting allows for curtains to be quickly pushed aside.

The DCT track can also be used to mount hardwall partitions in the data center.

Ceiling Attachments

Suspended T-bar mounting onto existing 1", 1-1/2" or 2" suspended T-bar ceilings.

Standard T-bar clips come in 1", 1-1/2" and 2" sizes.

These clips come in two sizes to fit architectural grids commonly found in office buildings.

Caddy clips come in 1" and 1-1/2" (inset) sizes.

Mounting AirBlock Curtain Panels

The reputation Simplex has for long lasting curtains lies in our unique patented mounting system. Simplex bases all its mountings on a bead mounting that allows the curtain to pivot in the mounting, substantially reducing the stress on the curtain at the mounting point. This dramatically increases the life of the curtains.

1. Mount the rear track. Self-threading, machine screws are provided.

2. Unroll software panels and hook into place.

3. Overlaps are automatic and panels are perfectly aligned each time.

4. Curtains can also be inserted into the end of the assembled mounting rail and slid into place.

What about fire suppression in the data center?

The first step in the design of any data center is a call to the local Fire Marshal. Their concern is going to be one of overall fire-prevention, and that the curtains do not interfere with the spray patterns of the fire sprinkler system.

AirBlock uses mounting hardware with fusible links held together with an alloy designed to melt at 135°, 30 degrees lower than the temperature at which fire sprinklers activate. When the fire sprinklers come on, the curtains will have already fallen away, allowing the sprinklers free operating range. This type of installation has been accepted by the State of California Fire Marshal on a case-by-case basis.

An alternative to fusible links are electronic fuse links, typically hardwired to your fire detection system and activated when smoke is detected. Simplex uses only UL approved fusible links.

Standard fuse link, operates at 135°F

Reusable electronic fuselink.

Electronic fuse link

AirBlock Lanyards

When required, AirBlock can be installed using 18" lanyards. In the event of fire the vinyl walls and mounting railings fall far enough to allow fire sprinklers full operating range, however the stainless steel cables prevent the assembly from falling to the floor.

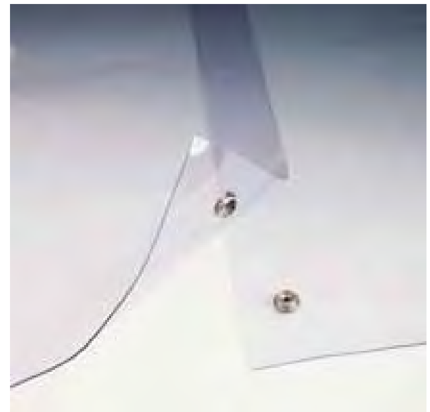
When installed, cables coil up and out of the way

Upon activation, curtains and mounting fall far enough to allow sprinklers full operating range.

Closures and Fastening Options

AirBlock fasting options can be used to join two curtains together, or to also fasten curtains to racks in your data center.

Flexible Magnet Self-Closures – Ideal for sealing overlap areas where frequent access is required. Chemical resistant.



Overlap Retention Snaps – An inexpensive way of closing overlap areas of curtains. Available in stainless steel and Nylon.

Dual Lock Fastener – A non-particulating, clear 3M flexible system uses a plasticizer-resistant adhesive. Ideal for attaching curtains vertically or horizontally to racks or overlaps.

Hook and Loop Fastener – For securing curtain overlaps. Attaches with plasticizer-resistant adhesive and then sewn.

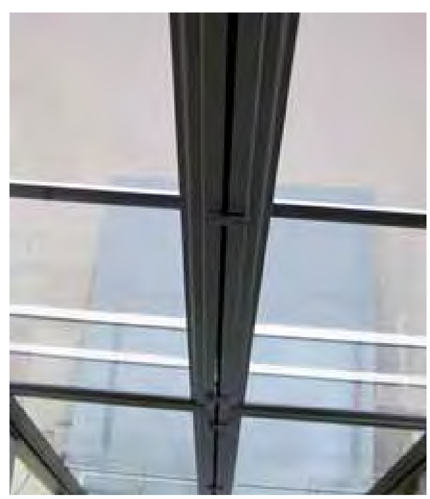
Mount the DCT track to the floor and use a batten strip to secure AirBlock curtains both top and bottom.

Other AirBlock Data Center Components from Simplex

Simplex also manufactures a complete line of hardwall panels for hot aisle and cold aisle isolation in the data center. Also see Simplex for door solutions, ceiling modules, blank fillers, CRAC enclosures and other data center cooling solutions.

Data Center Partitions

Other Door Options



Ceiling Caps

Part Numbers and Applications

40480	48" wide strips, 40 mil thick. Capable of being RF welded into various widths. Excellent for longer widths to create solid walls for dividing aisles. Available in FlexSim FR, standard and anti-static vinyls and PolySim.	**40122**	12" wide strips, 40 mil thick. 2" overlaps on either side extending beyond the hook-bead mount. This application is designed specifically for strip doors or end-of-aisle access. Strip doors part easily, come back together quickly. Available in FlexSim FR, standard and anti-static vinyls and PolySim.
40484	48" wide strips, 40 mil thick. 4" overlaps in either side, extending beyond the hook-bead mount. The double overlap helps to form a better seal, preventing the mixing of hot and cold air. Excellent for those applications that cannot have a solid wall. Available in FlexSim FR, standard and anti-static vinyls and PolySim.	**608 Series**	8" wide strips, 60 mil thick. Use for strip door applications in high-access area. Thicker vinyl provides more stability and better sealing power. Available only in standard and anti-static vinyls.

How to Order AirBlock Data Center Curtains from Simplex

Every data center is different. Use this Product Bulletin as a guide to the products and applications that might work for your data center, taking note of the product specifications and testing information on this page.

Using the data center questionnaire on the Simplex website (www.simplexstripdoors.com/pdf/DCquestionnaire.pdf) to detail the specifics of your data center project. Also, you can call your authorized AirBlock dealer, or call Simplex directly at 800-854-7951.

AirBlock Data Center Curtains Material Specifications and Testing Information

	MATERIAL		
TEST	**Polysim 509**	**FlexSim Std.**	**Simplex Standard & Anti-static**
Hardness Durometer (D-2240)	90A/47D	85A	79A
Tensile Strength % (D-412)	3800	2950	2400
Ultimate Elongation % (D-412)	450%	290%	350%
Ultimate Tear PSI (D-1004)		570 lbf/in (ASTM D-624)	440
100% Module PSI (D-412)	1200	1400	1400
Brittle Temp. (deg. F)	0° F/-17° C	0° F/-17° C	-36° F
Minimum Operating Temp. (deg. F)	32° F/ 0° C	32° F/ 0° C	0° F
Specific Gravity	1.16	1.26	1.21
UV Stability	Good	Excellent	Excellent
Flame Test UV 94 V-O	Pass	Pass	Pass
Flame NFPA 701 Small Scale	Pass	Pass	
ASTM E-84 Class 1 – Flame – Smoke	10 180	20 400	
Specific and ASTM Test Methods in ( )			

Simplex Warranty

Simplex warrants their products to be free of manufacturing defects and against product failure of any kind for a period of one year from date of shipment. This includes premature yellowing or curling of strips (excluding those components that do not have UV protection – see sales rep for details). This warranty is limited to the repair or replacement of vinyl strips, vinyl panels or softwall materials and/or attaching hardware, and does not include damage resulting from accident or malicious use. This warranty further applies only when the recommended material thickness and width are used for the originally specified application. Further, it applies only to Simplex doors, softwalls and frame systems which are properly installed in accordance with Simplex installation instructions. Additional extended warranty may be available on certain applications. See individual application sheets or ask your representative. ARMOR-BOND lifetime guarantee applies to first three inches of strip where stress is the greatest and attaches to the mounting hardware. Remainder of the strip is covered by the 1-year warranty.

SIMPLEX™ ISOLATION SYSTEMS

14500 Miller Ave. • Fontana, CA 92336
Toll-free: **800-854-7951**
Fax: 909-429-0217
www.simplexisolationsystems.com
info@simplexstripdoors.com

All AirBlock™ vinyl and hardware components are proudly designed and manufactured in the USA.

DCCurtains-102-0413-2500

From: Kevin Givens [mailto:kevingivens@tjc-nm.com]
Sent: Monday, October 19, 2015 10:36 AM
To: Craig Green <craig@questenergy.com>
Subject: FW: CyberMod Application

Craig,

See the below from Stulz application engineering. A VFD on the blower is not the best solution.

Thanks, Kevin

From: Dave Meadows [mailto:dmeadows@stulz-ats.com]
Sent: Monday, October 19, 2015 11:28 AM
To: Kevin Givens <kevingivens@tjc-nm.com>
Subject: RE: CyberMod Application

Kevin:

A VFD would give you variability of the fan speed and could save you some energy but there are two concerns. First the VFS DX software is for a constant speed fan and has no outputs to control the fan speed. Second, if the fan speed is not somehow linked to the suction pressure of the compressor you could have excessive latent cooling and coil ice formation which would lead to a low pressure shutdown.

Sincerely,

Dave Meadows
Applications Engineering Manager
STULZ Air Technology Systems, Inc.
1572 Tilco Drive • Frederick, MD 21704 U.S.A.
Office: +1 240.529.1282 • Cell: +1 240.285.6975 • Fax: +1 301.662.5487 • www.stulz-usa.com

From: Kevin Givens [mailto:kevingivens@tjc-nm.com]
Sent: Monday, October 19, 2015 11:47 AM
To: Dave Meadows
Subject: RE: CyberMod Application

Dave,

Since these units are not eligible for an EC fan upgrade, would a VFD on the blower work for an energy savings application?

Thanks, Kevin

From: Dave Meadows [mailto:dmeadows@stulz-ats.com]
Sent: Tuesday, October 13, 2015 1:01 PM
To: Parts Department <parts@stulz-ats.com>; Kevin Givens <kevingivens@tjc-nm.com>
Cc: Brian Johnston <brianjohnston@tjc-nm.com>; Application Engineering <ApplicationEngineering@stulz-ats.com>
Subject: RE: CyberMod Application

Kevin:

I am sorry, the CyberMod fan boxes are only designed to fit in Liebert's 740,600, 529, 422-C models and a single Compuair unit.

Sincerely,

Dave Meadows
Applications Engineering Manager
STULZ Air Technology Systems, Inc.
1572 Tilco Drive • Frederick, MD 21704 U.S.A.
Office: +1 240.529.1282 • Cell: +1 240.285.6975 • Fax: +1 301.662.5487 • www.stulz-usa.com

From: Craig Green
Sent: Wednesday, October 07, 2015 12:06 PM
To: Craig Green <craig@questenergy.com>
Subject: RE: Data Center Measures

Notes from conversation with Crawford Mechanical:

- About $10K per unit for a retrofit of EC fans, some Stulz units may already have them.
- Thermal imaging or data logging would normally be included by a mechanical contractor.
- Many customers are doing aisle containment themselves – lots of innovative ways

From: Dan Krueger [mailto:dan@cmsaz.com]
Sent: Wednesday, October 07, 2015 9:42 AM
To: Craig Green <craig@questenergy.com>
Subject: RE: Data Center Measures

Thanks Craig. Here's Erik's, and my, contact info.

Erik Crawford C3 Systems (STULZ) Managing Member (480) 926-2813 Work (480) 560-6147 Mobile erik@c3systems.com 408 S Hamilton Court Gilbert, AZ 85233 United States c3systems.com	**Dan Krueger** Crawford Mechanical Services Business Development Manager 480-722-1267 Work (480) 822-9502 Mobile Dan@cmsaz.com 408 S. Hamilton Court Gilbert, AZ 85233 www.cmsaz.com

Sincerely,

Dan Krueger
Business Development Manager
Mobile: (480) 822-9502

Crawford Mechanical Services, LLC
"A Leader in Mission Critical Air Conditioning"
408 S. Hamilton Court
Gilbert, AZ 85233
Office: (480) 722-1267
Fax: (480) 899-7349
www.cmsaz.com

CRAWFORD
MECHANICAL SERVICES

From: Craig Green [mailto:craig@questenergy.com]
Sent: Wednesday, October 07, 2015 9:40 AM
To: Dan Krueger
Subject: FW: Data Center Measures

Dan – here is my contact information. Thanks for your help.

Craig Green, PE

Quest Energy Group, LLC
1620 W Fountainhead Pkwy #303
Tempe, AZ 85282
Ph   480.467.2480
Fax 480.336.2291
Cell 928.699.1369
craig@questenergy.com
www.questenergy.com

Appendix C – Lighting Audit Results

Room by Room Audit

Customer ABQ Sunport International Airport

Address

Audit date: 9/2/2015

By: Vertical Pivot LLC

Branch:

Building or Address	Item	Floor #	Exact Location (Room #)	Room Type (Office, Hall, warehouse, etc)	Existing Fixture	Existing Watts	Fixture Type Wrap,strip, Layin,recessed, etc	Qty. of Fixt.	Baseline kW
Car Rental Building	1	1	Lobby	Office	MH	400	Wall mount, up light	60	24
Car Rental Building	2	1	Lobby	Office	T-8 3L	96	U Bend troffer	64	6.144
Car Rental Building	3	1	Lobby	Office	T-8 1L 4ft	32	Troffer	108	3.456
Car Rental Building	4	1	vending machines	Office	LED	15	recessed can	20	0.3
Car Rental Building	5	1	Bus loading area	Exterior	CFL	15	4" can	16	0.24
Car Rental Building	6	1	Bus loading area	Exterior	LED	30	up-light, pole mount wall pack	12	0.36
Car Rental Building	7	1	Parking lot	Exterior	LED	160	Pole light	12	1.92
Car Rental Building	9	1	Wall pack	Exterior	MH	250	Wall pack, vapor tight	25	6.25
Old Terminal	10	2	Upstairs	Office	T-8 2L 4ft	64	troffer, indirect	6	0.384
Old Terminal	11	2	Downstairs	Office	T-8 2L 4ft	64	troffer, indirect	14	0.896
Old Terminal	12	2	Downstairs	Office	Wall pack	30	CFL decorative, wall fixture	60	1.8
Old Terminal	13	2	Downstairs lobby	Office	2L CFL chandelier	25	CFL,	8	0.2
Old Terminal	14	2	walkway canopy	Exterior	2L CFL troffer	23	CFL, vapor tight	23	0.529
L1 ground level concourse	15	3	open concourse area	Interior/Exterior	1L HPS	150	HPS, vapor tight ceiling ount, hard lid	35	5.25
L1 ground level concourse	16	3	open concourse area	Interior/Exterior	T-5 6L	150	trofer, vapor tight	3	0.45
L1 ground level concourse	17	2	Between A & B concourse	Interior	T-8 2L 4ft	64	troffer	26	1.664
Tarmac	18	1	pole lighting	Exterior	HPS	1000	Shoe box, round pole	96	96
L1 ground level concourse	19	3	Stairwells	Interior	T-8 2L 4ft	64	vapor tight, flat mount troffer	64	4.096
L3 Concourse B	20	3	B9-B5	Interior	T-8 2L 4ft	64	troffer, connected in 5 troffer segments	32	2.048
L3 Concourse B	21	3	B9-B5	Interior	LED	90	LED can light, Acuity fixture	36	3.24
L3 Concourse B	22	3	B4-B1	Interior	T-8 2L 4ft	64	troffer, connected in 5 troffer segments	60	3.84

L3 Concourse A	23	3	A1-A3	Interior	T-8 2L 4ft	64	troffer, connected in 5 troffer segments	181	11.584
L3 Concourse A	24	3	A1-A3	Interior	LED	90	LED can light, Acuity fixture	16	1.44
L3 Concourse A	25	3	A6-A14	Interior	T-8 2L 4ft	64	troffer, connected in 5 troffer segments	230	14.72
L3 Concourse	26	3	Between A/B terminal and bag claim	Interior	LED	90	LED can light, Acuity fixture	92	8.28
L3 Concourse	27	3	Between A/B terminal and bag claim	Interior	T-8 2L 4ft	64	troffer, connected in 5 troffer segments	36	2.304
L3 Concourse	28	3	Security Screening	Interior	LED	90	LED can light, Acuity fixture	34	3.06
L3 Concourse	29	3	Security Screening	Interior	T-8 2L 4ft	64	troffer, connected in 5 troffer segments	90	5.76
L3 Concourse	30	3	Great Hall	Interior	MH	250	4" Can light 1L	77	19.25
L2 Concourse	31	3	Between Bag claim & Great Hall	Interior	T-8 2L 4ft	64	troffer, connected in 5 troffer segments	204	13.056
L2 Concourse	32	3	Between Bag claim & Great Hall	Interior	LED	110	LED can light, Acuity fixture	24	2.64
L2 Concourse	33	3	Southwest Ticketing	Interior	T-8 2L 4ft	64	troffer, connected in 5 troffer segments	103	6.592
L2 Concourse	34	3	Southwest Ticketing	Interior	T-8 1L 4ft	32	troffer	167	5.344
L2 Concourse	35	3	Southwest Ticketing	Interior	MH	150	recessed can	22	3.3
L2 Concourse	36	3	Delta/Us Airways Ticketing	Interior	T-8 2L 4ft	64	troffer, connected in 5 troffer segments	84	5.376
L2 Concourse	37	3	Delta/Us Airways Ticketing	Interior	T-8 1L 4ft	32	troffer	79	2.528
L2 Concourse	38	3	Jet Blue/American Airlines Ticketing	Interior	T-8 2L 4ft	64	troffer, connected in 5 troffer segments	178	11.392
L2 Concourse	39	3	Jet Blue/American Airlines Ticketing	Interior	T-8 1L 4ft	32	troffer	152	4.864
L2 Concourse	40	3	Gate E	Interior	T-8 2L 4ft	64	troffer, connected in 5 troffer segments	88	5.632

L2 Concourse	41	3	Gate E	Interior	LED	34	LED can light, Acuity fixture	8	0.272
L2 Concourse	42	3	Gate E	Interior	T-8 1L 4ft	32	troffer	50	1.6
L2 Concourse	43	3	Gate E	Interior	T-8 U Bend 1L	32	U bend troffer	12	0.384
L1 Concourse	44	3	Baggage Claim 1-3	Interior	T-8 2L 4ft	64	troffer, connected in 5 troffer segments	116	7.424
L1 Concourse	45	3	Baggage Claim 1-3	Interior	T-8 U Bend 1L	32	U Bend troffer	28	0.896
L1 Concourse	46	3	Baggage Claim Main Entrance	Interior	T-8 2L 4ft	64	troffer, connected in 5 troffer segments	18	1.152
L1 Concourse	47	3	Baggage Claim Main Entrance	Interior	LED	90	LED can light, Acuity fixture	20	1.8
L1 Concourse	48	3	Baggage Claim 4-6	Interior	T-8 2L 4ft	64	troffer, connected in 5 troffer segments	352	22.528
L1 Concourse	49	3	Baggage Claim 4-6	Interior	T-8 U Bend 1L	32	U Bend troffer	34	1.088
L1 Concourse	50	3	Baggage Claim Main entrance	Interior	T-8 2L 4ft	64	troffer, connected in 5 troffer segments	10	0.64
L1 Concourse	51	3	Baggage Claim Main entrance	Interior	T-8 U Bend 1L	32	U Bend troffer	4	0.128
L1 Concourse	52	3	Baggage Claim Main entrance	Interior	LED	90	LED can light, Acuity fixture	12	1.08
L1 Concourse	53	3	Baggage Claim Main entrance	Interior	LED	35	1' x 1' square LED fixture	10	0.35
L2 Arrival/Departure	54	3	Drop/pickup loading zone	Exterior	T-12 2L 4ft	96	Vapor tight, troffer	711	68.256
L2 Arrival/Departure	55	3	Drop/pickup loading zone	Exterior	MH	250	Vapor tight, troffer	4	1
L2 Arrival/Departure	56	3	Drop/pickup loading zone	Exterior	T-5 4L	140	Vapor tight, troffer	114	15.96
L2 Arrival/Departure	57	3	Drop/pickup loading zone	Exterior	CFL Pin Wall Pack	42	Vapor tight, wall pack	8	0.336
L3 Arrival/Departure	58	3	Drop/pickup loading zone	Exterior	T-12 2L 4ft	96	Vapor tight, troffer	198	19.008

Proposed Fixture/Product	Proposed Watts	Proposed Fixture Description	Proposed Quantity	Proposed kW
LED	160	Accuity Wall mount up light	60	9.60
LED Troffer Fixture	50	2ft LED troffer	64	3.20
LED Troffer Fixture	20	4ft LED troffer	108	2.16
N/A				0.30
N/A				0.24
N/A				0.36
N/A				1.92
LED	100	Accuity Wall mount up light	25	2.50
LED Troffer Fixture	40	4ft LED troffer	6	0.24
LED Troffer Fixture	40	4ft LED troffer	14	0.56
N/A				1.80
N/A				0.20
N/A				0.53
LED	60	Accuity Wall mount up light	35	2.10
trofer, vapor tight	90	LED Troffer Fixture	3	0.27
LED Troffer Fixture	40	4ft LED troffer	26	1.04
LED	580	Accuity Shoe box pole light	96	55.68
LED Troffer Fixture	40	4ft LED troffer	64	2.56
LED Troffer Fixture	40	4ft LED troffer	32	1.28
N/A				3.24
LED Troffer	40	4ft LED troffer	60	2.40

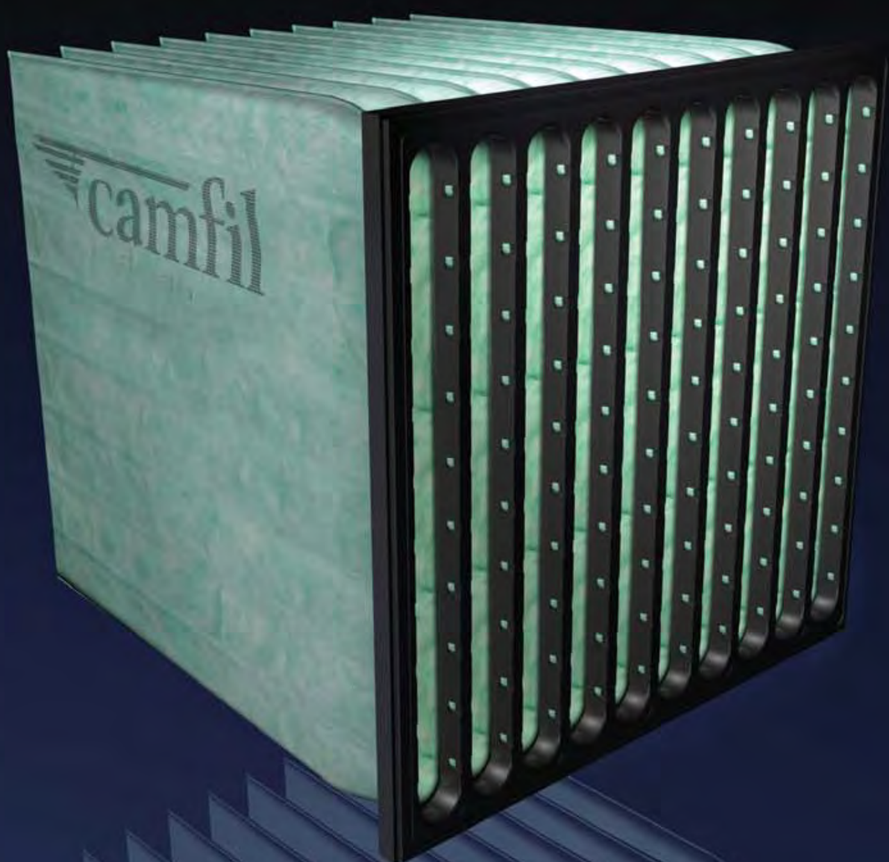
LED Troffer	40	4ft LED troffer	181	7.24
N/A				1.44
LED Troffer	40	4ft LED troffer	230	9.20
N/A				8.28
LED Troffer	40	4ft LED troffer	36	1.44
N/A				3.06
LED Troffer	40	4ft LED troffer	90	3.60
LED	100	LED Can Light	77	7.70
LED Troffer	40	4ft LED troffer	204	8.16
N/A				2.64
LED Troffer	40	4ft LED troffer	103	4.12
N/A				5.34
N/A				3.30
LED Troffer Fixture	40	4ft LED troffer	84	3.36
LED Troffer Fixture	20	2ft LED troffer	79	1.58
LED Troffer Fixture	40	4ft LED troffer	178	7.12
LED Troffer Fixture	20	2ft LED troffer	152	3.04
LED Troffer Fixture	40	4ft LED troffer	88	3.52

N/A				0.27
LED Troffer Fixture	20	2ft LED troffer	50	1.00
LED Troffer Fixture	20	2ft LED troffer	12	0.24
LED Troffer Fixture	40	4ft LED troffer	116	4.64
LED Troffer Fixture	20	2ft LED troffer	28	0.56
LED Troffer Fixture	40	4ft LED troffer	18	0.72
N/A				1.80
LED Troffer Fixture	40	4ft LED troffer	352	14.08
LED Troffer Fixture	20	2ft LED troffer	34	0.68
LED Troffer Fixture	40	4ft LED troffer	10	0.40
LED Troffer Fixture	20	2ft LED troffer	4	0.13
N/A				1.08
N/A				0.35
LED Troffer Fixture	40	4ft LED troffer vapor tight	711	28.44
LED	100	1ft box vapr tight LED flush mount	4	0.40
N/A				15.96
N/A				0.34
LED Troffer Fixture	40	4ft LED troffer vapor tight	198	7.92

Appendix D –Efficient HVAC Filters Documentation

Hi-Flo® ES

The Only Filter of its Kind Designed to Work Without a Prefilter



What's New? *EVERYTHING*

- **27-50% Less HVAC Energy Use than Competitive Filters**
- **25-50% Longer Life, Compared to Competitive Rigid Filters**

Clean air solutions

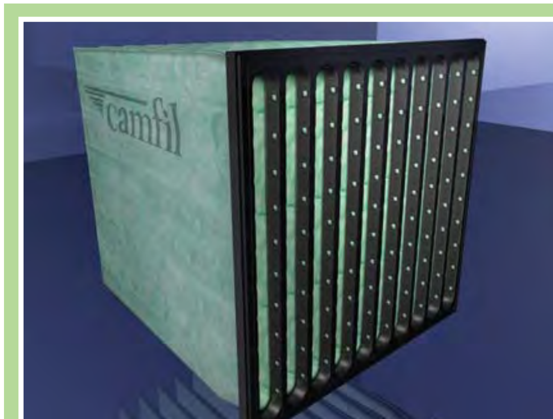
Hi-Flo® ES

Hi-Flo is a high-efficiency ASHRAE grade pocket filter that delivers longest service life, and lowest energy use. It is ideal for the removal of a broad range of contaminants. Hi-Flo has a unique pocket configuration, and special media that is proprietary to Camfil. As a result, unlike all other final filters, the Hi-Flo ES does not require a prefilter. This produces significant savings in filter, labor and disposal costs.

Hi-Flo Media Provides Superior Capture Performance

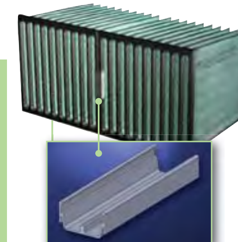
Hi-Flo ES uses exclusive Camfil high loft, air laid micro fiber glass media that assures optimal performance throughout the filter's life. Small fiber diameter and uniform lofting provides uniform capture of submicron particles and low resistance to airflow. **Its superior performance is unaffected by dust loading or humidity.**

A synthetic micromesh media backing protects the media from turbulent or variable airflows.



Plastic Header for Performance and Sustainability

The high-impact ABS header frame is assembled from matching halves, providing both flexible performance and sustainability. The Hi-Flo ES frame is both recyclable and incinerable.

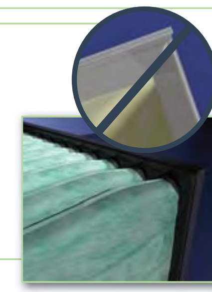


Unique Mounting Clip

The frame design allows for the use of a unique Camfil plastic u-channel clip that attaches two filters together. This allows multiple filters to be installed and removed concurrently saving time and labor. The clips are easily removable and reusable when replacing filters.

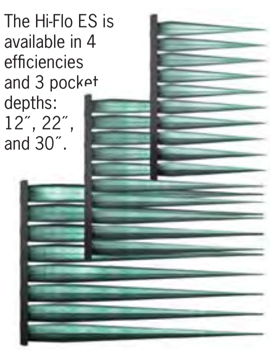
Molded Frame Provides Safety, Security and Convenience

Snap-together molded frame eliminates corner joints. No rivets, jagged edges or sharp corners. Safer and easier to install and remove, protecting service personnel. Pocket damage is also prevented. Aunique snap-to-seal pocket retainer that is integral to the header design prevents bypass between pockets.



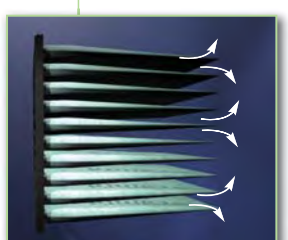
Pocket Depths

The Hi-Flo ES is available in 4 efficiencies and 3 pocket depths: 12˝, 22˝, and 30˝.



Tapered Pocket Stitching

Camfil is the only manufacturer that uses tapered pocket stitching to prevent pocket contact throughout the filter's depth. This ensures uniform airflow and full use of the media. Controlled media spacing gives the Hi-Flo ES lower pressure drop and longer life. In addition, a front-to-back side taper makes the filter extremely resilient, and not vulnerable to tearing or other damage during installation in a side access housing. **The end result: longer filter life and lowest life cycle cost.**



Filter Change Is Easy, Convenient, and Reduces Waste

The Hi-Flo ES shipping container has a transport handle,so service personnel can conveniently transport filters and discard the used filters in the same container. The Hi-Flo ES filter offers streamlined disposal, too. 3-4 used Hi-Flo filters fit in the same space as one rigid filter. **This equates to a 70% reduction in disposal cost.**

Pocket Separation Optimizes Performance

The exit side of the air tunnels includes a pocket flange to ensure pocket integrity throughout the filter's life. A down-stream pocket-to-pocket partition provides additional separation to assure full flow through the media.

5-Star ECI Rating

ENERGY COST INDEX ★★★★★

The **Hi-Flo ES** has earned five stars through the Energy Cost Index (ECI) program. Based on a five-star scale, the ECI is an indicator of what a filter will cost over its service life. Earning the top rating indicates that a filter is the most energy-efficient, longest-lasting filter available.

Hi-Flo® ES

The Hi-Flo® ES vs. the Competition

Final Filter Life (in Months) [1]	18	24	12	12	12	12	12
Annual Energy Consumption [2, 3]	$148.67	$236.17	$241.92	$252.78	$274.00	$303.94	$244.57
Annual Environmental Impact per Filter	$0.42	$2.23	$3.16	$3.16	$3.16	$1.90	$1.90
Prefilter/Labor Cost	$0.00	$48.00	$48.00	$48.00	$48.00	$48.00	$48.00
Initial Pressure [2, 4]	0.37	0.45	0.52	0.66	0.82	0.63	0.66
Performance Guarantee [3]	Yes	No	No	No	No	No	No
Prefilter Required	No	Yes	Yes	Yes	Yes	Yes	Yes
Incinerable	Yes	Some	Some	No	No	Some	No

Note 1: Filter in months based on standard change-out frequencies.
Note 2: Based on average of multiple competitor filters run on LCC.
Note 3: Higher energy usage is primarily a factor of the prefilter attaining maximum pressure every 3 months. The Hi-Flo ES is designed to operate without pre-filtration.
Note 4: Pressure Drop and LCC information contained is based upon 400 fpm (feet per minute) approach velocity which better reflects current industry practice.

The Hi-Flo ES Benefits Users from the First Day of Installation, with:

The Lowest HVAC Energy Costs. Energy cost per filter can be as high as four times the cost of the filter annually. The Hi-Flo ES has a low maintained pressure drop that saves 30% of electric utility costs, compared to other filters.

Fewer Filter Changes than other high efficiency filters. Savings include lower labor costs, decreased disposal, less landfill waste and lower carbon footprint.

Mistake-Free Identification. Alternate pockets are marked with MERV and MERV-Aratings for easiest identification.

Available in 4 Efficiencies: MERV 11, MERV 13, MERV 14 and MERV 15 as evaluated per ASHRAE standard 52.2.

All 4 Efficiencies Meet Appendix J Standards. MERV - 11A, MERV -13A, MERV-A14A, MERV-15A. The Appendix J rating assures that the Hi-Flo ES will provide maintained particle capture efficiency throughout its service life.

Header Available in 4 Sizes. 24x24 (10 pockets), 24x12 (5 pockets), 24x20 (8 pocket), 20x20 (8 pockets).

A 5-Star ECI Rating that ensures maintained efficiency and longer life than traditional high efficiency filters. The many “green” features of the Hi-Flo ES (including longer-lasting media and incinerable/recyclable frames) help building owners meet environmental and “sustainability” commitments. *And to do so at the lowest cost of ownership.*

1 North Corporate Drive | Riverdale, NJ 07457
Phone: 973.616.7300 | Fax: 973.616.7771
camfil@camfil.com
www.camfil.com

www.camfil.com
For further information please contact your nearest Camfil office.

HI-FLO® ES (ENERGY SAVER)
PRODUCT PERFORMANCE GUARANTEE

The Camfil Hi-Flo ES (Energy Saver) comes fully guaranteed to last as long or longer without requiring a prefilter while providing energy savings and performing better than traditional filters. This unique product design was developed solely for sustainability performance including energy savings, reduced waste, and reduced carbon footprint. No other filter can perform like the Hi-Flo ES. The product guarantee is as follows:

GUARANTEE: Camfil guarantees that the Hi-Flo ES (in any efficiency configuration) will last 12 months or longer without a prefilter. The Hi-Flo ES maintains lifetime efficiency by using a special fine fiber media. This guarantees the MERV rating will be maintained throughout the installed life of the filter, providing consistent and sustainable quality indoor air. (*Products made of charged coarse fiber media have been proven to have a rapid reduction in MERV rating once installed in an air handler.)*

CONDITIONS: Guarantee is based on a maximum of 400 FPM airflow and a final pressure drop not-to-exceed 1.5" water gauge. If the Hi-Flo ES fails to last at least 12 months, the following conditions will apply:

- The customer must contact Camfil to provide details of the installation. Requested information will include the customer name, shipping address, a contact name, a contact telephone number, the distributor that provided the filters, application information, the manufacturer and type of the previously used filters, and a description of the service life comparison.
- Camfil will directly ship a complete set of replacement Hi-Flo ES filters to the customer — up to a maximum quantity of 24 units.
- If the value of the replacement filters exceeds $500.00, a Camfil distributor or representative must visit the site to verify the accuracy of the information.
- Once the information has been verified in writing to Camfil, the replacement order will be shipped.
- A user may only qualify for one replacement set of filters.
- Disclaimers and exclusions that will apply include: Premature filter failure caused by mechanical damage or failure of the HVAC system; premature filter failure due to physical damage to the Hi-Flo ES caused by human intervention; premature filter failure due to application of the filter where differential pressure across the filter exceeds the published maximum recommended final pressure drop of 1.5" w.g.

If the Hi-Flo ES does not perform to the above standards,
Camfil promises to provide you one free set of replacement filters.

Contact us at 1-866-4CAMFIL

Appendix E –Solar Documentation

CONFIDENTIAL

10/19/15

PROJECT PERFORMANCE SUMMARY: PV System Only

ABQ airport, carports; prepared for: Quest Energy Group

Utility Name Service Area		**CASH PURCHASE**		
Turnkey Design-Build		Capacity:	1,166	kW
String/Central Inverter		Storage:	-	kWh

Performance Metrics: This system will produce 1,865,600 kWh per year, and 52,093,000 kWh over the system lifetime. The mounting area for this PV system is approximately 148,800 square feet.

Model is not taxing energy production savings

Capital Investment

$	2,773,000	Total PV installed cost, incl. tax
$	831,900	Total PV incentives, after taxes
$	1,941,100	PV system cost, after Yr-1 credits
$	1,941,100	Owner equity, PV only (70 %)
$	895,679	Depreciation, after-tax value
	NA	Estimated first cost for EEMs
	NA	Incentives for EEMs
$	2.38	/ W unit cost

Financial Performance, Unlevered

	11%	Internal Rate of Return, IRR
	8 yrs	Payback Period
$	1,765,788	Net Present Value
	6%	Cash-on-cash return, Yr-1

Estimated Annual Expenses

	NA	Annual debt service
$	7,000	Insurance
$	3,498	Operation and Maintenance

Environmental Benefits

3,426,000 lbs	CO2 emissions reduced annually
47,826 tons	Lifetime CO2 emissions reduction
150,700 gal	Gas not burned in cars annually
or 3,014,000	Miles not driven annually
1713 acres	Mature hardwood forest
4282.5 acres	Urban park area

Income Statement Benefits

	Year 1	Year 5	Year 15	Total for 30 years
Value of Energy Produced	$ 130,592	$ 144,065	$ 184,145	$ 5,719,658
Sale of Energy Credits	$ -	$ -	$ -	$ -
Increase to EBITDA	$ 120,094	$ 132,924	$ 170,565	$ 5,301,919
Increase in property value	$ 1,715,629	$ 1,898,917	$ 2,436,644	N/A

(Based on listed Cap Rate and the increase in Net Operating Income from PV output only.)

Figure 1: After-Tax Cash Flow Projection, PV System

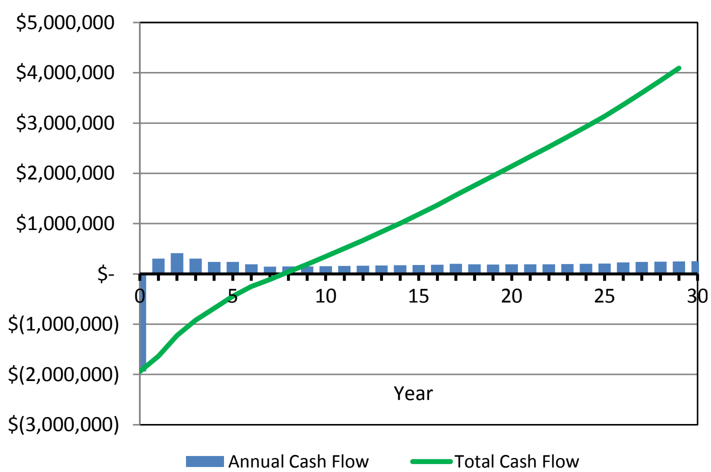
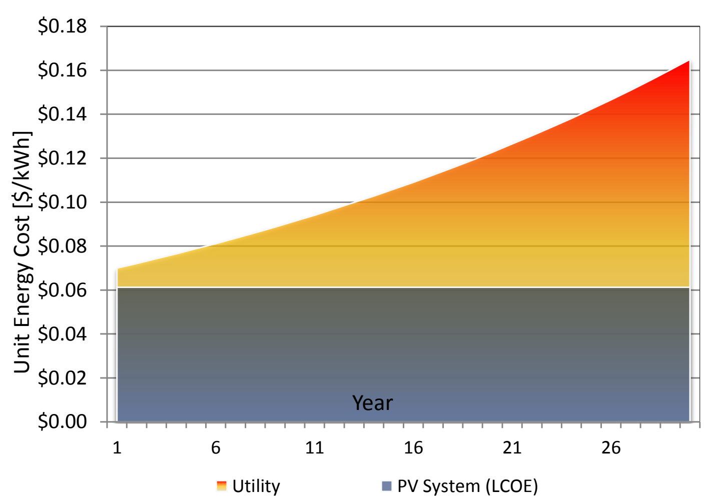


Figure 2: Electricity Costs Over Time {Note A}



Assumptions

Yr-1 cost of electricity	$0.07 / kWh	Discount Rate	4.00%
Annual energy cost increase	3.00%	Consumer Price Index	2.00%
Cost of capital	NA	Combined tax rate	38.00%
Debt term	NA	Depreciation term	6 years
Value of SRECs	$0 / MWh	Investment cap rate	7.00%
SREC Term	- Years	Building floor area [sf]	Unknown

{A} The electricity cost from the PV System in Figure 2 represents the Levelized Cost of Electricity from the PV System. This is calculated as the net cost to the owner after incentives divided by the lifetime energy production.

{B} No additional Shipping or Handling fees included.

{C} Model assumes energy savings from solar will be taxed but instead will be used for other expenses and not increase EBT for a business.

THIS SHEET BASED ON UNIT COST and IS NOT AN ACTUAL QUOTE

10/19/15

PROJECT PERFORMANCE SUMMARY: PV System Only

ABQ airport, solar field; prepared for: Quest Energy Group

AZIMUTH ENERGY

Utility Name Service Area		**CASH PURCHASE**	
Turnkey Design-Build	Capacity:	4,873	kW
String/Central Inverter	Storage:	-	kWh

Performance Metrics: This system will produce 8,479,000 kWh per year, and 236,760,000 kWh over the system lifetime. The mounting area for this PV system is approximately 621,800 square feet.

Model is not taxing energy production savings

Capital Investment

$ 7,641,000	Total PV installed cost, incl. tax
$ 2,292,300	Total PV incentives, after taxes
$ 5,348,700	PV system cost, after Yr-1 credits
$ 5,348,700	Owner equity, PV only (70 %)
$ 2,468,043	Depreciation, after-tax value
NA	Estimated first cost for EEMs
NA	Incentives for EEMs
$ 1.57	/ W unit cost

Financial Performance, Unlevered

18%	Internal Rate of Return, IRR
6 yrs	Payback Period
$ 10,256,281	Net Present Value
10%	Cash-on-cash return, Yr-1

Estimated Annual Expenses

NA	Annual debt service
$ 19,200	Insurance
$ 14,619	Operation and Maintenance

Environmental Benefits

15,568,000 lbs	CO2 emissions reduced annually
217,365 tons	Lifetime CO2 emissions reduction
685,100 gal	Gas not burned in cars annually
or 13,702,000	Miles not driven annually
7784 acres	Mature hardwood forest
19460 acres	Urban park area

Income Statement Benefits

	Year 1	Year 5	Year 15	Total for 30 years
Value of Energy Produced	$ 593,530	$ 654,763	$ 836,926	$ 25,995,378
Sale of Energy Credits	$ -	$ -	$ -	$ -
Increase to EBITDA	$ 559,711	$ 618,874	$ 793,177	$ 24,649,645
Increase in property value	$ 7,995,871	$ 8,841,052	$ 11,331,104	N/A

(Based on listed Cap Rate and the increase in Net Operating Income from PV output only.)

Figure 1: After-Tax Cash Flow Projection, PV System

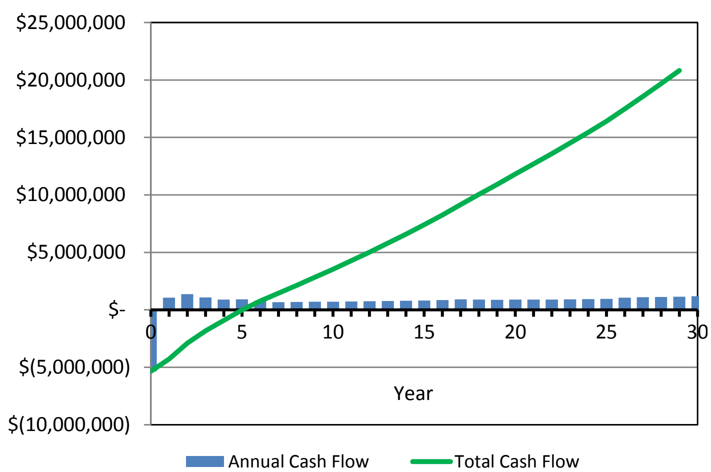
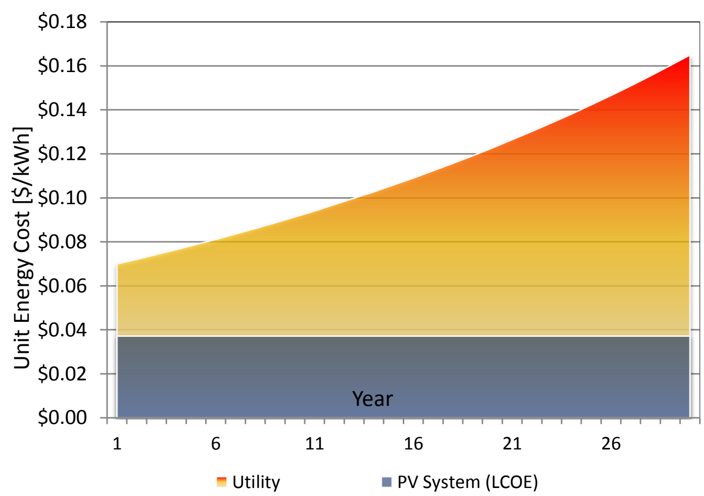


Figure 2: Electricity Costs Over Time {Note A}



Assumptions

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Annual energy cost increase	3.00%	Consumer Price Index	2.00%
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Debt term	NA	Depreciation term	6 years
Value of SRECs	$0 / MWh	Investment cap rate	7.00%
SREC Term	- Years	Building floor area [sf]	Unknown

{A} The electricity cost from the PV System in Figure 2 represents the Levelized Cost of Electricity from the PV System. This is calculated as the net cost to the owner after incentives divided by the lifetime energy production.

{B} No additional Shipping or Handling fees included.

{C} Model assumes energy savings from solar will be taxed but instead will be used for other expenses and not increase EBT for a business.

THIS SHEET BASED ON UNIT COST and IS NOT AN ACTUAL QUOTE

From: Marc Lopata [mailto:marc@azimuthenergy.net]
Sent: Monday, October 19, 2015 2:44 PM
To: Craig Green <craig@questenergy.com>
Subject: RE: ABQ Sunport solar projects

Craig, here are a couple of summaries. And some highlights.

1. Assuming these will be third-party financed, since the airport cannot capture the 30% Investment Tax Credit (ITC). Note the ITC expires end of next year unless it is extended. So these would have to be done fairly quickly.
2. The carport project has a couple of handicaps: lower tilt is required (closer to 5-7 degrees instead of 20 degrees) and the higher cost for the structures. It is a 10-year payback, and I doubt a financer would take it on unless there was other funding available to reduce the cap cost.
3. Yield from your NREL model is 1,740 kWh/kW. I used that for the solar field. For the carports, I guessed at 1,600 kWh/kW due to the lower tilt. Plus, not sure that array can be pointed south.
4. The field project has much better performance and probably can be financed easily.

- Marc Lopata
314.378.1913
skype: marc.lopata

Customize Your System To Your Roof

On the map below, click the corners of the desired system. Note that the roof tilt and azimuth cannot be automatically determined from the aerial imagery, and consequently the estimated system capacity may not reflect what is actually possible.

System Capacity: 133.9 kWdc (893 m^2)

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Caution: Photovoltaic system performance predictions calculated by PVWatts® include many inherent assumptions and uncertainties and do not reflect variations between PV technologies nor site-specific characteristics except as represented by PVWatts® inputs. For example, PV modules with better performance are not differentiated within PVWatts® from lesser performing modules. Both NREL and private companies provide more sophisticated PV modeling tools (such as the System Advisor Model at http://sam.nrel.gov) that allow for more precise and complex modeling of PV systems.

RESULTS

304,380 kWh per Year *

Month	Solar Radiation (kWh / m^2 / day)	AC Energy (kWh)	Energy Value ($)
January	6.37	21,953	2,239
February	7.25	21,977	2,242
March	7.86	26,412	2,694
April	8.95	28,071	2,863
May	9.51	30,167	3,077
June	9.20	27,577	2,813
July	8.89	27,320	2,787
August	8.78	27,136	2,768
September	8.22	24,657	2,515
October	8.10	26,139	2,666
November	6.85	21,973	2,241
December	6.12	20,999	2,142
Annual	8.01	304,381	**$ 31,047**

Location and Station Identification

Requested Location	2200 Sunport Blvd Albuquerque, NM 87106
Weather Data Source	(TMY2) ALBUQUERQUE, NM 0.6 mi
Latitude	35.05° N
Longitude	106.62° W

PV System Specifications (Commercial)

DC System Size	133.9 kW
Module Type	Standard
Array Type	1-Axis Tracking
Array Tilt	35.0°
Array Azimuth	180°
System Losses	14%
Inverter Efficiency	96%
DC to AC Size Ratio	1.1
Ground Coverage Ratio	0.4

Initial Economic Comparison

Average Cost of Electricity Purchased from Utility	0.10 $/kWh
Initial Cost	2.60 $/Wdc
Cost of Electricity Generated by System	0.07 $/kWh

These values can be compared to get an idea of the cost-effectiveness of this system. However, system costs, system financing options (including 3rd party ownership) and complex utility rates can significantly change the relative value of the PV system.

Appendix F –BAS Screenshots & Trend Logs


AutomatedLogic
Graphics
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Alarms
Trends
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Secondary Chilled Water Pumps - Bldg Flow
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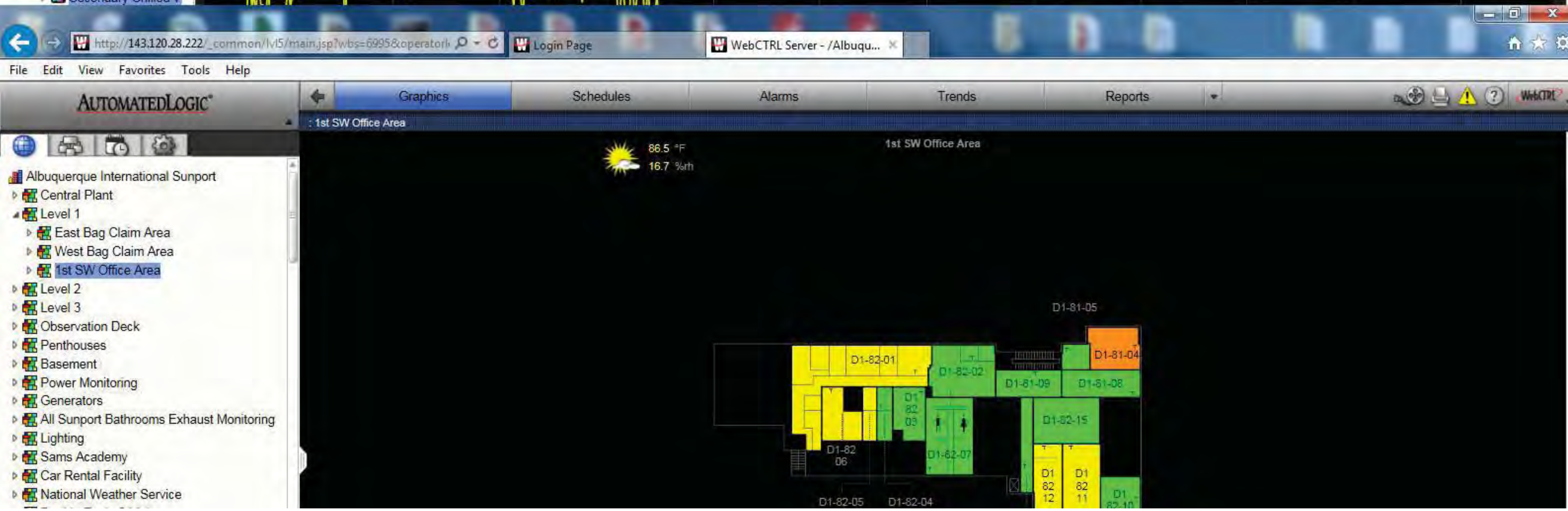
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Central Plant
Level 1
East Bag Claim Area
West Bag Claim Area
1st SW Office Area
Level 2
Level 3
Observation Deck
Penthouses
Basement
Power Monitoring
Generators
All Sunport Bathrooms Exhaust Monitoring
Lighting
Sams Academy
Car Rental Facility
National Weather Service
D1-81-05
D1-81-04
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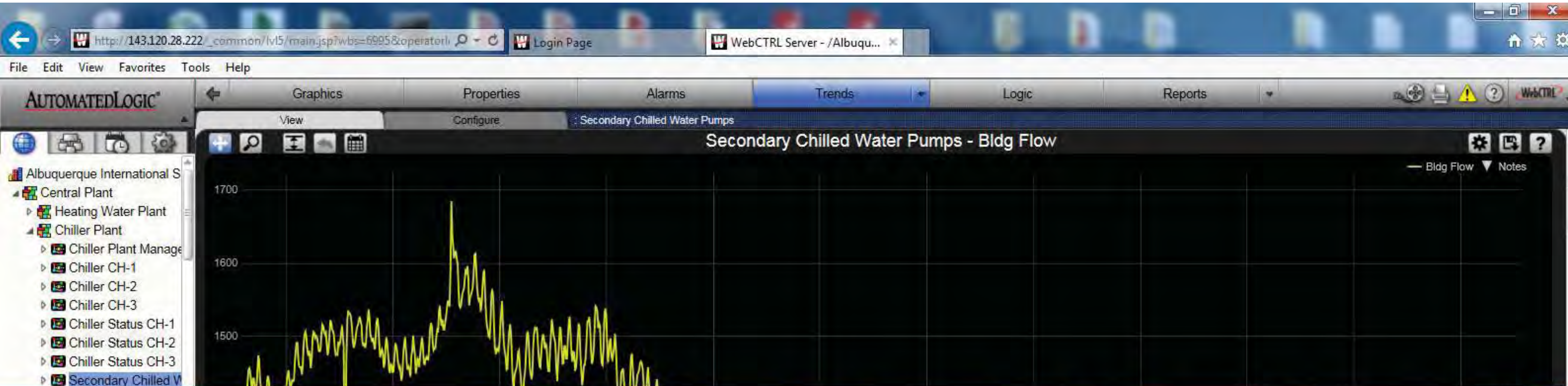
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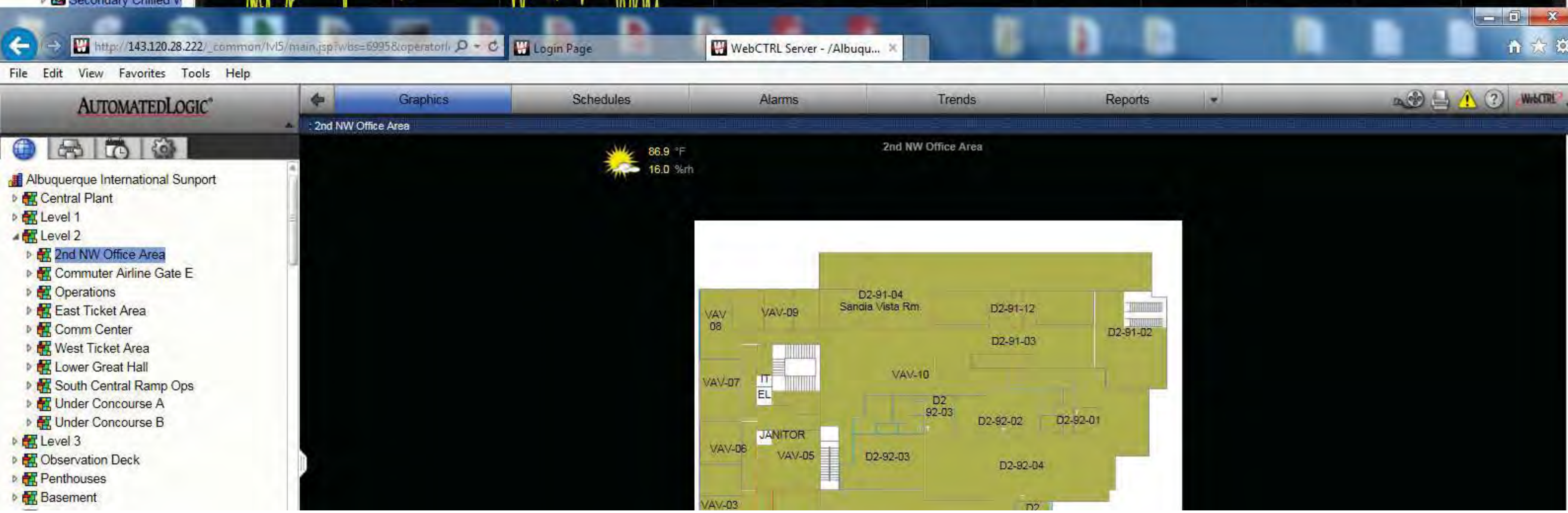
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Under Concourse A
Under Concourse B
Level 3
Observation Deck
Penthouses
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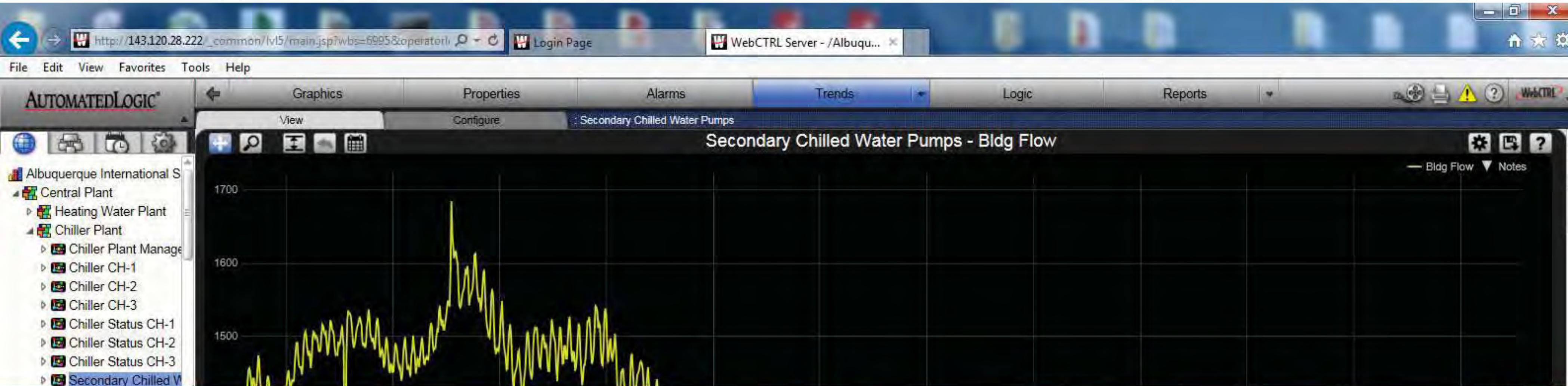
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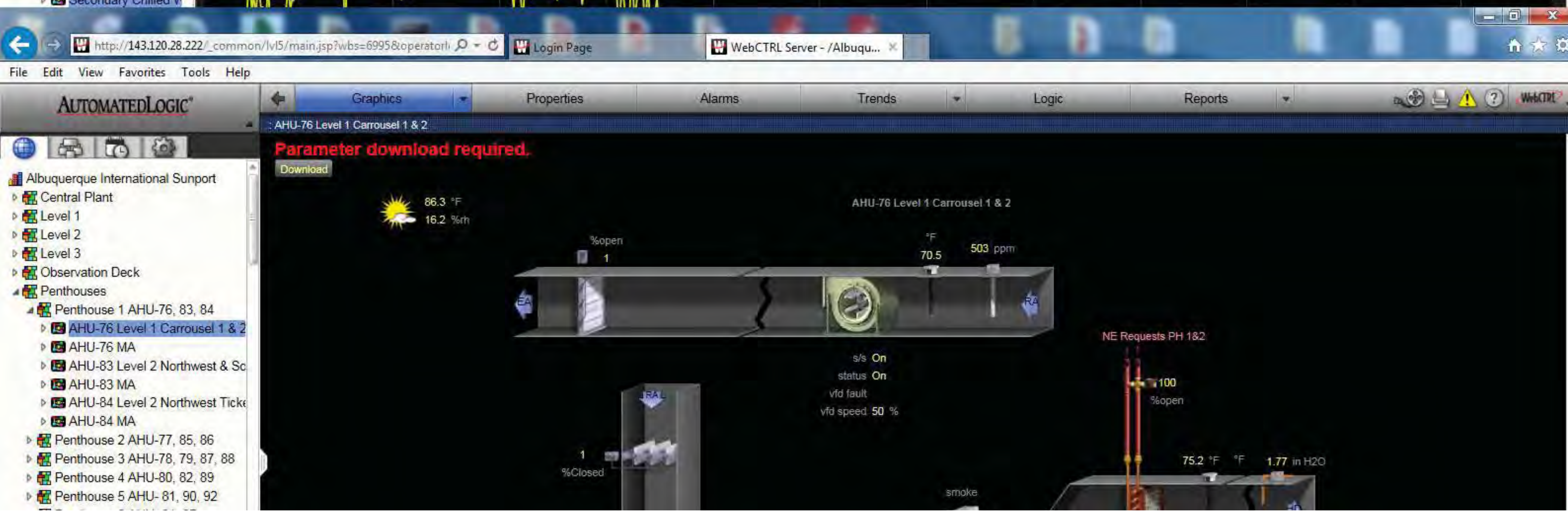
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Level 2
Level 3
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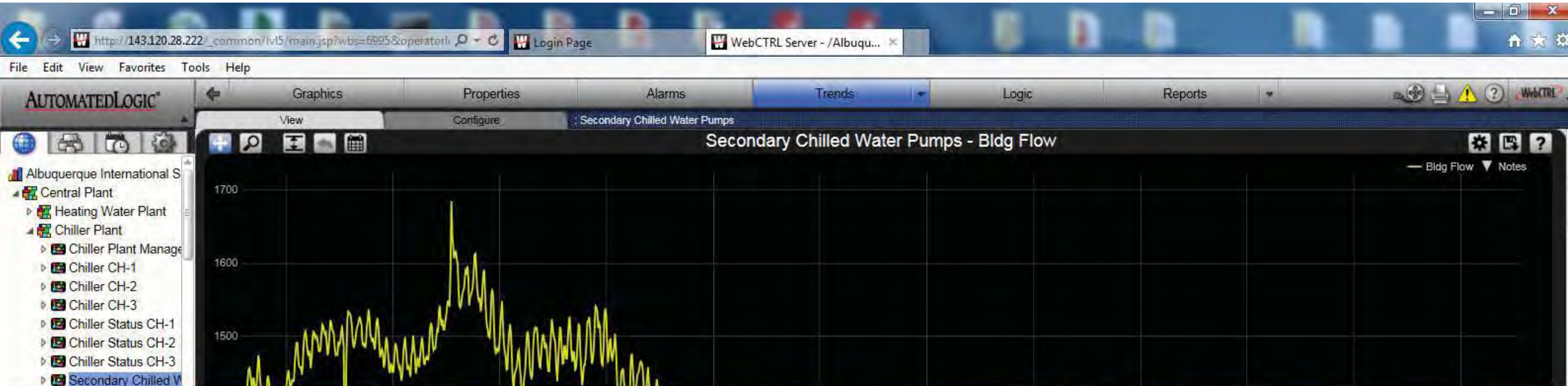
AHU-76 Level 1 Carrousel 1 & 2
AHU-76 MA
AHU-83 Level 2 Northwest & Sc
AHU-83 MA
AHU-84 Level 2 Northwest Ticke
AHU-84 MA
Penthouse 2 AHU-77, 85, 86
Penthouse 3 AHU-78, 79, 87, 88
Penthouse 4 AHU-80, 82, 89
Penthouse 5 AHU- 81, 90, 92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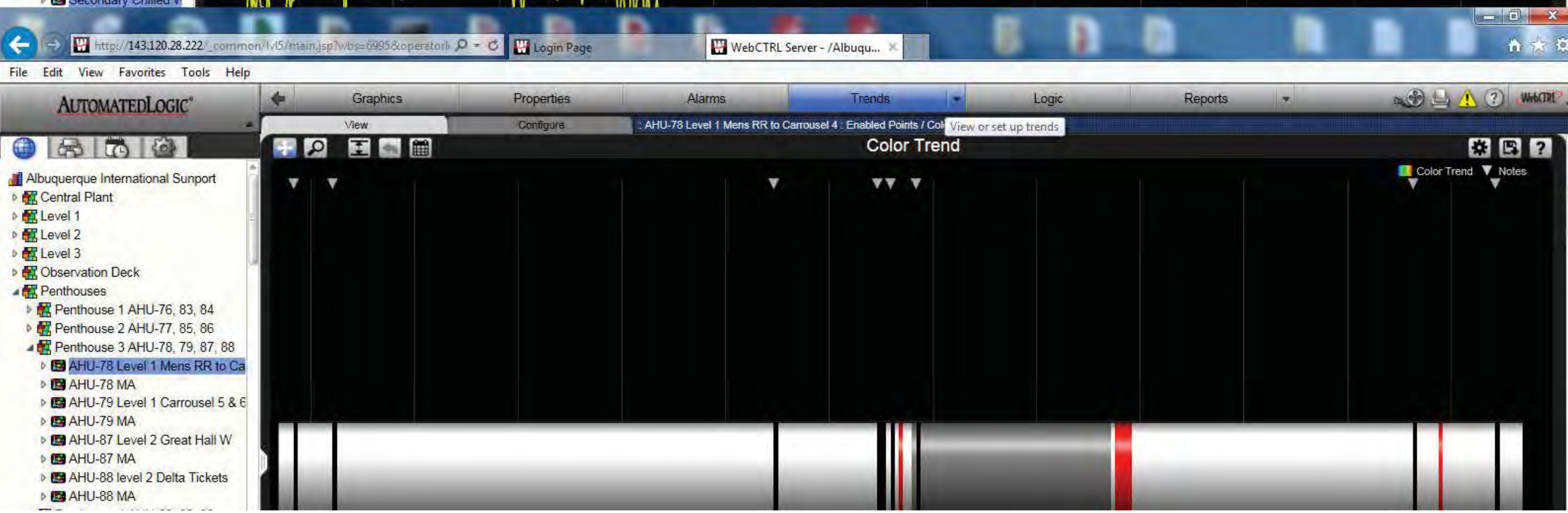
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Central Plant
Level 1
Level 2
Level 3
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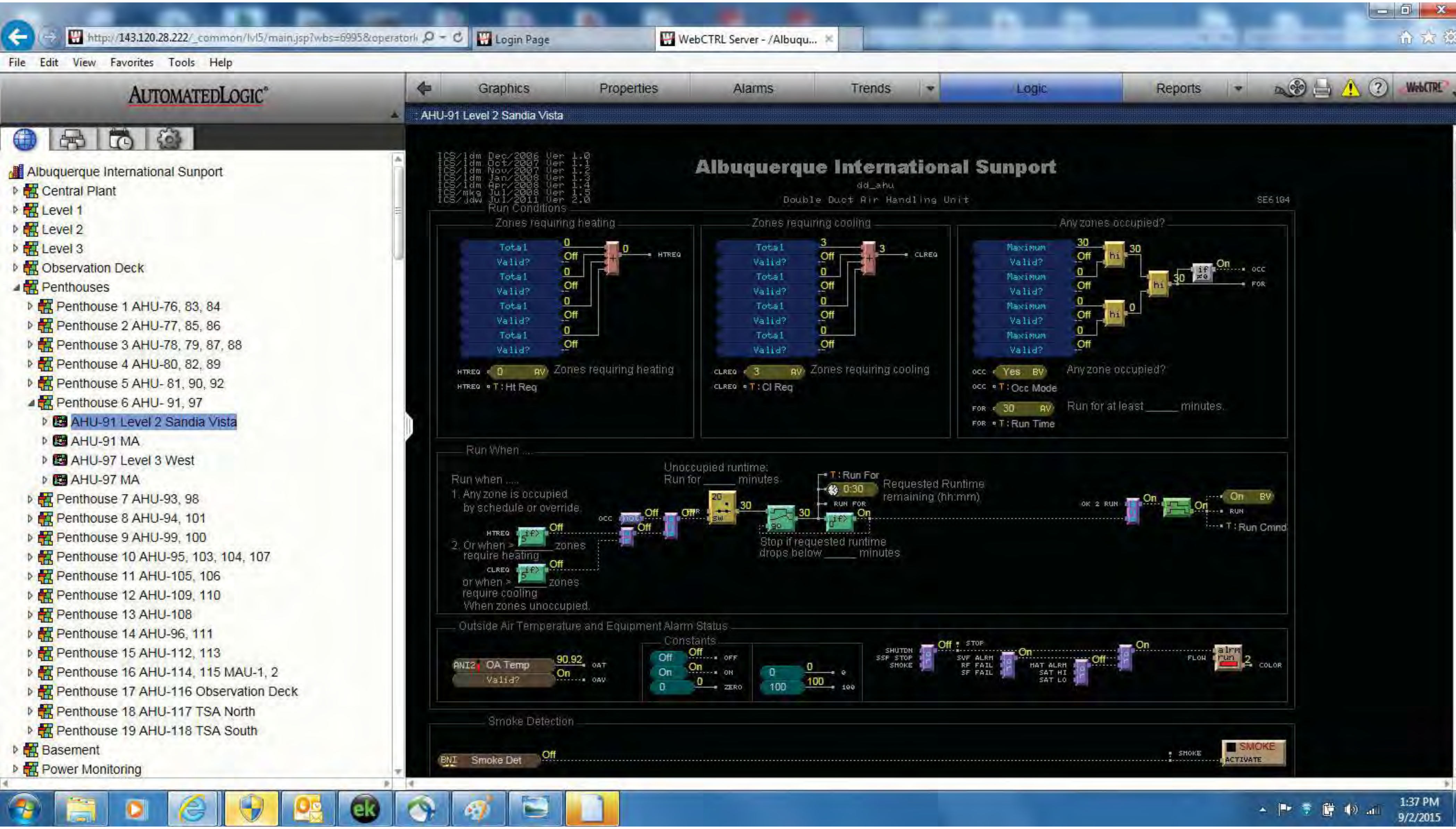
Penthouse 2 AHU-77, 85, 86
Penthouse 3 AHU-78, 79, 87, 88
AHU-78 Level 1 Mens RR to Ca
AHU-78 MA
AHU-79 Level 1 Carrousel 5 & 6
AHU-79 MA
AHU-87 Level 2 Great Hall W
AHU-87 MA
AHU-88 level 2 Delta Tickets
AHU-88 MA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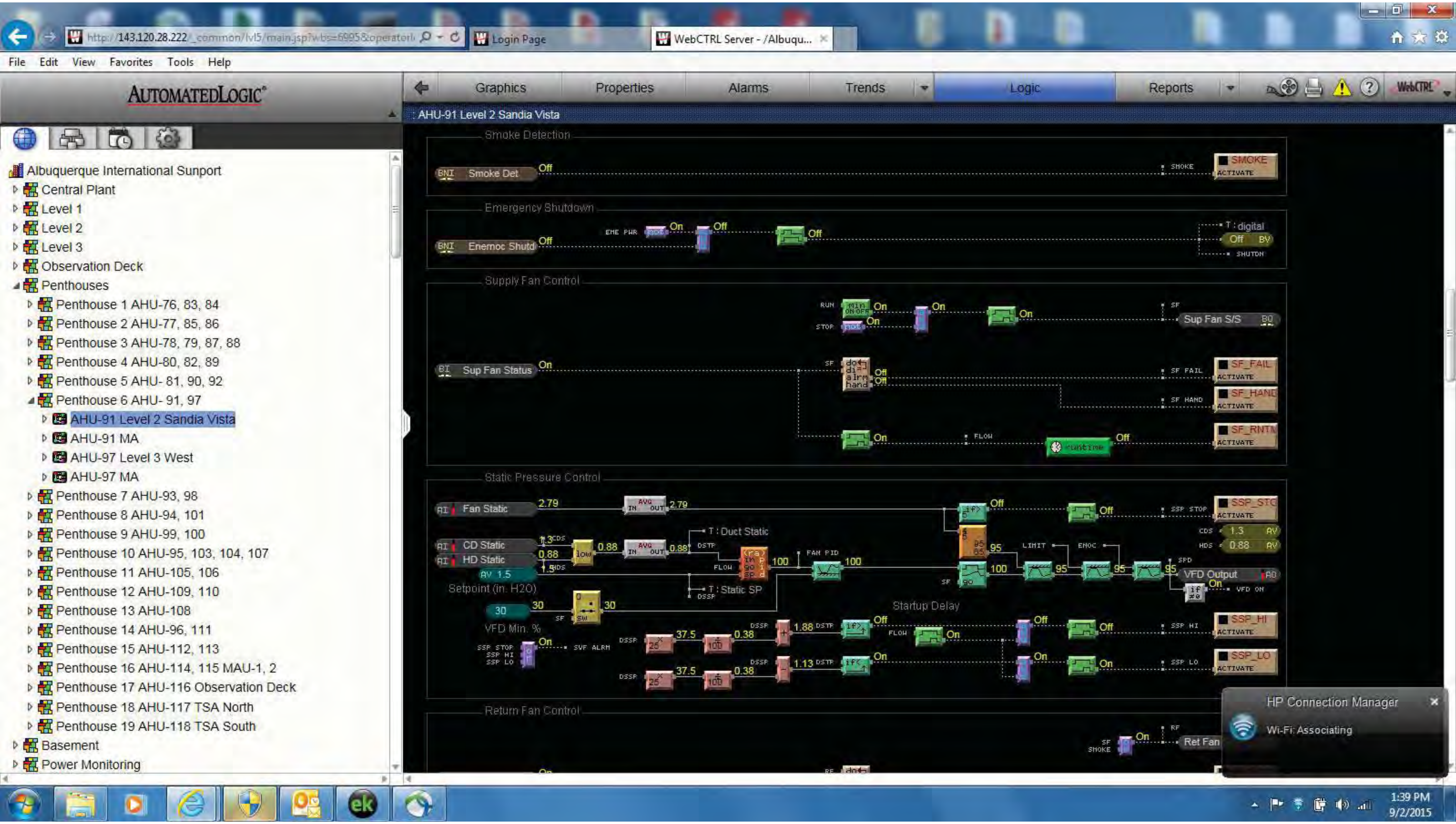
Albuquerque International Sunport
Central Plant
Level 1
Level 2
Level 3
Observation Deck
Penthouses
Penthouse 1 AHU-76, 83, 84
Penthouse 2 AHU-77, 85, 86
Penthouse 3 AHU-78, 79, 87, 88
Penthouse 4 AHU-80, 82, 89
Penthouse 5 AHU- 81, 90, 92
Penthouse 6 AHU- 91, 97
AHU-91 Level 2 Sandia Vista
AHU-91 MA
AHU-97 Level 3 West
AHU-97 MA
Penthouse 7 AHU-93, 98
Penthouse 8 AHU-94, 101
Penthouse 9 AHU-99, 100
Penthouse 10 AHU-95, 103, 104, 107
Penthouse 11 AHU-105, 106
Penthouse 12 AHU-109, 110
Penthouse 13 AHU-108
Penthouse 14 AHU-96, 111
Penthouse 15 AHU-112, 113
Penthouse 16 AHU-114, 115 MAU-1, 2
Penthouse 17 AHU-116 Observation Deck
Penthouse 18 AHU-117 TSA North
Penthouse 19 AHU-118 TSA South
Basement
Power Monitoring
Albuquerque International Sunport
dd_ahu
Double Duct Air Handling Unit
SE6104
Run Conditions
Zones requiring heating
Zones requiring cooling
Any zones occupied?
Zones requiring heating
Zones requiring cooling
Any zone occupied?
T : Ht Req
T : Cl Req
T : Occ Mode
Run for at least _____ minutes.
T : Run Time
Run When ...
Run when ....
1. Any zone is occupied by schedule or override.
2. Or when > _____ zones require heating
or when > _____ zones require cooling
When zones unoccupied.
Unoccupied runtime: Run for _____ minutes
T : Run For
Requested Runtime remaining (hh:mm)
Stop if requested runtime drops below _____ minutes
T : Run Cmnd
Outside Air Temperature and Equipment Alarm Status
Constants
OA Temp
Smoke Detection
Smoke Det
SMOKE
ACTIVATE
1:37 PM
9/2/2015


AUTOMATEDLOGIC
Graphics
Properties
Alarms
Trends
Logic
Reports
AHU-91 Level 2 Sandia Vista
Albuquerque International Sunport
Central Plant
Level 1
Level 2
Level 3
Observation Deck
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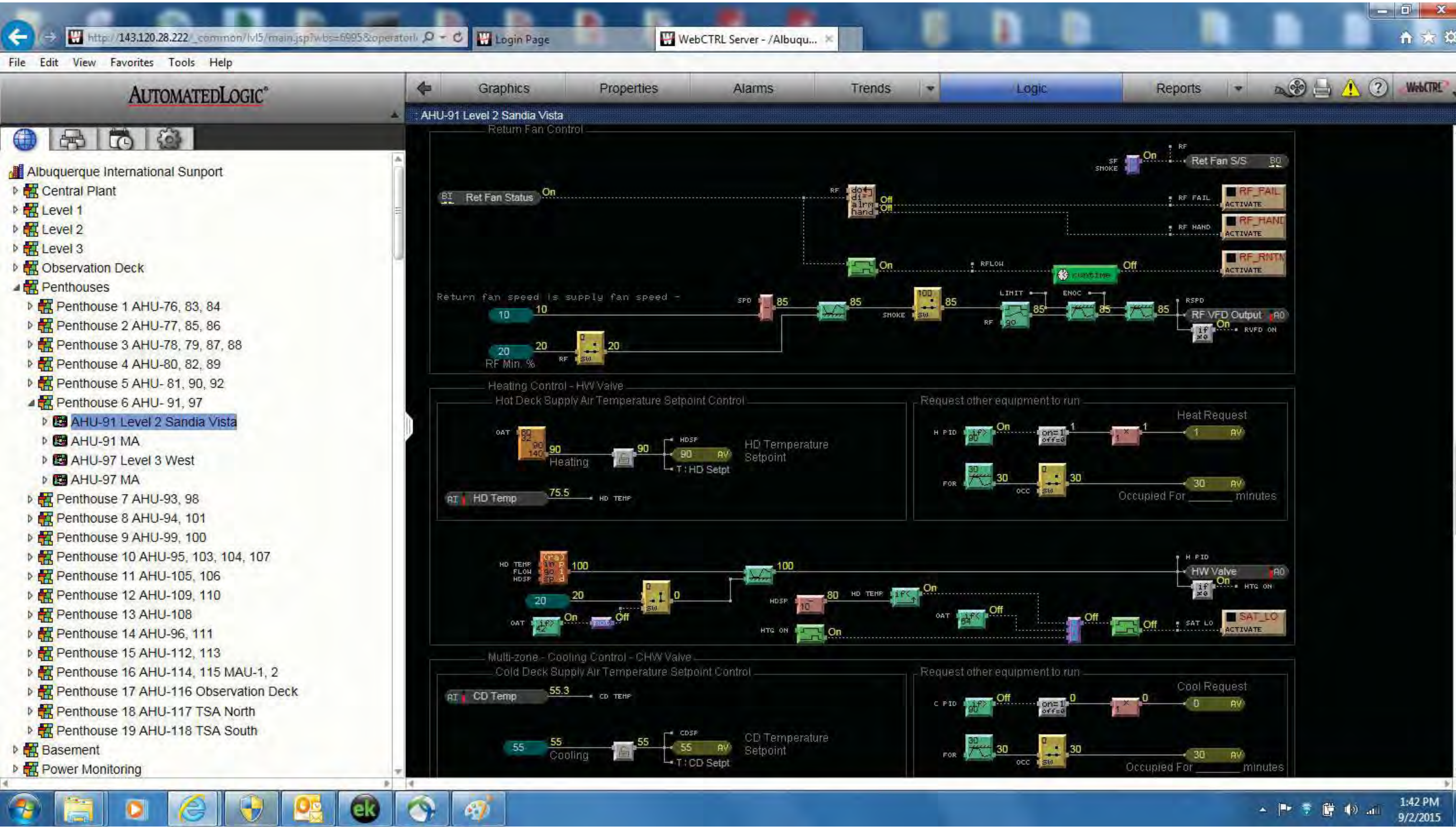
Penthouse 2 AHU-77, 85, 86
Penthouse 3 AHU-78, 79, 87, 88
Penthouse 4 AHU-80, 82, 89
Penthouse 5 AHU- 81, 90, 92
Penthouse 6 AHU- 91, 97
AHU-91 Level 2 Sandia Vista
AHU-91 MA
AHU-97 Level 3 West
AHU-97 MA
Penthouse 7 AHU-93, 98
Penthouse 8 AHU-94, 101
Penthouse 9 AHU-99, 100
Penthouse 10 AHU-95, 103, 104, 107
Penthouse 11 AHU-105, 106
Penthouse 12 AHU-109, 110
Penthouse 13 AHU-108
Penthouse 14 AHU-96, 111
Penthouse 15 AHU-112, 113
Penthouse 16 AHU-114, 115 MAU-1, 2
Penthouse 17 AHU-116 Observation Deck
Penthouse 18 AHU-117 TSA North
Penthouse 19 AHU-118 TSA South
Basement
Power Monitoring
Smoke Detection
Smoke Det
Emergency Shutdown
Emernoc Shutd
Supply Fan Control
Sup Fan Status
Sup Fan S/S
Static Pressure Control
Fan Static
CD Static
HD Static
Setpoint (in. H2O)
VFD Min. %
T : Duct Static
T : Static SP
VFD Output
Startup Delay
Return Fan Control
HP Connection Manager
Wi-Fi: Associating
1:39 PM
9/2/2015



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Login Page
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AUTOMATEDLOGIC
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Trends
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AHU-91 Level 2 Sandia Vista
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Penthouse 5 AHU- 81, 90, 92
Penthouse 6 AHU- 91, 97
AHU-91 Level 2 Sandia Vista
AHU-91 MA
AHU-97 Level 3 West
AHU-97 MA
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Penthouse 8 AHU-94, 101
Penthouse 9 AHU-99, 100
Penthouse 10 AHU-95, 103, 104, 107
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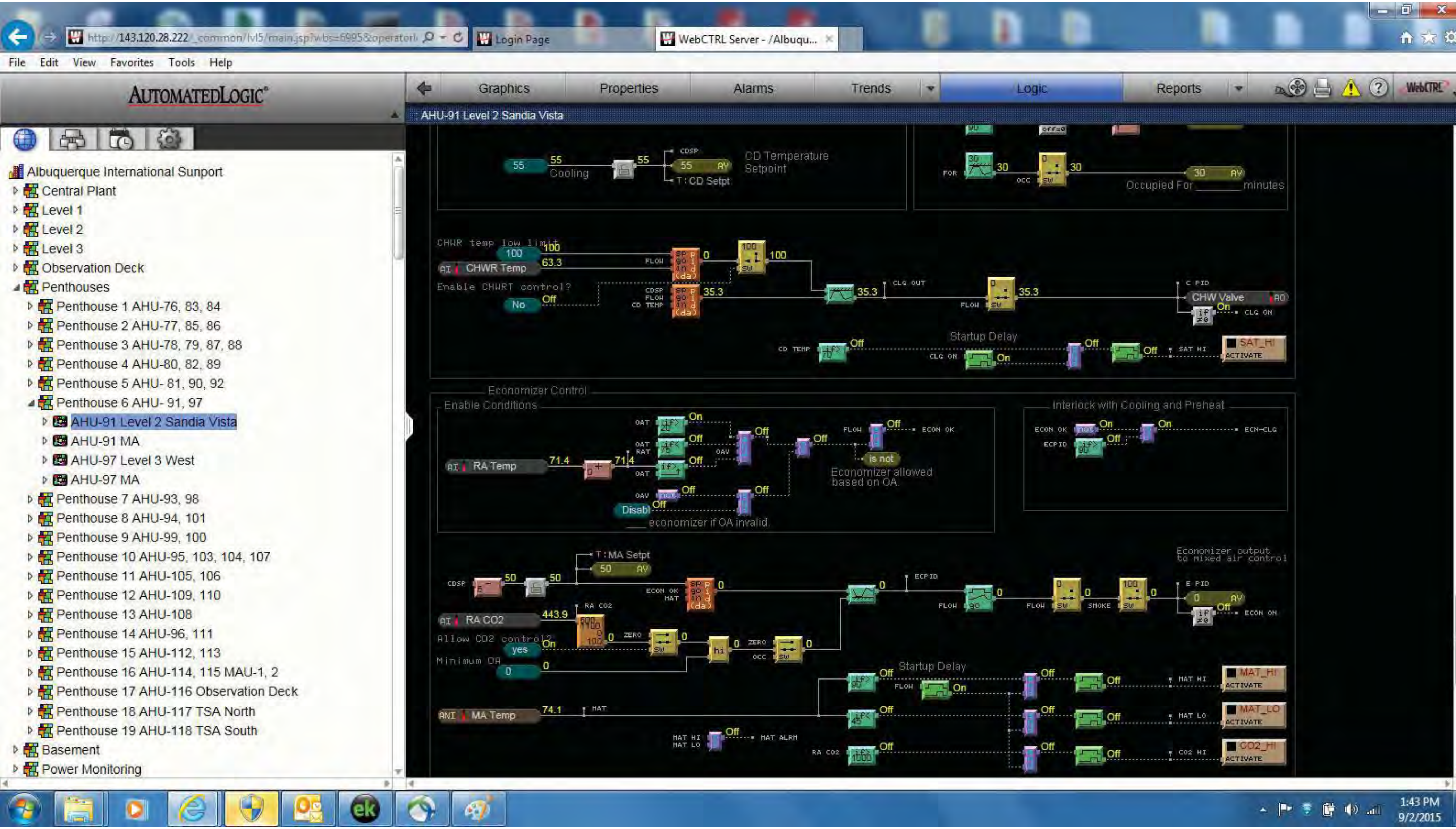
Penthouse 13 AHU-108
Penthouse 14 AHU-96, 111
Penthouse 15 AHU-112, 113
Penthouse 16 AHU-114, 115 MAU-1, 2
Penthouse 17 AHU-116 Observation Deck
Penthouse 18 AHU-117 TSA North
Penthouse 19 AHU-118 TSA South
Basement
Power Monitoring
Return Fan Control
Ret Fan S/S
Ret Fan Status
RF_FAIL
RF_HAND
RF_RNTM
Return fan speed is supply fan speed -
RF VFD Output
RF Min. %
Heating Control - HW Valve
Hot Deck Supply Air Temperature Setpoint Control
Request other equipment to run
Heat Request
HD Temperature Setpoint
T : HD Setpt
Heating
HD Temp
Occupied For minutes
HW Valve
SAT_LO
Multi-zone - Cooling Control - CHW Valve
Cold Deck Supply Air Temperature Setpoint Control
Cool Request
CD Temp
CD Temperature Setpoint
T : CD Setpt
Cooling
1:42 PM
9/2/2015


AUTOMATEDLOGIC
Graphics
Properties
Alarms
Trends
Logic
Reports
AHU-91 Level 2 Sandia Vista
Albuquerque International Sunport
Central Plant
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Level 3
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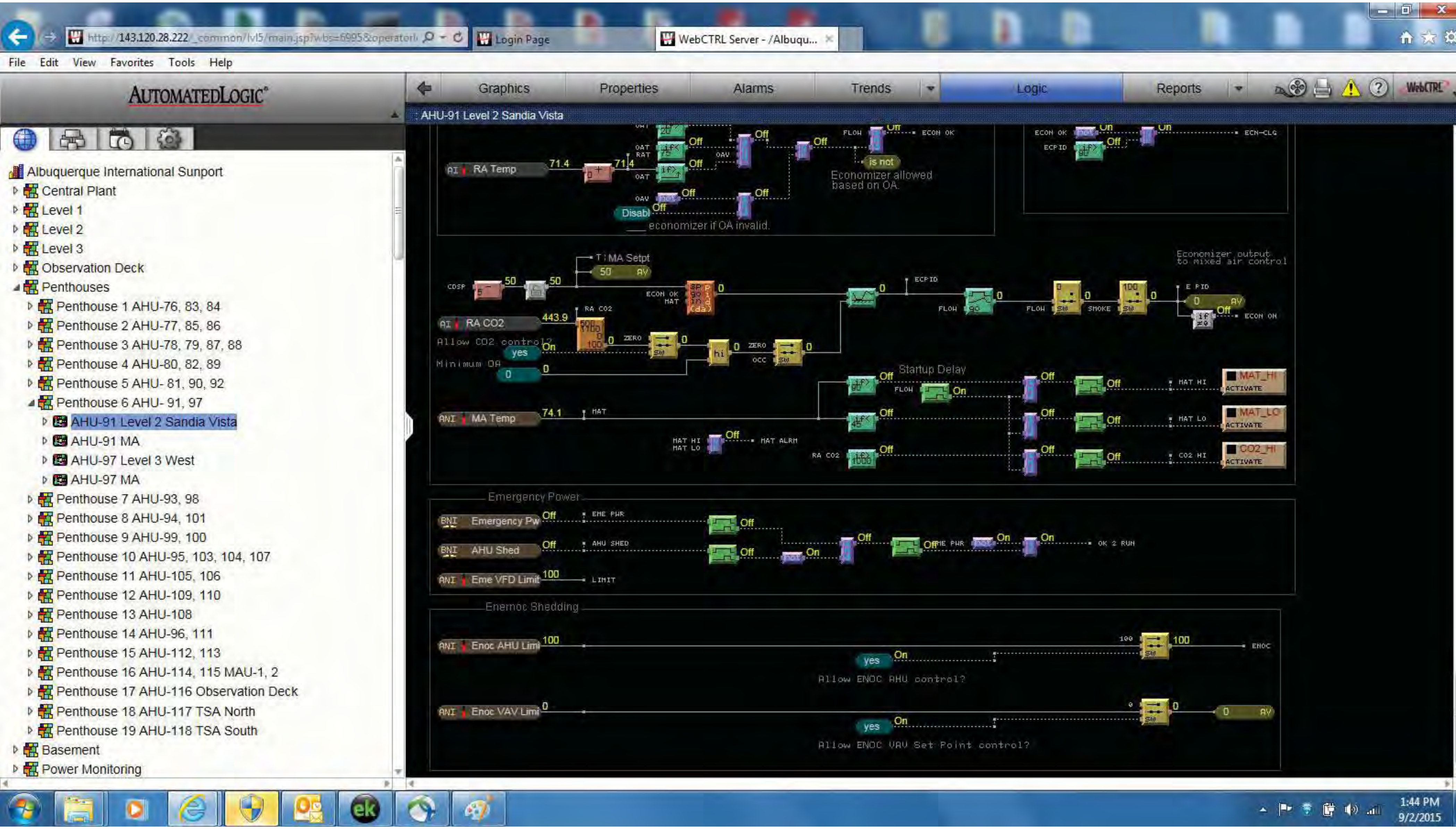
Penthouse 3 AHU-78, 79, 87, 88
Penthouse 4 AHU-80, 82, 89
Penthouse 5 AHU- 81, 90, 92
Penthouse 6 AHU- 91, 97
AHU-91 Level 2 Sandia Vista
AHU-91 MA
AHU-97 Level 3 West
AHU-97 RA
Penthouse 7 AHU-93, 98
Penthouse 8 AHU-94, 101
Penthouse 9 AHU-99, 100
Penthouse 10 AHU-95, 103, 104, 107
Penthouse 11 AHU-105, 106
Penthouse 12 AHU-109, 110
Penthouse 13 AHU-108
Penthouse 14 AHU-96, 111
Penthouse 15 AHU-112, 113
Penthouse 16 AHU-114, 115 MAU-1, 2
Penthouse 17 AHU-116 Observation Deck
Penthouse 18 AHU-117 TSA North
Penthouse 19 AHU-118 TSA South
Basement
Power Monitoring
CD Temperature Setpoint
Occupied For minutes
CHWR temp low limit
CHWR Temp
Enable CHWRT control?
CHW Valve
Startup Delay
Economizer Control
Enable Conditions
RA Temp
Economizer allowed based on OA
economizer if OA invalid
Interlock with Cooling and Preheat
Economizer output to mixed air control
RA CO2
Allow CO2 control?
Minimum OA
MA Temp
1:43 PM
9/2/2015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AUTOMATEDLOGIC
Graphics Properties Alarms Trends Logic Reports
AHU-91 Level 2 Sandia Vista
Albuquerque International Sunport
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Penthouse 5 AHU- 81, 90, 92
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AHU-91 MA
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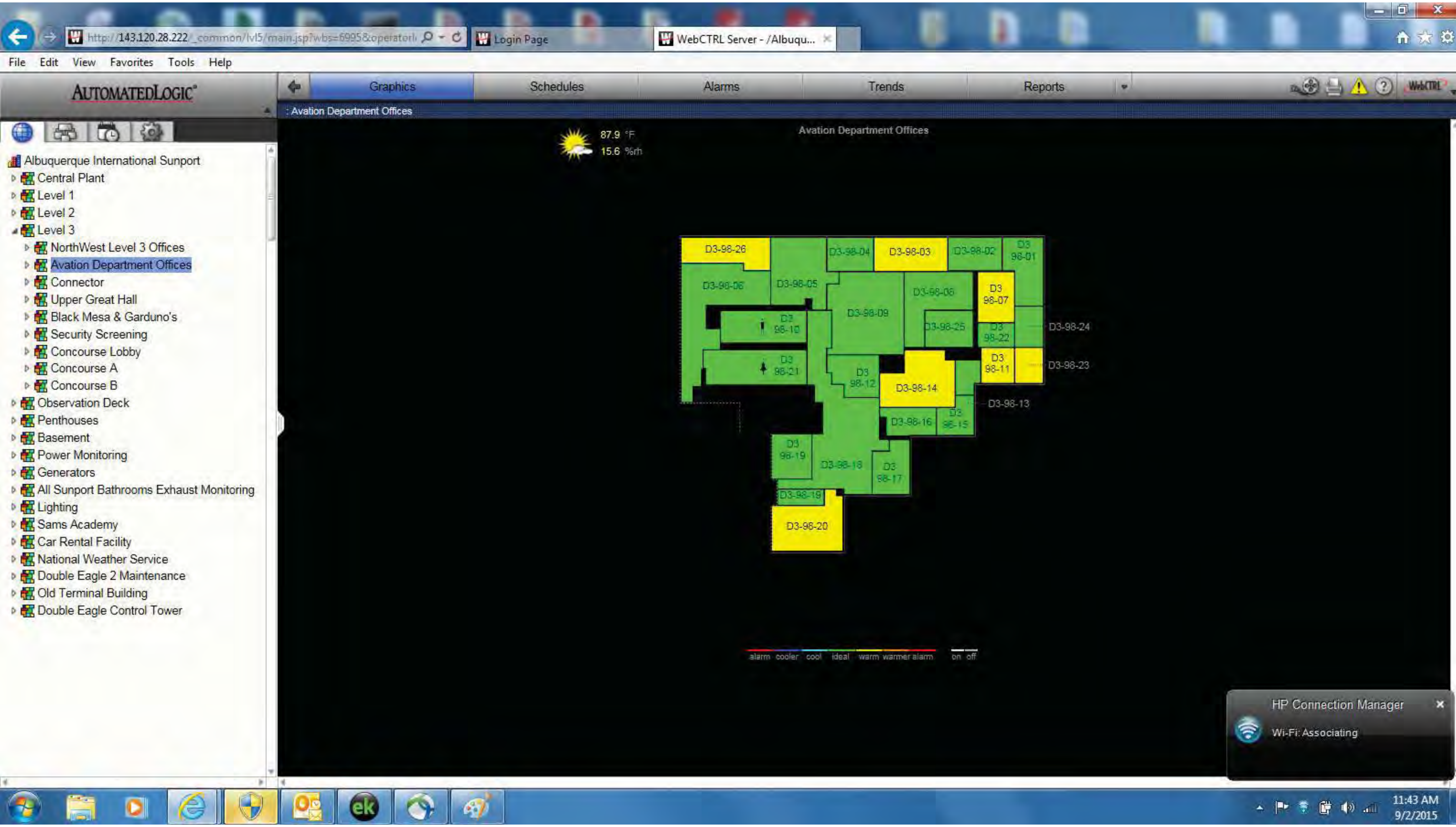
Penthouse 14 AHU-96, 111
Penthouse 15 AHU-112, 113
Penthouse 16 AHU-114, 115 MAU-1, 2
Penthouse 17 AHU-116 Observation Deck
Penthouse 18 AHU-117 TSA North
Penthouse 19 AHU-118 TSA South
Basement
Power Monitoring
RA Temp 71.4
Economizer allowed based on OA.
economizer if OA invalid.
T:MA Setpt
Economizer output to mixed air control
RA CO2 443.9
Allow CO2 control?
Minimum OA
Startup Delay
MA Temp 74.1
MAT_HI
MAT_LO
CO2_HI
Emergency Power
Emergency Pw
AHU Shed
Eme VFD Limit
Enernoc Shedding
Enoc AHU Limi
Allow ENOC AHU control?
Enoc VAV Limi
Allow ENOC VAV Set Point control?
1:44 PM
9/2/2015


File Edit View Favorites Tools Help
AutomatedLogic
Graphics
Schedules
Alarms
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Reports
Avation Department Offices
87.9 °F
15.6 %rh
Albuquerque International Sunport
Central Plant
Level 1
Level 2
Level 3
NorthWest Level 3 Offices
Avation Department Offices
Connector
Upper Great Hall
Black Mesa & Garduno's
Security Screening
Concourse Lobby
Concourse A
Concourse B
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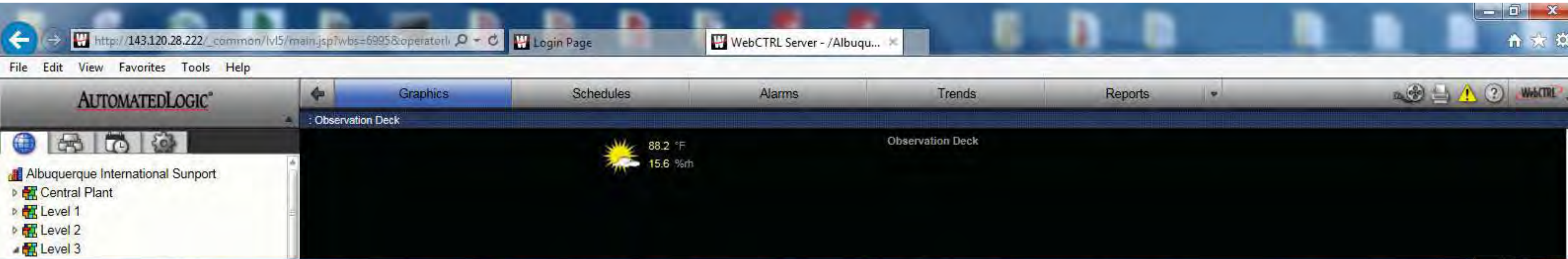
Lighting
Sams Academy
Car Rental Facility
National Weather Service
Double Eagle 2 Maintenance
Old Terminal Building
Double Eagle Control Tower
D3-98-26
D3-98-03
D3-98-14
D3-98-20
D3-98-24
D3-98-23
D3-98-13
alarm cooler cool ideal warm warmer alarm
on off
HP Connection Manager
Wi-Fi: Associating
11:43 AM
9/2/2015


Login Page
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File Edit View Favorites Tools Help
AUTOMATEDLOGIC
Graphics
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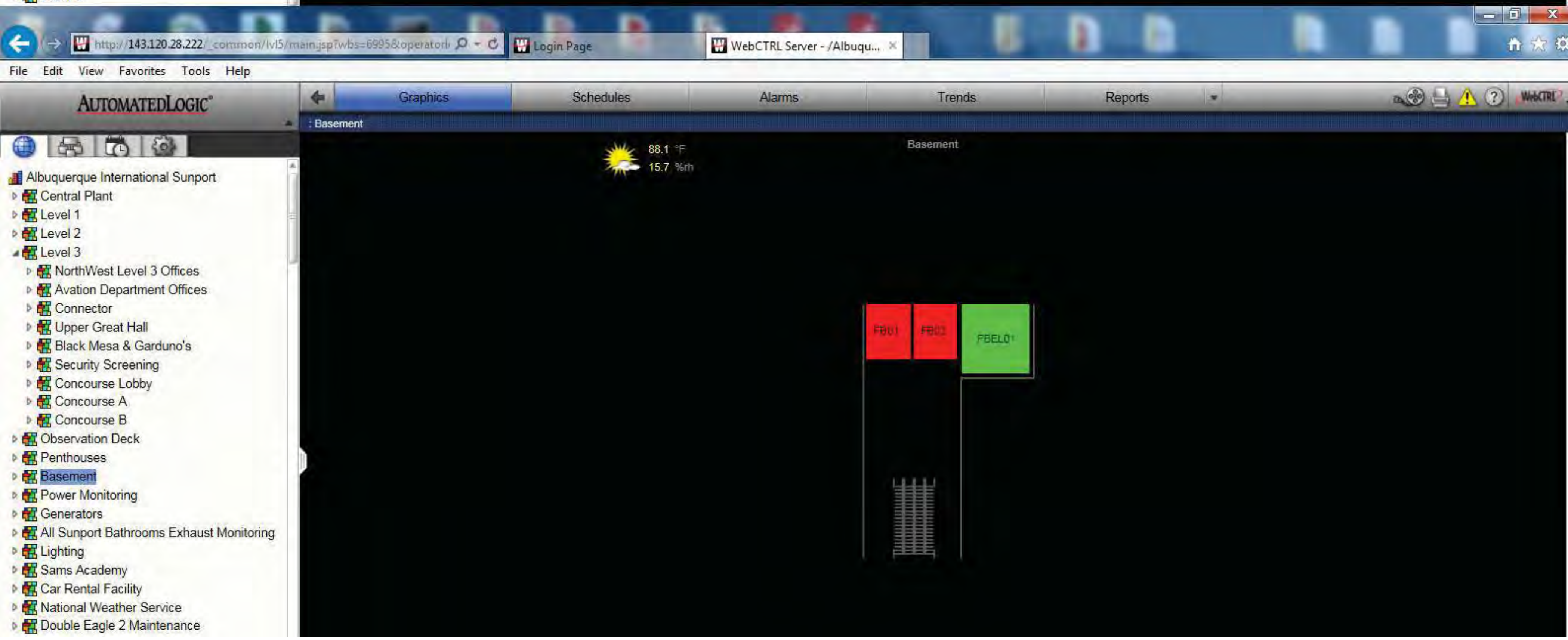
Trends
Reports
: Observation Deck
88.2 °F
15.6 %rh
Observation Deck
Albuquerque International Sunport
Central Plant
Level 1
Level 2
Level 3


Login Page
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File Edit View Favorites Tools Help
AUTOMATEDLOGIC
Graphics
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Trends
Reports
: Basement
88.1 °F
15.7 %rh
Basement
Albuquerque International Sunport
Central Plant
Level 1
Level 2
Level 3
NorthWest Level 3 Offices
Avation Department Offices
Connector
Upper Great Hall
Black Mesa & Garduno's
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Car Rental Facility
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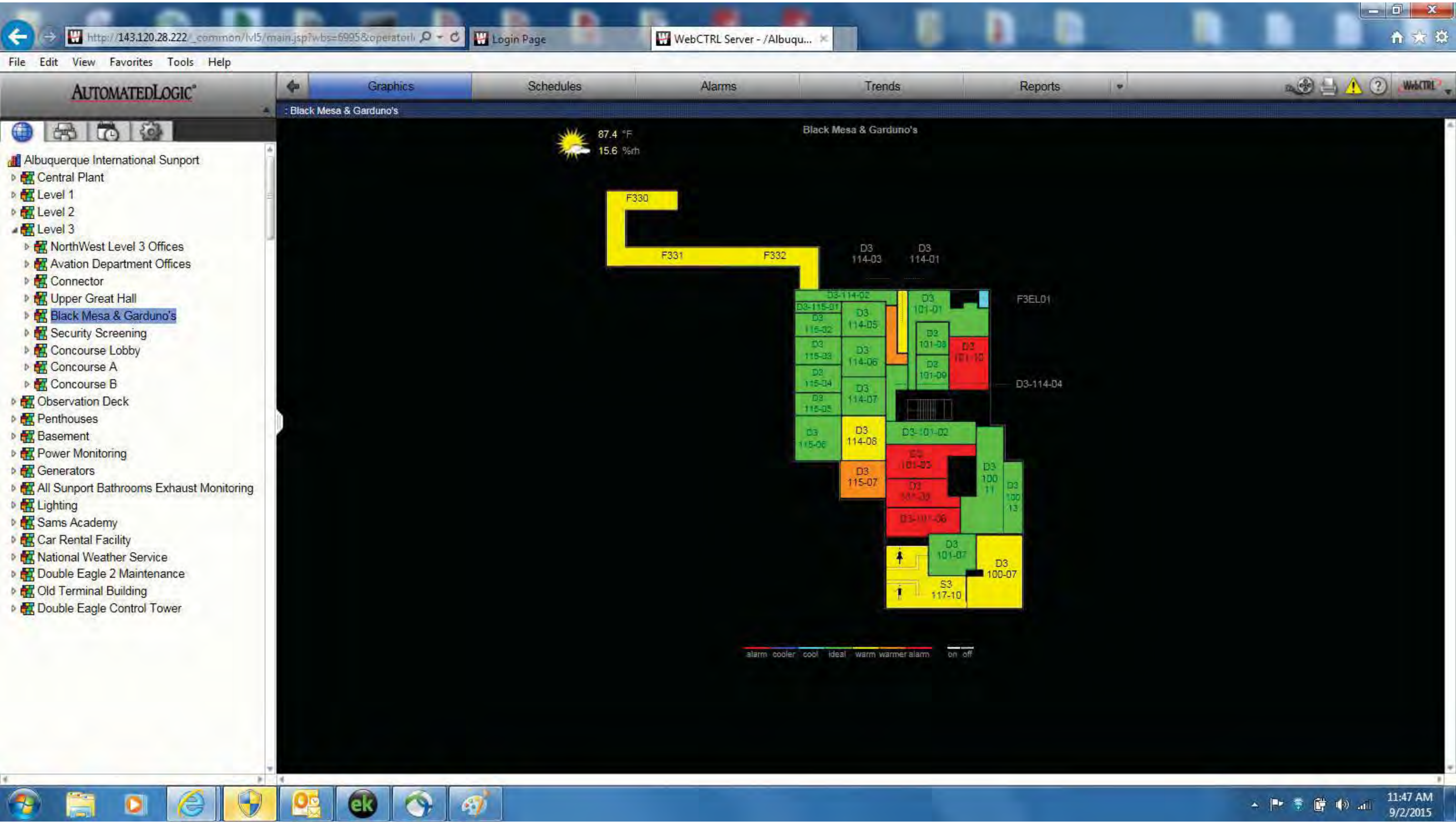
Double Eagle 2 Maintenance
FBEL01



File Edit View Favorites Tools Help
AutomatedLogic
Graphics
Schedules
Alarms
Trends
Reports
: Black Mesa & Garduno's
Black Mesa & Garduno's
87.4 °F
15.6 %rh
Albuquerque International Sunport
Central Plant
Level 1
Level 2
Level 3
NorthWest Level 3 Offices
Avation Department Offices
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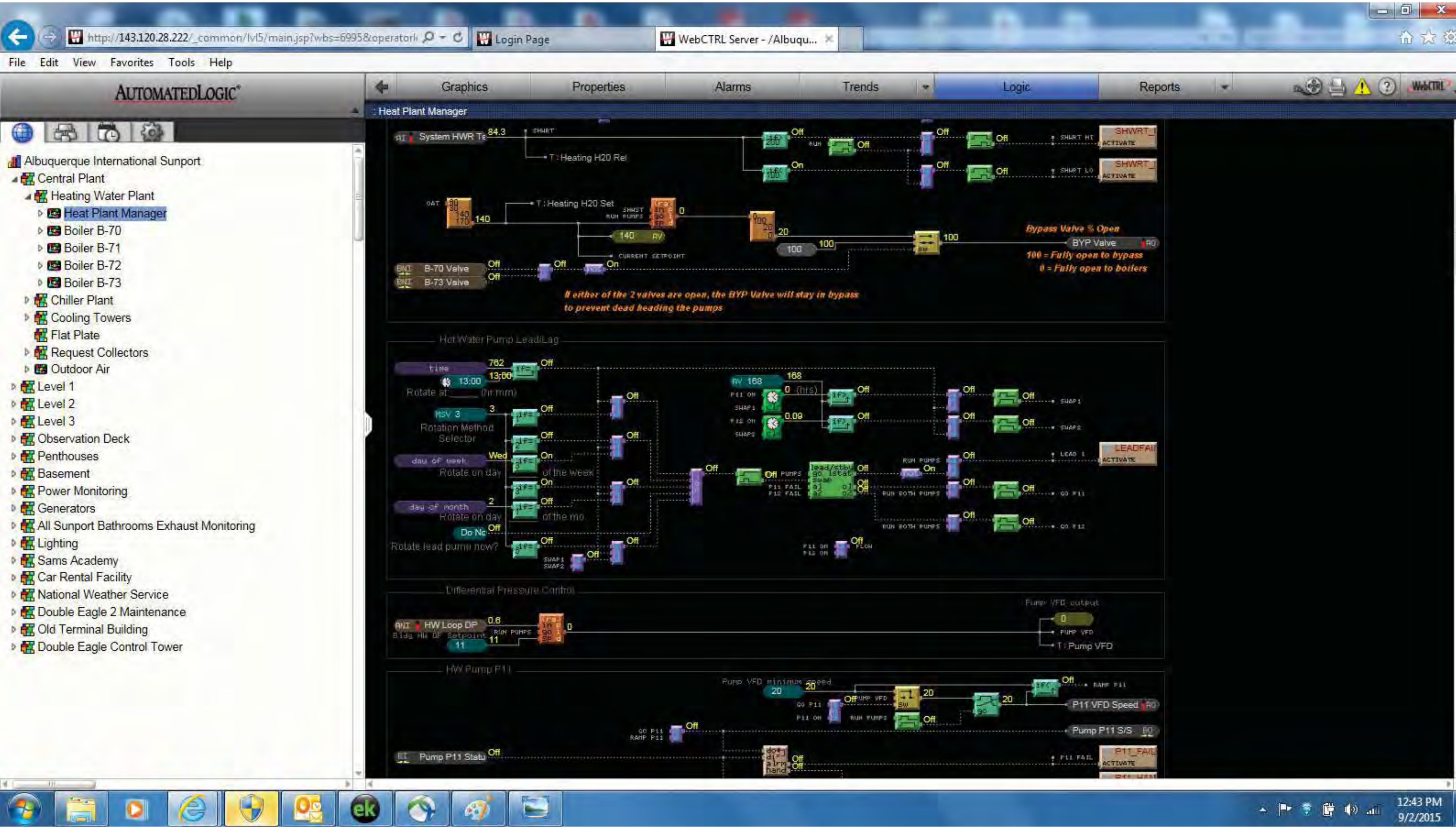
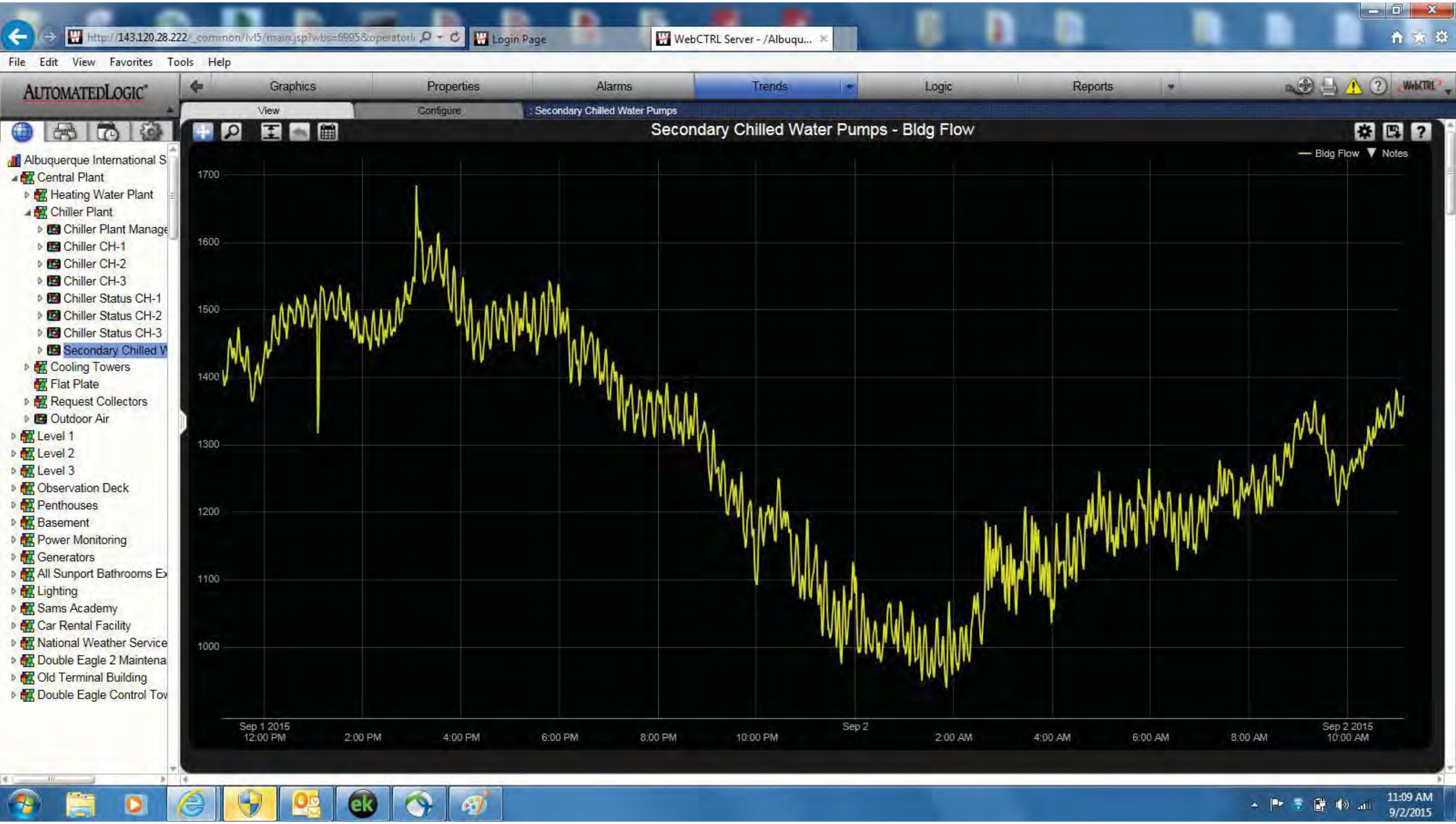
F330
F331
F332
D3 114-03
D3 114-01
F3EL01
D3-114-04
D3 114-08
D3 115-07
D3 100-07
S3 117-10
alarm cooler cool ideal warm warmer alarm
on off
11:47 AM
9/2/2015



http://143.120.28.222/_common/lvl5/main.jsp?wbs=6995&operatorl
Login Page
WebCTRL Server - /Albuqu...
File Edit View Favorites Tools Help
AUTOMATEDLOGIC
Graphics
Properties
Alarms
Trends
Logic
Reports
: Heat Plant Manager
Albuquerque International Sunport
Central Plant
Heating Water Plant
Heat Plant Manager
Boiler B-70
Boiler B-71
Boiler B-72
Boiler B-73
Chiller Plant
Cooling Towers
Flat Plate
Request Collectors
Outdoor Air
Level 1
Level 2
Level 3
Observation Deck
Penthouses
Basement
Power Monitoring
Generators
All Sunport Bathrooms Exhaust Monitoring
Lighting
Sams Academy
Car Rental Facility
National Weather Service
Double Eagle 2 Maintenance
Old Terminal Building
Double Eagle Control Tower
System HWR Te
T : Heating H20 Rel
T : Heating H20 Set
B-70 Valve
B-73 Valve
Bypass Valve % Open
BYP Valve
100 = Fully open to bypass
0 = Fully open to boilers
If either of the 2 valves are open, the BYP Valve will stay in bypass
to prevent dead heading the pumps
Hot Water Pump Lead/Lag
Rotate at (hr:mm)
Rotation Method Selector
Rotate on day of the week
Rotate on day of the mo
Rotate lead pump now?
Differential Pressure Control
HW Loop DP
Pump VFD output
T : Pump VFD
HW Pump P11
P11 VFD Speed
Pump P11 S/S
Pump P11 Statu
12:43 PM
9/2/2015



Secondary Chilled Water Pumps - Bldg Flow
Bldg Flow
Notes
1700
1600
1500
1400
1300
1200
1100
1000
Sep 1 2015 12:00 PM
2:00 PM
4:00 PM
6:00 PM
8:00 PM
10:00 PM
Sep 2
2:00 AM
4:00 AM
6:00 AM
8:00 AM
Sep 2 2015 10:00 AM
Graphics
Properties
Alarms
Trends
Logic
Reports
View
Configure
: Secondary Chilled Water Pumps
Albuquerque International S
Central Plant
Heating Water Plant
Chiller Plant
Chiller Plant Manage
Chiller CH-1
Chiller CH-2
Chiller CH-3
Chiller Status CH-1
Chiller Status CH-2
Chiller Status CH-3
Secondary Chilled W
Cooling Towers
Flat Plate
Request Collectors
Outdoor Air
Level 1
Level 2
Level 3
Observation Deck
Penthouses
Basement
Power Monitoring
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All Sunport Bathrooms Ex
Lighting
Sams Academy
Car Rental Facility
National Weather Service
Double Eagle 2 Maintena
Old Terminal Building
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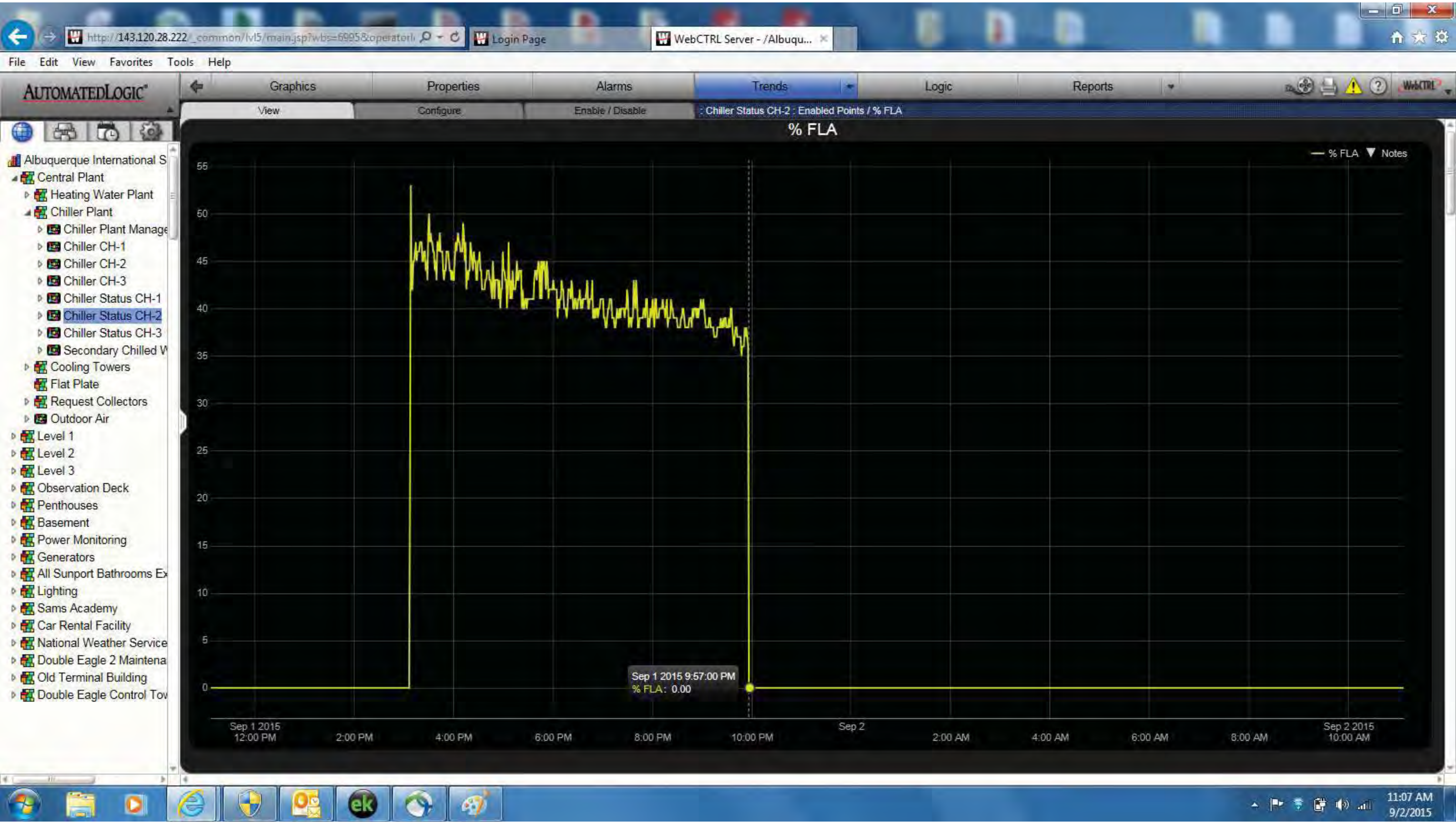
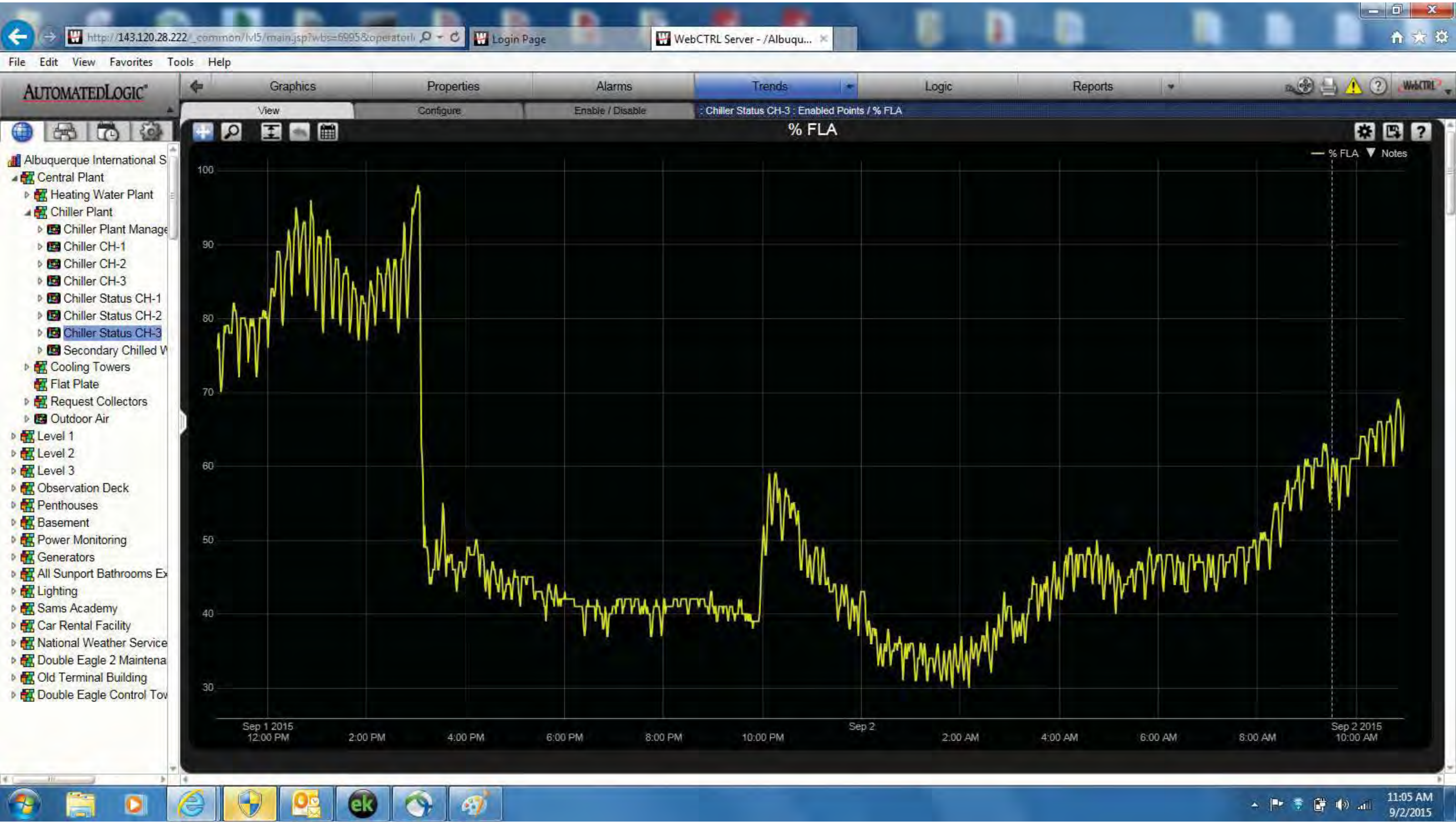
Login Page
WebCTRL Server - /Albuqu...
11:09 AM
9/2/2015



% FLA
Chiller Status CH-2 : Enabled Points / % FLA
Sep 1 2015 9:57:00 PM
% FLA: 0.00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AUTOMATEDLOGIC
Graphics
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Alarms
Trends
Logic
Reports
View
Configure
Enable / Disable
: Chiller Status CH-3 : Enabled Points / % FLA
% FLA
— % FLA ▼ Notes
Albuquerque International S
Central Plant
Heating Water Plant
Chiller Plant
Chiller Plant Manage
Chiller CH-1
Chiller CH-2
Chiller CH-3
Chiller Status CH-1
Chiller Status CH-2
Chiller Status CH-3
Secondary Chilled W
Cooling Towers
Flat Plate
Request Collectors
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Sams Academy
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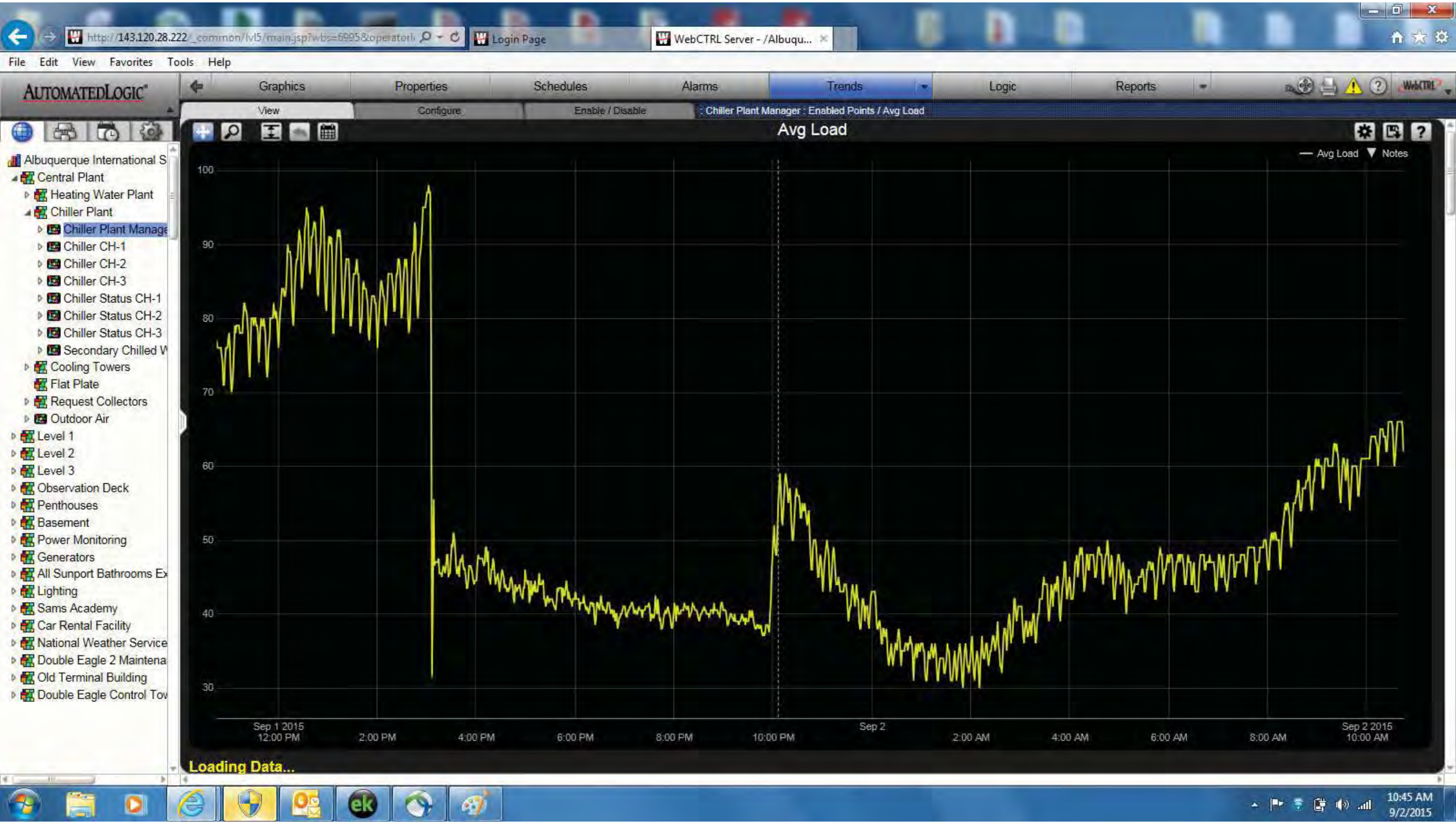
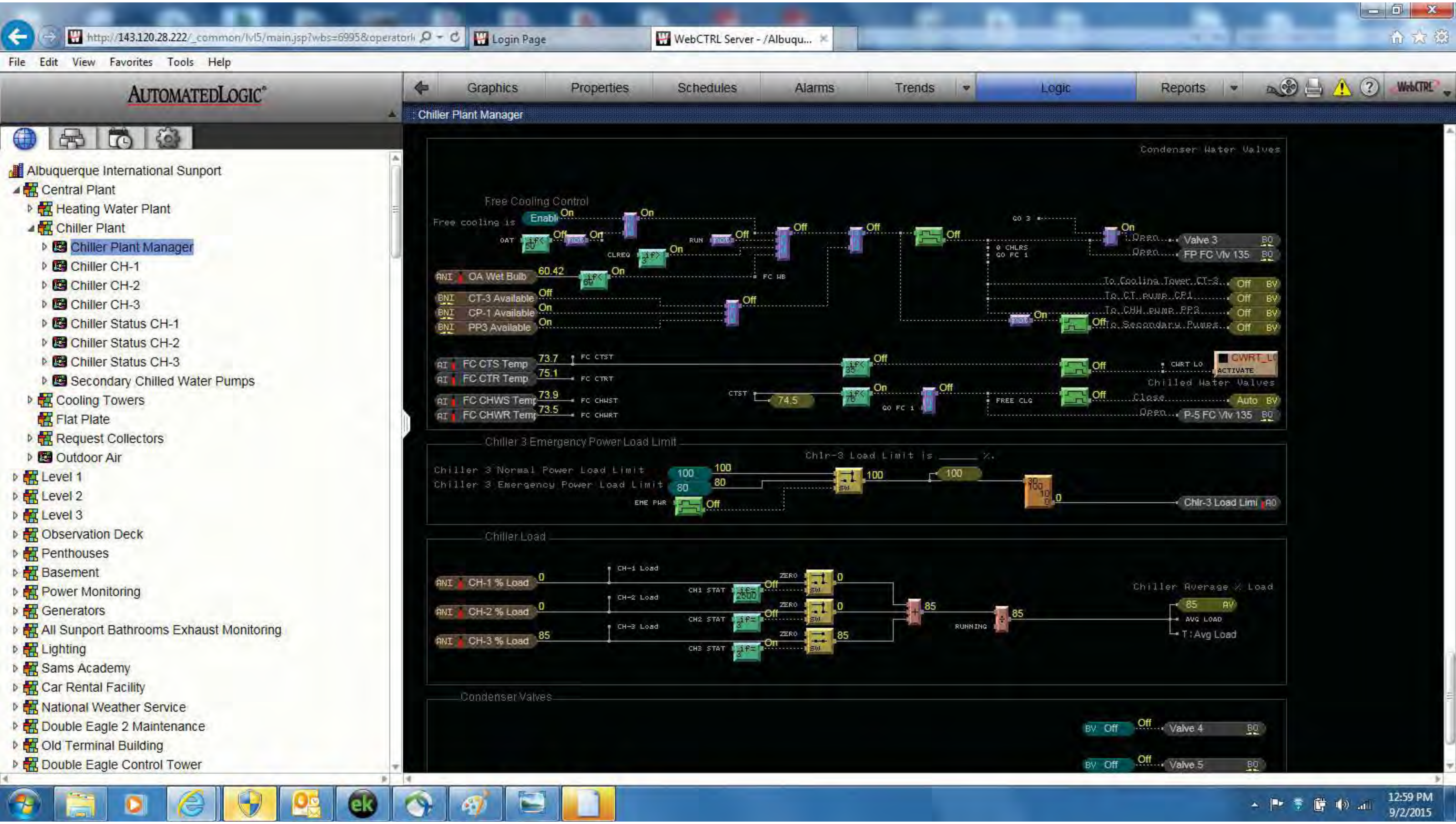
Double Eagle 2 Maintena
Old Terminal Building
Double Eagle Control Tov
100
90
80
70
60
50
40
30
Sep 1 2015 12:00 PM
2:00 PM
4:00 PM
6:00 PM
8:00 PM
10:00 PM
Sep 2
2:00 AM
4:00 AM
6:00 AM
8:00 AM
Sep 2 2015 10:00 AM
11:05 AM
9/2/2015


Chiller Plant Manager : Enabled Points / Avg Load
Avg Load
Avg Load
Notes
100
90
80
70
60
50
40
30
Sep 1 2015
12:00 PM
2:00 PM
4:00 PM
6:00 PM
8:00 PM
10:00 PM
Sep 2
2:00 AM
4:00 AM
6:00 AM
8:00 AM
Sep 2 2015
10:00 AM
Loading Data...



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AUTOMATEDLOGIC
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Chiller Plant Manager
Albuquerque International Sunport
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Heating Water Plant
Chiller Plant
Chiller Plant Manager
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Chiller CH-2
Chiller CH-3
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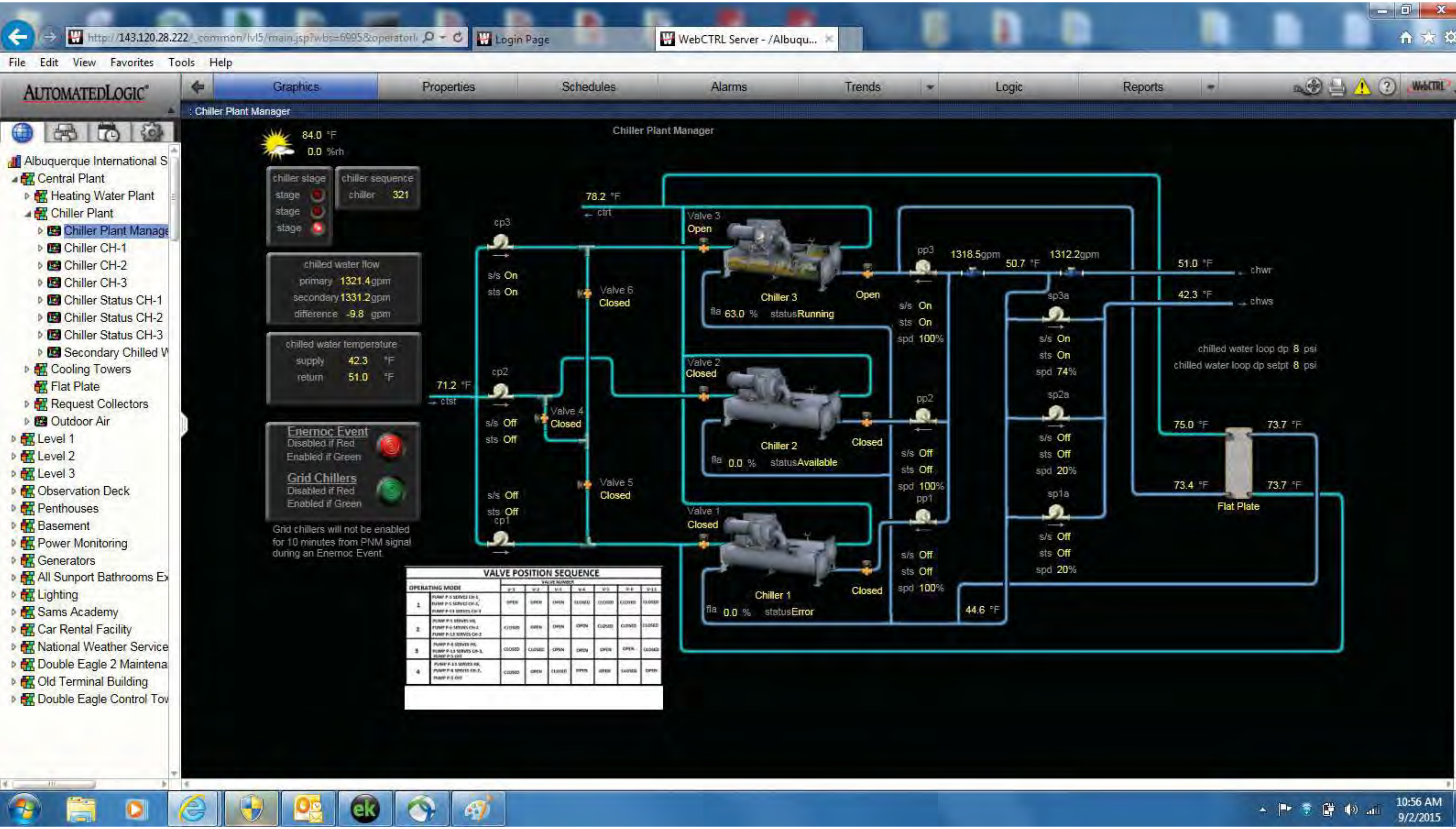
Double Eagle Control Tower
Condenser Water Valves
Free Cooling Control
Free cooling is
OA Wet Bulb
CT-3 Available
CP-1 Available
PP3 Available
FC CTS Temp
FC CTR Temp
FC CHWS Temp
FC CHWR Temp
Valve 3
FP FC Vlv 135
Chilled Water Valves
P-5 FC Vlv 135
Chiller 3 Emergency Power Load Limit
Chiller 3 Normal Power Load Limit
Chiller 3 Emergency Power Load Limit
Chlr-3 Load Limit is
Chlr-3 Load Limi
Chiller Load
CH-1 % Load
CH-2 % Load
CH-3 % Load
Chiller Average % Load
T:Avg Load
Condenser Valves
Valve 4
Valve 5
12:59 PM
9/2/2015



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Chiller CH-3
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Chiller Status CH-2
Chiller Status CH-3
Secondary Chilled W
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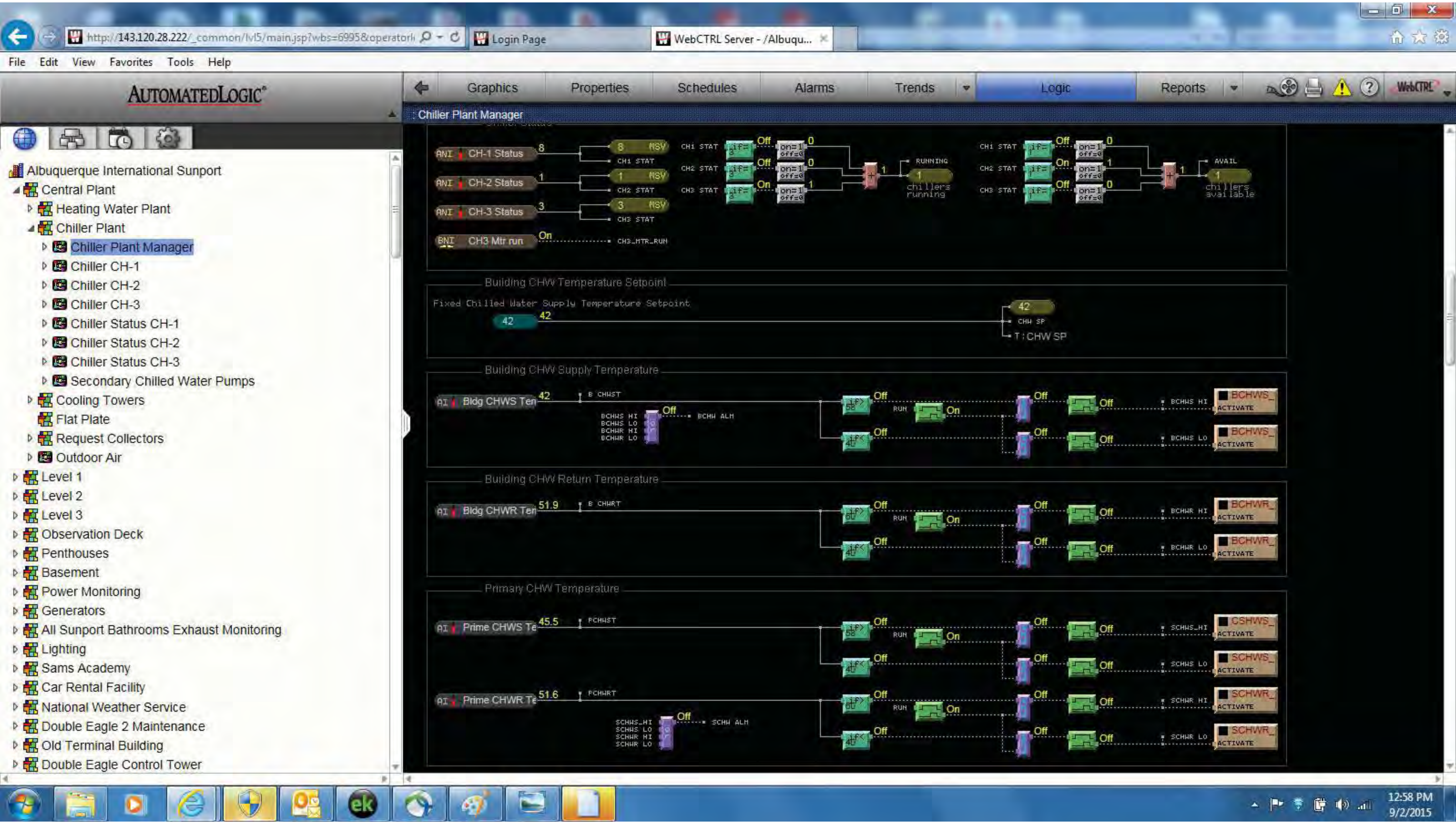
Lighting
Sams Academy
Car Rental Facility
National Weather Service
Double Eagle 2 Maintena
Old Terminal Building
Double Eagle Control Tov
84.0 °F
0.0 %rh
chiller stage
stage
stage
stage
chiller sequence
chiller 321
chilled water flow
primary 1321.4 gpm
secondary 1331.2 gpm
difference -9.8 gpm
chilled water temperature
supply 42.3 °F
return 51.0 °F
Enernoc Event
Disabled if Red
Enabled if Green
Grid Chillers
Disabled if Red
Enabled if Green
Grid chillers will not be enabled for 10 minutes from PNM signal during an Enernoc Event.
VALVE POSITION SEQUENCE
78.2 °F
ctrt
71.2 °F
ctst
cp3
cp2
cp1
s/s On
sts On
s/s Off
sts Off
Valve 6 Closed
Valve 4 Closed
Valve 5 Closed
Valve 3 Open
Valve 2 Closed
Valve 1 Closed
Chiller 3
fla 63.0 % status Running
Chiller 2
fla 0.0 % status Available
Chiller 1
fla 0.0 % status Error
Open
Closed
pp3
pp2
pp1
spd 100%
1318.5 gpm
50.7 °F
1312.2 gpm
sp3a
sp2a
sp1a
spd 74%
spd 20%
51.0 °F
chwr
42.3 °F
chws
chilled water loop dp 8 psi
chilled water loop dp setpt 8 psi
75.0 °F
73.7 °F
73.4 °F
73.7 °F
Flat Plate
44.6 °F
10:56 AM
9/2/2015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AUTOMATEDLOGIC
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Albuquerque International Sunport
Central Plant
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Chiller Plant
Chiller Plant Manager
Chiller CH-1
Chiller CH-2
Chiller CH-3
Chiller Status CH-1
Chiller Status CH-2
Chiller Status CH-3
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Cooling Towers
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CH-1 Status
CH-2 Status
CH-3 Status
CH3 Mtr run
Building CHW Temperature Setpoint
Fixed Chilled Water Supply Temperature Setpoint
T : CHW SP
Building CHW Supply Temperature
Bldg CHWS Ten
Building CHW Return Temperature
Bldg CHWR Ten
Primary CHW Temperature
Prime CHWS Te
Prime CHWR Te
12:58 PM
9/2/2015


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AUTOMATEDLOGIC
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Schedules
Alarms
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Reports
View
Configure
Enable / Disable
: Chiller Plant Manager : Enabled Points / Bldg CHWR Temp
Bldg CHWR Temp
Bldg CHWR Temp
Notes
Albuquerque International S
Central Plant
Heating Water Plant
Chiller Plant
Chiller Plant Manage
Chiller CH-1
Chiller CH-2
Chiller CH-3
Chiller Status CH-1
Chiller Status CH-2
Chiller Status CH-3
Secondary Chilled W
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Flat Plate
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Outdoor Air
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Level 3
Observation Deck
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All Sunport Bathrooms Ex
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Car Rental Facility
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Old Terminal Building
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Sep 2 2015 10:00 AM
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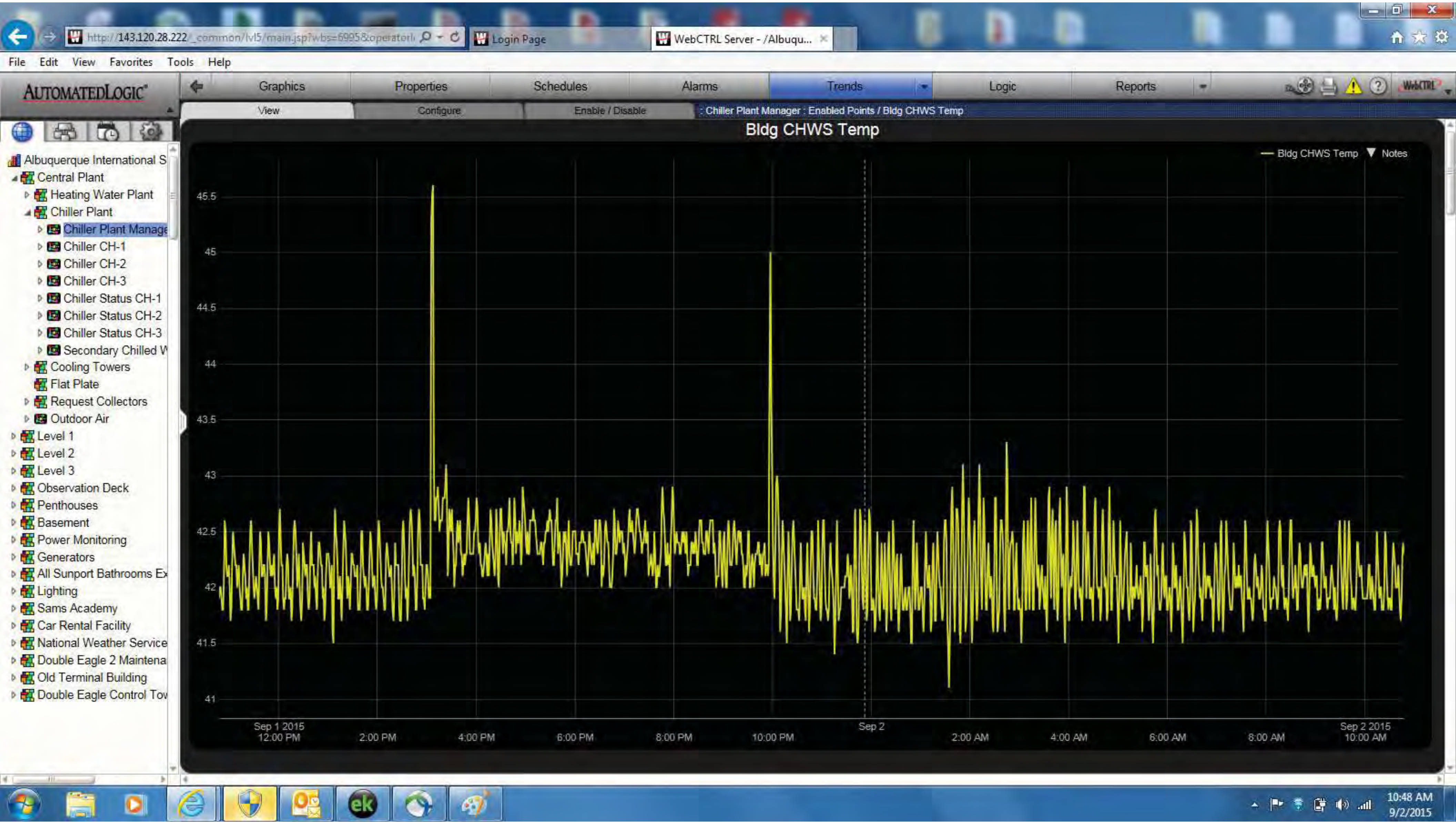
10:50 AM
9/2/2015



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AutomatedLogic
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Reports
View
Configure
Enable / Disable
: Chiller Plant Manager : Enabled Points / Bldg CHWS Temp
Bldg CHWS Temp
Bldg CHWS Temp
Notes
Albuquerque International S
Central Plant
Heating Water Plant
Chiller Plant
Chiller Plant Manage
Chiller CH-1
Chiller CH-2
Chiller CH-3
Chiller Status CH-1
Chiller Status CH-2
Chiller Status CH-3
Secondary Chilled W
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Outdoor Air
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Observation Deck
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All Sunport Bathrooms Ex
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10:48 AM
9/2/2015

Global Modify - Windows Internet Explorer

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Redo

Enable	Equipment	Current Value	New Value
☑	Penthouse 1 AHU-76, 83, 84 / AHU-76 Level 1 Carrousel 1 & 2	55	55
☑	Penthouse 1 AHU-76, 83, 84 / AHU-83 Level 2 Northwest & Southwest Back Offices	49	50
☑	Penthouse 1 AHU-76, 83, 84 / AHU-84 Level 2 Northwest Ticket Lobby	55	55
☑	Penthouse 2 AHU-77, 85, 86 / AHU-77 Level 1 Carrousel 3 to WRR	55	55
☑	Penthouse 2 AHU-77, 85, 86 / AHU-85 Level 2 Southwest Ticket Lobby	55	55
☑	Penthouse 2 AHU-77, 85, 86 / AHU-86 Level 2 Great Hall E	55	55
☑	Penthouse 3 AHU-78, 79, 87, 88 / AHU-78 Level 1 Mens RR to Carrousel 4	55	55
☑	Penthouse 3 AHU-78, 79, 87, 88 / AHU-79 Level 1 Carrousel 5 & 6 & Offices	55	55
☑	Penthouse 3 AHU-78, 79, 87, 88 / AHU-87 Level 2 Great Hall W	50	50
☑	Penthouse 3 AHU-78, 79, 87, 88 / AHU-88 level 2 Delta Tickets	55	55
☑	Penthouse 4 AHU-80, 82, 89 / AHU-80 Level 1 Hallway Carrousel 5 to 7	55	55
☑	Penthouse 4 AHU-80, 82, 89 / AHU-82 Level 1 West End to Maint. Office	55	55
☑	Penthouse 4 AHU-80, 82, 89 / AHU-89 Level 2 Continental & American Tickets	53	53
☑	Penthouse 5 AHU- 81, 90, 92 / AHU-90 Level 2 United & Vacant Tickets	55	55
☑	Penthouse 5 AHU- 81, 90, 92 / AHU-81 Level 1 Hallway Carrosel 8 to West Escalato	55	55
☑	Penthouse 5 AHU- 81, 90, 92 / AHU-92 Level 2 US Customs	55	55
☑	Penthouse 6 AHU- 91, 97 / AHU-91 Level 2 Sandia Vista	55	55
☑	Penthouse 6 AHU- 91, 97 / AHU-97 Level 3 West	55	55
☑	Penthouse 7 AHU-93, 98 / AHU-93 Ops offices to Mesa Lobby	55	55
☑	Penthouse 7 AHU-93, 98 / AHU-98 Level 3 Admin Offices	50	50
☑	Penthouse 9 AHU-99, 100 / AHU-99 Level 3 E Gift Shops to Escalators	55	55
☑	Penthouse 8 AHU-94, 101 / AHU-94 Level 2 Great Lakes Ticket to Gates E	55	55
☑	Penthouse 8 AHU-94, 101 / AHU-101 Level 3	45	55
☑	Penthouse 9 AHU-99, 100 / AHU-100 Level 3 W in front of Garnuno's & Black Mesa	55	55
☑	Penthouse 10 AHU-95, 103, 104, 107 / AHU-95 Level 2 American & United Ops	50	50
☑	Penthouse 10 AHU-95, 103, 104, 107 / AHU-103 Level 3 A side Shops	50	50
☑	Penthouse 10 AHU-95, 103, 104, 107 / AHU-104 Level 3 B Side Shops	50	50
☑	Penthouse 10 AHU-95, 103, 104, 107 / AHU-107 Level 3 Start of Concourse B	49	49
☑	Penthouse 15 AHU-112, 113 / AHU-112 Gates A9 thru A14	50	50
☑	Penthouse 15 AHU-112, 113 / AHU-113 Gates A6 and A8	50	50

4:10 PM
9/2/2015

Global Modify - Windows Internet Explorer

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Penthouse 4 AHU-80, 82, 89 / AHU-82 Level 1 West End to Maint. Office	55	55
Penthouse 4 AHU-80, 82, 89 / AHU-89 Level 2 Continental & American Tickets	53	53
Penthouse 5 AHU- 81, 90, 92 / AHU-90 Level 2 United & Vacant Tickets	55	55
Penthouse 5 AHU- 81, 90, 92 / AHU-81 Level 1 Hallway Carrosel 8 to West Escalato	55	55
Penthouse 5 AHU- 81, 90, 92 / AHU-92 Level 2 US Customs	55	55
Penthouse 6 AHU- 91, 97 / AHU-91 Level 2 Sandia Vista	55	55
Penthouse 6 AHU- 91, 97 / AHU-97 Level 3 West	55	55
Penthouse 7 AHU-93, 98 / AHU-93 Ops offices to Mesa Lobby	55	55
Penthouse 7 AHU-93, 98 / AHU-98 Level 3 Admin Offices	50	50
Penthouse 9 AHU-99, 100 / AHU-99 Level 3 E Gift Shops to Escalators	55	55
Penthouse 8 AHU-94, 101 / AHU-94 Level 2 Great Lakes Ticket to Gates E	55	55
Penthouse 8 AHU-94, 101 / AHU-101 Level 3	45	55
Penthouse 9 AHU-99, 100 / AHU-100 Level 3 W in front of Garnuno's & Black Mesa	55	55
Penthouse 10 AHU-95, 103, 104, 107 / AHU-95 Level 2 American & United Ops	50	50
Penthouse 10 AHU-95, 103, 104, 107 / AHU-103 Level 3 A side Shops	50	50
Penthouse 10 AHU-95, 103, 104, 107 / AHU-104 Level 3 B Side Shops	50	50
Penthouse 10 AHU-95, 103, 104, 107 / AHU-107 Level 3 Start of Concourse B	49	49
Penthouse 15 AHU-112, 113 / AHU-112 Gates A9 thru A14	50	50
Penthouse 15 AHU-112, 113 / AHU-113 Gates A6 and A8	50	50
Penthouse 11 AHU-105, 106 / AHU-105 Gate A2, Lobby, Route 66	50	50
Penthouse 11 AHU-105, 106 / AHU-106 Gates A1, A3	50	50
Penthouse 12 AHU-109, 110 / AHU-110 Gate A4	50	50
Penthouse 12 AHU-109, 110 / AHU-109 Gates A5, A7	55	55
Penthouse 14 AHU-96, 111 / AHU-96 Gates B6 thru B10	50	50
Penthouse 14 AHU-96, 111 / AHU-111 Gate B5, RR & Level 2	54	54
Penthouse 13 AHU-108 / AHU-108 Gates B1 thru B4	55	55

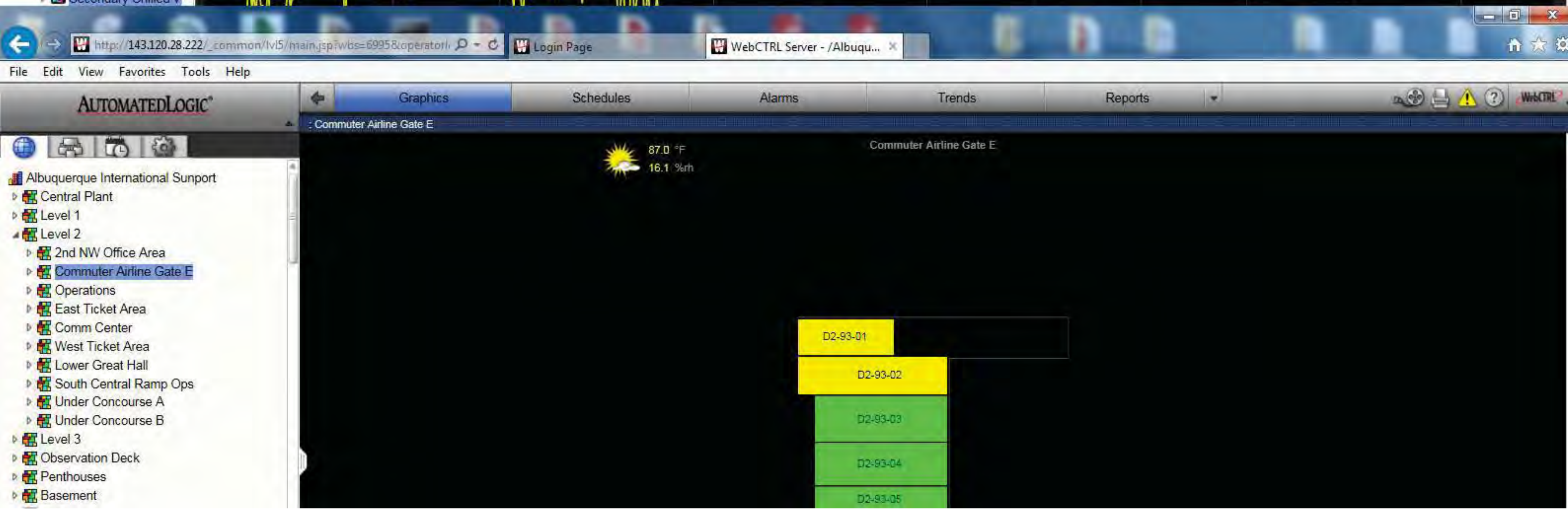
Enable All 55 Set All To

? Change All By

Apply Changes

4:14 PM 9/2/2015

Secondary Chilled Water Pumps - Bldg Flow
Albuquerque International S
Central Plant
Heating Water Plant
Chiller Plant
Chiller CH-1
Chiller CH-2
Chiller CH-3
Chiller Status CH-1
Chiller Status CH-2
Chiller Status CH-3
Graphics
Properties
Alarms
Trends
Logic
Reports
View
Configure
: Secondary Chilled Water Pumps
Bldg Flow
Notes
1700
1600
1500



Graphics
Schedules
Alarms
Trends
Reports
: Commuter Airline Gate E
Commuter Airline Gate E
87.0 °F
16.1 %rh
Albuquerque International Sunport
Central Plant
Level 1
Level 2
2nd NW Office Area
Commuter Airline Gate E
Operations
East Ticket Area
Comm Center
West Ticket Area
Lower Great Hall
South Central Ramp Ops
Under Concourse A
Under Concourse B
Level 3
Observation Deck
Penthouses
Basement
D2-93-01
D2-93-02
D2-93-03
D2-93-04
D2-93-05

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AUTOMATEDLOGIC
Graphics
Schedules
Alarms
Trends
Reports
: Concourse A
Concourse A
87.8 °F
16.0 %rh
Albuquerque International Sunport
Central Plant
Level 1
Level 2
Level 3
NorthWest Level 3 Offices
Avation Department Offices
Connector
Upper Great Hall
Black Mesa & Garduno's
Security Screening
Concourse Lobby
Concourse A
Concourse B
Observation Deck
Penthouses
Basement
Power Monitoring
Generators
All Sunport Bathrooms Exhaust Monitoring
Lighting
Sams Academy
Car Rental Facility
National Weather Service
Double Eagle 2 Maintenance
Old Terminal Building
Double Eagle Control Tower
concourse lobby.png - Paint
alarm cooler cool ideal warm warmer alarm
on off
11:52 AM
9/2/2015


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Login Page
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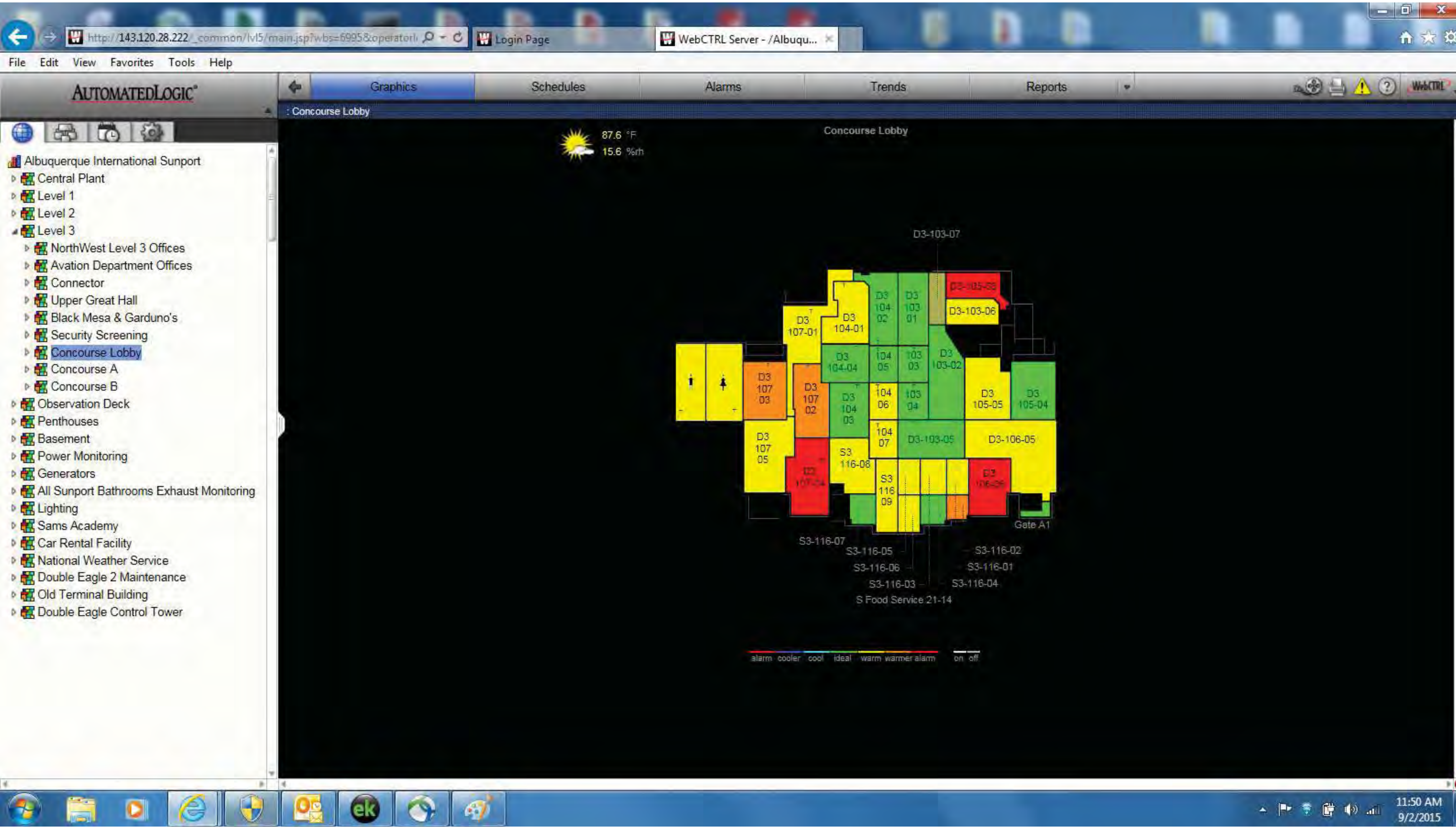
AUTOMATEDLOGIC
Graphics
Schedules
Alarms
Trends
Reports
: Concourse B
Albuquerque International Sunport
Central Plant
Level 1
Level 2
Level 3
NorthWest Level 3 Offices
Avation Department Offices
Connector
Upper Great Hall
Black Mesa & Garduno's
Security Screening
Concourse Lobby
Concourse A
Concourse B
Observation Deck
Penthouses
Basement
Power Monitoring
Generators
All Sunport Bathrooms Exhaust Monitoring
Lighting
Sams Academy
Car Rental Facility
National Weather Service
Double Eagle 2 Maintenance
Old Terminal Building
Double Eagle Control Tower
88.0 °F
16.1 %rh
Concourse B
G3-108-01
D3 96-01
D3 96-06
G3-96-03
D3 96-01
F325
F324
F323
G3 108-04
D3 108-02
G3-96-07
D3 96-05
D3-96-04
D3 96-01
F328
F327
G3 108-06
D3 108-07
G3 108-05
D3-96-08
F326
G3 96-10
D3 96-09
D3 111-11
G3-111-10
D3 111-9
D3 111-12
alarm cooler cool ideal warm warmer alarm
on off
11:53 AM
9/2/2015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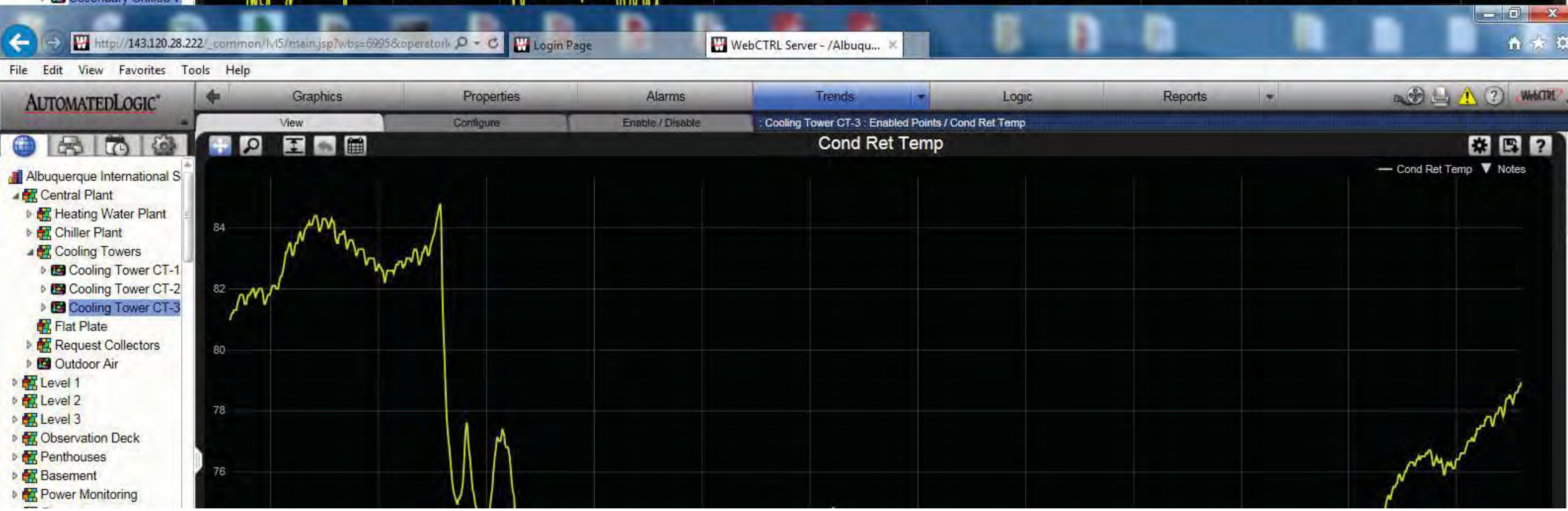
AUTOMATEDLOGIC
Graphics
Schedules
Alarms
Trends
Reports
: Concourse Lobby
Concourse Lobby
87.6 °F
15.6 %rh
Albuquerque International Sunport
Central Plant
Level 1
Level 2
Level 3
NorthWest Level 3 Offices
Avation Department Offices
Connector
Upper Great Hall
Black Mesa & Garduno's
Security Screening
Concourse Lobby
Concourse A
Concourse B
Observation Deck
Penthouses
Basement
Power Monitoring
Generators
All Sunport Bathrooms Exhaust Monitoring
Lighting
Sams Academy
Car Rental Facility
National Weather Service
Double Eagle 2 Maintenance
Old Terminal Building
Double Eagle Control Tower
D3-103-07
D3-103-06
D3 107-01
D3 104-01
D3 104 02
D3 103 01
D3 104-04
104 05
103 03
D3 103-02
D3 107 03
D3 107 02
D3 104 03
104 06
103 04
D3 105-05
D3 105-04
104 07
D3-103-05
D3-106-05
D3 107 05
S3 116-08
S3 116 09
Gate A1
S3-116-07
S3-116-05
S3-116-06
S3-116-03
S3-116-02
S3-116-01
S3-116-04
S Food Service 21-14
alarm cooler cool ideal warm warmer alarm
on off
11:50 AM
9/2/2015


Secondary Chilled Water Pumps - Bldg Flow
Bldg Flow
Notes
1700
1600
1500
Albuquerque International S
Central Plant
Heating Water Plant
Chiller Plant
Chiller CH-1
Chiller CH-2
Chiller CH-3
Chiller Status CH-1
Chiller Status CH-2
Chiller Status CH-3
Graphics
Properties
Alarms
Trends
Logic
Reports


Cond Ret Temp
Cond Ret Temp
Notes
84
82
80
78
76
Cooling Tower CT-3 : Enabled Points / Cond Ret Temp
Albuquerque International S
Central Plant
Heating Water Plant
Chiller Plant
Cooling Towers
Cooling Tower CT-1
Cooling Tower CT-2
Cooling Tower CT-3
Flat Plate
Request Collectors
Outdoor Air
Level 1
Level 2
Level 3
Observation Deck
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Basement
Power Monitoring
Graphics
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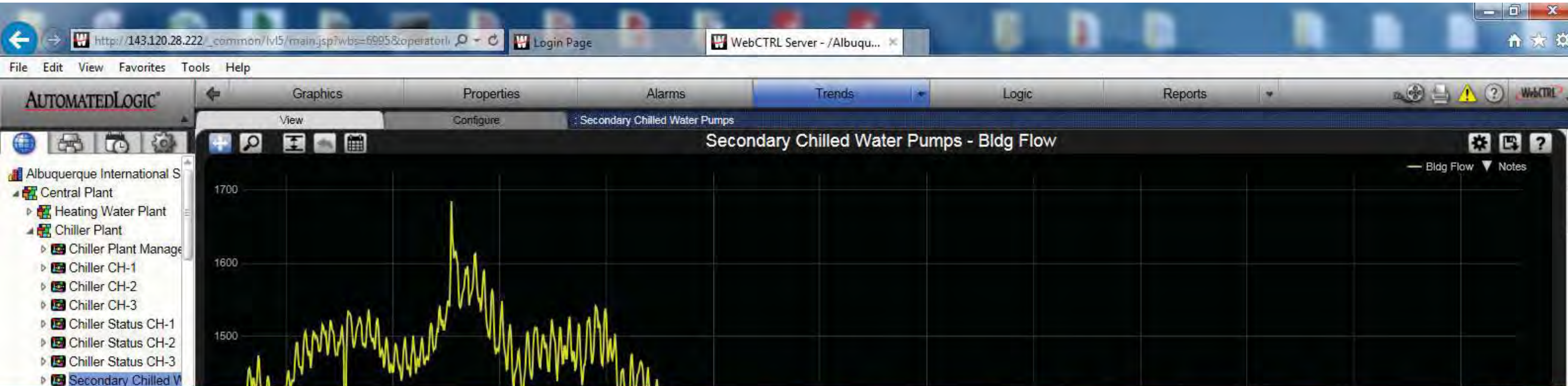
Alarms
Trends
Logic
Reports


Secondary Chilled Water Pumps - Bldg Flow
: Secondary Chilled Water Pumps
Bldg Flow
Notes
1700
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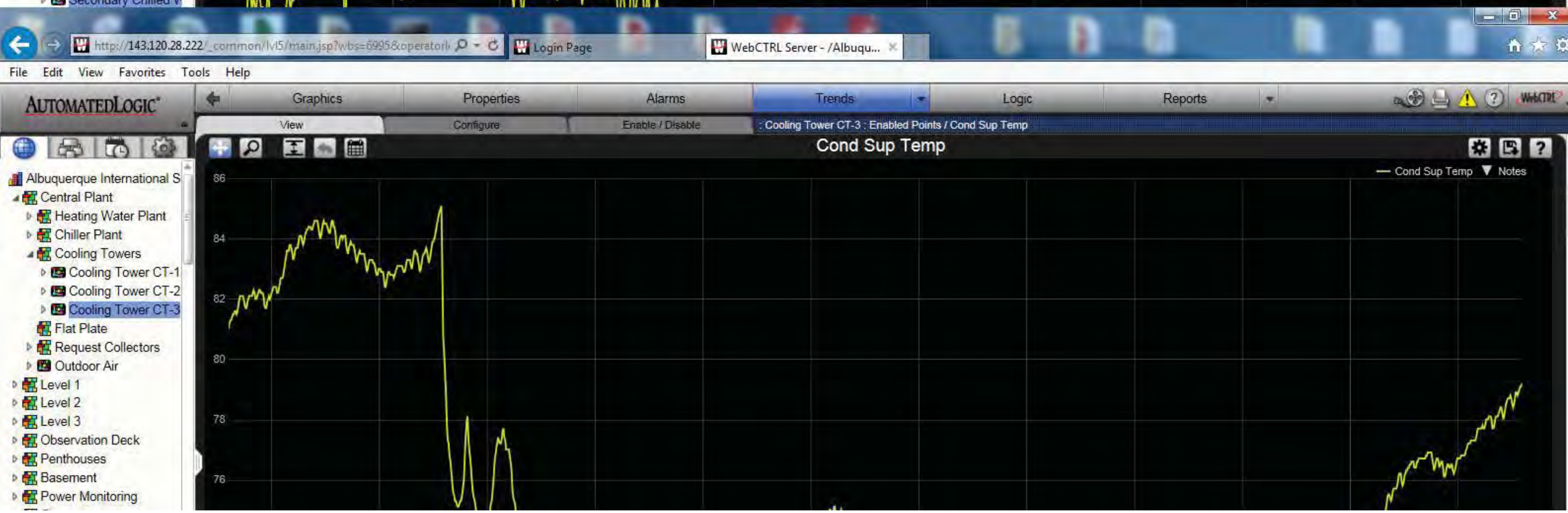
Albuquerque International S
Central Plant
Heating Water Plant
Chiller Plant
Chiller Plant Manage
Chiller CH-1
Chiller CH-2
Chiller CH-3
Chiller Status CH-1
Chiller Status CH-2
Chiller Status CH-3
Secondary Chilled W


Cond Sup Temp
: Cooling Tower CT-3 : Enabled Points / Cond Sup Temp
Cond Sup Temp
Notes
86
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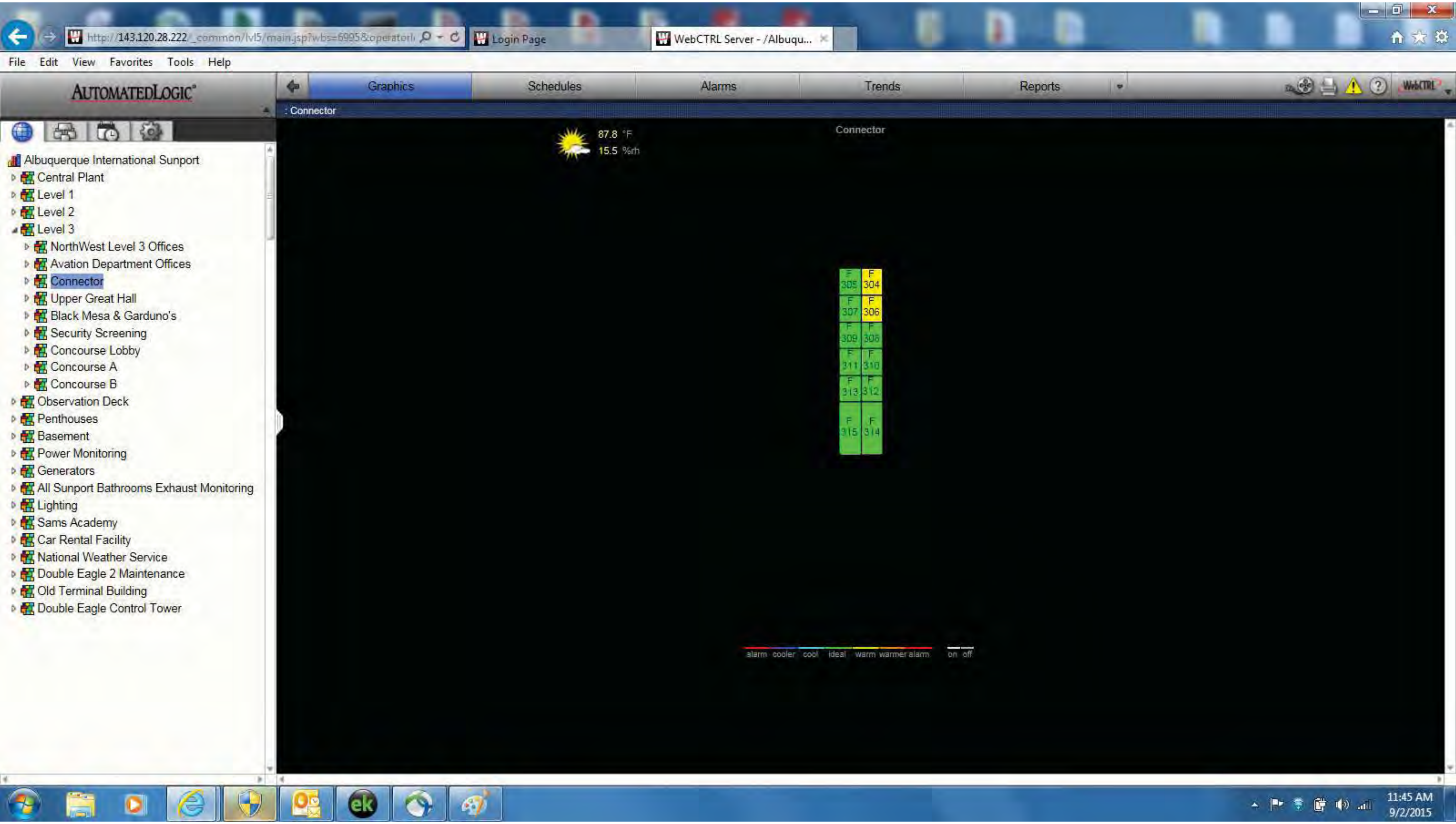
76
Albuquerque International S
Central Plant
Heating Water Plant
Chiller Plant
Cooling Towers
Cooling Tower CT-1
Cooling Tower CT-2
Cooling Tower CT-3
Flat Plate
Request Collectors
Outdoor Air
Level 1
Level 2
Level 3
Observation Deck
Penthouses
Basement
Power Monitoring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Trends
Reports
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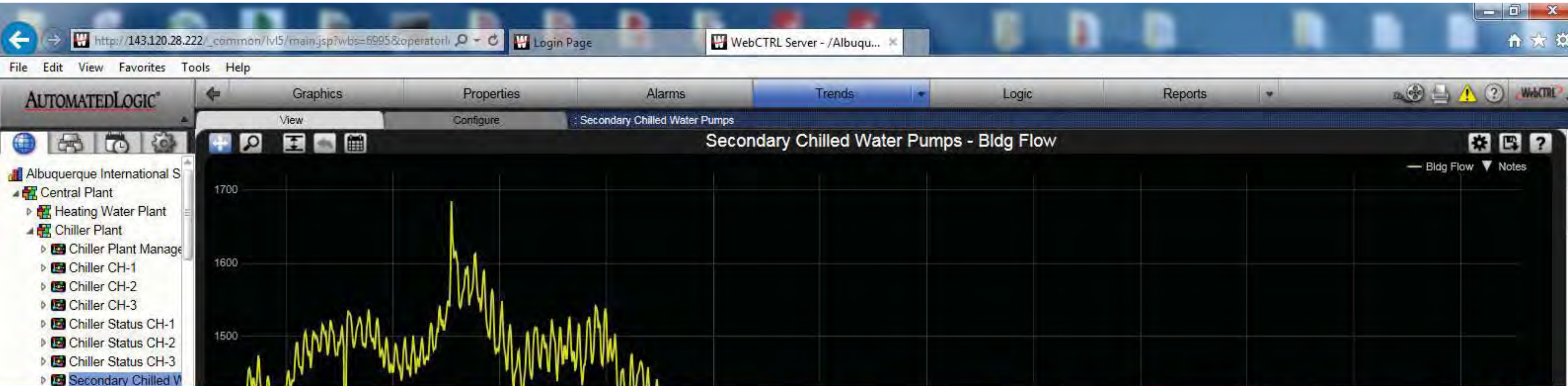
Albuquerque International Sunport
Central Plant
Level 1
Level 2
Level 3
NorthWest Level 3 Offices
Avation Department Offices
Connector
Upper Great Hall
Black Mesa & Garduno's
Security Screening
Concourse Lobby
Concourse A
Concourse B
Observation Deck
Penthouses
Basement
Power Monitoring
Generators
All Sunport Bathrooms Exhaust Monitoring
Lighting
Sams Academy
Car Rental Facility
National Weather Service
Double Eagle 2 Maintenance
Old Terminal Building
Double Eagle Control Tower
87.8 °F
15.5 %rh
Connector
305
304
307
306
309
308
311
310
313
312
315
314
alarm cooler cool ideal warm warmer alarm
on off
11:45 AM
9/2/2015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AUTOMATEDLOGIC
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Configure
Secondary Chilled Water Pumps
Secondary Chilled Water Pumps - Bldg Flow
Bldg Flow
Notes
1700
1600
1500
Albuquerque International S
Central Plant
Heating Water Plant
Chiller Plant
Chiller Plant Manage
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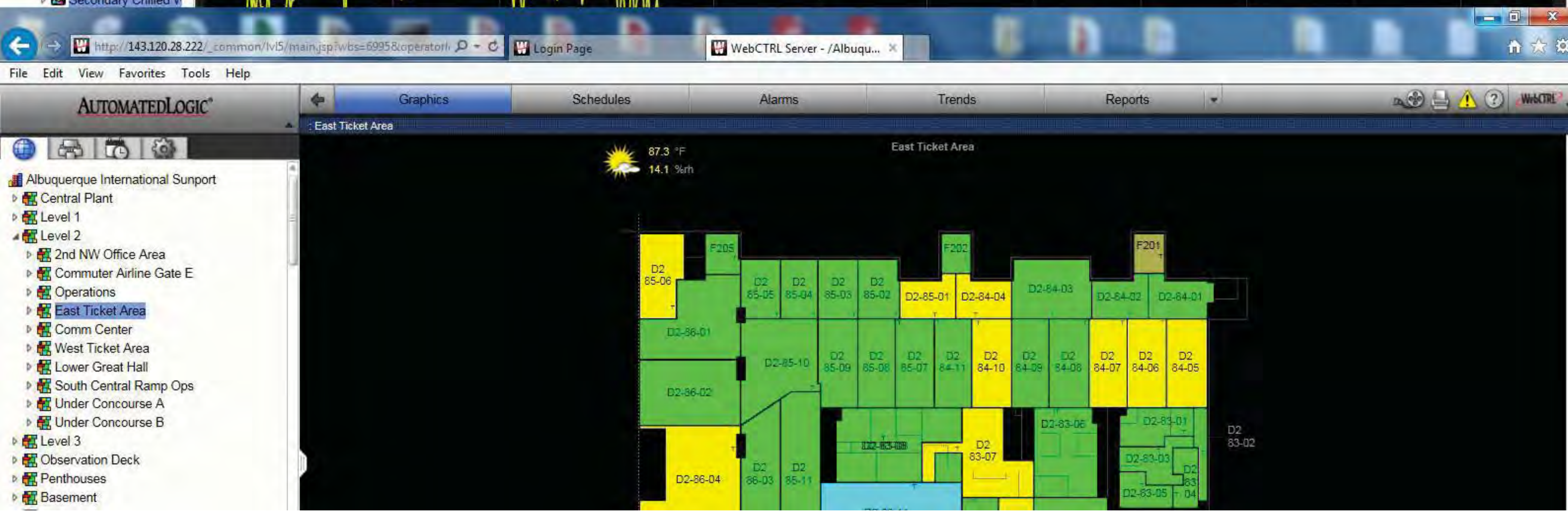
Chiller CH-2
Chiller CH-3
Chiller Status CH-1
Chiller Status CH-2
Chiller Status CH-3
Secondary Chilled W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AUTOMATEDLOGIC
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Trends
Reports
East Ticket Area
East Ticket Area
87.3 °F
14.1 %rh
Albuquerque International Sunport
Central Plant
Level 1
Level 2
2nd NW Office Area
Commuter Airline Gate E
Operations
East Ticket Area
Comm Center
West Ticket Area
Lower Great Hall
South Central Ramp Ops
Under Concourse A
Under Concourse B
Level 3
Observation Deck
Penthouses
Basement
F205
F202
F201
D2-85-01
D2-84-04
D2-84-03
D2-84-02
D2-84-01
D2-86-01
D2-85-10
D2-86-02
D2-86-04
D2-83-06
D2-83-01
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D2 83-02
D2 83-07

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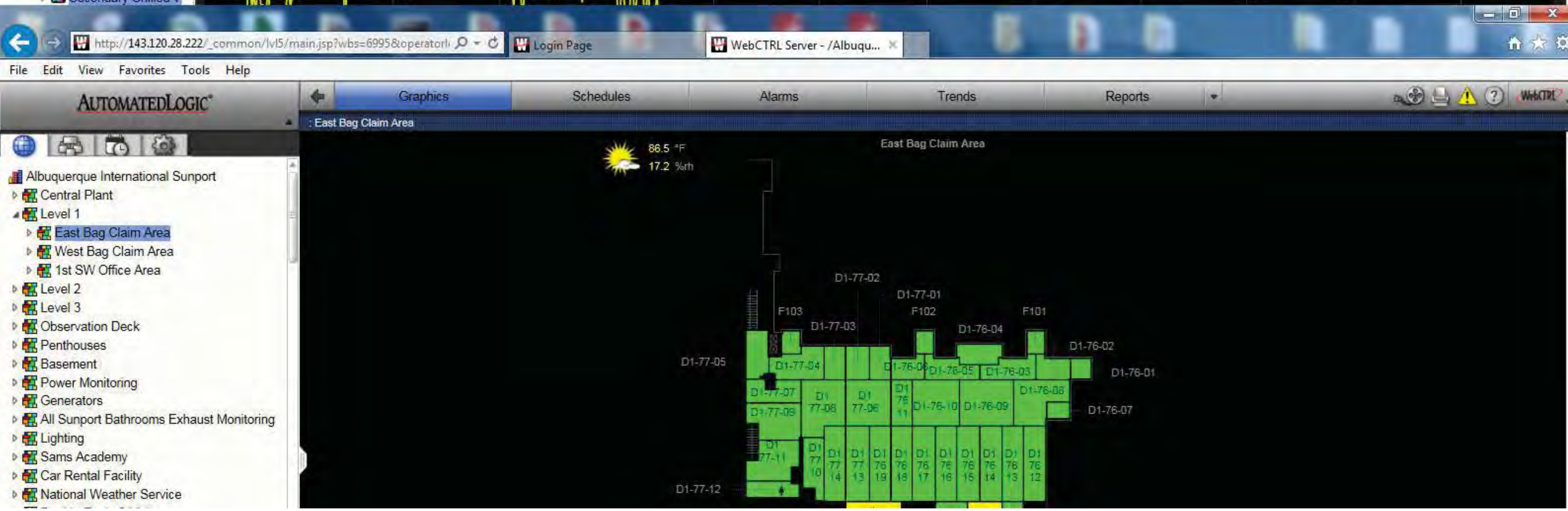
Configure
: Secondary Chilled Water Pumps
Secondary Chilled Water Pumps - Bldg Flow
Bldg Flow
Notes
1700
1600
1500
Albuquerque International S
Central Plant
Heating Water Plant
Chiller Plant
Chiller Plant Manage
Chiller CH-1
Chiller CH-2
Chiller CH-3
Chiller Status CH-1
Chiller Status CH-2
Chiller Status CH-3
Secondary Chilled W



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AUTOMATEDLOGIC
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Alarms
Trends
Reports
: East Bag Claim Area
East Bag Claim Area
86.5 °F
17.2 %rh
Albuquerque International Sunport
Central Plant
Level 1
East Bag Claim Area
West Bag Claim Area
1st SW Office Area
Level 2
Level 3
Observation Deck
Penthouses
Basement
Power Monitoring
Generators
All Sunport Bathrooms Exhaust Monitoring
Lighting
Sams Academy
Car Rental Facility
National Weather Service
D1-77-02
D1-77-01
F103
F102
F101
D1-77-03
D1-76-04
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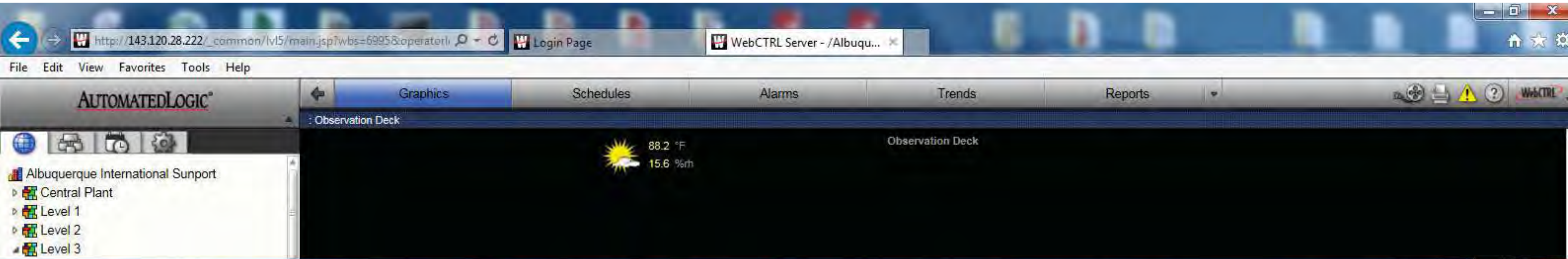
D1-76-07
D1-77-12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Trends
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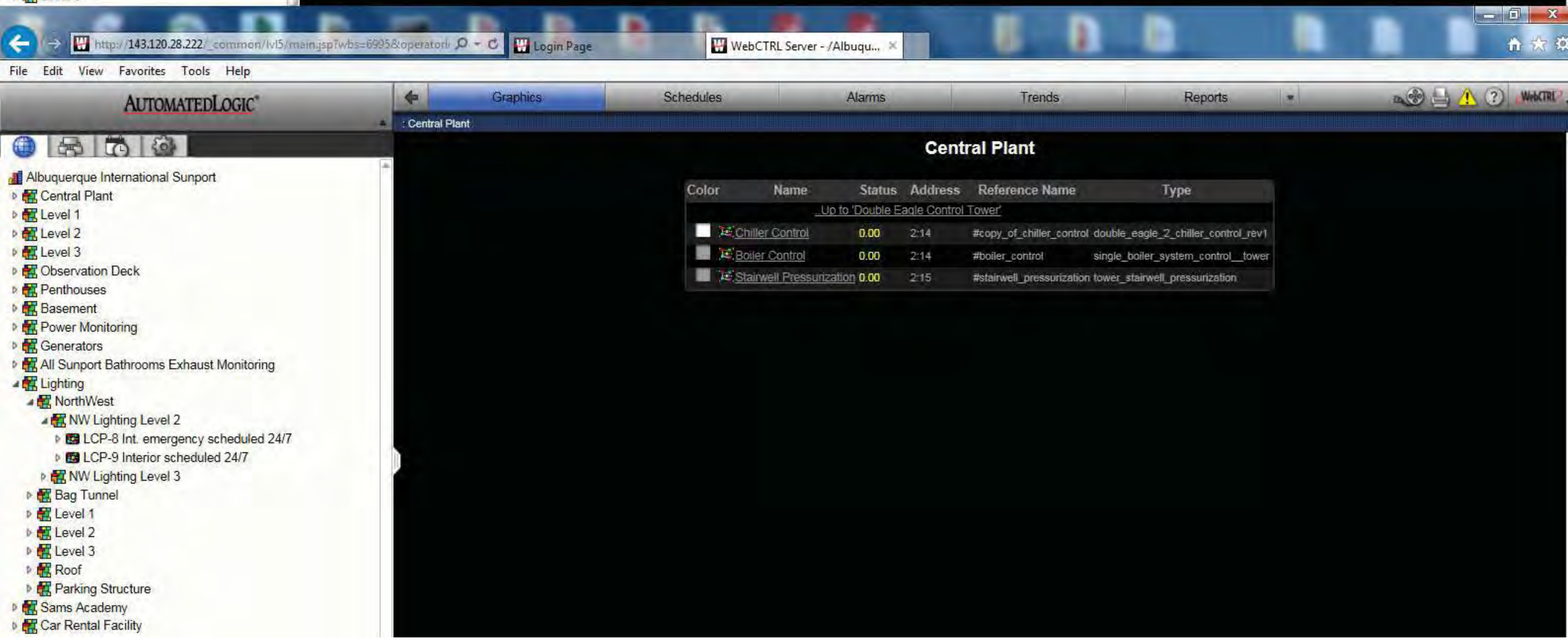
: Observation Deck
Observation Deck
88.2 °F
15.6 %rh
Albuquerque International Sunport
Central Plant
Level 1
Level 2
Level 3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Login Page
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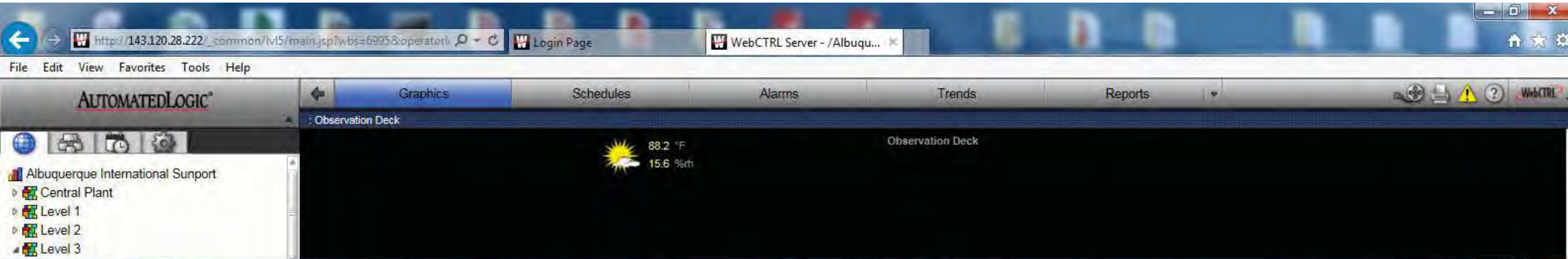
File Edit View Favorites Tools Help
AUTOMATEDLOGIC
Graphics
Schedules
Alarms
Trends
Reports
: Central Plant
Central Plant
Color Name Status Address Reference Name Type
..Up to 'Double Eagle Control Tower'
Chiller Control 0.00 2:14 #copy_of_chiller_control double_eagle_2_chiller_control_rev1
Boiler Control 0.00 2:14 #boiler_control single_boiler_system_control__tower
Stairwell Pressurization 0.00 2:15 #stairwell_pressurization tower_stairwell_pressurization
Albuquerque International Sunport
Central Plant
Level 1
Level 2
Level 3
Observation Deck
Penthouses
Basement
Power Monitoring
Generators
All Sunport Bathrooms Exhaust Monitoring
Lighting
NorthWest
NW Lighting Level 2
LCP-8 Int. emergency scheduled 24/7
LCP-9 Interior scheduled 24/7
NW Lighting Level 3
Bag Tunnel
Level 1
Level 2
Level 3
Roof
Parking Structure
Sams Academy
Car Rental Facility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Alarms
Trends
Reports
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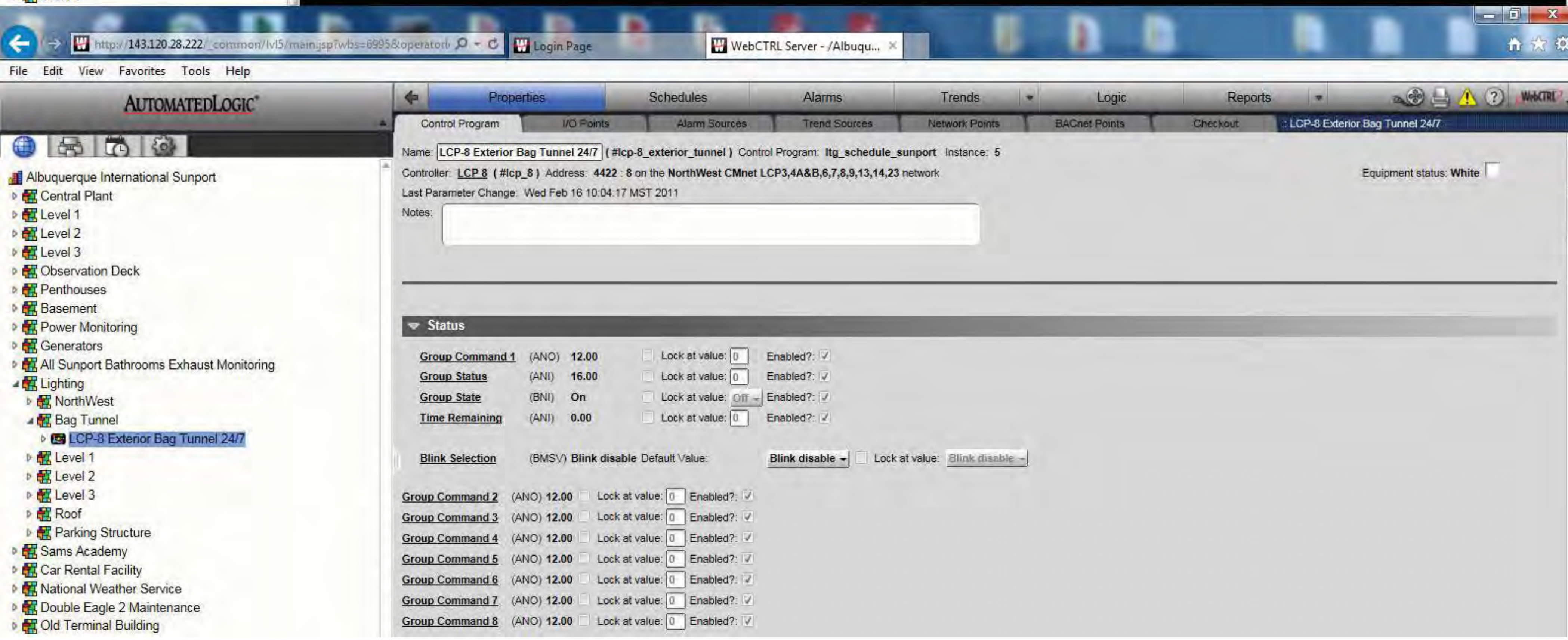
88.2 °F
15.6 %rh
Observation Deck
Albuquerque International Sunport
Central Plant
Level 1
Level 2
Level 3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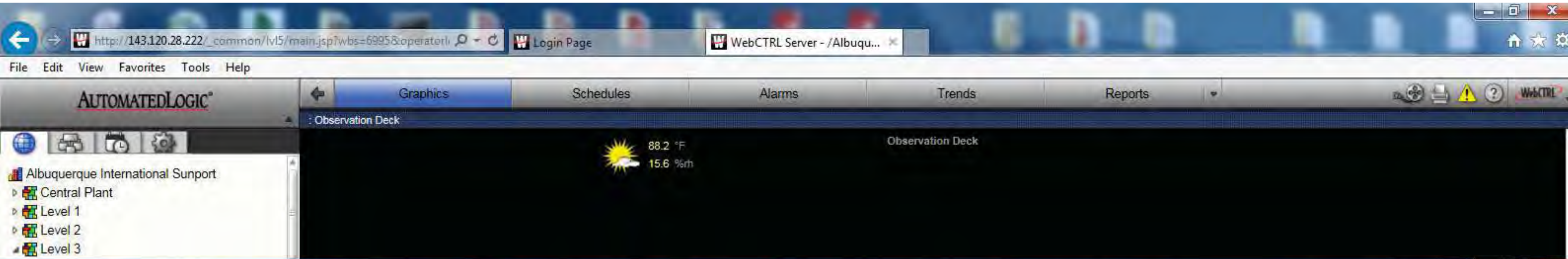
Trends
Logic
Reports
Control Program
I/O Points
Alarm Sources
Trend Sources
Network Points
BACnet Points
Checkout
: LCP-8 Exterior Bag Tunnel 24/7
Name: LCP-8 Exterior Bag Tunnel 24/7 (#lcp-8_exterior_tunnel) Control Program: ltg_schedule_sunport Instance: 5
Controller: LCP 8 (#lcp_8) Address: 4422 : 8 on the NorthWest CMnet LCP3,4A&B,6,7,8,9,13,14,23 network
Equipment status: White
Last Parameter Change: Wed Feb 16 10:04:17 MST 2011
Notes:
Status
Group Command 1 (ANO) 12.00 Lock at value: 0 Enabled?:
Group Status (ANI) 16.00 Lock at value: 0 Enabled?:
Group State (BNI) On Lock at value: Off Enabled?:
Time Remaining (ANI) 0.00 Lock at value: 0 Enabled?:
Blink Selection (BMSV) Blink disable Default Value: Blink disable Lock at value: Blink disable
Group Command 2 (ANO) 12.00 Lock at value: 0 Enabled?:
Group Command 3 (ANO) 12.00 Lock at value: 0 Enabled?:
Group Command 4 (ANO) 12.00 Lock at value: 0 Enabled?:
Group Command 5 (ANO) 12.00 Lock at value: 0 Enabled?:
Group Command 6 (ANO) 12.00 Lock at value: 0 Enabled?:
Group Command 7 (ANO) 12.00 Lock at value: 0 Enabled?:
Group Command 8 (ANO) 12.00 Lock at value: 0 Enabled?:
Albuquerque International Sunport
Central Plant
Level 1
Level 2
Level 3
Observation Deck
Penthouses
Basement
Power Monitoring
Generators
All Sunport Bathrooms Exhaust Monitoring
Lighting
NorthWest
Bag Tunnel
LCP-8 Exterior Bag Tunnel 24/7
Level 1
Level 2
Level 3
Roof
Parking Structure
Sams Academy
Car Rental Facility
National Weather Service
Double Eagle 2 Maintenance
Old Terminal Building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Schedules
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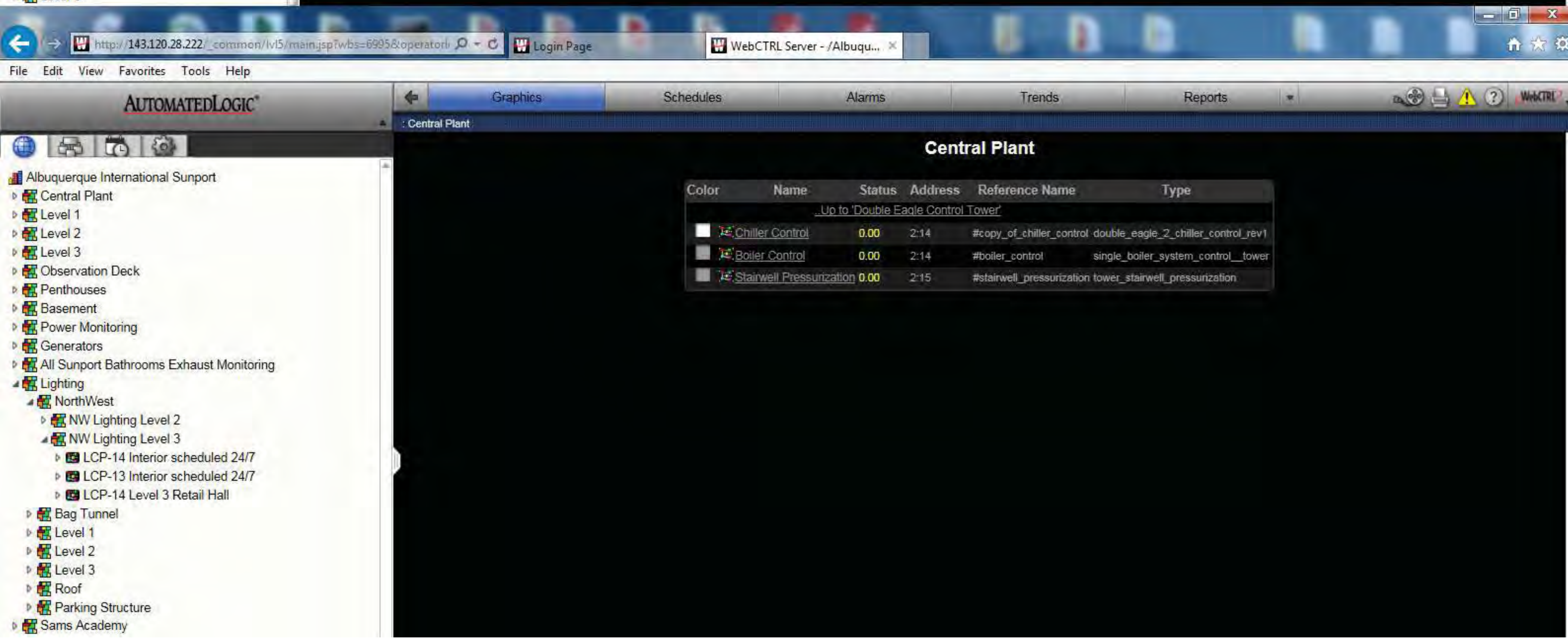
Trends
Reports
: Observation Deck
88.2 °F
15.6 %rh
Observation Deck
Albuquerque International Sunport
Central Plant
Level 1
Level 2
Level 3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Schedules
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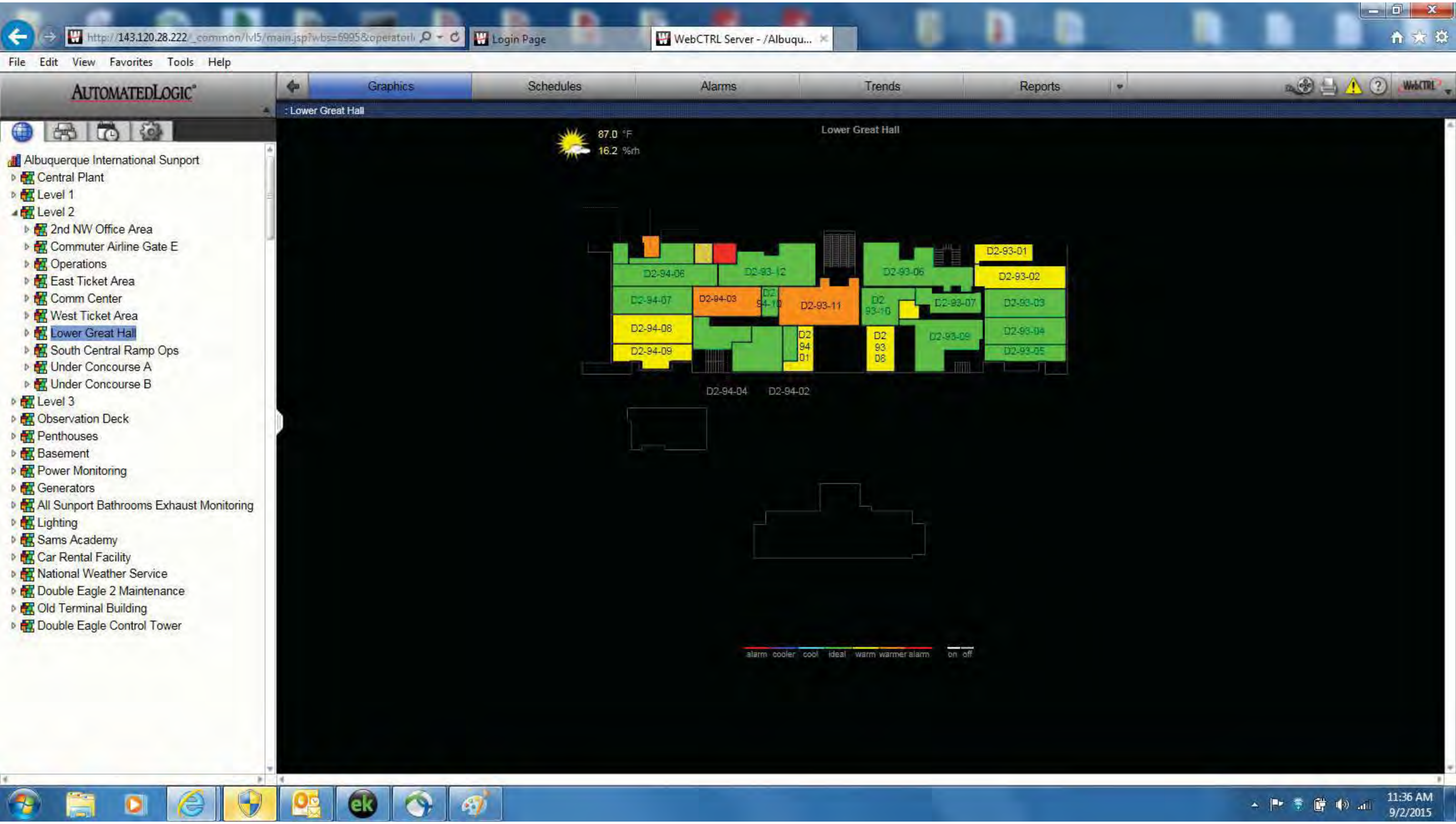
Reports
: Central Plant
Central Plant
Color
Name
Status
Address
Reference Name
Type
..Up to 'Double Eagle Control Tower'
Chiller Control 0.00 2:14 #copy_of_chiller_control double_eagle_2_chiller_control_rev1
Boiler Control 0.00 2:14 #boiler_control single_boiler_system_control__tower
Stairwell Pressurization 0.00 2:15 #stairwell_pressurization tower_stairwell_pressurization
Albuquerque International Sunport
Central Plant
Level 1
Level 2
Level 3
Observation Deck
Penthouses
Basement
Power Monitoring
Generators
All Sunport Bathrooms Exhaust Monitoring
Lighting
NorthWest
NW Lighting Level 2
NW Lighting Level 3
LCP-14 Interior scheduled 24/7
LCP-13 Interior scheduled 24/7
LCP-14 Level 3 Retail Hall
Bag Tunnel
Level 1
Level 2
Level 3
Roof
Parking Structure
Sams Academy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Lower Great Hall
87.0 °F
16.2 %rh
Albuquerque International Sunport
Central Plant
Level 1
Level 2
2nd NW Office Area
Commuter Airline Gate E
Operations
East Ticket Area
Comm Center
West Ticket Area
Lower Great Hall
South Central Ramp Ops
Under Concourse A
Under Concourse B
Level 3
Observation Deck
Penthouses
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Generators
All Sunport Bathrooms Exhaust Monitoring
Lighting
Sams Academy
Car Rental Facility
National Weather Service
Double Eagle 2 Maintenance
Old Terminal Building
Double Eagle Control Tower
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D2-93-12
D2-93-06
D2-93-01
D2-93-02
D2-94-07
D2-94-03
D2-93-11
D2-93-07
D2-93-03
D2-94-08
D2-93-09
D2-93-04
D2-94-09
D2-93-05
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D2-94-02
alarm cooler cool ideal warm warmer alarm
on off
11:36 AM
9/2/2015

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Albuquerque International S
Central Plant
Heating Water Plant
Chiller Plant
Cooling Towers
Flat Plate
Request Collectors
Outdoor Air
Level 1
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Level 3
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Car Rental Facility
National Weather Service
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Old Terminal Building
Double Eagle Control Tov
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SUNPORT
METASYS
Remote Buildings
Parking Tunnel
Observation Deck
Level 3
Level 2
Penthouses
Level 1
alarm cooler cool ideal warm warmer alarm
on off
10:41 AM
9/2/2015


Cannot communicate with controller.
D3-98-22
95.1 °F
10.8 %rh
hot duct airflow 5 cfm
setpoint 0 cfm
total airflow -10 cfm
cold duct airflow -15 cfm
setpoint 600 cfm
OCCUPIED
Heating 69.00
Cooling 72.00
60 65 70 75 80 85
74.2
setpoint adj by 0.0 °F
On until 12:00 AM
Graphics
Properties
Schedules
Alarms
Trends
Logic
Reports
HP Connection Manager
Wi-Fi: Associating
3:20 PM
9/2/2015


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Operations
East Ticket Area
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F203
F204
F205
D2-83-01
D2-83-02
D2-83-03
D2-83-04
D2-83-05
D2-83-06
D2-83-07
D2-83-08
D2-83-09
D2-83-10
D2-83-11
D2-83-12
D2-83-13 Chapel Sp
D2-84-01
D2-84-02
D2-84-03
D2-84-04
D2-84-05
D2-84-06
D2-84-07
D2-84-08
D2-84-09
T: Htg Setpt
T: Clg Setpt
T: Clg%
T: Htg%
Opt Start Inhibit
Demand Level
OA Temp
Startup Delay
Outgoing Requests to Run Interlocked Equipment
Request Heat Source
Request Cool Source
Zone Occupied for - Minutes
Heat Request
Cool Request
Occupied For minutes
Zone Dual Duct VAV Unit Airflow Control
Use constant or minimum air flow?
Constant or minimum air flow is
CFM
T: C Flow
T: H Flow
T: T Flow
cold duct
hot duct
3:10 PM
9/2/2015


Login Page
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AUTOMATEDLOGIC
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Reports
: NorthWest Level 3 Offices
87.7 °F
16.2 %rh
NorthWest Level 3 Offices
Albuquerque International Sunport
Central Plant
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Level 2
Level 3
NorthWest Level 3 Offices
Avation Department Offices
Connector
Upper Great Hall
Black Mesa & Garduno's
Security Screening
Concourse Lobby
Concourse A
Concourse B
Observation Deck
Penthouses
Basement
Power Monitoring
Generators
All Sunport Bathrooms Exhaust Monitoring
Lighting
Sams Academy
Car Rental Facility
National Weather Service
Double Eagle 2 Maintenance
Old Terminal Building
Double Eagle Control Tower
D3 97-04
D3 97-01
D3-97-02
D3-97-03
D3-97-05
D3-97-07
D3-97-06
D3 97-08
alarm cooler cool ideal warm warmer alarm
on off
11:41 AM
9/2/2015


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Trends
Reports
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Level 2
Level 3
NorthWest Level 3 Offices
Avation Department Offices
Connector
Upper Great Hall
Black Mesa & Garduno's
Security Screening
Concourse Lobby
Concourse A
Concourse B
Observation Deck
Penthouses
Basement
Power Monitoring
Generators
All Sunport Bathrooms Exhaust Monitoring
Lighting
Sams Academy
Car Rental Facility
National Weather Service
Double Eagle 2 Maintenance
Old Terminal Building
Double Eagle Control Tower
S4-116-12
S4-116-10
S4-116-13
S4-116-11
alarm cooler cool ideal warm warmer alarm
on off
11:54 AM
9/2/2015


Secondary Chilled Water Pumps - Bldg Flow
Albuquerque International S
Central Plant
Heating Water Plant
Chiller Plant
Chiller CH-1
Chiller CH-2
Chiller CH-3
Chiller Status CH-1
Chiller Status CH-2
Chiller Status CH-3
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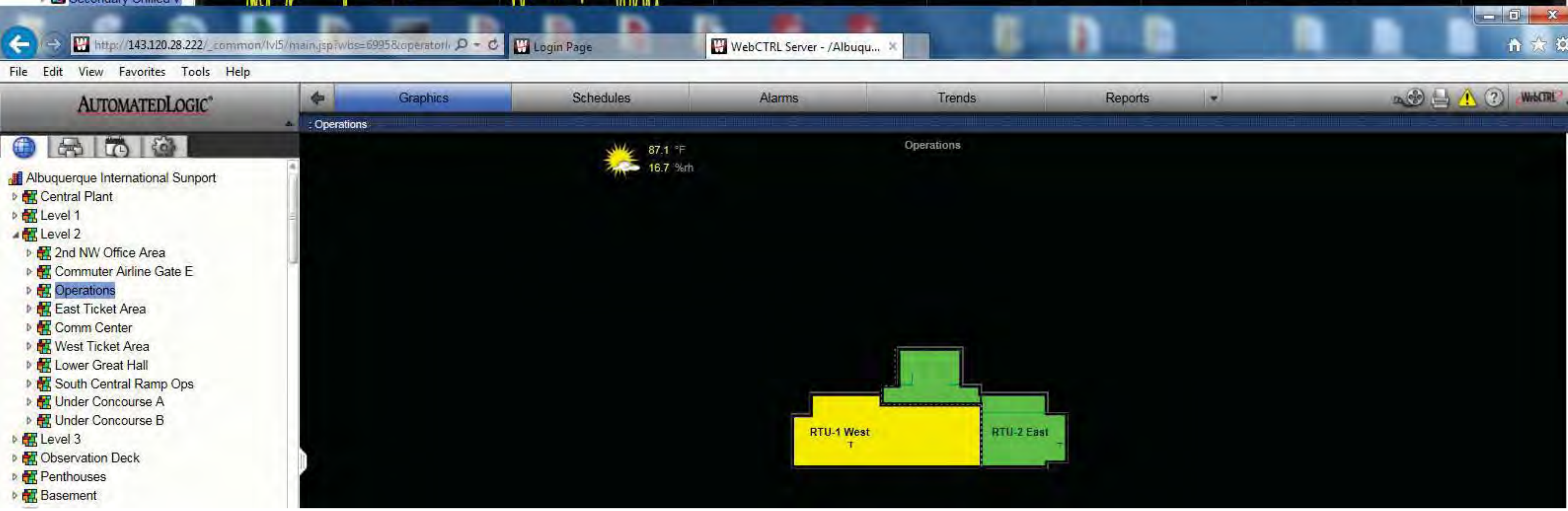
1600
1500


Albuquerque International Sunport
Central Plant
Level 1
Level 2
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Operations
East Ticket Area
Comm Center
West Ticket Area
Lower Great Hall
South Central Ramp Ops
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Under Concourse B
Level 3
Observation Deck
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Trends
Reports
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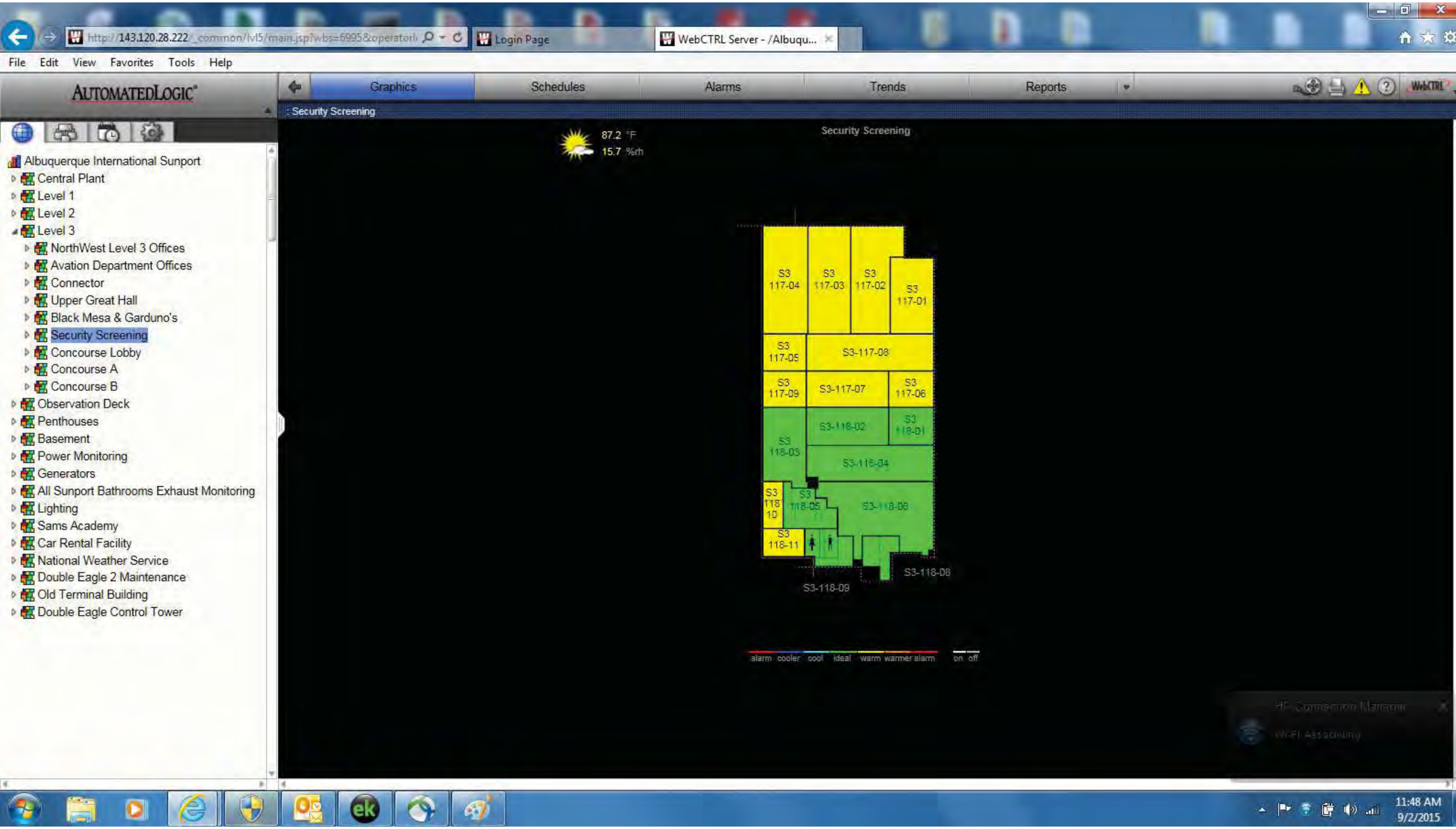
16.7 %rh
RTU-1 West
RTU-2 East



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National Weather Service
Double Eagle 2 Maintenance
Old Terminal Building
Double Eagle Control Tower
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S3 117-03
S3 117-02
S3 117-01
S3 117-05
S3-117-08
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S3 117-06
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S3 118-03
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S3 118 10
S3 118-05
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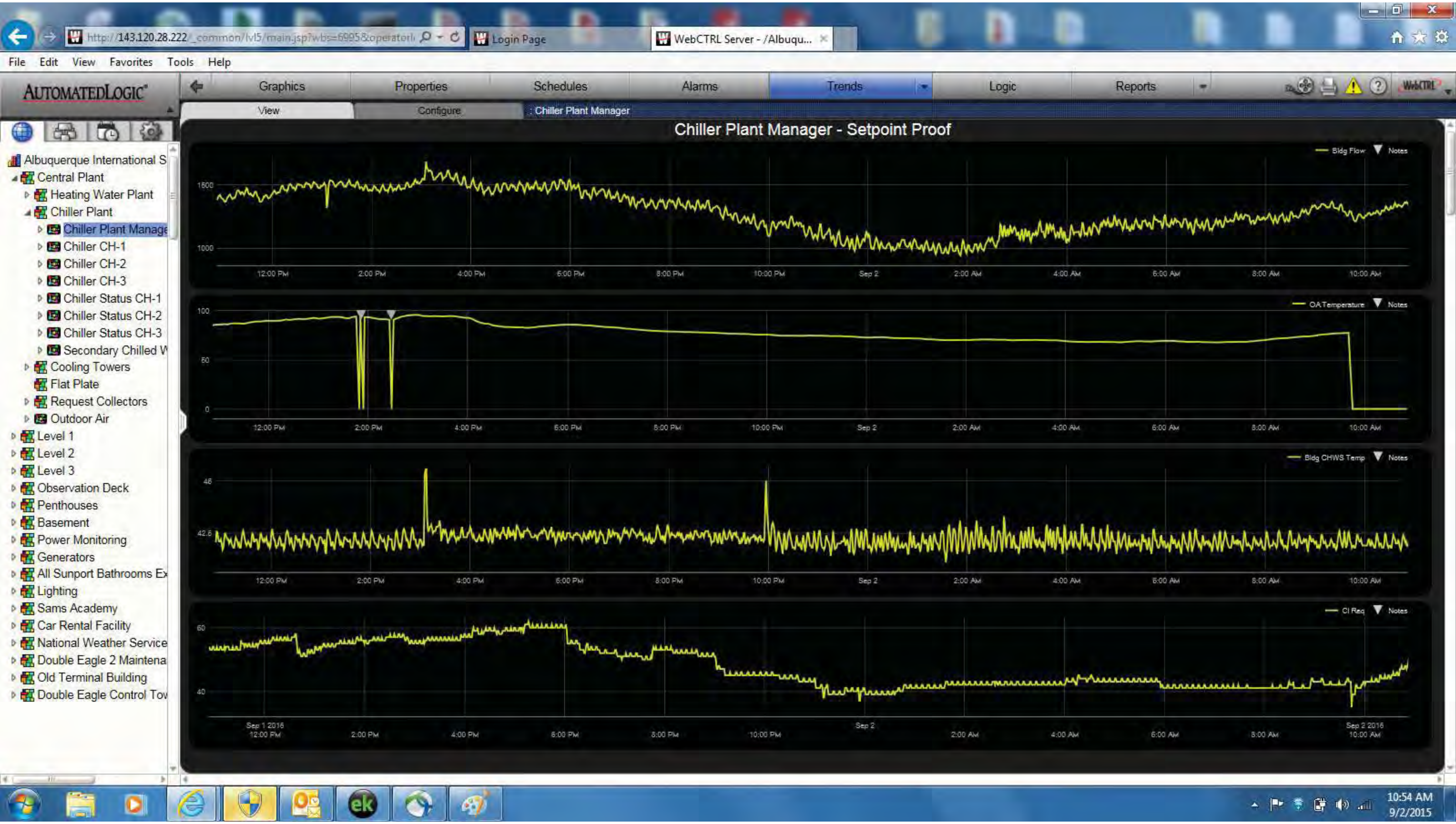
S3-118-09
alarm cooler cool ideal warm warmer alarm
on off
11:48 AM
9/2/2015



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Configure
Chiller Plant Manager
Chiller Plant Manager - Setpoint Proof
Albuquerque International S
Central Plant
Heating Water Plant
Chiller Plant
Chiller Plant Manage
Chiller CH-1
Chiller CH-2
Chiller CH-3
Chiller Status CH-1
Chiller Status CH-2
Chiller Status CH-3
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Cooling Towers
Flat Plate
Request Collectors
Outdoor Air
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Observation Deck
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Car Rental Facility
National Weather Service
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Old Terminal Building
Double Eagle Control Tov
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Notes
OA Temperature
Bldg CHWS Temp
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Sep 2
Sep 2 2015
10:54 AM
9/2/2015


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Comm Center
West Ticket Area
Lower Great Hall
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Under Concourse B
Level 3
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Penthouses
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Generators
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Double Eagle Control Tower
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D2-95-01
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D2-95-10
D2-95-09
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D2-95-16
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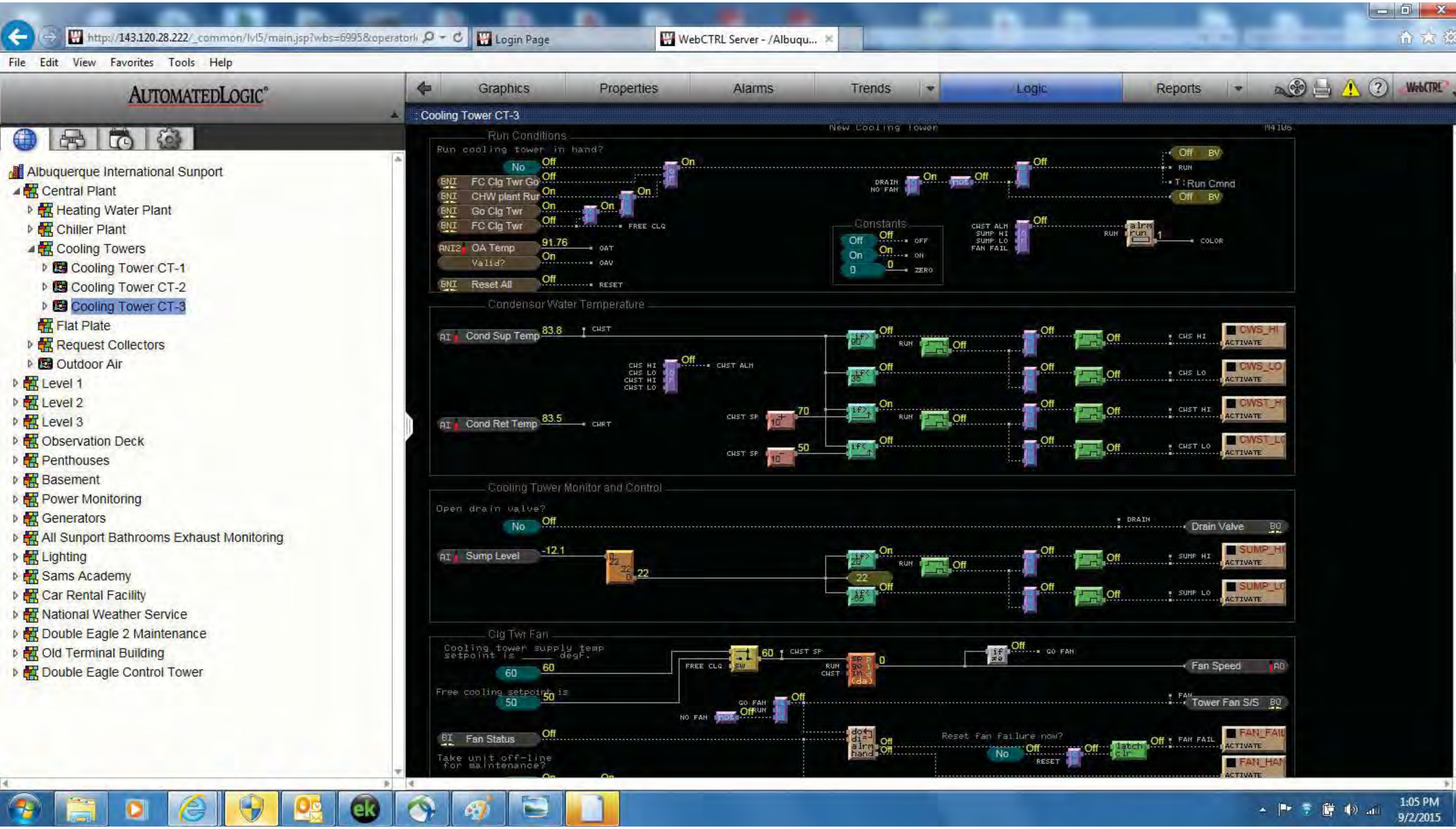
on off
11:38 AM
9/2/2015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Albuquerque International Sunport
Central Plant
Heating Water Plant
Chiller Plant
Cooling Towers
Cooling Tower CT-1
Cooling Tower CT-2
Cooling Tower CT-3
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Request Collectors
Outdoor Air
Level 1
Level 2
Level 3
Observation Deck
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Generators
All Sunport Bathrooms Exhaust Monitoring
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Sams Academy
Car Rental Facility
National Weather Service
Double Eagle 2 Maintenance
Old Terminal Building
Double Eagle Control Tower
Run Conditions
Run cooling tower in hand?
FC Clg Twr Go
CHW plant Rur
Go Clg Twr
FC Clg Twr
OA Temp
Reset All
Constants
Run Cmnd
Condensor Water Temperature
Cond Sup Temp
Cond Ret Temp
Cooling Tower Monitor and Control
Open drain valve?
Sump Level
Drain Valve
Clg Twr Fan
Fan Speed
Tower Fan S/S
Fan Status
Reset fan failure now?
1:05 PM
9/2/2015

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2nd NW Office Area
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East Ticket Area
Comm Center
West Ticket Area
Lower Great Hall
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Under Concourse B
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Car Rental Facility
National Weather Service
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Old Terminal Building
Double Eagle Control Tower
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D2-95-18
D2-109-07
D2-113-01
D2-112-01
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alarm cooler cool ideal warm warmer alarm
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on off
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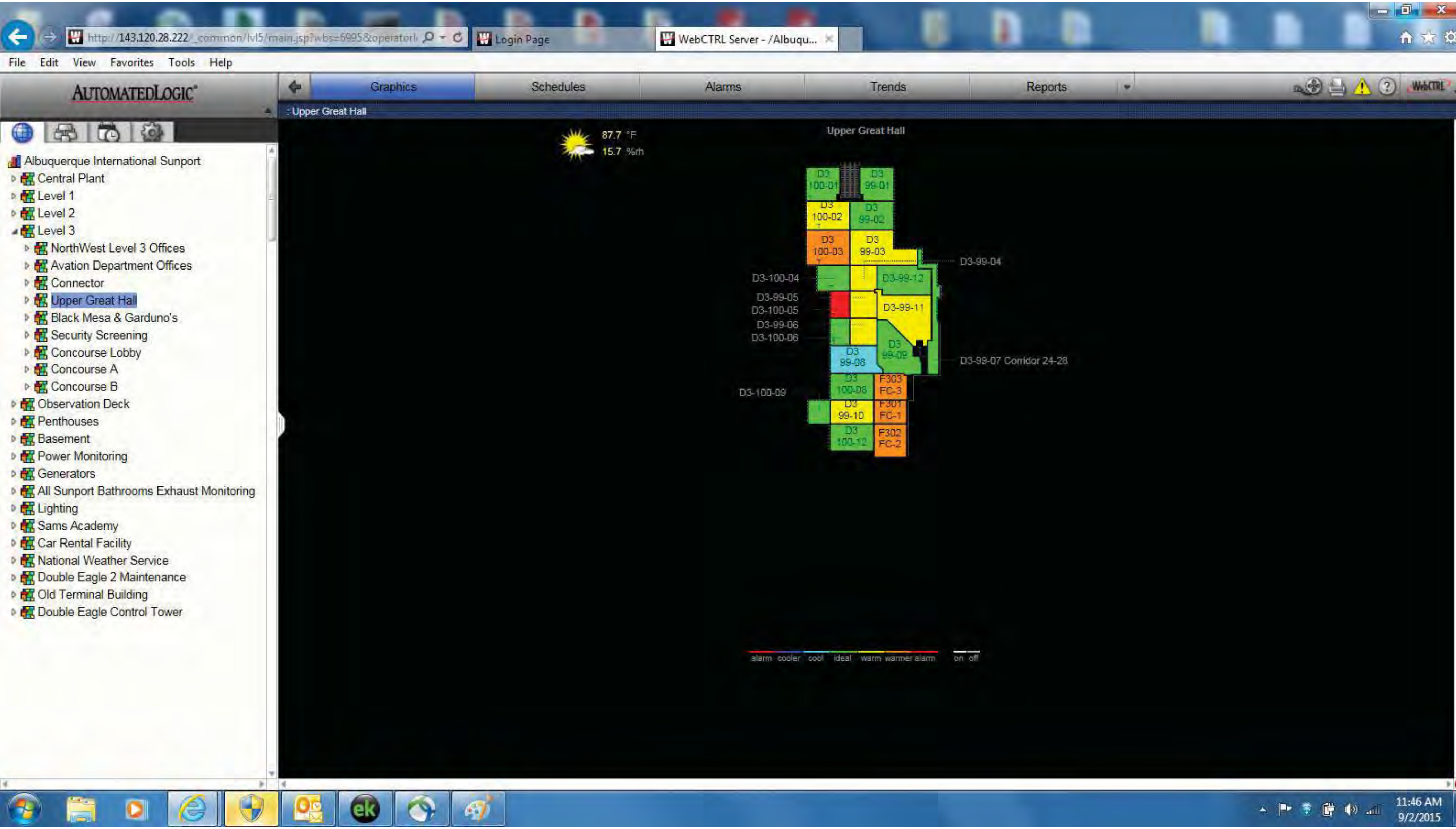
9/2/2015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Level 3
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Connector
Upper Great Hall
Black Mesa & Garduno's
Security Screening
Concourse Lobby
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Penthouses
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All Sunport Bathrooms Exhaust Monitoring
Lighting
Sams Academy
Car Rental Facility
National Weather Service
Double Eagle 2 Maintenance
Old Terminal Building
Double Eagle Control Tower
87.7 °F
15.7 %rh
Upper Great Hall
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D3-100-04
D3-99-12
D3-99-05
D3-100-05
D3-99-11
D3-99-06
D3-100-06
D3-99-07 Corridor 24-28
D3-100-09
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F301 FC-1
F302 FC-2
alarm cooler cool ideal warm warmer alarm
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9/2/2015

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Sams Academy
Car Rental Facility
National Weather Service
Double Eagle 2 Maintenance
Old Terminal Building
Double Eagle Control Tower
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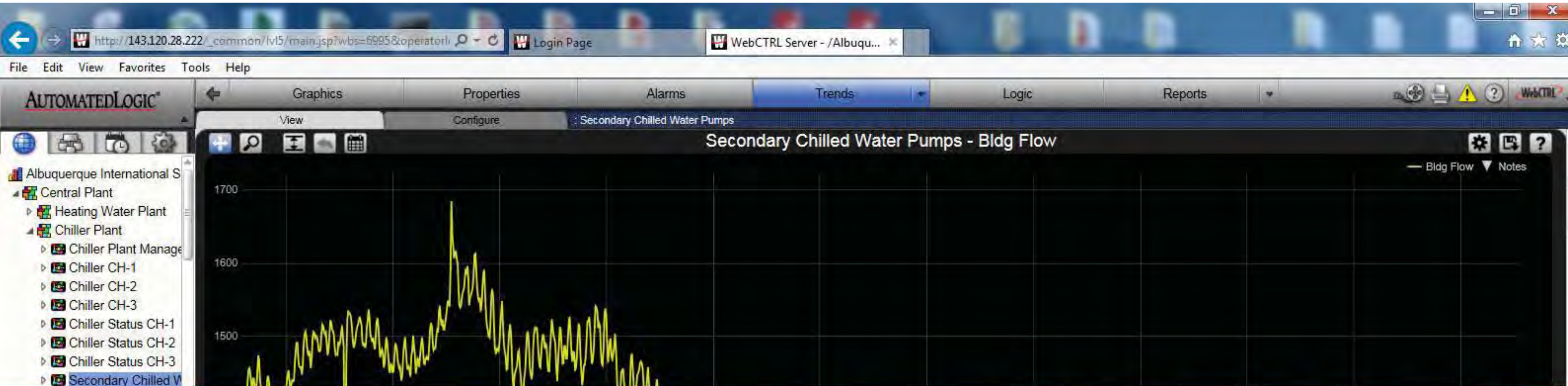
11:35 AM
9/2/2015



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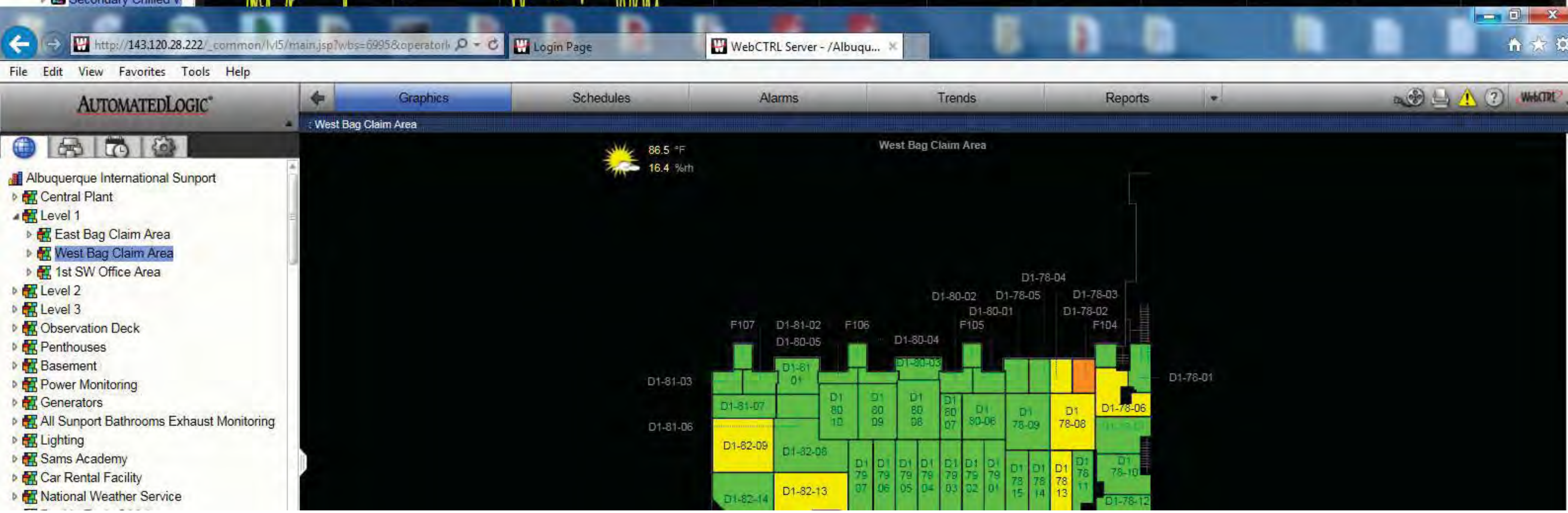
Configure
: Secondary Chilled Water Pumps
Secondary Chilled Water Pumps - Bldg Flow
Bldg Flow
Notes
1700
1600
1500
Albuquerque International S
Central Plant
Heating Water Plant
Chiller Plant
Chiller Plant Manage
Chiller CH-1
Chiller CH-2
Chiller CH-3
Chiller Status CH-1
Chiller Status CH-2
Chiller Status CH-3
Secondary Chilled W



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West Bag Claim Area
86.5 °F
16.4 %rh
Albuquerque International Sunport
Central Plant
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East Bag Claim Area
West Bag Claim Area
1st SW Office Area
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Power Monitoring
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National Weather Service
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D1-78-05
D1-78-03
D1-80-01
D1-78-02
F107
D1-81-02
F106
F105
F104
D1-80-05
D1-80-04
D1-81-03
D1-78-01
D1-81-07
D1-78-06
D1-81-06
D1-82-09
D1-82-08
D1-82-14
D1-82-13
D1-78-12

Appendix G –Utility Incentive Information

PNM Business Energy Efficiency Program
2015 Custom Application

Why Improve Energy Efficiency?

- Cuts your operating costs and improves profitability, allowing you to use energy savings to finance business growth.
- Reduces maintenance expenses.
- Distinguishes your business as energy conscious
- **Qualifies you for energy efficiency rebates from PNM.**

How to Participate

1. Submit a Pre-Notification Application to reserve funding. (Optional, but strongly recommended.)

2. Install the qualified technology.

3. Complete, sign and submit Final Application with all required documentation within 6 months of project completion.

4. The incentive check will be sent 4 to 6 weeks after approval of the Final Application.

PNM Business Energy Efficiency Team

320 Gold Avenue SW, Suite 600
Albuquerque, NM 87102
Toll free: (877) 607-0741
Fax: (877) 607-0742
energyefficiency@pnm.com
pnmenergyefficiency.com

Look Inside for:

$$ **Higher Rebates**

Version: February 2015 V.2

Application Checklist

1 Verify

- ☐ Submit application within 6 months of project completion and includes the following components:

2 Application Information Form

Customer Information

- ☐ Customer name is the same as it appears on PNM bills.
- ☐ PNM account number is complete and accurate. (Note: New construction account information may not be available for Pre-Application, but is required for the Final Application.)
- ☐ Taxpayer ID is complete and accurate; first-time customers submit W-9.

Contractor Information

- ☐ Provide complete contact information for project contractor. (We may need to contact your contractor to verify any project details.)
- ☐ If the job is completed by in-house staff, list Contractor as “done in-house.”

Incentive Check Information

- ☐ Complete contact information and taxpayer ID; first-time customers submit W-9.
- ☐ Indicate whether the customer or a third party should receive the check. If a third party is to receive the check:
  - Customer must check box indicating third party payment
  - Both the customer and third party must sign Payment Release and Agreement Form.

3 Total Incentives Requested

- ☐ Customer must fill out the following sections:
  - Total project cost
  - Project completion date

4 Terms & Conditions of Application

- ☐ Customer must read and agree with the terms and conditions of the PNM Business Energy Efficiency Program.
- ☐ If a third party is applying on behalf of the customer, the customer must sign the Agreement Form, allowing the third party to sign the application on the customer’s behalf. First-time customers must submit W-9.

5 Incentive Worksheets

- ☐ Complete incentive worksheet for each applicable measure (e.g., lighting, HVAC, refrigeration). Calculators are included where required (e.g., occupancy sensors).
- ☐ Ensure the measures installed meet the specifications listed in the application (e.g., specifications for lighting measures).

6 Additional Documentation

Financial

- ☐ Include W-9 with application.

Invoices

- ☐ Submit invoices dated no more than 6 months prior to rebate application date.
- ☐ List the installation address, which must be in PNM service territory, on the invoice.
- ☐ Ensure invoices show correct model number for each measure installed.
- ☐ Ensure invoices indicate payment by the customer (e.g., shows zero balance due, stamped paid, or check number and paid date are included).
- ☐ Submit copies of all cancelled checks.

Specification Sheets

- ☐ Provide a manufacturer’s specification sheet for each measure installed (e.g., lamp, ballast, controls, refrigerator, freezer, ice machine, etc.).
- ☐ Ensure specification sheets include all program eligibility requirements for the measure (e.g., CRI of lamps, ballast factors, IPLV for AC units, etc.). Note: AHRI (Air-Conditioning, Heating and Refrigeration Institute) offers a helpful website for cooling specifications at ahridirectory.org.
- ☐ Ensure the model numbers of all installed components match those listed on the invoices.

7 Submit Application

- ☐ Email completed application, and print Agreement Form, sign and submit via email or fax.

- or -

- ☐ Print completed application, sign and email, fax or mail to PNM Business Energy Efficiency Program team.

Applicant Information

Office Use Only - Custom	
Application # ____________	Revision # ____________

☐ Pre-Notification Date____________

or

☐ Final Application Date____________

Name as it appears on your utility bill______________________________

PNM Account Number (Where Measures Installed) ☐☐☐☐☐☐☐☐☐ + ☐☐☐☐☐☐☐

☐ This application represents multiple accounts/premises Number of accounts/premises ___________

Customer Information

Building Type (select one) ____

Name of Company ____

Name of Contact Person________________________________ Title________________

Phone # ______________ Fax # ______________ Email ______________________________

Installation Address ____

City ______________________________ State NM Zip____________

☐ Check here if installation address and mailing address are the same.

Mailing Address ____

City ______________________________ State NM______ Zip____________

Taxpayer ID (SSN/FEIN)________________ Tax Status______________________________

Contractor Information

Contracting Company______________________________ Contact________________

Phone # ______________ Fax # ______________ Email ______________________________

Mailing Address ____

City ______________________________ State NM______ Zip____________

Applicant Information

Third Party Payment Release

☐ I request that the incentive check be sent to the third party indicated below.

☐ Check here if third party payee is the contractor.

Name of Third Party ______________________ **Contact/Title** ______________

Phone # ______________ **Fax #** ______________ **Email** ______________________

Mailing Address ____

City ______________________ **State** NM ______ **Zip** ______________

Third Party Taxpayer ID (SSN/FEIN) ______________ **Tax Status** ______________________

Total Incentive Requested, Total Project Cost and Project Completion Date

Total Incentive Requested* ______________

Total Project Cost REQUIRED ______________

Project Completion Date** ______________

*Total Incentive Requested is an auto-populating field based on the entries in this application. Incentive cannot exceed 100% of the incremental measure cost or 50% of total project cost, whichever is lowest.

**If submitting a Pre-Notification Application, Project Completion Date is an estimated date.

Agreement Form

As an eligible PNM customer, I certify that the indicated energy efficiency measures, which will be demonstrated with supporting documentation required by PNM, were installed after May 19, 2009. The energy efficiency measures are for use in my business facility and not for resale. I have attached documentation establishing proof of payment for the items installed according to this application and certify that the project costs identified in this application are correct and represent the actual costs paid to implement the project. Project documentation, such as copies of dated invoices for the purchase and installation of the measures and product specification sheets, is required. Further documentation requirements can be found in the Policy and Procedures Manual which can be found at the program website PNM.com/rebates or can be ordered by calling the program hotline. Documentation indicating installation dates prior to May 19,2009, will render this application ineligible.

I understand that the location or business name on the invoice must be consistent with the application information. Final Applications and all required supporting documentation should be received within 60 days of the completion of the project with all required documentation. The customer may request, subject to approval by the PNM New Construction and Retrofit Rebates Team, that the funding be reserved for more than 180 days if the project schedule is expected to extend more than six months. **Applications submitted more than 6 months after project completion without specific permission from the PNM New Construction and Retrofit Rebate Team will be ineligible for incentives.**

I agree to verification by the utility or their representatives of both sales transactions and equipment installation.

The energy savings from installed measures must occur on a meter with an eligible rate schedule. Most non-residential rate schedules are eligible. Master metered non-residential rate schedules within multifamily facilities are eligible. Individually metered residential rate schedules within multifamily facilities are eligible only within the context of a property owner/manager sponsored full-facility project. A qualifying multifamily facility consists of a single commercial property containing more than four dwelling units. See below:

PNM Tariffs

- 2A, 2B, 3B, 3C, 4B, 5B
- Water and Sewage Pumping 11B
- Large Service for Public Universities 15B
- Large Service for Manufacturing 17B
- Special Contract Service for Large Customers 23
- Large Service for Manufacturing - Distribution Level 30B

Any and all environmental credits generated by the project described in this application will be retained by PNM.

I certify that the information on this application is true and correct, and that the Taxpayer ID Number is the applicant's. I understand that incentive payments assume related energy benefits over a period of 5 years or for the life of the product, whichever is less.

I agree that if: (1) I do not install the related product(s) identified in my application, or (2) I remove the related product(s) identified in my application before a period of 5 years or the end of the product life, whichever is less; then I shall refund a prorated amount of incentive funds to PNM based on the actual period of time in which the related product(s) were installed and operating (or the full amount if the product was never installed). This is necessary to assure that the project's related energy benefits will be achieved.

I understand that the program may be modified or terminated without prior notice.

I understand that this project must involve a capital improvement with associated out-of-pocket cost that results in improved energy efficiency. I understand it is my responsibility to comply with any applicable local, state and federal code requirements. I agree that my eligibility to participate in the program and receive program funds is contingent upon compliance. I also understand that all materials removed, including lamps and PCB ballasts, must be taken out of service and disposed of in accordance with local codes and ordinances. Information about hazardous waste disposal can be found at: epa.gov/osw/hazwaste.htm.

In no case will PNM pay more than 100% of the incremental measure cost or 50% of total project cost, whichever is lowest. I understand that PNM or their representatives have the right to ask for additional information at any time. The PNM New Construction and Retrofit Rebates program will make the final determination of incentive levels for this project. I understand that my company may be recognized as a program participant in promotional materials; however, project details will not be released without prior consent. If I choose to opt-out of any recognition, I will indicate my choice in a written letter.

Agreement Form

I understand that PNM does not guarantee the energy savings and does not make any warranties associated with the measures eligible for incentives under this program, and, further, that PNM has no obligations regarding and does not endorse or guarantee any claims, promises, work, or equipment made, performed, or furnished by any contractors or equipment vendors, including Trade Allies listed on PNM's website, that sell or install any energy efficiency measures.

I understand that in the event funds are reserved based on a pre-notification the payment of incentives will be based upon the final application and program terms and conditions, and that the PNM New Construction and Retrofit Rebates program is subject to change or cancellation at any time and without notice. PNM is not responsible for any lost, late, stolen, ineligible, illegible, misdirected or postage-due mail. All completed submissions become the property of PNM and will not be returned. PNM makes no guarantees about the availability of products or rebate forms. By participating in the PNM New Construction and Retrofit Rebates program, customers agree to waive any claims and release PNM from any liability for damages, of any kind. Rebates are funded by a charge on PNM electric customer bills.

I have read and understand the program requirements and Measure Specifications and Terms and Conditions set forth in this application and agree to abide by those requirements. Furthermore, I concur that I must meet all eligibility criteria in order to be paid under this program.

Agreement Form

Reference:
Third Party Signature Required

I understand that in the event funds are reserved based on a pre-notification, the payment of incentives will be based upon the Final Application and program terms and conditions, and that the PNM Business Energy Efficiency program is subject to change or cancellation at any time and without notice. PNM is not responsible for any lost, late, stolen, ineligible, illegible, misdirected or postage-due mail. All completed submissions become the property of PNM and will not be returned. PNM makes no guarantees about the availability of products or rebate forms. By participating in the PNM Business Energy Efficiency program, customers agree to waive any claims and release PNM from any liability for damages of any kind. Rebates are funded by a charge on PNM electric customer bills.

Total Incentive Requested, Total Project Cost and Project Completion Date

Total Incentive Requested	Total Project Cost	Project Completion Date
______________________	______________________	______________________

I have read and understand the program requirements, measure specifications, and terms and conditions set forth in this application and agree to abide by those requirements. Furthermore, I concur that I must meet all eligibility criteria in order to be paid under this program. (Initial here) _________

As an eligible customer, I verify that the signature below is my own and that the information is correct. I am requesting consideration for participation under this program. (Initial here) _________

Customer Signature (PNM Customer)
Please sign by hand.

____

Print Customer Name

____

Date 02/23/15 ______________________

Third Party Signature
Please sign by hand.

____

Print Third Party Name

____

Date ______________________

To Submit Application

OPTION 1: Email completed application. Print Agreement Form, sign and submit via email or fax.

Email Application AND **Print Agreement Form**

OPTION 2: Print completed application, sign and email, fax or mail to PNM Business Energy Efficiency Program team.

Print Entire Application

PNM Business Energy Efficiency Team
energyefficiency@pnm.com
Fax: (877) 607-0742
Toll free: (877) 607-0741
320 Gold Avenue SW, Suite 600
Albuquerque, NM 87102
pnmenergyefficiency.com

Custom Incentives

Please attach supporting documentation as described in the specifications.

Link to Specifications

Item 1				
Description			**$/kWh**	**Subtotal**
	Annual kWh Savings		$$ $0.075	
	kW Savings			
	Annual Operating Hours			
	Incremental Measure Cost			
	Total Project Cost			

Item 2				
Description			**$/kWh**	**Subtotal**
	Annual kWh Savings		$$ $0.075	
	kW Savings			
	Annual Operating Hours			
	Incremental Measure Cost			
	Total Project Cost			

Item 3				
Description			**$/kWh**	**Subtotal**
	Annual kWh Savings		$$ $0.075	
	kW Savings			
	Annual Operating Hours			
	Incremental Measure Cost			
	Total Project Cost			

Item 4				
Description			**$/kWh**	**Subtotal**
	Annual kWh Savings		$$ $0.075	
	kW Savings			
	Annual Operating Hours			
	Incremental Measure Cost			
	Total Project Cost			

Total Custom Incentives	

Incremental measure cost (IMC) is the difference between the cost of an energy-efficient piece of equipment and a new standard-efficiency piece of equipment. The IMC of energy-efficient equipment installed before an old piece of equipment reaches the end of its life (such as lighting equipment) generally is equal to the total cost of the energy-efficient equipment, including labor. The IMC of energy-efficient equipment installed at or near the end of life of an old piece of equipment (such as chillers, motors, air-conditioning units) generally is equal to the difference in cost between the energy-efficient equipment and the new standard-efficiency piece of equipment, not including labor.

Custom Specifications

Pre-Notification Application strongly encouraged.

Link to Worksheet

The PNM New Construction and Retrofit Rebates program offers custom incentives for those eligible improvements not included under the program's prescriptive measures. Custom incentives are available under the New Construction and Retrofit Rebates program to non-residential customers within PNM service territory. The incentive will be calculated at $0.06 per estimated kilowatt hour saved (first year only). Actual incentive payments will be based on either (1) documented electrical energy (kWh) reduction or (2) an electrical energy reduction estimate approved by PNM New Construction and Retrofit Rebates program staff.

The energy savings from installed measures must occur on a meter with an eligible rate schedule. Most non-residential rate schedules are eligible. See table of eligible rates in Agreement Form.

Custom projects must involve measures that result in a reduction in electric energy due to an improvement in system efficiency. Projects that result in a reduced energy consumption without an improvement in system efficiency are not eligible for a custom incentive. However, projects that involve an automated control technology such as energy management system programming are eligible for an incentive. All projects must meet PNM's cost-effectiveness requirements.

Projects involving measures covered by the prescriptive incentive portion of the program are not eligible for a custom incentive. However, if the applicant can justify significant interactive effects between prescriptive and custom measures, the applicant may apply for the entire project using a custom application. For example, a chiller system upgrade project that includes a chiller replacement and staging controls could go through custom, even though the chiller replacement would normally go through the prescriptive portion. PNM reserves the right to make the final determination of which application is appropriate.

Therefore, submitting a Pre-Notification Application for combined prescriptive and custom measures is strongly encouraged.

Project requirements under the New Construction and Retrofit Rebates program include the following:

- Projects must involve a facility improvement that results in a permanent reduction in electrical usage (kWh)
- Project savings must be sustainable for a period of five years or the life of the product, whichever is less
- PNM is required to conduct a cost-effectiveness test on each custom application. Generally, projects with a financial payback beyond 5-8 years are unlikely to pass this test and could be ineligible for incentives. While this test will be based upon the final installation, Pre-Notification Applications offer the opportunity to determine if projects are likely to pass this test prior to investing in a project.
- Projects that are NOT eligible for an incentive include the following:
  - Fuel switching (e.g., electric to gas or gas to electric)
  - Changes in operational and/or maintenance practices or simple control modifications not involving capital costs
  - On-site electricity generation
  - Projects involving gas-driven equipment in place of electric equipment (such as a chiller)
  - Projects that involve peak-shifting (and not kWh savings)
  - Measures installed with funding from or under another incentive program
  - Renewables
- PNM reserves the right to inspect proposed projects prior to equipment installation and to inspect projects post-installation.

Supporting Documentation

Please attach the following documentation in addition to required documentation as described in the PNM New Construction and Retrofit Rebates program policies and procedures:

- Complete description of the proposed project, the products and technologies used, and how they will be employed. Include definitions of the base case and details of the proposed equipment (provide manufacturer's specification sheets for both base and proposed cases, if possible).
- All facilities, buildings or equipment that will be affected by the project; include all PNM account numbers
- Detailed cost breakdown by measure

Savings Calculations

Include all relevant data that will allow an engineer to duplicate the savings estimate provided, such as:

- Concise description of the existing energy systems to be affected
- Facility physical description and occupancy (include activities in building and hours of operation)
- Location of affected equipment
- Condition and age of equipment if a degradation in nameplate efficiency is assumed

Custom Specifications

- Hours of operation of the affected equipment
- Number of existing units
- Ratings of equipment (wattage, nameplate, tonnage, voltage, etc.)
- Measure-by-measure summary of the calculated savings associated with the project
- Historical peak power (if demand metered) and/or energy consumption data
- Clearly indicate all assumptions and variables used in the analysis
- Describe the basis or rationale for each assumption and variable

It is the applicant's responsibility to present a convincing case for estimating energy savings. If it is unclear if your preferred method is sufficient, contact us at (877) 607-0741.

Incentive Payment Limits

The total incentive paid cannot exceed 100% of the incremental measure cost or 50% of total project cost, whichever is lowest. Contractor labor costs can be considered in project cost. Internal customer labor costs should not be included in project costs.

PNM Business Energy Efficiency Program
2015 Prescriptive Application - All Measures

Why Improve Energy Efficiency?

- Cuts your operating costs and improves profitability, allowing you to use energy savings to finance business growth.
- Reduces maintenance expenses.
- Distinguishes your business as energy conscious.
- **Qualifies you for energy efficiency rebates from PNM.**

How to Participate

1. Submit a Pre-Notification Application to reserve funding. (Optional, but strongly recommended.)

2. Install the qualified technology.

3. Complete, sign and submit Final Application with all required documentation within 6 months of project completion.

4. The incentive check will be sent 4 to 6 weeks after approval of the Final Application.

PNM Business Energy Efficiency Team

320 Gold Avenue SW, Suite 600
Albuquerque, NM 87102
Toll free: (877) 607-0741
Fax: (877) 607-0742
energyefficiency@pnm.com
pnmenergyefficiency.com

Look Inside for:

NEW New Measures   Higher Incentives

Version: February 2015 V.2

PNM®

Table of Contents

Application Checklist

1 Verify

- ☐ Submit application within 6 months of project completion and includes the following components:

2 Application Information Form

Customer Information

- ☐ Customer name is the same as it appears on PNM bills.
- ☐ PNM account number is complete and accurate. (Note: New construction account information may not be available for Pre-Application, but is required for the Final Application.)
- ☐ Taxpayer ID is complete and accurate; first-time customers submit W-9.

Contractor Information

- ☐ Provide complete contact information for project contractor. (We may need to contact your contractor to verify any project details.)
- ☐ If the job is completed by in-house staff, list Contractor as "done in-house."

Incentive Check Information

- ☐ Complete contact information and taxpayer ID; first-time customers submit W-9.
- ☐ Indicate whether the customer or a third party should receive the check. If a third party is to receive the check:
  - ☐ Customer must check box indicating third party payment
  - ☐ Both the customer and third party must sign Payment Release and Agreement Form.

3 Total Incentives Requested

- ☐ Customer must fill out the following sections:
  - Total project cost
  - Project completion date

4 Terms & Conditions of Application

- ☐ Customer must read and agree with the terms and conditions of the PNM Business Energy Efficiency Program.
- ☐ If a third party is applying on behalf of the customer, the customer must sign the Agreement Form, allowing the third party to sign the application on the customer's behalf. First-time customers must submit W-9.

5 Incentive Worksheets

- ☐ Complete incentive worksheet for each applicable measure (e.g., lighting, HVAC, refrigeration). Calculators are included where required (e.g., occupancy sensors).
- ☐ Ensure the measures installed meet the specifications listed in the application (e.g., specifications for lighting measures).

6 Additional Documentation

Financial

- ☐ Include W-9 with application.

Invoices

- ☐ Submit invoices dated no more than 6 months prior to rebate application date.
- ☐ List the installation address, which must be in PNM service territory, on the invoice.
- ☐ Ensure invoices show correct model number for each measure installed.
- ☐ *Ensure invoices indicate payment by the customer (e.g., shows zero balance due, stamped paid, or check number and paid date are included).*
- ☐ *Submit copies of cancelled checks.*

Specification Sheets

- ☐ Provide a manufacturer's specification sheet for each measure installed (e.g., lamp, ballast, controls, refrigerator, freezer, ice machine, etc.).
- ☐ Ensure specification sheets include all program eligibility requirements for the measure (e.g., CRI of lamps, ballast factors, IPLV for AC units, etc.). Note: AHRI (Air-Conditioning, Heating and Refrigeration Institute) offers a helpful website for cooling specifications at ahridirectory.org.
- ☐ Ensure the model numbers of all installed components match those listed on the invoices.

7 Submit Application

- ☐ Email completed application, and print Agreement Form, sign and submit via email or fax.

- or -

- ☐ Print completed application, sign and email, fax or mail to PNM Business Energy Efficiency Program team.

Applicant Information

Office Use Only - All Measures	
Application # ____________	Revision # ____________

☐ **Pre-Notification** **Date**____________

or

☐ **Final Application** **Date**____________

Name as it appears on your utility bill______________________________

PNM Account Number (Where Measures Installed) ☐☐☐☐☐☐☐☐☐ + ☐☐☐☐☐☐☐

Customer Information

Building Type (select one)

Name of Company ______________________________

Name of Contact Person______________________________ **Title**____________

Phone # ____________ **Fax #** ____________ **Email** ______________________

Installation Address ______________________________

City ______________________________ **State** NM ______ **Zip**____________

☐ **Check here if installation address and mailing address are the same.**

Mailing Address ______________________________

City ______________________________ **State** NM ______ **Zip**____________

Taxpayer ID (SSN/FEIN)____________________ **Tax Status**______________________

Contractor Information

Contracting Company______________________________ **Contact**____________

Phone # ____________ **Fax #** ____________ **Email** ______________________

Mailing Address ______________________________

City ______________________________ **State** NM ______ **Zip**____________

Applicant Information

Third Party Payment Release

☐ I request that the incentive check be sent to the third party indicated below.

☐ Check here if third party payee is the contractor.

Name of Third Party____________________ **Contact/Title** ________________

Phone # ________________ **Fax #** ________________ **Email** ____________________

Mailing Address ____

City________________________ **State** NM ____ **Zip**____________

Third Party Taxpayer ID (SSN/FEIN)________________ **Tax Status** ____________________

Total Incentive Requested, Total Project Cost and Project Completion Date

Total Incentive Requested* ________________

Total Project Cost REQUIRED ________________

Project Completion Date** ________________

*Total Incentive Requested is an auto-populating field based on the entries in this application. Incentive cannot exceed 100% of the incremental measure cost or 50% of total project cost, whichever is lowest.

**If submitting a Pre-Notification Application, Project Completion Date is an estimated date.

For Office Use Only

Retrofit Lighting Incentives (Interior)		Food Service Equipment Incentives	
Retrofit Lighting Incentives (Exterior)		Motors Incentives	
Retrofit Lighting Incentives (24 Hour)		Variable Speed Drive Incentives	
HVAC Incentives		Building Envelope Incentives	
Refrigeration Incentives		Plug Load Controls Incentives	
High-Efficiency Ice Makers Incentives			

Agreement Form

As an eligible PNM customer, I certify that the indicated energy efficiency measures, which will be demonstrated with supporting documentation required by PNM, were installed after May 19, 2009. The energy efficiency measures are for use in my business facility and not for resale. I have attached documentation establishing proof of payment for the items installed according to this application and certify that the project costs identified in this application are correct and represent the actual costs paid to implement the project. Project documentation, such as copies of dated invoices for the purchase and installation of the measures and product specification sheets, is required. Further documentation requirements can be found in the Policy and Procedures Manual which can be found at the program website PNM.com/rebates or can be ordered by calling the program hotline. Documentation indicating installation dates prior to May 19,2009, will render this application ineligible.

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I understand that the program may be modified or terminated without prior notice.

I understand that this project must involve a capital improvement with associated out-of-pocket cost that results in improved energy efficiency. I understand it is my responsibility to comply with any applicable local, state and federal code requirements. I agree that my eligibility to participate in the program and receive program funds is contingent upon compliance. I also understand that all materials removed, including lamps and PCB ballasts, must be taken out of service and disposed of in accordance with local codes and ordinances. Information about hazardous waste disposal can be found at: epa.gov/epawaste/hazard/index.htm.

In no case will PNM pay more than 100% of the incremental measure cost or 50% of total project cost, whichever is lowest. I understand that PNM or their representatives have the right to ask for additional information at any time. The PNM New Construction and Retrofit Rebates program will make the final determination of incentive levels for this project.

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Total Incentive Requested, Total Project Cost and Project Completion Date

Total Incentive Requested	Total Project Cost	Project Completion Date
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As an eligible customer, I verify that the signature below is my own and that the information is correct. I am requesting consideration for participation under this program. (Initial here) _________

Customer Signature (PNM Customer) **Please sign by hand.** ________________________________	**Third Party Signature** **Please sign by hand.** ________________________________
Print Customer Name ________________________________	**Print Third Party Name** ________________________________
Date 03/19/15 ___________________	**Date** ___________________________

To Submit Application

OPTION 1: Email completed application. Print Agreement Form, sign and submit via email or fax.

Email Application **AND** **Print Agreement Form**

OPTION 2: Print completed application, sign and email, fax or mail to PNM Business Energy Efficiency Program team.

Print Entire Application

PNM Business Energy Efficiency Team
energyefficiency@pnm.com
Fax: (877) 607-0742
Toll free: (877) 607-0741
320 Gold Avenue SW, Suite 600
Albuquerque, NM 87102
pnmenergyefficiency.com

PNM®

Lighting Incentives - Interior Retrofit

Link to Specifications

These lighting incentive worksheets should be used when retrofitting existing lighting. If the lighting project is for new construction, please use the New Construction worksheets.

Equipment Type[1]	Incentive	Unit	# of Units	Incentive Subtotal
Screw-In Compact Fluorescent Lights				
5-15 Watts	$1.00	Lamp		
16-26 Watts	$1.00	Lamp		
27 Watts or Higher	$2.00	Lamp		
Screw-In Compact Fluorescent Lights - Inside Dwelling Units[2] (Pre-Notification Application REQUIRED)				
5-15 Watts	$1.00	Lamp		
16-26 Watts	$1.00	Lamp		
27 Watts or Higher	$2.00	Lamp		
Hardwired Compact Fluorescent Fixtures				
29W or Less	$20.00	Fixture		
30W or Greater	$40.00	Fixture		
Hardwired Compact Fluorescent Lights - Inside Dwelling Units[2] (Pre-Notification Application REQUIRED)				
29W or Less	$5.00	Fixture		
30W or Greater	$10.00	Fixture		
Permanent Removal of Lamp from Existing Fixture (Pre-Notification Application REQUIRED)				
2-ft Lamp - T12 Basecase	$3.00	Lamp Removed		
3-ft Lamp - T12 Basecase	$4.00	Lamp Removed		
4-ft Lamp - T12 Basecase	$5.00	Lamp Removed		
8-ft Lamp - T12 Basecase	$10.00	Lamp Removed		
Permanent Removal of Lamp from Existing Fixture (Pre-Notification Application REQUIRED)				
2-ft Lamp - T8 Basecase	$3.00	Lamp Removed		
3-ft Lamp - T8 Basecase	$4.00	Lamp Removed		
4-ft Lamp - T8 Basecase	$5.00	Lamp Removed		
8-ft Lamp - T8 Basecase	$10.00	Lamp Removed		
High Performance (HP) T8, Reduced Wattage (RW) T8 and Electronic Ballast or LED and Driver				
4-ft HP Lamp and Ballast	$4.00	Lamp		
4-ft RW Lamp and Ballast	$4.00	Lamp		
4-ft LED Lamp and Driver	$4.00	Lamp		
1-Lamp 8-ft T12 to 2-Lamp 4-ft HP T8	$4.00	Lamp		
1-Lamp 8-ft T12 to 2-Lamp 4-ft RW T8	$4.00	Lamp		
Standard T8 and Electronic Ballast				
2-ft Lamp and Ballast	$2.00	Lamp		
3-ft Lamp and Ballast	$2.00	Lamp		
4-ft or U-Tube and Ballast	$2.00	Lamp		

Lighting Incentives - Interior Retrofit

Equipment Type[1]	Incentive	Unit	# of Units	Incentive Subtotal
T12 to T5 Lamps and Ballast				
T12 to T5 Lamps and Ballast	$4.00	Lamp		

Reduced Wattage (RW) 8-Foot T8 and Electronic Ballast				
8-ft T12 to RW T8	$4.00	Lamp		

Reduced Wattage (RW) 4-Foot OR 8-Foot T8 LAMP ONLY				
4-ft T8 Reduced Wattage Lamp Only	$1.00 ★	Lamp		
8-ft T8 Reduced Wattage Lamp Only	$1.00 ★	Lamp		

LED Lighting				
LED, T-1 or Electroluminescent Exit Signs	$20.00	Sign		
LED Lamp	$12.00	Lamp		
LED Recessed Downlight Fixture	$20.00	Fixture		
LED Open Sign	$25.00	Sign		
LED Channel Sign ≤ 2-ft Interior	$8.00	Letter		
LED Channel Sign > 2-ft Interior	$16.00	Letter		

High-Efficiency HID Fixture				
Integrated Ballast Ceramic Metal Halide Lamps	$8.00	Fixture		
Metal Halide (Pulse Start or Ceramic) 100W or Less	$20.00	Fixture		
Metal Halide (Pulse Start or Ceramic) 101W - 200W	$25.00	Fixture		
Metal Halide (Pulse Start or Ceramic) 201W - 350W	$45.00	Fixture		
Metal Halide (Pulse Start or Ceramic) 351W - 400W	$65.00	Fixture		

Specialty Lamps				
Cold Cathode	$3.00	Lamp		
Dimmable; 3-Way; Locking Base CFL	$5.00	Lamp		
Dimmable; 3-Way; Locking Base CFL (Dwelling Units)	$3.00	Lamp		

Controls				
Watts Controlled Calculator REQUIRED **Download Here**				
Occupancy Sensors	$0.09 ★	Watts Controlled		
Daylighting Sensor Controls	$0.09 ★	Watts Controlled		

Lighting Incentives - Interior Retrofit

New High-Efficiency T8, T5 or LED Fixtures Replacing HID (Pre-Notification Application Required)				
New High-Efficiency T8, T5 or LED Fixture	$0.30	Watt Reduction[3]		

Fill out the form below to calculate Watt Reduction.

BASECASE — Link to Full Calculator

Fixture Type	Ballast Type	Fixture Description	Lamps/ Fixture	Lamp Wattage	Fixture Quantity	Fixture Wattage	Basecase Watts
Total Basecase Wattage							

INSTALLED

Fixture Type	Ballast Type	Fixture Description	Lamps/ Fixture	Lamp Wattage	Fixture Quantity	Fixture Wattage	Installed Watts
Total Installed Wattage							

NEW

Interior LED fixture replacing T12 or T8 Linear Fluorescent Fixture (Pre-Notification Application Required)				
Interior LED Fixture Replacing T12 or T8 Fixture	$0.25	Watt Reduction[3]		

Fill out the form below to calculate Watt Reduction.

BASECASE — Link to Full Calculator

Fixture Type	Ballast Type	Fixture Description	Lamps/ Fixture	Lamp Wattage	Fixture Quantity	Fixture Wattage	Basecase Watts
Total Basecase Wattage							

INSTALLED

Fixture Type	Fixture Description	Fixture Quantity	Fixture Wattage	Installed Watts
Total Installed Wattage				

Total Retrofit Lighting Incentives (Interior)	

[1]For clarification, additional documentation including a description of the retrofit, lighting layouts, fixture counts or calculation spreadsheets are recommended.
[2]A dwelling unit is defined as an interior space that is residential in nature (i.e., hotel rooms, dormitories, multi-family apartments, apartments in retirement and senior living communities, etc.). Please see eligibility as described in the Agreement Form.
[3]Watts reduction = old connected wattage - new connected wattage

Lighting Incentives - Exterior/Dusk-to-Dawn/12-Hour Operation

Link to Specifications

Equipment Type[1]	Incentive	Unit	# of Units	Incentive Subtotal
Exterior LED Lighting				
LED Channel Sign ≤ 2-ft Exterior	$8.00	Letter		
LED Channel Sign > 2-ft Exterior	$16.00	Letter		
Bi-Level LED Parking Lot Fixture	$60.00	Fixture		
Bi-Level LED Wall Pack Fixture	$60.00	Fixture		
Exterior Specialty Lamps				
Cold Cathode	$3.00	Lamp		
CFL - High Wattage (>40W) Screw-In, Dimmable or 3-Way	$15.00	Lamp		
Outdoor Area or Street Lights				
Metal Halide (Pulse Start or Ceramic) 100W or Less	$20.00	Fixture		
Metal Halide (Pulse Start or Ceramic) 101W-200W	$25.00	Fixture		
Metal Halide (Pulse Start or Ceramic) 201W-350W	$45.00	Fixture		
Metal Halide (Pulse Start or Ceramic) 351W-400W	$65.00	Fixture		
Induction Replacing 175W or Less HID	$40.00	Fixture		
Induction Replacing 176W-250W HID	$50.00	Fixture		
Induction Replacing 251W-400W HID	$60.00	Fixture		
Exterior Hardwired Compact Fluorescent Fixtures				
29W or Less	$20.00	Fixture		
30W or Greater	$40.00	Fixture		
New High-Efficiency T8, T5 or LED Fixtures Replacing HID (Pre-Notification Application Required)				
New High-Efficiency T8, T5 or LED Fixture	$0.40 ★	Watt Reduction[3]		

Fill out the form below to calculate Watt Reduction.

BASECASE							Link to Full Calculator
Fixture Type	Ballast Type	Fixture Description	Lamps/ Fixture	Lamp Wattage	Fixture Quantity	Fixture Wattage	Basecase Watts
Total Basecase Wattage							

INSTALLED							
Fixture Type	Ballast Type	Fixture Description	Lamps/ Fixture	Lamp Wattage	Fixture Quantity	Fixture Wattage	Installed Watts
Total Installed Wattage							

Total Retrofit Lighting Incentives (Exterior)	

[1]For clarification, additional documentation including a description of the retrofit, lighting layouts, fixture counts or calculation spreadsheets are recommended.
[2]A dwelling unit is defined as an interior space that is residential in nature (i.e., hotel rooms, dormitories, multi-family apartments, apartments in retirement and senior living communities, etc.). Please see eligibility as described in the Agreement Form.
[3]Watts reduction = old connected wattage - new connected wattage

Lighting Incentives - 24/7, Garage or 3-Shift Operation

Link to Specifications

Equipment Type[1]	Incentive	Unit	# of Units	Incentive Subtotal
LED Lighting				
Bi-Level LED Parking Lot Fixture	$60.00	Fixture		
Bi-Level LED Wall Pack Fixture	$60.00	Fixture		

Specialty Lamps				
Cold Cathode	$3.00	Lamp		
CFL - High Wattage (>40W) Screw-In (Exterior ONLY)	$15.00	Lamp		
CFL - Dimmable or 3-Way	$15.00	Lamp		

Outdoor Area or Street Lights				
Metal Halide (Pulse Start or Ceramic) 100W or Less	$20.00	Fixture		
Metal Halide (Pulse Start or Ceramic) 101W-200W	$25.00	Fixture		
Metal Halide (Pulse Start or Ceramic) 201W-350W	$45.00	Fixture		
Metal Halide (Pulse Start or Ceramic) 351W-400W	$65.00	Fixture		
Induction Replacing 175W or Less HID	$40.00	Fixture		
Induction Replacing 176W-250W HID	$50.00	Fixture		
Induction Replacing 251W-400W HID	$60.00	Fixture		

Traffic and Pedestrian Signals				
LED Traffic Light - Green 8"	$10.00	Lamp		
LED Traffic Light - Green 12"	$20.00	Lamp		
LED Traffic Light - Red 8"	$10.00	Lamp		
LED Traffic Light - Red 12"	$20.00	Lamp		
LED Traffic Light - Walk/Don't Walk or Arrow - 9"	$5.00	Lamp		
LED Traffic Light - Walk/Don't Walk or Arrow - 12"	$5.00	Lamp		

Controls				
Bi-Level Stairwell/Hall/Garage Fixtures With Integrated Sensors	$20.00	Fixture		

[1]For clarification, additional documentation including a description of the retrofit, lighting layouts, fixture counts or calculation spreadsheets are recommended.
[2]A dwelling unit is defined as an interior space that is residential in nature (i.e., hotel rooms, dormitories, multi-family apartments, apartments in retirement and senior living communities, etc.). Please see eligibility as described in the Agreement Form.
[3]Watts reduction = old connected wattage - new connected wattage

Lighting Incentives - 24/7, Garage or 3-Shift Operation

New High-Efficiency T8, T5 or LED Fixtures Replacing HID (Pre-Notification Application Required)				
New High-Efficiency T8, T5 or LED Fixture	$0.50	Watt Reduction³		

Fill out the form below to calculate Watt Reduction.

BASECASE							Link to Full Calculator	
Fixture Type	Ballast Type	Fixture Description	Lamps/ Fixture	Lamp Wattage	Fixture Quantity	Fixture Wattage	Basecase Watts
Total Basecase Wattage							

INSTALLED							
Fixture Type	Ballast Type	Fixture Description	Lamps/ Fixture	Lamp Wattage	Fixture Quantity	Fixture Wattage	Installed Watts
Total Installed Wattage							

NEW

24/7 LED fixture replacing T12 or T8 Linear Fluorescent Fixture (Pre-Notification Application Required)				
24/7 LED Fixture Replacing T12 or T8 Fixture	$0.50	Watt Reduction³		

Fill out the form below to calculate Watt Reduction.

BASECASE							Link to Full Calculator
Fixture Type	Ballast Type	Fixture Description	Lamps/ Fixture	Lamp Wattage	Fixture Quantity	Fixture Wattage	Basecase Watts
Total Basecase Wattage							

INSTALLED				
Fixture Type	Fixture Description	Fixture Quantity	Fixture Wattage	Installed Watts
Total Installed Wattage				

Total Retrofit Lighting Incentives (24 Hour)	

¹For clarification, additional documentation including a description of the retrofit, lighting layouts, fixture counts or calculation spreadsheets are recommended.
²A dwelling unit is defined as an interior space that is residential in nature (i.e., hotel rooms, dormitories, multi-family apartments, apartments in retirement and senior living communities, etc.). Please see eligibility as described in the Agreement Form.
³Watts reduction = old connected wattage - new connected wattage

Lighting Retrofit Specifications

Link to Worksheet

All lighting projects are expected to comply with the Illuminating Engineering Society of North America (IESNA) recommended lighting levels or the local code.

Screw-In Compact Fluorescent Lamps and Fixtures

Screw-in CFLs must replace existing incandescent or HID lamps and have an efficacy ≥ 40 lumens per watt (LPW).

Screw-In Compact Fluorescent Lamps and Fixtures Inside Dwelling Units

A dwelling unit is defined as a space type that is used primarily for living quarters and that includes a kitchen unit. Typical dwelling units are university dorm rooms, multifamily complexes and apartments. The equipment specifications are identical to those listed above.

Hardwired Compact Fluorescent Fixtures

Only complete new fixtures or modular hardwired retrofits with hardwired electronic ballasts qualify. The CFL ballast must be programmed start or programmed rapid start with a power factor (PF) ≥ 90 and a total harmonic distortion (THD) ≤ 20%.

Hardwired Compact Fluorescent Fixtures Inside Dwelling Units

A dwelling unit is defined as a space type that is used primarily for living quarters and that includes a kitchen unit. Typical dwelling units are university dorm rooms, multifamily complexes and apartments. The equipment specifications are identical to those listed above.

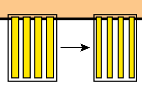
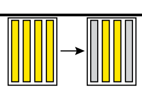
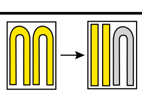
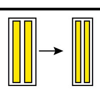
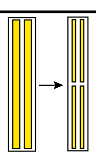
Permanent Lamp Removal (Pre-Application Required)

Incentives are paid for the permanent removal of existing fluorescent lamps. Permanent lamp removal is the net reduction in the quantity of lamps after a project is completed. Customers are responsible for determining whether or not to use reflectors in combination with lamp removal in order to maintain adequate lighting levels. Lighting retrofits are expected to meet the Illuminating Engineering Society of North America (IESNA) recommended light levels. Unused lamps, lamp holders and ballasts must be permanently removed from the fixture and disposed of in accordance with local regulations. This measure is applicable when retrofitting from T12 lamps to T8 lamps or reconfiguring a T8 fixture to reduce the number of lamps. The removal of lamps from a T12 fixture that is not being retrofitted with T8 lamps is not eligible for this incentive. A pre-notification application is required for this measure to allow PNM to conduct a pre-inspection.

High-Performance 4-Foot T8 Lamps and Electronic Ballasts

This measure addresses replacing existing T12 lamps and magnetic ballasts with high-performance T8 lamps and electronic ballasts at a rate of $4.00 per lamp. The measure is based on the Consortium for Energy Efficiency (CEE) high-performance T8 specification (cee1.org) and is summarized below. A list of qualified lamps and ballasts can be found at cee1.org/content/cee-program-resources. Both the lamp and ballast must meet the specification in order to qualify for an incentive. Incentives for this measure are calculated per lamp installed. A manufacturer's specification sheet must accompany the application.

Quick Guide to Incentives for Popular T12 to T8 Upgrades

	Popular T12 to T8 Upgrades	Applicable Incentives for Each Fixture	
	Retrofit 4-foot 4-lamp T12 to 4-foot 4-lamp T8	4-foot high performance (HP) T8 lamp and ballast	$4 per lamp installed
	Retrofit 4-foot 4-lamp T12 to 4-foot 2-lamp T8 to maintain light levels	4-foot HP T8 lamp and ballast	$4 per lamp installed
		Remove 4-foot lamp	$5 per lamp removed
	Retrofit 2-lamp 4-foot T12 U-tube to 2-lamp 2-foot T8 to maintain light levels	2-foot T8 lamp and ballast	$2 per lamp installed
		Remove 4-foot lamp	$5 per lamp removed
	Retrofit 2-lamp 4-foot T12 to 2-lamp 4-foot T8	4-foot HP or reduced wattage (RW) T8 lamp and ballast	$4 per lamp installed
	Retrofit 2-lamp 8-foot T12 to 4-lamp 4-foot T8	One 8-foot T12 lamp to two 4-foot HP T8 lamps	$4 per lamp installed

Lighting Retrofit Specifications

Performance Characteristics for Systems				
Mean System Efficiency	≥ 90 Mean Lumens per Watt (MLPW) for Instant Start Ballasts			
	≥ 88 MLPW for Programmed Rapid Start Ballasts			
Performance Characteristics for Lamps				
Color Rendering Index (CRI)	≥ 80			
Minimum Initial Lamp Lumens	≥ 3100 Lumens*			
Lamp Life	≥ 24,000 Hours			
Lumen Maintenance or Minimum Mean Lumens	≥ 94% or ≥ 2900 Mean Lumens			
Performance Characteristics for Ballasts				
Ballast Efficacy Factor (BEF) BEF = (BFx100)/ Ballast Input Watts	Instant Start Ballast (BEF)			
	Lamps	Low BF ≤ 0.85	Norm 0.85 < BF ≤ 1.0	High BF ≥ 1.01
	1	> 3.08	> 3.11	≥ 3.03
	2	> 1.60	> 1.58	≥ 1.55
	3	≥ 1.04	≥ 1.05	≥ 1.04
	4	≥ 0.79	≥ 0.80	≥ 0.77
	Programmed Rapid Start Ballast (BEF)			
	1	≥ 2.84	≥ 2.84	≥ 2.95
	2	≥ 1.48	≥ 1.47	≥ 1.51
	3	≥ 0.97	≥ 1.00	≥ 1.00
	4	≥ 0.76	≥ 0.75	≥ 0.75
Ballast Frequency	20 to 33 kHz or ≥ 40 kHz			
Power Factor	≥ 0.90			
Total Harmonic Distortion	≤ 20%			
*For lamp with color temperatures ≥ 4500k. 2950 minimum initial lamp lumens are allowed.				

4-Foot LED Lamp and Driver

This measure addresses the replacement of existing T12 4-foot fluorescent lamps in existing 1x4 or 2x4 lighting fixtures. T8s are not eligible. The new LED tubes must not exceed 23 watts in power. The existing lamps and ballasts must be removed and the new LED lamps and, if applicable, LED drivers must be installed. The installation must also be accompanied by a sticker inside the fixture that indicates a fluorescent lamp(s) must not be re-installed. A post-inspection will be required prior to payment being issued. All LED lamps must be DesignLights Consortium or ENERGY STAR® qualified.

Standard T8 and Electronic Ballasts

This measure addresses replacing T12 systems with 2-foot, 3-foot or 4-foot T8 or U-tube lamps and electronic ballasts. The T8 lamps must have a color rendering index (CRI) ≥ 80. Electronic ballasts must be high frequency (≥ 20 kHz), UL listed and warranted against defects for 5 years. Ballasts must have a power factor (PF) ≥ 0.90. Ballasts for 4-foot lamps must have total harmonic distortion (THD) ≤ 20% at full light output. For 2- and 3-foot lamps, ballasts must have THD ≤ 32% at full light output.

T12 to T5 Lamps and Ballasts

This measure is for the replacement of T12 fixtures with T5 lamps and new electronic ballasts. T5 lamps must have a color rendering index (CRI) > 80 and be 4 feet in length. Electronic ballasts must be high frequency (>20MHz), UL listed and warranted against defects for 5 years. Ballasts for 4-foot lamps must have total harmonic distortion (THD) U20% at full light.

Reduced-Wattage 4-Foot T8 Lamps and Ballasts

This measure is for the replacement of T12 systems with reduced-wattage lamp and electronic ballast systems at a rate of $4.00 per lamp. The lamps and ballasts must meet the Consortium for Energy Efficiency (CEE) specification (cee1.org). Qualified lamps and ballast products can be found at cee1.org/content/cee-program-resources. Both the lamp and ballast must qualify in order to receive an incentive for the system. The mean system efficacy must be ≥ 90 MLPW, CRI ≥ 80 and lumen maintenance at 94%. Visit the CEE website for further qualifications and a list of pre-qualified lamps and ballasts. A manufacturer's specification sheet must accompany the application.

Reduced-Wattage 4-Foot T8 Lamps (Lamps Only)

Incentives are available when replacing 32-watt T8 lamps with reduced-wattage T8 lamps if an electronic ballast is already present. The incentive rate is $0.50 per lamp. The lamps must be reduced wattage in accordance with the Consortium for Energy Efficiency (CEE) specification (cee1.org). Qualified products can be found at cee1.org/content/cee-program-resources. The nominal wattage must be 28W (≥ 2585 initial lumens) or 25W (≥ 2400 initial lumens) to qualify.

8-Foot T12 to Reduced-Wattage 8-Foot T8 Lamps and Ballasts

This measure is for the replacement of existing T12 lamps and magnetic ballasts with reduced-wattage T8 lamps and electronic ballasts at a rate of $4.00 per lamp. Lamps must have a minimum MLPW of 90 and must have a nominal wattage of less than 57W. A manufacturer's specification sheet must accompany the application.

Reduced-Wattage 8-Foot T8 Lamps (Lamps Only)

Incentives are available for replacing 59-watt T8 lamps with reduced-wattage 8-foot T8 lamps at a rate of $0.50 per lamp. Lamps must have a minimum MLPW of 90 and must have a nominal wattage of less than 57W. The incentive is calculated on a per-lamp basis and ballast replacement is not necessary. A manufacturer's specification sheet must accompany the application.

LED, T-1 or Electroluminescent Exit Signs

High-efficiency exit signs must replace or retrofit an existing incandescent exit sign. Electroluminescent, T-1 and light emitting diode (LED) exit signs are eligible under this category. Non-electrified and remote exit signs are not eligible. All new exit signs or retrofit exit signs must be UL- or ETL-listed, have a minimum lifetime of 10 years, and have an input wattage ≤ 5 watts per face or be ENERGY STAR® qualified.

LED Lamps

This measure addresses the replacement of 20-100 watt incandescent lamps with integral screw-in or pin-type replacement lamps. Eligible lamp types include A, R, Par, MR, G and Candle lamps. LED wattage may not exceed 20 watts. See LED lighting specifications for qualifying criteria. All LED lamps, strips or fixtures must be DesignLights Consortium or ENERGY STAR® qualified.

LED Recessed Down-light Fixtures

This measure is for the replacement of incandescent down-light lamps/fixtures greater than 40 watts. LED wattage may not exceed 18 watts. See LED lighting specifications for qualifying criteria. All LED lamps, strips or fixtures must be DesignLights Consortium or ENERGY STAR® qualified.

LED Open Signs

Light-emitting diodes (LED) "open" signs are eligible for incentives under this category. LED open signs must replace existing neon open signs. LED drivers can be either electronic switching or linear magnetic, with the electronic switching supplies being the most efficient. The on/off power switch may be found on either the power line or load side of the driver, with the line side location providing significantly lower standby losses when the sign is turned off and is not operating. Replacement signs cannot use more than 20% of the input power rating of the sign being replaced.

LED Channel Signs

This incentive applies to retrofitting or replacing incandescent, HID, argon-mercury or neo-lighted channel letter signs with LED channel signs. Replacement signs cannot use more than 20% of the input power of the sign that is being replaced. Maximum letter height determines credit.

Integrated Ballast Ceramic Metal Halide Lamps

Qualifying lamps are 25 watts or less integrated ballast ceramic metal halide PAR lamps with a rated life of 10,500 hours or greater. This measure must replace an incandescent lamp.

High-Efficiency HID Fixtures

This incentive applies to retrofitting fixtures to either pulse start metal halide or ceramic metal halide fixtures. Total replacement wattage must be lower than existing wattage to insure energy savings. This measure is subject to possible pre-inspection. Retrofit kits may be used on existing mercury vapor, standard metal halide or high-pressure sodium fixtures only.

Cold Cathodes

All cold cathode fluorescent lamps (CCFLs) must replace incandescent lamps of greater than or equal to 10 watts and not greater than 40 watts. Cold cathode lamps may be medium (Edison) or candelabra base. Product must be rated for at least 18,000 average life hours.

Dimmable, 3-Way and Locking- Base CFLs

Dimmable, 3-way and locking-base CFLs must replace incandescent, metal halide or other non-CFL lamps and have an efficacy ≥ 40 lumens per watt (LPW) and be ENERGY STAR® rated.

Controls: Occupancy Sensors

All lighting controls must be listed by UL- or other OSHA-approved nationally recognized testing laboratory (NRTL) in accordance with applicable U.S. standards. Passive infrared, ultrasonic detectors and fixture-integrated sensors or sensors with a combination thereof are eligible. Sensors may be hardwired or wireless if they have a minimum 10-year battery life. All sensors must control interior lighting fixtures. The incentive is per watt controlled. Incentives are also available for new fixtures with integrated occupancy controls. These fixtures must meet specifications for both new and control measures. To assist in rebate processing, an inventory of controlled fixtures MUST be submitted with the Final Application (see Watts Controlled Calculator).

Lighting Retrofit Specifications

Controls: Daylight Sensors

This incentive is for daylight sensor controls in spaces with suitable available ambient light for at least part of the day. Light may be through skylights, clerestories, windows or “light tubes”. The controls can be on/off, stepped or continuous (dimming). The on/off controller should turn off artificial lighting when the interior illuminance meets the desired indoor lighting level. The stepped controller generally dims the artificial lighting 50% when the interior illuminance levels reach 50% of the desired lighting levels. Continuous or dimming controllers dim artificial lighting proportional to the available ambient light. All types of daylight sensor controls are required to be commissioned in order to ensure proper sensor calibration and energy savings. Incentives are per watt controlled. To assist in rebate processing, an inventory of controlled fixtures MUST be submitted with the Final Application (see Watts Controlled Calculator).

New High-Efficiency T8, T5 or LED Fixtures Replacing HID Fixtures (Pre-Application Required)

This measure consists of replacing one or more existing HID fixture with new fixtures containing T8 or T5 lamps and electronic ballasts or new LED fixtures with driver. The T8 or T5 lamps must have a color rendering index (CRI) ≥ 80. High-output T8 or T5 lamps also qualify. This incentive can be used in interior high-bay, low-bay, wall and surface-mount applications. This incentive is also available for HID fixture replacement in exterior 12/7 and 24/7 applications such as canopy, wall, surface, pole/arm-mounted or exterior bollard or decorative applications. Electronic ballasts must be high-frequency (≥ 20 kHz), UL-listed and warranted against defects for 5 years. Ballasts must have a power factor (PF) ≥ 0.90. Ballasts for 4-foot lamps must have total harmonic distortion (THD) ≤ 20% at full light output. For 2- and 3-foot lamps, ballasts must have THD ≤ 32 at full light output. All LED fixtures must be DesignLights Consortium or ENERGY STAR® qualified. A pre-notification application is required for this measure to allow PNM to conduct a pre-inspection.

New LED Fixtures Replacing Linear Fluorescent Fixture (Pre-Application Required)

This measure consists of replacing one or more existing linear fluorescent fixtures with fully integrated overhead LED lighting in an interior workspace. All LED fixtures must be DesignLights Consortium or ENERGY STAR® qualified. A pre-notification application is required for this measure to allow PNM to conduct a pre-inspection.

Bi-Level LED Parking Lot or Wall Pack Fixtures (Exterior Only)

This incentive is offered for replaced HID or T12 lighting. The fixture is integrated with an occupancy sensor that allows the light to switch between high and low levels based on the presence of vehicle or pedestrian traffic. Sufficient light for security and way-finding must be maintained while maximizing energy savings. New fixture maximum wattage must be 110W or less. All LED lamps, strips or fixtures must be DesignLights Consortium or ENERGY STAR® qualified.

Compact Fluorescent Lamps, Screw-ins (> 40W) (Exterior or 24/7-Garage Only)

This incentive applies to screw-in lamps and only applies if an incandescent or high-intensity discharge (HID) lamp is replaced. Total replacement fixture wattage must be 40W or greater and have an efficacy of > 40 LPW.

High-Efficiency HID Fixtures (Exterior or 24/7-Garage Only)

Only retrofits with either pulse-start metal halide or ceramic metal halide fixtures that replace existing “standard” probe start high-intensity discharge lamps and ballasts qualify. Total replacement wattage must be 20% lower than existing wattage to ensure energy savings.

Induction Replacing HID (Exterior or 24/7-Garage Only)

This incentive is offered for the replacement of existing exterior high-intensity discharge or incandescent outdoor light fixtures or induction fixtures. Existing fixtures must operate > 3,833 hours per year (> 10.5 hours per day). Total replacement fixture wattage must be at least 30% lower than existing fixture wattage to ensure energy savings. Eligible applications include pole-mounted or canopy lighting and wall-packs. This incentive can be combined with incentives for exterior/garage bi-level control.

LED Traffic and Pedestrian Lights

This incentive is offered for LED traffic lights on a per-signal basis (including arrows) that replace or retrofit an existing incandescent traffic signal. At minimum, red and green lamps must be retrofitted to qualify for the signal incentive. Signals shall have a maximum LED module wattage of 17. Incentives are not available for spare lights. Lights must be hardwired, with the exception of pedestrian hand signals.

Bi-Level Fixtures (24/7 Garage Only)

The new fixture must be integrated with an occupancy sensor that allows the light to switch between high and low levels based on the presence of vehicle or pedestrian traffic. Switching between high and low light levels based on occupancy maintains sufficient light for security and way-finding while maximizing energy savings. The new fixture must be pulse-start metal halide, induction or LED and have lower nominal wattage than the existing fixture. The reduced wattage lamp must operate at a wattage that is at least 30% lower than the full output lighting wattage level. LED equipment specifications as discussed in the LED specifications apply. No additional incentives for this measure can be claimed when applying for this incentive. Incentive is per fixture. All LED lamps, strips or fixtures must be Design-Lights Consortium or ENERGY STAR® qualified.

Bi-Level Stairwell/Hall/Garage Fixtures with Integrated Sensors (24/7 Only)

This incentive is for hardwired two-lamp T8 fluorescent fixtures with electronic ballasts and manufacturer-integrated occupancy sensors used in areas where lighting operates 24 hours a day (such as stairwells, halls and garages). Fixtures with manual override capabilities are not eligible. During occupied periods, the fixture should operate at full light output. The fixture must operate at a wattage that is at least 30% lower than the full output lighting wattage level. This measure is not eligible for the occupancy sensor incentive also. Note: PCB ballasts and lamps are hazardous materials and should be properly disposed.

IMPORTANT!

LED Lighting

The integral lamp or fixture <u>must</u> appear on one of the following lists:

- **ENERGY STAR® Qualified Products List** energystar.gov/index.cfm?fuseaction=ssl.display_products_com_html
- **DesignLights Consortium Qualified Products List** designlights.org

HVAC Incentives- Values Based on CEE Tier 2 Efficiencies

Link to Specifications

Equipment Type	Size Category	Qualifying Efficiency	Incentive (Per Ton)	Efficiency Bonus[1,2]
Unitary and Split Air Conditioning Systems and Air Source Heat Pumps	< 65,000 Btu/h (5.4 tons)	14 SEER	$15.00	$10.00
	≥ 65,000 Btu/h and < 135,000 Btu/h (5.4-11.25 tons)	12 EER[3]/13.8 IEER	$20.00	$10.00
	≥ 135,000 Btu/h and < 240,000 Btu/h (11.25-20 tons)	12 EER[3]/13 IEER		
	≥ 240,000 Btu/h and < 760,000 Btu/h (20-63 tons)	10.6 EER[3]/12.1 IEER		
	≥ 760,000 Btu/h (> 63 tons)	10.2 EER[3]/11.4 IEER		
Chillers: Water-Cooled, Centrifugal	< 150 tons	0.60 kW/ton-IPLV	$15.00	$10.00
	≥ 150 tons and < 300 tons	0.54 kW/ton-IPLV		
	≥ 300 tons	0.49 kW/ton-IPLV		
Chillers: Water-Cooled, Scroll	< 150 tons	0.61 kW/ton-IPLV		
	≥ 150 tons and < 300 tons	0.57 kW/ton-IPLV		
	≥ 300 tons	0.51 kW/ton-IPLV		
Chillers: Water-Cooled, Reciprocating	ALL	0.63 kW/ton-IPLV		
Chillers: Air-Cooled	ALL	1.04 kW/ton-IPLV	$30.00	$15.00
PTAC/PTHP	ALL	13.08-(0.2556 x Btu/h/1000) EER	$20.00	N/A

Equipment Model	Tons	Equipment Efficiency Rating	Quantity	Equipment Type	Size Category	Incentive
Total HVAC Incentives						

Equipment Type	Incentive Unit	Unit Size (ton)	Quantity	Incentive/ HP	Incentive
Guest Room Energy Management System					
Hotel Guest Room Occupancy Sensor	Per Ton Per Room			$80.00	
Hotel Guest Room Occupancy Sensor	Per Ton Per Room			$80.00	
Hotel Guest Room Occupancy Sensor	Per Ton Per Room			$80.00	
Total GREM Incentives					
Total All HVAC Form Incentives					

[1]For unitary and split systems, Efficiency Bonus = $ / ton / 0.1 EER/IEER improvement over baseline.
[2]For chillers, Efficiency Bonus = $ / ton / 0.01 IPLV improvement over baseline (IPLV = integrated part load value).
[3]Units with electric resistance heating must have EER values 0.2 higher than the efficiencies listed.

HVAC Specifications

Link to Worksheet

Unitary and Split Air Conditioning Systems and Air Source Heat Pumps

New unitary air conditioning units or air source heat pumps that meet or exceed the qualifying cooling efficiency shown in the HVAC incentive worksheet table are eligible for an incentive. They can be either split systems or single package units.

The efficiency of split systems is based on an AHRI (Air-Conditioning, Heating and Refrigeration Institute) reference number. Water-cooled systems, evaporative coolers and water-source heat pumps do not qualify under this program, but may qualify under the custom incentive program. All packaged and split system cooling equipment must meet AHRI standards (210/240, 320 or 340/360), be UL listed or use a minimum ozone-depleting refrigerant (e.g., HCFC or HFC). All required efficiencies are based on the Consortium for Energy Efficiency (CEE) high-efficiency commercial air conditioning and heat pump specifications (cee1.org). A manufacturer's specification sheet indicating the system efficiency must accompany the application. Disposal of the existing unit must comply with local codes and ordinances.

Water- and Air-Cooled Chillers

Chillers are eligible for an incentive if they have a rated kW/ton for the integrated part load value (IPLV) that is less than or equal to the qualifying Level 1 and Level 2 efficiency shown in the table below. The chiller-efficiency rating must be based on ARI Standard 550/590-2003 for IPLV conditions and not based on full-load conditions. The chillers must meet ARI standards 550/590-2003, be UL listed and use a minimum ozone-depleting refrigerant (e.g., HCFC or HFC). The ARI net capacity value should be used to determine the chiller tons. A manufacturer's specification sheet with the rated kW/ton-IPLV or COP-IPLV must accompany the application. Qualifying efficiencies for chillers are summarized below.

Chiller Type	Size (Tons)	kW/ton IPLV
Scroll or Helical-Rotary	< 150	0.61
	150 to < 300	0.57
	≥ 300	0.51
Centrifugal	< 150	0.60
	150 to < 300	0.54
	≥ 300	0.49
Reciprocating	ALL	0.63
Air-Cooled	ALL	1.04

Package Terminal Systems (Replacements)

Package terminal air conditioners and heat pumps are through-the-wall, self-contained units that are 2 tons (24,000 Btu/h) or less. All EER values must be rated at 95°F outdoor dry-bulb temperature.

Hotel Guest Room Occupancy Sensors

Incentives are offered for occupancy-based controls that regulate cooling-only HVAC units for individual hotel rooms. Sensors must be controlled by automatic occupancy detectors or a key-card system, and the default setting for controlled units must differ by at least 5 degrees (or shut the unit fan and heating or cooling off completely) from the operating set point during unoccupied periods. The incentive is per room controlled, not per sensor. The control system also may be tied into other electric loads, such as lighting and plug loads, to shut them off when occupancy is not sensed. Replacement or upgrades of existing occupancy-based controls are not eligible as a prescriptive incentive.

Refrigeration Incentives

Link to Specifications

Measures	Incentive Unit	Incentive/Unit	# of Units	Incentive
Strip Curtains on Walk-Ins and Freezers	Square Foot	$3.00		
Night Covers for Displays	Linear Foot of Case	$5.00		
EC Motor for Reach-In Refrigerator or Freezer Cases	Motor	$25.00		
Evaporator Fan Controller - Shade-Pole Motor	Motor	$40.00		
Anti-Sweat Heater Controls	Linear Foot of Case	$20.00		
LED Refrigeration Case Lighting	Door	$40.00		
ENERGY STAR® Solid-Door Freezer	Unit	$100.00		
ENERGY STAR® Glass-Door Freezer	Unit	$350.00		

EC Motors for Walk-In Coolers and Freezers			
Size / Control Combo	**Incentive**	**Size / Control Combo**	**Incentive**
16 watt; motor only	$ 35.00	16 watt w/ controls	$ 45.00
1/15-1/20 hp; motor only	$ 70.00	1/15-1/20 hp w/ controls	$ 90.00
1/5 hp; motor only	$ 135.00	1/5 hp w/ controls	$ 170.00
1/3 hp; motor only	$ 210.00	1/3 hp w/ controls	$ 270.00
1/2 hp; motor only	$ 300.00	1/2 hp w/ controls	$ 400.00
3/4 hp; motor only	$ 400.00	3/4 hp w/ controls	$ 550.00

Size	Control	Unit	Incentive/Unit	# of Units	Incentive
		Motor			
		Motor			
		Motor			
		Motor			
Total Refrigeration Incentives					

High-Efficiency Ice Makers				
Capacity	**Installed kWh per 100 lbs.**	**Incentive/Machine**	**# of Units**	**Incentive**
101-200 lbs./24 hours	Unit	$100.00		
201-300 lbs./24 hours	Unit	$100.00		
301-400 lbs./24 hours	Unit	$100.00		
401-500 lbs./24 hours	Unit	$100.00		
501-1,000 lbs./24 hours	Unit	$225.00		
1,001-1,500 lbs./24 hours	Unit	$350.00		
>1,500 lbs./24 hours	Unit	$400.00		
Total High-Efficiency Ice Makers Incentives				

Refrigeration Specifications

Link to Worksheet

Strip Curtains on Walk-In Coolers and Freezers

New strip curtains or clear plastic swinging doors must be installed on doorways of walk-in boxes and refrigerated warehouses. This incentive is not available for display cases or for the replacement of existing strip curtains that have useful life left. A pre-inspection may be performed. Incentive is based on square footage of doorway.

Night Covers for Displays

This measure supports the installation of a cover on open vertical or horizontal refrigerated cases to decrease cooling load. Installing films with small, perforated holes to decrease moisture buildup is recommended. The use of proper compressor capacity modulation mechanisms (such as VSDs or unloaders) also is recommended. Incentive is based on the length of the case.

Electrically Commutated Evaporator Fan Motor (Refrigerated Cases or Walk-Ins)

ECMs must be certified for operation in intended end-use environment, and supplied the correct voltage and match the existing (replaced) fan motor with regard to horsepower, rotation and high-speed airflow. If changing fan blades with the evaporator ECM change out, the new blade/s shall provide air flow equal to the coil manufacturer's specifications. Matched high-performance blades with reduced H.P. ECMs may be exempt from motor horsepower and fan blade requirements. Program administrators must review project prior to installation.

Evaporator Fan Controllers for Non-EC Motors

This measure applies to the installation of controls on shade-pole or permanent split capacitors (PSC) in medium-temperature walk-in coolers. The controller reduces airflow of the evaporator fans when there is no refrigerant flow. The measure must control a minimum of 1/20 HP, where fans operate continuously at full speed. The measure also must reduce fan motor power by at least 75% during the off cycle.

This measure is not applicable if any of the following conditions apply:

1. The compressor runs continuously on high-duty cycle.
2. The evaporator fan does not run continuously at full speed.
3. The evaporator fan motor runs on poly-phase power.
4. The evaporator fan motor is not shaded-pole or permanent split capacitor (PSC).
5. Evaporator does not use off-cycle or time-off defrost.

Evaporator Fan Controllers for EC Motors

The EC fan motor controller will have a coil sensor (temperature sensor) that prevents ice accumulation on the evaporator coil. The existing site voltage will match the controller's required input voltage. The controller will maintain a refrigerated box temperature of no less than 41º F unless the refrigerated box is for special use i.e. floral case. The actual set temperature may be decided by on-site staff. The controller will maintain a freezer box temperature of no less that 10ºF. On-site staff may decide the actual set temperature. The total amp requirement of all evaporator fans will not exceed the controllers rated value. The controller may allow for minor adjustments of temperature no less than 35º F and no more than 41º F, unless the refrigerated box is for special use, i.e. floral case.

Upon failure, the controller will allow the evaporator fans to function at high speed full time. Upon controller failure, temperature control will revert to the preexisting temperature control. The controller should either indicate a failure by flashing light and/or sound or be accompanied by a mounted and visible description of failure conditions and contact information. The controller must be rated to match and exceed the total amp load requirement. The controller shall not operate at more than 90% of maximum amperage capacity.

Anti-Sweat Heater Controls (ASH)

The ASH controller will maintain an adequate door frame temperature to prevent the accumulation of condensation on door frame or mullion. The ASH controller will monitor the humidity and temperature (dew point) outside of the refrigerated device. The controller will maintain the coldest temperature possible without causing the formation of condensation. No temperature sensors shall be mounted in or on any controlled door. If a single controller simultaneously controls heaters on a refrigerator and freezer, the controller must have the means to control each device separately.

Upon failure, the controller will default to full on. The heaters will become 100% active. The controller will indicate a failure by flashing light and/or sound, or send notice of failure via email, text or similar notification. The controller must be rated to match and exceed the total amp load requirement, and shall not operate at more than 90% of maximum amperage capacity.

Refrigeration Specifications

LED Refrigeration Case Lighting

This measure consists of replacing fluorescent refrigerated case lighting with light emitting diode (LED) source illumination. Only 5′ or 6′ LED light bars are eligible. The LED lighting must meet Design Lights Consortium specifications summarized in the table below.

<table>
<tr><th>Minimum Light Output</th><th>Zonal Lumen Density</th><th>Minimum Luminaire Efficacy</th><th>Allowable CCTs (ANSI C78.377-2008)</th></tr>
<tr><td>Center-mounted: >=100 lm/ft
End-mounted: >= 50 lm/ft</td><td>>=95%
0º-80º</td><td>35 lm/W</td><td>2700K, 3000K, 3500K, 4000K, 4500K and 5000K</td></tr>
<tr><th>Minimum CRI</th><th colspan="2">Minimum LED Lumen Maintenance at 6,000 Hrs</th><th>Minimum Luminaire Warranty</th></tr>
<tr><td>70</td><td colspan="2">95.80%</td><td>5 years</td></tr>
</table>

ENERGY STAR® Solid- or Glass-Door Freezers

Incentives are offered for the replacement of existing self-contained, open-display freezers with ENERGY STAR listed freezers. Only units with built-in refrigeration systems qualify. Units with remote refrigeration systems or units do not qualify. Customers must provide proof that the appliance meets the CEE-efficiency or ENERGY STAR efficiency specifications using ASHRAE Standard 72-2005 (38°F ± 2°F). Incentive is per freezer.

Efficiency Standards for ENERGY STAR Qualified Commercial Glass-Door Freezers (kWh per day)

Product Volume, Cubic Feet	Freezer (kWh/day)
$0 < V < 15$	$\leq 0.607V + 0.893$
$15 \leq V < 30$	$\leq 0.733V - 1.000$
$30 \leq V < 50$	$\leq 0.250V + 13.500$
$50 \leq V$	$\leq 0.450V + 3.500$

energystar.gov, Note: V = internal volume in ft^3

ENERGY STAR Qualified Commercial Solid-Door Freezers (kWh per day)

Product Volume, Cubic Feet	Freezer (kWh/day)
$0 < V < 15$	$\leq 0.250V + 1.250$
$15 \leq V < 30$	$\leq 0.400V - 1.000$
$30 \leq V < 50$	$\leq 0.163V + 6.125$
$50 \leq V$	$\leq 0.158V + 6.333$

energystar.gov, Note: V = internal volume in ft^3

High-Efficiency Ice Makers

The incentive covers ice machines that generate 60 grams (2 oz.) or lighter ice cubes, flaked, crushed or fragmented ice. Only air-cooled machines qualify (self-contained, ice-making heads or remote condensing). The machine must have a minimum capacity of 101 lbs. of ice per 24-hour period (per day). The minimum efficiency required is per ENERGY STAR or CEE Tier 2.6 (cee1.org). A manufacturer's specification sheet that shows rating in accordance to ARI standard 810 must accompany the application.

Food Service Equipment Incentives

Measures	Incentive Unit	Incentive/Unit	# of Units	Incentive
ENERGY STAR® Steam Cookers	Unit	$400.00		
Combination Ovens	Unit	$800.00		
ENERGY STAR® Hot Holding Cabinets - ½ Size	Unit	$200.00		
ENERGY STAR® Hot Holding Cabinets - ¾ Size	Unit	$300.00		
ENERGY STAR® Hot Holding Cabinets - Full Size	Unit	$400.00		
ENERGY STAR® Beverage Vending Machines	Unit	$80.00		
Total Food Service Equipment Incentives				

Food Service Equipment Specifications

Steam Cookers

Installed steam cooker must be ENERGY STAR® listed. The commercial steam cooker shall have a tested heavy-load potato-cooking energy efficiency of > 50% utilizing ASTM Standard F1484.

Pan Capacity	Idle Rate (Watts)
3-pan	400
4-pan	530
5-pan	670
≤ 6-pan	800

Combination Ovens

The oven shall meet or exceed a heavy-load cooking energy efficiency of > 60% utilizing ASTM Standard F1639.

Hot Holding Cabinets

Installed hot holding cabinet must be a qualifying ENERGY STAR® listed unit. This measure does not include cook-and hold equipment. All measures shall be electric hot-food holding cabinets that are fully insulated and have solid doors in full, three-quarter and half sizes respectively. Qualifying cabinets shall not exceed the maximum idle energy rate of 20 watts per cubic foot in accordance with the ASTM Standard F2140 test method as stated by ENERGY STAR.

ENERGY STAR® Beverage Vending Machines

ENERGY STAR beverage vending machines qualify for an incentive. Qualifying machines can be found at energystar.gov/index.cfm?fuseaction=find_a_product.showproductgroup&pgw_code=VMC.

Motors Incentives

Link to Specifications

Premium-Efficiency Motors - Minimum Qualifying Efficiencies

Horsepower	1200		1800		3600		Incentive per 0.1% Efficiency Improvement Over Baseline Efficiencies
	Open	Closed	Open	Closed	Open	Closed	
1	82.5%	85.5%	77.0%	82.5%	85.5%	77.0%	$1.00
1.5	86.5%	86.5%	84.0%	87.5%	86.5%	84.0%	$2.00
2	87.5%	86.5%	85.5%	88.5%	86.5%	85.5%	$2.00
3	88.5%	89.5%	85.5%	89.5%	89.5%	86.5%	$3.00
5	89.5%	89.5%	86.5%	89.5%	89.5%	88.5%	$4.00
7.5	90.2%	91.0%	88.5%	91.0%	91.7%	89.5%	$9.00
10	91.7%	91.7%	89.5%	91.0%	91.7%	90.2%	$10.00
15	91.7%	93.0%	90.2%	91.7%	92.4%	91.0%	$11.00
20	92.4%	93.0%	91.0%	91.7%	93.0%	91.0%	$12.00
25	93.0%	93.6%	91.7%	93.0%	93.6%	91.7%	$15.00
30	93.6%	94.1%	91.7%	93.0%	93.6%	91.7%	$17.00
40	94.1%	94.1%	92.4%	94.1%	94.1%	92.4%	$20.00
50	94.1%	94.5%	93.0%	94.1%	94.5%	93.0%	$24.00
60	94.5%	95.0%	93.6%	94.5%	95.0%	93.6%	$25.00
75	94.5%	95.0%	93.6%	94.5%	95.4%	93.6%	$30.00
100	95.0%	95.4%	93.6%	95.0%	95.4%	94.1%	$40.00
125	95.0%	95.4%	94.1%	95.0%	95.4%	95.0%	$50.00
150	95.4%	95.8%	94.1%	95.8%	95.8%	95.0%	$60.00
200	95.4%	95.8%	95.0%	95.8%	96.2%	95.4%	$75.00

Motor Make/ Model	Quantity	Motor Size (HP)	Motor Speed (RPM)	Motor Type (Open/ Closed)	Baseline Efficiency	Actual Motor Efficiency	Total Incentive
Total Motors Incentives							

Variable Speed Drive on HVAC Motors Incentives[1]

VSD Application Description	VSD Size (HP)	Incentive Unit	Incentive/ Unit	Quantity	Incentive ($50/HP)
		per HP	$50.00		
		per HP	$50.00		
		per HP	$50.00		
		per HP	$50.00		
		per HP	$50.00		
		per HP	$50.00		
		per HP	$50.00		
		per HP	$50.00		
Total VSD Incentives					

Motors and VSDs Specifications

NEMA Premium-Efficiency Motors

Prescriptive incentives are available for open drip proof (ODP) and totally enclosed fan cooled (TEFC) three-phase AC-induction general-purpose electric motors (subtype I) from 1 to 200 HP that exceed federal regulations. Incentives are based on the motor's nominal full-load efficiencies, tested in accordance with IEEE Standard 112, method B. The application must include the manufacturer's performance data sheet that shows motor type, horsepower, model number and full-load nominal-efficiency rating. Customers should consider matching RPMs of the existing pump or fan when installing energy-efficient motors that inherently have higher speeds (less slip), which may affect electric energy use.

Variable Speed Drives on Fan and Pump Applications

Variable speed drives (VSDs) installed on HVAC fans or pumps are eligible for this incentive. The installation of a VSD must accompany the permanent removal or disabling of any flow control devices such as inlet vanes, bypass dampers and throttling valves to be eligible.

Other requirements include:

- Rated motor horsepower < 200 HP
- Does not apply to redundant or backup/standby motors that are expected to operate less than 1,200 hours per year.
- Does not apply to variable pitch fans and forward curve with inlet guide vanes, unless applicant supplies proof of kWh savings from logged or measured data.
- Does not apply to replacement of a multispeed motor.
- Does not apply to VFDs on new chillers (existing chillers qualify under the custom program).
- Applies only to VSDs installed with an automatic control technology.

[1]The variable speed drive incentive is calculated based on the horsepower (HP) that is actually being controlled.

Building Envelope Incentives

Window Film Application Description (Existing Windows Only)	Incentive Unit	Incentive/Unit	Square Feet of Glazing	Incentive
	per square foot	$1.20		
	per square foot	$1.20		
	per square foot	$1.20		
	per square foot	$1.20		
	per square foot	$1.20		
	per square foot	$1.20		
	per square foot	$1.20		
	per square foot	$1.20		
	per square foot	$1.20		
Total Window Film Incentives				

Building Envelope Specifications

Window Film

Window film must have a shading coefficient (SC) of 0.50 or less or a solar heat gain coefficient (SHGC) of 0.40 or less. New construction buildings are not eligible for this incentive.

Plug Load Controls Incentives

Measures	Incentive Unit	Incentive/Unit	# of Units	Incentive
Beverage Vending Machine Control	Unit	$120.00		
Refrigerated Cooler Control	Unit	$80.00		
Snack Machine Control	Unit	$25.00		
Plug Load Occupancy Sensor	Sensor	$25.00		
Total Food Service Incentives				

Plug Load Controls Specifications

Beverage Vending, Snack Machine Controls

The beverage machine is assumed to be a refrigerated vending machine that contains only nonperishable bottled and canned beverages. Controller for both types of systems must include a passive infrared occupancy sensor to turn off fluorescent lights and other vending machine systems when the surrounding area is unoccupied for 15 minutes or longer. For the beverage machine, the control logic should power up the machine at 2-hour intervals to maintain product temperature and provide compressor protection.

Reach-In Cooler Controls

The reach-in cooler control is for refrigerated merchandise coolers with glass fronts. The cooler must contain only nonperishable bottled and canned beverages. The controller must include a passive infrared occupancy sensor to turn off fluorescent lights and other systems when the surrounding area is unoccupied for 15 minutes or longer. The control logic should power up the machine at 2-hour intervals to maintain product temperature and provide compressor protection.

Plug Load Occupancy Sensors

This rebate applies to passive infrared and/or ultrasonic detectors only. Plug load sensors must control electricity using equipment in offices or cubicles, including shared copiers and/ or printers.

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Retro-commissioning

Retro-Commissioning (RCx) is the process of monitoring, troubleshooting and adjusting electrical, mechanical and control systems in existing buildings.

Improve the Performance of Your Building

Your building may have met the energy codes when it was originally designed, but do you know how well it is performing now?

The purpose of the PNM Retro-Commissioning (RCx) program is to provide PNM customers the opportunity to obtain information from experts on how to improve the system efficiency of commercial buildings. Study incentives help pay for the building assessment and savings incentives help reduce the cost of implementing the findings.

RCx Tier 1 and Tier 2 Savings Rebates

The PNM RCx program offers rebates for identifying and implementing relatively low-cost operational and maintenance improvements. Click on the Rebate Application tab on the left to access the writable PDF incentive applications.

RCx Tier 1 and RCx Tier 2 energy savings are paid at 7.5¢ per kWh of one year of projected, annualized savings.

The Rebate is based on meeting the eligibility requirements and hiring a qualified RCx trade ally.

RCx Tier 1

Focus on Common Measures

Study Incentive

RCx Tier 1 study incentives are available for all projects that meet the minimum eligibility criteria. The study incentive is paid directly to the program contractor (Trade Ally), to help buy down the cost of the study, based on annual energy usage as follows:

Building Annual kWh Usage	Study Incentive
<750,000	$1,500
750,000-1,000,000	$2,000
1,000,000-2,000,000	$2,500
2,000,000-3,000,000	$3,000
3,000,000+	$3,500

RCx Tier 2

Building Optimization for Greater Savings

Larger buildings may have opportunities for a more complex RCx audit to yield even greater savings.

Study Incentive

A RCx Tier 2 study incentive of $10,000 is available to building owners whose facilities meet the minimum eligibility criteria. The study incentive is paid directly to the Trade Ally to help buy down the cost of the study. Trade Allies receive 50% of the incentive after the study is conducted and a master list of findings is reported, on the condition that the customer agrees to implement all no-cost and low-cost measures. The remaining 50% of the study incentive is paid upon receipt, review, inspection and payment of the final project application.

Customer Eligibility

RCx Tier 1
To be eligible, all of the following criteria must be met:

1) Applicant must provide PNM program team with an Energy Star Portfolio Manager benchmarking report;

2) Building must meet at least one of the following size criteria:

- Be at least 50,000 ft^2 in size, OR
- Use at least 750,000 annual kWh, OR
- Use at least 500 kW annual peak demand;

3) Customer must commit to installing all identified no-cost and low-cost measures, defined as those measures with payback of less than two years and less than $2,000.

RCx Tier 2 pre-application
To be eligible, all of the following criteria must be met:

1) Building must have direct digital controls (DDC) in place connected to a building management system (BMS);

2) Customer must commit to installing all identified no-cost and low-cost measures, defined as those measures with payback of less than two years and less than $5,000;

3) Building must meet at least one of the following size criteria:

- Be at least 100,000 ft^2 in size, OR
- Use at least 1,500,000 annual kWh, OR
- Use at least 1,000 kW annual peak demand;

4a) Customer must have participated in required RCx Tier 1 identified improvements, OR

4b) Applicant must provide PNM program team with an Energy Star Portfolio Manager benchmarking report
AND
4c) Applicant must show a minimum 5% energy savings opportunity through a documented study, most likely conducted by the firm representing the customer.

(The 4b plus 4c option allows for eligible Tier 2 buildings undergoing a more thorough RCx process or a performance contracting process to consolidate assessments into one project).

Low-Cost or No-Cost Improvements

The following are examples of the PNM RCx upgrades Tier 1 program, and are typically low- or no-cost energy efficiency measures:

1) Re-set

- Duct Static Pressure (DSP)
- Supply Air Temperature (SAT)
- Chilled Water Supply Temperature (CHWST)
- Condenser Water Supply Temperature (CWST)
- Zone Temp Deadband
- Discharge Air Temperature (DAT)

2) Optimize

- Economizer control
- Air Handling Unit (AHU) Schedule
- Lighting Schedule
- Night low limit controls
- Variable Air Volume (VAV) box operation

3) Add

- Supply Fan Variable Frequency Drive (VFD)
- Chilled Water (CHW) Pump VFD
- Lighting Controls
- Garage exhaust fan controls

Some Benefits for Your Business

- Return equipment to proper operational state
- Extend equipment service life
- Reduce maintenance and repair costs
- Improve occupant comfort

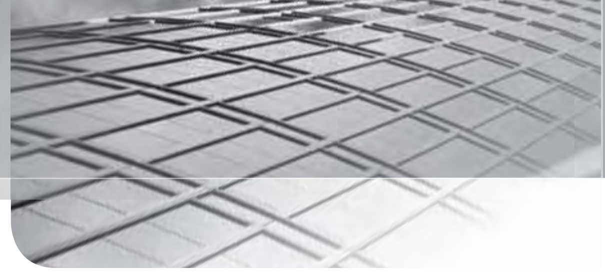
Participating PNM RCx Contractors:

B&D Industries	(505) 299-4464 x502
Bridgers & Paxton	(505) 883-4111
EEI	(505) 830-6069
Energy Control Inc./ECI	(505) 830-6069
GEW Mechanical	(505) 345-3033
Siemens	(505) 263-0028
Trane	(505) 884-2044
Vibrantcy	(505) 639-4162
WH Pacific	(505) 247-0294
Yearout Service	(505) 884-0994

Questions? Call 877-607-0741.

Appendix H –Window Film Product Information

3M™ All Season Window Film
Low E 35 Product Family



Heat In
Glare Out

Low E 35

Benefits

- Improves comfort during the cold winter months as well as during the heat of summer
- High Heat rejection helps provide energy savings in the summer
- Increased insulation helps provide energy savings in the winter
- Potential Paybacks in less than 3 years
- Reduces glare which may help improve productivity at work stations
- Helps extend the life of furnishings by significantly reducing harmful UV rays, the largest cause of fading
- Comprehensive warranty from 3M

Winter Insulation	★★★
Energy Savings	★★★★
Glare Rejection	★★

In comparison to other 3M Window Films

Best ★★★★ Better ★★★ Good ★★ Fair ★

Valued Associations & Alliances

Low E 35 Case Study

Nashville, TN

Climate Zone 3

Over 125,000 sq ft installation of Low E 35

Payback period less than 3 years

Customer Issues:

- High energy costs and consumption
- Tenant comfort issues due to direct sun

Product Performance & Technical Data

Glass Type (All 1/4")	Film Type	Visible Light			Total Solar Energy Rejected	Solar Heat Gain Coefficient	U Value	Solar Heat Reduction	UV Light Rejected	Glare Reduction	Visible Light to Solar Heat Gain Ratio
		Reflected (interior)	Reflected (exterior)	Transmitted							
Clear	Low E 35	60%	54%	30%	75%	0.25	0.85	69%	99%	67%	1.2
Tinted	Low E 35	60%	22%	17%	73%	0.27	0.85	57%	99%	67%	0.7
Double Clear	Low E 35	61%	53%	28%	68%	0.32	0.42	54%	99%	65%	0.8
Double Tinted	Low E 35	61%	22%	16%	74%	0.26	0.42	48%	99%	66%	0.6

LEED Certification

Window films may be used towards the following LEED credits:

- SS-8
- EA-1
- MR 1.1-1.2
- MR 5.1-5.2
- EQ-7.1
- EQ-7.2
- EQ-8.1-8.2
- ID

Warranty, Limited Remedy, and Disclaimer:
Many factors beyond 3M's control and uniquely within user's knowledge and control can affect the use and performance of a 3M product in a particular application User is solely responsible for evaluating the 3M product and determining whether it is fit for a particular purpose and suitable for user's method of application. Unless an additional warranty is specifically stated on the applicable 3M product packaging or product literature, 3M warrants that each 3M product meets the applicable 3M product specification at the time 3M ships the product. **3M MAKES NO OTHER WARRANTIES OR CONDITIONS, EXPRESS OR IMPLIED, INCLUDING, BUT NOT LIMITED TO, ANY IMPLIED WARRANTY OR CONDITION OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE OR ANY IMPLIED WARRANTY OR CONDITION ARISING OUT OF A COURSE OF DEALING, CUSTOM OR USAGE OF TRADE.** If the 3M product does not conform to this warranty, then the sole and exclusive remedy is, at 3M's option, replacement of the 3M product or refund of the purchase price.

Limitation of Liability:
Except where prohibited by law, 3M will not be liable for any loss or damage arising from the 3M product, whether direct, indirect, special, incidental or consequential, regardless of the legal theory asserted, including warranty, contract, negligence or strict liability.

3M Renewable Energy Division
Window Films
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St. Paul, MN 55144-1000
3M.com/windowfilm

Please recycle.

98-0150-0403-3