An Energy Audit of the Monterey Building

presented to THE UNIVERSITY OF TEXAS AT SAN ANTONIO

Final - May 2008

Nicholas B. Arnold | Architecture Intern
Michael E. Bejrowski | Mechanical Engineer Intern
Dr. Hazem Rashed-Ali | Architecture Professor
Dr. Randal Manteufel | Engineer Professor
Downtown FCMS
1. Acknowledgements – This chapter acknowledges the people involved with the project.

2. Executive Summary – This chapter is a brief overview of the entire project.

3. Project Goals – This chapter establishes the basis for the project. It describes why the project is required.

4. Building Survey Forms – This chapter deals with the creation of forms that were needed to conduct the survey.

5. Building Space Survey – This chapter deals with an analysis of the building’s spaces and envelope.

6. HVAC Survey – This chapter is an analysis of the building's HVAC system.

7. Computer Simulation – This chapter deals with the input and analysis of data in a computer simulation program.

8. Observations – This chapter lists the observations noted while physically touring the building, analyzing logged data, or thermal imagery.

9. Analysis of Utility Data – This chapter explains the analysis and discoveries of the recorded utility data.

10. Results – This chapter describes the results from the audit and the possible energy conservation measures.

11. Recommendations and Conclusions – This chapter explains the final recommendations for UTSA based on the complete energy audit.

12. Appendix – The appendix is meant to display major supporting data and be used as point of reference.
Acknowledgments

The University of Texas at San Antonio – Monterey Building Energy Audit

Acknowledgments

College of Architecture
Hazem Rashed-Ali, Ph.D., LEED AP Mentor, Architecture Professor, Co-author
Nicholas Arnold Architecture Intern

College of Engineering
Randy Manteufel, Ph.D. Mentor, Mechanical Engineering Professor, Co-author
Michael Bejrowski Mechanical Engineer Intern

Facility Services
Dave Riker Facilities, Associate Vice President for Facilities
Dagoberto Rodriguez Facilities, Managed project and handled funding
Joe Rubio Facilities, Director of Downtown Campus Facilities
Vladimir Andzic Facilities, Tech II
Dale Moore Facilities, Tech II
George Wurth Facilities, Tech II
Lynn Morehead Facilities, Manitenance Worker II
Gilbert Perez Electrician I
Matt May Facilities, Thermal Imaging
EXECUTIVE SUMMARY

The purpose of this study was to conduct a detailed energy audit for the Monterey building in the University of Texas at San Antonio’s (UTSA) Downtown Campus, with the aim of improving the energy performance of the building. The project represented a collaborative effort between UTSA’s Facilities Department, the Department of Architecture and the Department of Mechanical Engineering. The project aimed to take advantage of existing faculty expertise in the university by allowing students the departments to gain valuable experience, while providing a needed and important service to the university.

The Monterey building, with a gross floor area of approximately 92,000 ft² (8547 m²), was originally built in 1984 as an industrial/commercial facility and later purchased by the university in 2005. After several renovations and retrofits, it currently serves as the location for UTSA’s College of Architecture and other departments.

The project consisted of conducting a thorough survey of the building envelop, lighting and electrical systems, heating, ventilation and air conditioning (HVAC) systems, and other miscellaneous systems in the building. The survey results were initially used to identify problems requiring immediate attention as well as no cost/low cost energy conservation opportunities in
the building. The outcome of the project consisted of a detailed report which was presented to the university administration with the aim of identifying funding sources for implementing its outcomes.

BUILDING SURVEY FORM CREATION
The first objective of the energy audit was to conduct an entire building survey. The building envelope, lighting and HVAC were the main areas of concern when conducting the survey. To begin the process three universal forms were created to record the gathered information; A General Building Form, Building Space Survey Form, HVAC Form which can be utilized by the university for future audits.

BUILDING SPACE SURVEY
The purpose of the survey phase was to collect as much information about the current state of the building for input into the simulation software. The information collected during the physical survey of the spaces included the envelope, lighting, electrical equipment and occupancy. Another part of this phase of the audit was to collect measurements of temperature, CO₂ level, light level and humidity in several of the space types within the building using data loggers.
HVAC SURVEY
The majority of the energy usage in the building was accounted for by the HVAC system. A thorough and accurate inventory of the system had to be gathered for the simulation. Just as in the case of the building space survey, a form was created to record information about the system; however, with the HVAC survey, this form was not responsible for gathering the majority of the data. The bulk of the information came from extensive data collection using an assortment of measurement tools.

SIMULATION AND CALIBRATION
The DOE-2 derived simulation software eQUEST was used to create the model of the Monterey building. The simulation process started with the baseline model which was created in the wizard; then detailed changes were made to increase the accuracy of the model. After a satisfactory baseline model was created a thorough calibration was then conducted using monthly and then hourly utility data from the utility company.
Indoor Air Quality
The CO₂ levels present in the building were observed that the air quality in the building is a serious issue. CO₂ levels reached 2000+ ppm in many areas of the building during periods of high occupancy and would not get below 800-1000 ppm even after several hours at no occupancy. Although not necessarily an energy saving opportunity, it was an issue that had to be taken into account when developing the ECOs which dealt with the HVAC system.

RESULTS AND ANALYSIS FROM BUILDING SURVEY
During the process of conducting the survey several observations were made concerning issues that did not require a building simulation to diagnose. Some items could be fixed during the audit with the assistance of the UTSA facilities personnel, while other issues required further testing and analysis to determine a cause and/or solution. With these observations and the development of possible solutions/ECMs, the next step was to take these solutions/ECMs, plug them into the whole-building simulation and determine the energy savings.
ANALYSIS OF UTILITY DATA

Hourly utility data showed significant trends in building performance. This data was obtained from the local utility provider, who installed loggers on the main supply of power. This data could then be viewed online through the provider’s website. Based on these observations gathered from the utility data, it was found necessary to conduct more data collection to better understand the building and explain these performance trends and issues.

ENERGY CONSERVATION MEASURES

This section contains the recommended action that will give the most effective results in energy and economic savings. The overview of the savings and payback is given in Table 1, below. These are the actions that were recommended to the university after conducting the entire energy audit.

<table>
<thead>
<tr>
<th>Group</th>
<th>ECM #</th>
<th>Description</th>
<th>Energy Savings (kWh/yr)</th>
<th>Economic Savings ($/yr)</th>
<th>Payback Period (years)</th>
<th>Cost to Implement</th>
<th>Overall Payback (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lights</td>
<td>ECM1</td>
<td>T8 Bulbs</td>
<td>200,543</td>
<td>$11,845</td>
<td>10</td>
<td>$165,440</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>ECM2</td>
<td>Occupancy Sensors</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Envelope</td>
<td>ECM4</td>
<td>Remove Overhead Doors</td>
<td>12,882</td>
<td>$545</td>
<td>46</td>
<td>$165,440</td>
<td>8</td>
</tr>
<tr>
<td>HVAC</td>
<td>ECM8</td>
<td>Temperature Set-Backs</td>
<td>209,324</td>
<td>$10,470</td>
<td>7</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>ECM9</td>
<td>Pump VFDs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
CONCLUSIONS

• Payback of less than 8 years

• Energy savings of 23.7%

• Total annual savings of $22,860 after a total cost to implement the ECMs of $165,440

• Light levels improve with the installation of more efficient T8 bulbs

• Base load will decrease as a result of automatic system shut-downs during unoccupied periods

• Improved building pressurization and decreased air infiltration

• Erratic, inaccurate temperature controls are replaced with new electronic temperature controls which will also allow for the implementation of temperature set-backs

• Many building performance, safety and comfort issues were presented and possible solutions were given
Overview

An energy audit is a study which aims to:

(1) Determine how a building uses its energy

(2) Identify energy conservation measures (ECMs)

The purpose of this study was to conduct a detailed energy audit of the Monterrey building in the University of Texas at San Antonio’s (UTSA) Downtown Campus, with the aim of improving the energy performance of the building. The project represented a collaborative effort between UTSA’s Facilities Department, the Department of Architecture and the Department of Mechanical Engineering. The project aimed to take advantage of existing faculty expertise in the university by allowing students from both departments to be employed by the office of facilities to conduct the audit under the supervision of faculty from both departments. This format allowed the students to gain valuable experience, while providing a needed and important service to the university.

The Monterey building, with a gross floor area of approximately 92,000 ft² (8547 m²), was originally built in 1984 as an industrial/commercial facility. It was purchased by the university in 2005 and after several renovations and retrofits, currently serves as the location for UTSA’s College of Architecture and other
departments. There are two distinct structures that make up the Monterey building, (1) a 67,000 ft\(^2\) (6225 m\(^2\)) four-level commercial building (hereafter referred to as “Tower”), originally designed as commercial office space, now used for university faculty and staff offices and a few large design studios, and (2) a 25,000 ft\(^2\) (2323 m\(^2\)) single-level industrial warehouse (hereafter referred to as “Annex”), originally designed as a manufacturing/distribution center, now used for design studios, computer labs and more faculty offices. This radical change in function, from industrial/commercial to educational, resulted in a variety of energy performance issues/problems. These problems, along with the dated systems used in the building, whose maintenance prior to UTSA acquisition was almost nonexistent, made the Monterey building a prime candidate for this project.

![Figure 1. Southern elevation view of the Monterey building.](image)

The project consisted of conducting a thorough survey of the building envelop, lighting and electrical systems, heating,
ventilation and air conditioning (HVAC) systems, and other miscellaneous systems in the building. The survey also included a thermal imaging survey and a recording of the internal conditions in key areas of the building using data loggers. The survey results were initially used to identify problems requiring immediate attention as well as no cost/low cost energy conservation opportunities in the building. Following this, a whole-building energy simulation model was developed using the software eQUEST, and calibrated using hourly building electricity usage data obtained from the local utilities. This model was then used to conduct a detailed life cycle cost analysis of energy conservation opportunities in the building. The outcome of the project consisted of a detailed report which was presented to the university administration with the aim of identifying funding sources for implementing its outcomes.
Forms

The first objective of the energy audit was to conduct an entire building survey. The building envelope, lighting and HVAC were the main areas of concern when conducting the survey. To begin the process three universal forms were created to record the gathered information. (See Appendix A: Apparatus for complete forms) These forms included:

1. A General Building Form was created which was used to gather information such as, building name, location, manager, type, function, age, etc. Another key component of this form was a building layout figure. In this figure, a rough sketch was made showing the building footprint, building orientation and location of key exterior components (i.e. HVAC equipment, Electrical equipment, etc.)

2. A Building Space Survey Form was created which was used to collect information from all building spaces. The envelope and lighting information was gathered almost exclusively by this form. Basic HVAC data such as the amount and set points of thermostats within a space was included as well as a comments section to list observations or no-cost/low-cost opportunities.
3. An HVAC Form was created which was used to collect detailed information about the heating, cooling, ventilation and controls. Within the HVAC Form there was a section for general information, cooling plant, heating plant, air-handling system and any packaged or unitary system information. In each of the abovementioned sections information was recorded for, controls, set points, pumps, motors, etc. were recorded where appropriate.
Introduction
The purpose of the survey phase was to collect as much information about the current state of the building as possible for input into the simulation software. The survey phase, both building and HVAC, of the energy audit took 50% of the entire project time. The process of conducting the building space survey involved going into all spaces of the building and recording observations onto the Building Space Survey Forms. The information collected during the physical survey of the spaces included the envelope, lighting, electrical equipment (computers, monitors, printers, task lighting, etc.) and occupancy. Another part of this phase of the audit was to collect measurements of temperature, CO₂ level, light level and humidity in several of the space types within the building using data loggers (see Appendix A: Apparatus). Another task included in this phase of the audit was to capture thermal images in key areas of the building to learn more about the quality of the building’s envelope (see Appendix D: Thermal Images).
Envelope

One of the major components to accurately simulate the building was the proper input of the building envelope information. The largest part of the information collected from each space of the building was the information regarding the building envelope. In all areas of the building information was recorded on that particular space’s glazing area and type, door area and type, wall area and type, floor area and type and ceiling height and type. Other information about components such as insulation and construction materials had to be obtained from building maintenance staff and architectural plans.
Lighting

A large fraction of any building’s energy usage is from lighting. Lighting type, quantity and level were recorded onto the Building Space Survey Forms during the survey of the individual spaces. This information was taken and used to calculate power density for the light usage in different types of spaces. Ballast factor had to be measured in many areas as well. This was done using a power quality meter connected to the space’s light circuit and comparing the measurement to the bulb’s rating (see Appendix A: Apparatus). Another important part of collecting the lighting information was to note the type of lighting controls used in the spaces.
Electrical Equipment

Electrical equipment, particularly in office spaces where computers, monitors, printers, scanners, mini-refrigerators and copy machines were common, had to be quantified. Like most of the information collected in this phase of the audit, the majority of the useful data came from the recorded data on the Building Space Survey Forms. These forms collected information on the type, quantity and, if available, the power consumption of equipment found. In most situations the power information was not available through normal observation. To determine the power consumption of this equipment, a WattsUp! Meter was used (see Appendix A: Apparatus). By connecting the electrical device directly into the WattsUp! Meter, the actual power consumption of that electrical device could be measured. This was done using several typical electrical devices to determine accurate information about the plug load power density in typical spaces throughout the building.
Occupancy

The building occupancy relates to almost every aspect of a building simulation. One of the major advantages of software simulation tools are their ability to coordinate all the functions of building energy usage and accurately represent the performance of a building. Occupancy is one of the major independent variables that come together to calculate a building's performance. In this survey occupancy schedules were based on observations made during space surveys, common knowledge of university semester and between semester occupancy trends and the measurement of CO₂ using data loggers (see Appendix A: Apparatus). For the simulation preparation, an accurate understanding of daily, weekly and annual occupancy schedules was very important. The simulation software uses occupancy schedules to generate the usage of all building variables such as, lighting, electrical plug loads, HVAC, etc.
Thermal Imaging

Many observations were gleaned from the use of thermal imaging. The images captured were very useful in determining the quality and actual functionality of the building's insulation. If it were discovered that insulation was missing or damaged to the extent that it was allowing large quantities of heat transfer, adjustments were made to the simulation of the building to account for this. Average R-values were calculated for areas where insulation was inconsistent or missing. Thermal imaging also indicated areas of concern due to infiltration or exfiltration. (For the complete set of thermal images taken during the energy audit see Appendix D.)
Data Logging

Figure 2, which shows a graph that uses carbon dioxide levels obtained from a data logger to indicate occupancy, is an example of the use of data logging to learn more about the dynamics of a building and its spaces. When conducting the building space survey, data loggers proved most useful in determining space information such as temperature, humidity, occupancy, infiltration/exfiltration and lighting usage. For the collection of the data, the loggers were staged in a variety of different space types to provide an understanding of the characteristics of each space type. The data loggers were set at 10 min intervals for periods of approximately two weeks. Each logger was set to record the desired data, which usually included temperature, humidity, light level and CO₂. Graphs of CO₂ levels, such as the graph in Figure 2, contain useful information for determining occupancy schedules. (See Appendix C: Data, for a complete set of graphs and data.)
For the determination of infiltration/exfiltration rates, a method for estimating average values was used. The method used the same type of graph seen in Figure 2, however, to determine the rate of infiltration or exfiltration to a space, the outside air dampers were fully closed and the CO₂ decay rate, occurring when occupancy was approximately 0%, was used to estimate the amount of air changes resulting from infiltration or exfiltration in the building. This method was only valid late at night when it could be assumed that fresh air, other than that provided by infiltration or exfiltration, was not provided to the interior of the building. To get an air change rate from the graph, Equation 1 was
used which comes from a section in the 2001 ASHRAE Handbook that discusses the use of a tracer gas to determine air change rate (ASHRAE 2001). (See Appendix B: Calculations, for a complete set of calculations.)

\[ \ln C(t) = \ln C_0 - It \quad (1) \]

where

- \( C(t) \) = final concentration
- \( C_0 \) = initial concentration
- \( I \) = air change rate
- \( t \) = elapsed time
Introduction

The majority of the energy usage in the building was accounted for by the HVAC system. A thorough and accurate inventory of the system had to be obtained for the DOE-2 model. Just as in the case of the building space survey, a form was created to record information about the system; however, with the HVAC survey, this form was not responsible for gathering the majority of the data. The bulk of the information came from extensive data collection using an assortment of measurement tools. Some of these tools included, data loggers, a power quality logger, an air-flow meter, a fluid-flow meter, thermocouples and current loggers. (See Appendix A for the project apparatus.) The simulation software inputs large amounts of information by default. In some simulations, such as a future building design or a less detailed analysis, this may be acceptable; however, in this detailed energy audit, every bit of data we could obtain was gathered and used to increase the accuracy of the whole-building simulation.
HVAC Survey

System Overview

Tower

Figure 3 shows a rough layout of the mechanical equipment in the Tower. The overall layout of the system in the Tower was a single-duct, variable air volume (VAV) system with cooling supplied by two 1.56 MBtu/h (457 kW) chillers. Heating was supplied by perimeter zone electric reheat coils with parallel booster fans. The air distribution was accomplished by two 576,000 Btu/hr (169 kW) air-handlers (AHUs) that supply approximately 16,000 cfm (7.55 m³/s) each. Outside-air (OA) was supplied by a large intake louver located inside the mechanical room on a perimeter wall. Control of the OA intake was nonexistent at the time of the survey and remained at 0%. Return air flowed through the plenum and was not fan controlled. The core zones had standard single-duct VAV boxes without any heating capability, while the perimeter zones had standard single-duct VAV boxes with electric heat coils. Each perimeter VAV box supplied heat to the space with a parallel booster fan. When a zone called for heat the VAV box first cut the flow of cold air from the AHUs and then subsequently turned on the booster fan and heating coil. During a call for heat, the core zone VAV boxes cut off the flow of cold air and relied on the perimeter zones for heating capacity. The controls for the system were all pneumatic and the
thermostats were all reverse-acting. The pressure in the pneumatic system was maintained by a dual motor air compressor. The AHUs were controlled by VFDs.

Figure 3. Second Floor layout of the Tower HVAC System.
Annex

Figure 4 shows the basic layout of equipment in the Annex. The Annex’s system was completely different from the Tower’s. The cooling was supplied by the same chilled water loop that fed the Tower; however, just at the entrance to the mechanical room in the Tower, the chilled water split off in two directions. One pipe fed the Tower AHUs and the other pipe went to the Annex to feed twenty-two 48,000 Btu/h (14.1 kW) ceiling-mounted, single-zone, fan-coil units. Attached to the duct, just at the air outlet of each fan-coil unit, was an electric reheat coil for heating. In addition to the fan-coil units in the Annex, there were six 36,000 Btu/h (10.6 kW) DX units. These units did not provide any heating or OA intake. The controls for the system were pneumatic, other than the six DX units which used electric thermostats. Each fan-coil unit had its own thermostat, chilled-water valve and heater coil. There was no OA intake in the Annex and return air was fed directly.
Figure 4. Layout of the Annex HVAC System
Introduction

Figure 5 shows a screen-shot of the building modeled in eQUEST®. The DOE-2 derived simulation software eQUEST® was used to create the model of the Monterey building. The simulation process started with the Design Development Wizard. Once the baseline model was created in the wizard, detailed changes were made to increase the accuracy of the baseline model. After a satisfactory baseline model was created in the detailed mode, a thorough calibration was then conducted using monthly and then hourly utility data from the utility company. Once an accuracy of within 3-5% was achieved on monthly and hourly usage, the calibration process was complete and the evaluation and analysis of ECMs could begin. The modeling and analysis phase of the energy audit took 50% of the total project time.

Figure 5. Screen-shot of Monterey building model in eQUEST®.
Computer Simulation

Design Development Wizard

**Design Development Wizard**

Within the Design Development Wizard the basic building information was inputted using the data gathered during the survey phase of the audit. The building was modeled as five separate shells, one for each of the levels of the Tower and one for the Annex. Each shell was set up separately and all of the appropriate information was filled in. The footprints and zones were sketched in using imported AutoCAD® plans. The HVAC systems were all created in the wizard separately. To account for the multiple units throughout the Annex, separate zones were created for each fan-coil and DX unit. Once all of the systems were set up, they were all assigned to their respective zones.
Detailed Mode

Upon completion of the wizard the model was switched over to the detailed mode. The first order of business at that point was to input all of the detailed schedules. Detailed schedules were created for occupancy, lighting, plug-loads and heating and cooling design days. Once created, the schedules were assigned to their respective zones. After the detailed schedules were created, several detailed changes were then made to the building envelope and HVAC system. Most of these changes were things that were known to be mistakes in the wizard mode, but could not be changed or accounted for at the time. Since the detailed mode is much more specific and provides much more adjustment capability, it allowed for tremendous accuracy in our model.
Calibration

Figure 6 shows a sample screen-shot of the electric consumption summary report from eQUEST®. Along with this report comes a very detailed report of the building model (see Appendix B: Simulation Images). These reports were compared with utility bills and hourly data obtained from the utility company in order to ensure the model was accurately representing the building. The calibration process was a time consuming process that involved comparing the model consumption with actual data, going back to the model to make necessary modifications and then re-comparing the consumption. This back-and-forth process continued until the building was within an acceptable amount of accuracy when compared to all monthly and hourly utility data. Once this threshold was reached, the evaluation and analysis of ECMs could begin.

![Electric Consumption Chart]

*Figure 6. Screen-shot of a sample electricity usage summary from eQUEST®.*
**Introduction**

During the process of conducting the survey several observations were made concerning issues that did not require a building simulation to diagnose. Some items could be fixed during the audit with the assistance of the UTSA facilities personnel, while other issues required further testing and analysis to determine a cause and/or solution. The greatest benefit of these observations was how they initiated the development of almost all of the ECMs. With these observations and the development of possible solutions/ECMs, the next step was to take these solutions/ECMs, plug them into the whole-building simulation and determine the energy savings.
Indoor Air Quality

Figure 2 shows a graph of the CO₂ levels present in a studio in the Annex. From graphs like the one in Figure 2, spot measurements taken during the survey of spaces and knowledge of the lack of any OA intake into the Monterey building, it was quickly determined that the air quality in the building was a serious issue. CO₂ levels reached 2000+ ppm in many areas of the building during periods of high occupancy and would not get below 800-1000 ppm even after several hours at no occupancy. In a properly ventilated space the CO₂ level should reach the same concentration as the concentration of the air outside the building, which was between 400 and 600 ppm. Although not necessarily an energy saving opportunity, it was an issue that had to be taken into account when developing the ECMs which dealt with the HVAC system.

Figure 7 shows a graph of the same data seen in Figure 2, however, the natural log of the CO₂ data has been calculated in order to determine the air-changes using Equation 1. The underlined number indicates the amount of air-changes per hour (ACH) in that space once the occupants had left the space. The value indicated by the graph, of 0.81 ACH, is much lower than the minimum recommended value of 4 ACH.
Therefore, when developing solutions for saving energy in the Monterey building, the indoor air quality was addressed as a health and safety issue. By simply introducing OA ventilation to the building at any amount will improve the air-quality throughout the building.

Figure 7. A graph of the natural log of the carbon dioxide level versus time with an equation indicating the amount of air changes per hour. The underlined values is the air changes per hour.
Observations

Envelope

Envelope
The most impacting evidence of envelope issues came from thermal images (see Appendix D: Thermal Images, for complete set of thermal images). Thermal barrier and building leakage issues were easily detected from the images captured. Some of the specific observations made were, missing insulation in 25% of all exterior walls in the Annex, severe leakage at all exterior doors in the Monterey building, especially the overhead doors in the Annex, and several locations, particularly in the Annex, where holes or pipes through walls had not been properly insulated or sealed. Figure 8 shows example of many of these issues. In the development of the ECMs, solutions were created to address some of these concerns. Many require little or no cost to implement, for example, properly sealing doors with weather stripping.

Figure 8: Thermal image of a studio indicating large amounts of infiltration around the doors, missing insulation and leaks through holes in the wall.
Lighting

When conducting the survey of the building spaces, many issues were identified quickly when looking at the building's lighting systems. Three main areas of concern were (1) the type of lights being used, (2) the low light levels throughout the building and (3) the lack of lighting controls, resulting in many areas with lights on when they were not needed. Since lighting typically accounts for 30% of a building's base load, these were priority issues addressed in the development of ECMs.

The lights that were in place throughout the Monterey building were primarily T12 type fluorescent bulbs with magnetic fixtures. After measuring the ballast factors of many spaces using the power quality meter, it was found that these magnetic fixtures use almost 5% more power than required by the bulbs, while the electric ballast equivalent used about 5% less than the bulbs required. It was also observed that the T12 bulbs, in the Annex for instance (8 ft – T12), use 27% more power than the T8 equivalent.

By changing lighting types, a large savings could be achieved. Average light levels in the building were found to be much lower than necessary for the function of the Monterey building. Most areas were around 20 lumen/ft² (215 lumen/m²), while many key areas were much lower. When developing the ECMs for lighting, this was a priority concern, although not necessarily an
energy saver. For the spaces in the Monterey building, which include tasks such as reading, writing, drafting, architectural design, etc…, the minimum light levels should be at 46-186 lumen/ft² (500-2000 lumen/m²) depending on the task. This could be achieved through the proper amount and placement of lights as well as through the use of task lighting devices.

Figure 9 shows a graph of the light level and CO₂ in a space in the Monterey. However, it is important to note that the graph is not used to identify light level within the space due to the meters orientation in the space. What the graph in Figure 8 does indicate are the periods when lights are on or off (indicated by light intensity) and when people are present or not (indicated by CO₂ concentration). In the 24 hour period shown in this graph the lights were only off for 3 hours while it appears that the space was only occupied for 8 hours. This indicates that the lights could have been off for 13 additional hours. That equates to a possible energy savings of 56.5 kWh in this space alone. Carry that out over a month and that comes out to more than a days worth of energy for the entire Annex.

While conducting the building survey, no lighting controls systems were found in the Monterey building. On several occasions a space’s lights were completely illuminated while there were no occupants present in the space, as seen in Figure 8.
Although the university does have an active “lights-off” policy, the lights continue to be left on wasting large amounts of energy. ECMs addressing this issue were developed to save that energy.

Figure 9. Graph showing light activation with carbon dioxide, indicating need for lighting controls.
HVAC Controls

During the building space surveys and the HVAC survey many obvious issues were identified with the HVAC system. As mentioned before, air-quality and proper ventilation was a major concern regarding health and comfort for the occupants. While these issues are very important, they did not address any opportunity for energy savings. One obvious area where possible energy savings were identified involving the HVAC system was controls. As stated previously, the controls in the Monterey building are pneumatic. When properly set-up and maintained, pneumatic controls can be an effective means of controlling an HVAC system; however, prior to UTSA acquisition in 2005, the system was not maintained properly and was not set-up for the function that it serves today. Some of the major problem areas included the thermostats, control valves, control system air leakage, erratic or improper heat activation and the extreme inaccuracy or non-existence of controls in many areas.

Figure 10 gives one example of several of these issues. The graph contains 24 hours of a space’s temperature along with the electrical current of the heater coil. The first thing indicated by the graph was that the space never reaches its temperature set-point of 74 °F (23 °C). The next thing that the graph shows was how erratically and ineffectively the heater coil was being controlled. With a
heater like the one shown in Figure 10, the unit can be heard “clicking” on and off constantly while the room is still not reaching the proper temperature. This is one example of how the system was malfunctioning at one fan-coil unit in the Annex. A common reaction by many uncomfortable occupants is to remove the lock-box and cover from the pneumatic thermostat and wind the temperature dial all the way in one direction or the other. This common reaction by the occupant causes much more unintentional harm to the system by damaging the bimetalic strip that moves the small valve one way or the other to control the system. To add to the problem, the majority of the chilled water valves on the fan-coil units, such as the one graphed in Figure 10, are not operating properly either. Most of them were either rotted out and broken or disconnected from their control air hose, causing many areas to experience full cooling and full heating simultaneously. Many other types of issues and scenarios, like the one given here were seen throughout the building. One thing was certain, no matter what may be the problem, the system is not effectively controlling the HVAC system and large quantities of energy were being lost as a result.
Figure 10. Shows a graph of a studio in the Annex that has a typical problem with its controls system.
Incomplete Renovations

The Monterey building was not always an academic facility and therefore it required several renovations in order to meet the needs of the university. During the course of these renovations, it was apparent during the survey that many things were left incomplete. The issues identified as a result of these renovations are areas where the building performance could be improved.

The first and most significant of these issues was in the Annex. The Annex was originally designed and used as an industrial type building and is referred to in the building plans as the “Manufacturing” building. It has 17 ft (5.18 m) metal ceilings that extend all the way to the roof. On both the North and the South sides of the building (the long sides) there are overhead “garage” doors that were originally used to load and unload trucks. All mechanical and electrical equipment is exposed since there is no type of dropped ceiling. Today the Annex contains several large architectural design studios, galleries, offices and computer labs. There have been many renovations and retrofits to get it to where it is today, but more could be done that would improve the overall performance and user-friendliness of the building. The garage doors leak large amounts of air, as seen in the thermal images, and the exposed mechanical equipment is noisy and distracting to the students. The Annex would benefit in many ways from the
Observations
Renovations

installation of a typical acoustic tile ceiling and the replacement of
the overhead doors with windows or an insulated wall.

Another issue seen throughout the Monterey building was related
to completed renovation projects where the mechanical systems
were not properly adapted to the new spaces. In several areas a
renovation project would consist of simply putting up walls to
redefine spaces and resize offices. These projects would result in
diffusers being located on top of walls, spaces not receiving the
proper amount of air, zoning issues with lights and HVAC,
improper location of thermostats, ducts being disconnected from
diffusers so that air was not reaching the space and closets or
unoccupied spaces receiving HVAC that do not require it. In the
Annex, room 1.103 B contains eight separate units conditioning air
in the space, each with its own thermostat. Since the thermostats
were also not set to the same temperature, none of the units were
able to meet their set-points and would remain running
constantly. Many of these issues are things that are easy to fix
while some of them are more difficult to address. They all add up
to significant savings of energy and improvements in
performance.
Introduction

Hourly utility data, as seen in Figure 11, showed significant trends in building performance. This data was obtained from the local utility provider, who installed loggers on the main supply of power to both the Annex and the Tower. This data could then be viewed online through the provider’s website. These graphs showed areas of concern that included, a low power factor in the Annex, high base demand in both buildings and an odd, flat shaped, load profile for the Annex. Based on these observations gathered from the utility data, it was found necessary to conduct more data collection to better understand the building and explain these performance trends and issues.
Annex Power Factor

Figure 11 shows the power factor and apparent power in the Annex for each hour of a weekend day. From this utility data, the primary concern was with the low power factor occurring in the afternoon in the Annex. In order to track down the cause of the low power factor, the power quality meter was first attached to the main power supply to the Annex to verify the issue. Figure 11 shows the results of these measurements, which indicated a power factor as low as 0.705 at some instances. Since anything below 0.85 is considered low and could be charged to the university, this data caused further concern.

Figure 11. Shows a graph of the Annex power factor and apparent power for each weekend hour of the day.
The next step was to track down the root cause of the issue. Since power factor problems usually stem from fluorescent lighting ballasts or electric motors, these were the items that were measured next. The lighting system was measured and it was determined not to be the cause of the issue since spot-check measurements indicated power factors between 0.97 and 1.00. The next step was to check the electric motors in the fan-coil units. A measurement of the first unit indicated that these motors were the cause of the low power factor. This particular motor indicated a 0.52 power factor and it was one of the newer motors of the 22 in the building. After discovering this issue, it was then noticed that

Figure 12. Shows a graph of the Annex power factor over a three day period.
the lowest power factors were typically occurring on the weekends when the Annex load was at its lowest. This indicated that, since the 22 motors are always running at a constant speed, the effect of their low power factor was most significant as they became a greater portion of the overall building load. To solve this problem, these motors would need to be removed or replaced.
High Base Demand in Both Buildings

Figure 13 shows a graph of average hourly usage for the Tower.

One of the observed problem areas in this graph and similar graphs from the Annex was with the high base demand from the building. Determining the cause of this high demand was a good place to start for targeting savings.

![Figure 13. Graph of the Tower electricity usage.](image)

From the graph in Figure 13 of the Tower and similar graphs of the Annex usage, the average hourly base loads in the buildings appear to be around 140 kWh and 42 kWh, respectively. The first step taken to diagnose this problem was to start listing components that consume energy in the building at all times and...
would make a significant impact on this base load. The two major areas considered were, mechanical equipment (such as, the pumps, the AHUs, the fan-coil units and the chillers) and the lighting systems. Then, from graphs in the simulation software like the one seen in Figure 6, the amount these systems contributed to the overall base load was determined. For the lighting system, the load was found to be approximately 45.8 kWh of the total 182 kWh base hourly load for both buildings. This was as much as the entire Annex alone contributed. The mechanical system base load was determined to be 117 kWh of the base load. This amounted to 162.8 kWh of the entire 182 kWh base load. Satisfied at this point with these amounts, the next task was to determine if there were ways to lower these two significant areas of demand.

Some of the methods for decreasing this base demand from the light systems include, implementing lighting system controls, changing out T12 bulbs with T8 bulbs, changing over to electronic ballasts, rezoning light systems within spaces to accurately accommodate the occupants and re-installing light systems where the improper quantity or placement of lights may be an issue.

To decrease mechanical system demand, some possible methods are to place VFDs on the pumps, to turn down air-flow requirements at night, to set-back thermostats from the current
year-round set-point of 74 °F, changing over to an electronic controls system for more accurate control and increased system security and replacing all Annex fan-coil units, which run constantly, with the proper size, amount and placement of new fan-coil units. The new properly sized fan-coil units would solve many of the issues found in the Annex pertaining to the mechanical systems performance and controls.
Flat Annex Load Profile

As seen in Figures 11, the Annex maintains a very flat load profile. The concern here was that the building had a lot of potential for savings through systems that are currently causing this constant profile. Just as in the case of the high base load diagnosis, the primary contributing factors had to be determined first. In the Annex it was not difficult to discern that the main causes were from the fan-coil units, the HVAC controls and the lighting system. Possible fixes include, installing lighting controls in the Annex allowing the light load to be shut down automatically during unoccupied periods and re-zoning the lighting system in the Annex to serve the occupants by accounting for space subdivisions in which only one segment of a space may be in use at any given time. By replacing the 28 total HVAC units in the Annex with properly sized and zoned units, the system could be controlled in a way that would allow units to cycle down when they are not needed. By replacing the existing pneumatic controls with electric controls, the system would be controlled more accurately and shut down when it is supposed to. Another controls related issue that would produce a more normal load profile in the Annex would be to implement temperature setbacks that are activated when a space is unoccupied. This would also require new controls since the current system does not allow for these types of
set-backs, not to mention their inability to maintain even a constant set-point. These suggestions mentioned will produce a more normal shaped load profile and allow for significant energy savings during unoccupied periods of the day.
Introduction

This section provides analysis and discussion of the possible Energy Conservation Measures (ECMs) selected based on the survey and simulation of the Monterey building. At the end of the section Table 1 provides a breakdown of the ECMs evaluated separately.
Conservation Measures

ECM1. Replace T12 Bulbs with T8 Bulbs

ECM1 is intended to replace all the existing T12 fluorescent light bulbs with more efficient T8 bulbs. ECM1 would reduce the base lighting load and improve the lighting levels in the building. T8 bulbs use 21% less power than the equivalent T12 bulbs and as the bulbs are replaced, those fixtures still using magnetic ballasts would be replaced as well.

ECM2. Install Occupancy Sensors for Lighting Controls

ECM2 is intended to reduce the use of the lighting systems when they are not needed. As seen during the survey and from evidence obtained through data logging, the implementation of this ECO will decrease the base load and lighting loads will be decreased significantly by the automatic shut-down of unoccupied space lighting systems.


Since 30% of the Tower’s exterior wall space consists of windows, ECM3 was created to determined the possible savings with replacing the existing windows with more efficient double-pane window. This would decrease the amount of heat transferred to the interior of the building during the summer and possibly decrease the overall base load of the building.
ECM4. Remove Overhead Doors in the Annex

ECM4 was created to eliminate a large source of building leakage in the Annex. The thermal images taken during the survey indicate a significant amount of infiltration due to these doors. Many of these doors have already been replaced by windows, but many of them still remain and should be removed and replaced with a window or a new section of wall.

ECM5. Install Dropped Ceiling in the Annex

By installing an acoustic ceiling tile grid in the Annex ECM5 would improve the lighting, HVAC demand and the distraction to the students created by noisy mechanical and electrical systems. The installation of the ceiling tiles would also create an extra thermal barrier between the space and the roof. Some areas of the Annex, mainly offices, have been equipped with this type of ceiling, but the majority of the Annex contains the 17 ft ceiling with all of the exposed overhead equipment.

ECM6. Install Insulation Where Missing

As a result of thermal imaging it was noticed that over 25% of the Annex’s exterior walls were missing insulation. ECM6 is intended to correct that by installing insulation in these areas. If selected together with the acoustic ceiling, the option of installing the ceiling below the height at which the insulation stops and then simply applying insulation on top of the wall where the insulation is missing would be available. This would save in upfront cost since
Results

ECMs

the wall would not need to be rebuilt to add the missing insulation.

**ECM7. Replace Annex HVAC Units**

ECM7 was developed to address some of the fan-coil unit issues including the broken chilled water valves, bad electric motors, improper sizing, poor placement and the excessive amount of units. During the survey it was determined that nearly all of these units had broken or malfunctioning chilled water valves and their electric motors had power factors as low as 0.52. ECM7 will replace these 28 units with only 12 new more efficient units. These new units could be zoned properly and set-up to provide the proper amount of ventilation to address the serious concerns with the air-quality in the building.

**ECM8. New Thermostat Controls**

ECM8 includes the replacement of all the existing pneumatic thermostats with electronic controls that could be controlled by the facilities personnel only and allow for the implementation of temperature set-backs during unoccupied periods. These controls would eliminate the issues with accuracy and allow the system to properly maintain the condition within the building. The controls would eliminate erratic control of the systems which is currently wasting large amounts of energy. This ECM would improve the performance of the system and save a significant amount of
energy by allowing temperature set-points to vary throughout the day based on the requirements of the zone.

**ECM9. Install VFDs on Chilled Water Pumps**

Currently the chilled water pumps run constantly at full speed while at the same time the valves are not fully opened. ECM9 would install VFDs on the pump motors to vary the speed of the motors as they are needed. The valves could then be opened and the motors would vary their speed based on the demand rather than leaving them to run at full speed and varying the flow by closing off the valves.

<table>
<thead>
<tr>
<th>ECM #</th>
<th>Description</th>
<th>Cost</th>
<th>Energy Savings (kWh/yr)</th>
<th>Economic Savings ($/yr)</th>
<th>Payback Period (yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECM1</td>
<td>Change Lighting Type</td>
<td>$75,600</td>
<td>60,736</td>
<td>$3,785</td>
<td>31</td>
</tr>
<tr>
<td>ECM2</td>
<td>Install Lighting Controls</td>
<td>$18,340</td>
<td>168,749</td>
<td>$9,239</td>
<td>3</td>
</tr>
<tr>
<td>ECM3</td>
<td>Replace Windows</td>
<td>$406,000</td>
<td>29,433</td>
<td>$2,181</td>
<td>N/A</td>
</tr>
<tr>
<td>ECM4</td>
<td>Remove Overhead Doors</td>
<td>$13,400</td>
<td>12,882</td>
<td>$545</td>
<td>46</td>
</tr>
<tr>
<td>ECM5</td>
<td>Annex Dropped Ceiling</td>
<td>$98,000</td>
<td>16,983</td>
<td>$923</td>
<td>N/A</td>
</tr>
<tr>
<td>ECM6</td>
<td>Annex Insulation</td>
<td>$11,620</td>
<td>4,182</td>
<td>-$118</td>
<td>N/A</td>
</tr>
<tr>
<td>ECM7</td>
<td>Annex HVAC</td>
<td>$138,600</td>
<td>58,430</td>
<td>$3,302</td>
<td>N/A</td>
</tr>
<tr>
<td>ECM8</td>
<td>HVAC Temperature Controls</td>
<td>$42,000</td>
<td>220,876</td>
<td>$10,391</td>
<td>5</td>
</tr>
<tr>
<td>ECM9</td>
<td>Pump VFDs</td>
<td>$16,100</td>
<td>104,386</td>
<td>$6,026</td>
<td>3</td>
</tr>
</tbody>
</table>
Recommendations

The recommended actions that will give the most effective results in energy and economic savings. The overview of the savings and payback is given in Table 2, below. These are the actions that were recommended to the university after conducting the entire energy audit.

<table>
<thead>
<tr>
<th>Group</th>
<th>ECM #</th>
<th>Description</th>
<th>Energy Savings (kWh/yr)</th>
<th>Economic Savings ($/yr)</th>
<th>Payback Period (years)</th>
<th>Cost to Implement</th>
<th>Overall Payback (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lights</td>
<td>ECM1</td>
<td>T8 Bulbs</td>
<td>200,543</td>
<td>$11,845</td>
<td>10</td>
<td>$165,440</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>ECM2</td>
<td>Occupancy Sensors</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Envelope</td>
<td>ECM4</td>
<td>Remove Overhead Doors</td>
<td>12,882</td>
<td>$545</td>
<td>46</td>
<td>$165,440</td>
<td>8</td>
</tr>
<tr>
<td>HVAC</td>
<td>ECM8</td>
<td>Temperature Set-Backs</td>
<td>209,324</td>
<td>$10,470</td>
<td>7</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>ECM9</td>
<td>Pump VFDs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Conclusion

• Payback of less than 8 years

• Energy savings of 23.7%

• Total annual savings of $22,860 after a total cost to implement the ECMs of $165,440

• Light levels improve with the installation of more efficient T8 bulbs

• Base load will decrease as a result of automatic system shut-downs during unoccupied periods

• Improved building pressurization and decreased air infiltration

• Erratic, inaccurate temperature controls are replaced with new electronic temperature controls which will also allow for the implementation of temperature set-backs.
## General Building Information

Name of Institution: ____________________________________________________
Address: ____________________________________________________________

Name of Building: ____________________________________________________
Address: ____________________________________________________________

Date of Audit: 
Type of Institution:  Public_____ Private_____ Other_____
Building Manager (administrator responsible for bldg.): ______________________
Contact: ___________________________________________________________

Energy Management Coordinator: _______________________________________
Contact: ___________________________________________________________

Person(s) Completing this Audit: _______________________________________
Contact: ___________________________________________________________

### Building Type and Category:

<table>
<thead>
<tr>
<th>School</th>
<th>Hospital</th>
<th>Government</th>
<th>Public Care</th>
</tr>
</thead>
<tbody>
<tr>
<td>__Elementary</td>
<td>__General</td>
<td>__Federal</td>
<td>__Nurs. Home</td>
</tr>
<tr>
<td>__Secondary</td>
<td>__Psychiatric</td>
<td>__State</td>
<td>__Long-Term Care</td>
</tr>
<tr>
<td>__Comm. Coll.</td>
<td>__Other, Specify</td>
<td>__City/County</td>
<td>__Rehab. Center</td>
</tr>
<tr>
<td>__Coll./Univ.</td>
<td></td>
<td>__Special Dist.</td>
<td>__Orphanage</td>
</tr>
<tr>
<td>__Voc. Tech. Ctr.</td>
<td></td>
<td>__Indian Tribe</td>
<td>__Public Health</td>
</tr>
<tr>
<td>__Other, Specify</td>
<td></td>
<td></td>
<td>__Other, Specify</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Building Use:

<table>
<thead>
<tr>
<th>Office</th>
<th>Police Station</th>
<th>Other, Specify</th>
</tr>
</thead>
<tbody>
<tr>
<td>Storage</td>
<td>Fire Station</td>
<td></td>
</tr>
<tr>
<td>Library</td>
<td>Dormitory</td>
<td>Prisoner Detention</td>
</tr>
</tbody>
</table>

Date of Construction, If Known: ______________________
Original Architects: ______________________
Original Engineers: ______________________

Does the Institution have an ongoing energy management program? Y  N

Previous Energy Audits Completed? (If Yes, give dates) Y  N
Dates ______________________  ______________________  ______________________

Previous Architectural/Engineering Studies Undertaken? (If Yes, Specify) Y  N

Is this building on the National Historic Preservation Register? Y  N
# Building Space Survey Form

## General Room Information
Name of Auditor: __________________________
Date of Audit: ___________    Building: _______________________________
Room Number: ___________    Room Function: ________________________
Square Foot Total: _________    Cubic Foot Total: __________

## Walls
1) Type: ____    Sq. Ft.: ____   Qty.: ____   Hole in Wall: [ ] yes   [ ] no
2) Type: ____    Sq. Ft.: ____   Qty.: ____   Hole in Wall: [ ] yes   [ ] no
3) Type: ____    Sq. Ft.: ____   Qty.: ____   Hole in Wall: [ ] yes   [ ] no
Total Wall Area: ______
Comments: ___________________________________________________________

## Ceiling
1) Type: _____    Height: ______
2) Type: _____    Height: ______
Roof Type: ______
Comments: ___________________________________________________________

## Doors
1) Type: _____    Sq. Ft.: _____   Qty.: ____   W. Strip: [ ] yes   [ ] no
2) Type: _____    Sq. Ft.: _____   Qty.: ____   W. Strip: [ ] yes   [ ] no
3) Type: _____    Sq. Ft.: _____   Qty.: ____   W. Strip: [ ] yes   [ ] no
4) Type: _____    Sq. Ft.: _____   Qty.: ____   W. Strip: [ ] yes   [ ] no
Total Door Area: ______
Comments: ___________________________________________________________

## Windows
1) Type: _____    Sq. Ft.: _____   Qty.: ____   W. Strip: [ ] yes   [ ] no   Damage: [ ] yes   [ ] no
2) Type: _____    Sq. Ft.: _____   Qty.: ____   W. Strip: [ ] yes   [ ] no   Damage: [ ] yes   [ ] no
3) Type: _____    Sq. Ft.: _____   Qty.: ____   W. Strip: [ ] yes   [ ] no   Damage: [ ] yes   [ ] no
Total Window Area: ______
Comments: ___________________________________________________________
### Electric

<table>
<thead>
<tr>
<th>Device</th>
<th>Qty.</th>
<th>Watts</th>
</tr>
</thead>
<tbody>
<tr>
<td>1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Comments: ___________________________________________________________
_____________________________________________________________________
_____________________________________________________________________
_____________________________________________________________________
_____________________________________________________________________
_____________________________________________________________________
_____________________________________________________________________

### Lighting

<table>
<thead>
<tr>
<th>Light Type</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1)</td>
<td></td>
</tr>
<tr>
<td>2)</td>
<td></td>
</tr>
<tr>
<td>3)</td>
<td></td>
</tr>
</tbody>
</table>

Task Lighting Notes: ______________________________________________

Number of Bulbs Not Working: ___________

Measure Lighting Level at Different Areas of the Room at Task Locations:

<table>
<thead>
<tr>
<th>Lighting Level</th>
<th>(Lights On):</th>
<th>(Lights Off):</th>
</tr>
</thead>
<tbody>
<tr>
<td>1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Comments: ___________________________________________________________
_____________________________________________________________________
_____________________________________________________________________
_____________________________________________________________________
_____________________________________________________________________

### HVAC

Number of Supply Grills: _______  Type of Supply Grills: ________________
Number of Return Grills: _______  Type of Return Grills: ________________
Number of Thermostats: _______  Temp. Set Point of Thermostats: _______
Air Conditioned Sq. Ft.: _______  Temperature (F): ______
Humidity (RH): ______
Comments: ___________________________________________________________
_____________________________________________________________________
_____________________________________________________________________
_____________________________________________________________________
_____________________________________________________________________

### General Comments and No Cost/Low Cost Opportunities

_____________________________________________________________________
_____________________________________________________________________
_____________________________________________________________________
_____________________________________________________________________
_____________________________________________________________________
_____________________________________________________________________
_____________________________________________________________________
_____________________________________________________________________
_____________________________________________________________________
_____________________________________________________________________
## Occupancy

### Building Occupancy Profile

<table>
<thead>
<tr>
<th>100%</th>
<th>Daily Profile</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>0%</th>
<th>12 mid</th>
<th>6 am</th>
<th>12 noon</th>
<th>6 pm</th>
<th>12 mid</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>100%</th>
<th>Weekly Profile</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>100%</th>
<th>Annual Profile</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Building Occupancy Schedule

<table>
<thead>
<tr>
<th>Area/Zone</th>
<th># of Sq.Ft.</th>
<th>Week Days</th>
<th>Weekends, Holidays</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>hours</td>
<td># of People</td>
</tr>
<tr>
<td></td>
<td></td>
<td>from to</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Comments: ____________________________________________________

________________________________________________________________
HVAC System Survey Form

General Information
Auditor Name: _______________    Audit Date Begin: __________    Audit Date Completion: ___________
Building Name: ______________    Original Mechanical System Designer: __________________________
Cooling Degree Days: _________ Heating Degree Days: _________ System Type: ___________________
ASHRAE Air Change Specifications for Building Function: _______________________________________
Outdoor Weather Conditions:  _____________________________________________________________
Notes: ________________________________________________________________________________
_____________________________________________________________________________________

Cooling Plant
System Type: __________________________________________    Refrigerant Type: ________________
Number of Units (in use): _____________   Maintenance Status: __________________________________
Observed Condition: __________________________ Condenser Type: ____________________________
Pressure Condenser Side (High): _____________    Pressure Evaporator Side (Low): ___________
Temperature CWS: _______    Temperature CWR: ________    Temp SP CWS: ________
Temperature CHWS: _______    Temperature CHWR: _______    Temperature SP CHWS: _______
Number Chilled Water Pumps (in use): ___/___   V: ______   A: _____ Phase: _____ Power Factor: _____
Motor Plate Data:________________________________________________________________________
_____________________________________________________________________________________
_____________________________________________________________________________________
Chilled Water Pump Notes: __________________________________________________________________
_____________________________________________________________________________________
_____________________________________________________________________________________
_____________________________________________________________________________________


Number Condenser Pumps (in use): ___/___   V: ______ A: _______ Phase: ______ Power Factor: _____
Motor Plate Data: ________________________________________________________________
_____________________________________________________________________________
Condenser Pump Notes: __________________________________________________________
_____________________________________________________________________________
_____________________________________________________________________________

Number Condenser Fan Motors (in use): ___/___   V: ______ A: ______ Phase: ____ Power Factor: _____
Motor Plate Data: _________________________________________________________________
_____________________________________________________________________________
Condenser Fan Motor Notes: ______________________________________________________
_____________________________________________________________________________
_____________________________________________________________________________

Number Compressor Motors (in use): ___/___   V: _____   A: _____   Phase: _____ Power Factor: ______
Motor Plate Data: _________________________________________________________________
_____________________________________________________________________________
Compressor Motor Notes: __________________________________________________________
_____________________________________________________________________________
_____________________________________________________________________________

Control Type: __________________________    Control Method: _________________________________
Control Notes: __________________________________________________________________________
______________________________________________________________________________________
Notes: ________________________________________________________________________________
______________________________________________________________________________________

**Heating Plant**

Boiler Type: ________________   Energy Source: _____________    Number of Units (in use): ___/___
Temperature HWS: __________    Temperature HWR: ___________    Temp SP HWS: ________
Pressure in: _________    Pressure out: __________
Number of Pump Motors (in use): ___/___  V: ______  A: ______  Phase: ______  Power Factor: ______
Motor Plate Data: _______________________________________________________________
_____________________________________________________________________________
Pump Motor Notes: _____________________________________________________________
_____________________________________________________________________________
_____________________________________________________________________________

Number of Blower Motors (in use): ___/___  V: ______  A: ______  Phase: ______  Power Factor: ______
Motor Plate Data: _______________________________________________________________
_____________________________________________________________________________
Exhaust Fan Notes: _____________________________________________________________
_____________________________________________________________________________
_____________________________________________________________________________

Controls Type: ___________________________  Controls Method: _______________________________
Control Notes: __________________________________________________________________________
Notes: ________________________________________________________________________________
______________________________________________________________________________________

Air Handling System

Number of Units (in use): ___/___  VFD (Yes/No): _________  Number of Zones: _____________
System Description: _____________________________________________________________________
______________________________________________________________________________________
______________________________________________________________________________________
Zones per Unit: __________  Zone Method: ____________

Number of Blower Motors (in use): ___/___  V: ______  A: ______  Phase: ______  Power Factor: ______
Motor Plate Data: _______________________________________________________________
_____________________________________________________________________________
Air Handling System cont.

Controls Type: ___________________________   Controls Method: _______________________________

Controls Notes: _________________________________________________________________________
______________________________________________________________________________________
______________________________________________________________________________________

Condition of Ductwork: __________________________________________________________________

Filter Type: ___________________________   Filter Efficiency: __________________________________
Filter Condition: __________________   Filter Locations: ________________________________________

Air Change Rate (OA): ___________________________________________________________________

Static Pressures: _______________________________________________________________________

Notes: ________________________________________________________________________________
______________________________________________________________________________________
______________________________________________________________________________________
Packaged Systems

System Type: _______________ Location of Unit: _____________________

Unit Plate Data: _________________________________________________________________________
______________________________________________________________________________________
______________________________________________________________________________________
______________________________________________________________________________________
______________________________________________________________________________________

Compressor:  V: ________ A:  ________ Phase:  _______ Power Factor:  ________
Total Power (Supply):  V:  ________ A:  _________ Phase:  ______ Power Factor:  ________
Cooling Capacity:  _________
Heating:  List Information below.

Controls Type: ___________________________ Controls Method: _______________________________
Controls Notes: _________________________________________________________________________
______________________________________________________________________________________
______________________________________________________________________________________
______________________________________________________________________________________

Outside Air Exchange: __________________________________________________________________
______________________________________________________________________________________
______________________________________________________________________________________

Notes: ________________________________________________________________________________
______________________________________________________________________________________
______________________________________________________________________________________
______________________________________________________________________________________
L12
OUTDOOR LIGHTING

L13
4' T12 2 BULB

L14
U-SHAPED FLUORESCENT
W1
INTERIOR WALL
METAL STUDS
SHEETROCK

W2
EXTERIOR WALL

W3
GLASS WALL

REFERENCE SECTIONS
G1
SINGLE PANE
WITH FILM

G2
SINGLE PANE
WITHOUT FILM

G3
INTERIOR WINDOW

WINDOW LEGEND
S1
LINEAR DIFFUSER

S2
SQUARE CEILING PANEL DIFFUSER

S3
DUCT MOUNTED VENT

S4
WALL MOUNTED
**Studio 102 Heater Coil Current and Room Temperature**

(Outside Temperature: Low 46, High 79, Avg. 63)

![Graph of Studio 102 Heater Coil Current and Room Temperature](image)

---

**Studio 106 Fan/Coil Unit and Heater Current Log**

(Outside Temperature: Low 49, High 77, Avg 63)

![Graph of Studio 106 Fan/Coil Unit and Heater Current Log](image)
Studio 320 Temperature Over 24 Hour Period
(Outside Temperature: Low 38, High 70, Avg. 54)

Annex Main ChWS/R Temperature

Temperature (F)


Temperature (F)

24 Hour Period (1/17/2008)
<table>
<thead>
<tr>
<th>MODEL</th>
<th>QTY</th>
<th>VOLTS AC</th>
<th>PH</th>
<th>HZ</th>
<th>RLA</th>
<th>LRA</th>
<th>REFRIG/ SYSTEM</th>
<th>R-22</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMP</td>
<td>2</td>
<td>460</td>
<td>3</td>
<td>60</td>
<td>46.8</td>
<td>253</td>
<td>133 LBS</td>
<td>60.4 kg</td>
</tr>
<tr>
<td>COMP</td>
<td>2</td>
<td>460</td>
<td>3</td>
<td>60</td>
<td>65.4</td>
<td>345</td>
<td>137 LBS</td>
<td>62.2 kg</td>
</tr>
<tr>
<td>DESIGN / TEST PRESSURE GAGE</td>
<td>HIGH PSI</td>
<td>450 kPa</td>
<td>3102</td>
<td>278 kPa</td>
<td>1917</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FAN MOTORS</td>
<td>QTY</td>
<td>VOLTS AC</td>
<td>PH</td>
<td>HZ</td>
<td>FLA</td>
<td>HP</td>
<td>KW OUT</td>
<td></td>
</tr>
<tr>
<td>OUTDOOR</td>
<td>6</td>
<td>460</td>
<td>3</td>
<td>60</td>
<td>3.0</td>
<td>2.0</td>
<td>1.9</td>
<td></td>
</tr>
<tr>
<td>OUTDOOR</td>
<td>4</td>
<td>460</td>
<td>3</td>
<td>60</td>
<td>2.6</td>
<td>2.0</td>
<td>1.9</td>
<td></td>
</tr>
<tr>
<td>OTHER</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HEATERS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>POWER SUPPLY</td>
<td>VOLTS</td>
<td>460</td>
<td>3</td>
<td>60</td>
<td></td>
<td></td>
<td>MIN CIRCUIT AMPS</td>
<td></td>
</tr>
<tr>
<td>CONTROL VOLTage AT UNIT</td>
<td>50% MAX</td>
<td>41</td>
<td>14</td>
<td>1 MIN</td>
<td>1</td>
<td></td>
<td>FUSE OR MAGNETIC CIRCUIT BREAKER</td>
<td></td>
</tr>
<tr>
<td>CONTROL</td>
<td>VOLTS</td>
<td>115</td>
<td>3</td>
<td>60</td>
<td></td>
<td></td>
<td>AMP</td>
<td>5</td>
</tr>
</tbody>
</table>
Cieling cavity created by dropped acoustic panels
NOT AIR CONDITIONED
AIR CONDITIONED VOLUME

8'9 cavity

17'6 cavity
20 GA. 25'6" MIL. STUDS
1 1/2" T.C. TYPE
PLACE WALE SECURELY
TO STRUCTURE ABOVE.

1 HOUR RATED
CEILING SYSTEM

FIRE RATED (ZIP)
BOARD (STRIP)
FOURASO WALL SYSTEM
OPTIONAL REPAIR RAIL

20 GA. 25'6" MIL.
STUDS 5/8" O.C. H
5/8" PRECODE T.C.
R.C. BAK SIDE.

3/4" CONCRETE ON MIL.
DECK - REFER STRUCTURAL

OPEN HOLE ON MILL
REFER STRUCTURAL

FILL ALL HOLES WITH
CONCRETE MIL. TH.
CEMENT WALL

4" STANDARD FACE CMU
1/2" VERTICAL REINFORCING
@ 12" O.C. - FILL CELL HOLES
W/ SAND.

1 HOUR RATED
CEILING SYSTEM

2.5" MIL. STUDS @ 24" O.C. W/ 1/2"
FIRE RATED (ZIP) R.C. BAK. W/ 5/8"
CMU BASE BLOCK W/ HANGER TIES @ 16" O.C.
FILL HOLES IN BLOCK W/ SAND - 2 STICKS W/ SAND
ATTENUATION RUMBLE TERR SORB

INTERIOR AT MECH. ROOM- OFFICE
SECTION AT GLAZING - MANUFACT.
SECTION AT GLAZING-OFFICE