SUSTAINABILITY ASSESSMENT
OF THE ROBERT E. JOHNSON
STATE OFFICE BUILDING

Final Report

Prepared for
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The General Service Commission of Texas
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EXECUTIVE SUMMARY

The Robert E. Johnson State (REJ) Office building is a 5-story, 303,389 square foot office building for state legislative support staff, including Legislative House Committees, Legislative Council, State Auditor, the Legislative Reference Library, the Senate Print Shop, and the Sunset Commission. Overall, the building is divided into three sections with divisions created by a ground-level breezeway and vehicular access area, which are covered by the upper floors above these areas. The building’s northern facade is approximately 14 degrees west of north, exposing it to direct sunlight during the late afternoon hours in the winter. It is also important to note that the building contains over 50% glazing in the façade consisting of two types of energy efficient, low-E glazing. Deciduous trees shade a large portion of the south façade up to the 3rd level.

To analyze the sustainability of the Robert E. Johnson Building, this study: 1) measured the hourly energy use of the building’s heating, cooling, and electrical systems, 2) created a calibrated energy simulation matched to the whole-building energy consumption of the as-built, energy efficient building, 3) measured the performance of selected Energy Conservation Measures (ECMs) using the calibrated simulation program, and 4) compared the annual energy consumption of the Robert E. Johnson building with selected state buildings in the LoanSTAR database.

For this research, the following Energy Conserving Measures were studied: 1) an energy efficient HVAC system, 2) high efficiency chillers, 3) T-8 fluorescent lamps with electronic ballasts, 4) motion sensors for lighting control, and 5) low-E window glazing. ECMs that were identified but not studied in this report include: electrical savings due to daylighting, an enthalpy-heat recovery system on the Senate print shop, an outside-air, preconditioning system that contained special-purpose dehumidification equipment, low-head pumping in the over-sized
cooling towers, variable-speed pumping in the chilled water loop, a high albedo roof, and several other measures.

A review of the mechanical equipment in the Robert E. Johnson building showed that the building contained high efficiency centrifugal chillers, an over-sized cooling tower (located directly above the chillers with two 20 horsepower pumps used to circulate water through the tower). The building uses a primary-secondary chilled water supply system, which uses variable-speed drives on the secondary loop. The building also has a low-NOx boiler that provides the building’s heating. Domestic water heating is provided by electric water heaters. The air distribution system is a dual-duct system that pre-conditions the incoming outside air with a special air-handling unit that contains a run-around coil for dehumidification. A variable-air-volume (VAV) system is used in most other areas, except the basement (Senate print shop), which uses a constant volume system with an enthalpy-recovery feature to treat the large volumes of fresh air needed for the print shop.

For the lighting system, specially designed light shelves were installed on the south façade of the building to project the daylight into the interior offices. Dimmable ballasts were installed in about 15-18% of the offices to dim the supplemental lighting when natural lighting could provide adequate levels of illumination. Unfortunately, on-site inspections revealed that window blinds had also been installed and were in use on all glazed surfaces, negating the effect of the daylighting-dimming system¹. Furthermore, the choice of office furniture blocked the access to the blind controls, which further reduced the likelihood that the daylighting-dimming system could ever be used. Therefore, the electricity savings associated with the daylighting-dimming system were not considered.

¹ These window blinds were requested by the building’s occupants who complained that they were unable to use their computers in the offices when the sunlight was shining into the space.
In this report, the use of the terminology “as-built simulation” refers to the existing building conditions, which includes all the energy efficient features analyzed in this study. To create the most accurate simulation, the as-built energy simulation was based on pre-construction data provided by a previous study, which was adjusted to match the verifiable information from the constructed building. Interviews were conducted with the building’s administration and the building operators, as well as the architects and engineers that designed the building.

Metering equipment was installed and used to measure the hourly performance of selected aspects of the building. An analysis of the sub-metered data of then 4th floor was used to represent the lighting and equipment schedules of the simulated as-built building. To further calibrate the as-built model, the building’s electricity use was analyzed and equipment schedules were adjusted to account for observed variations in the system operation. Equipment efficiencies in the as-built simulation were adjusted to match the installed manufacturer’s specifications or, in the case of the chiller, were matched with measured efficiencies.

Comparative, whole-building x-y scatter plots of daily heating and cooling data were then used to perform the final calibration of the thermal loads. Special attention was given to make sure that the building matched the known energy efficient features (i.e., low-E glazing, chiller efficiency, etc.). In several cases where the building’s as-built features were unclear or too complex, simplifications were made with the DOE-2 model due to the program’s limitations, which include: 1) an inability to simulate the exact features of the air-handling systems (i.e., enthalpy recovery on the Senate print shop, run-around-coils, etc.), 2) codeword limitations, which limited the number of surfaces, zones, etc., and 3) and incomplete understanding of all the operational variations during the metering period.
In this analysis the results of the calibrated simulation were first compared to similar buildings within the LoanSTAR database (Haberl et al., 2001) to determine how the building compared to similar buildings without adjustment. In the comparison with similar buildings, the Robert E. Johnson building has a simulated annual energy intensity of 148,260 Btu per square foot, which compares well with the measured energy use of Texas State Supreme Court Building. The measured energy of the selected buildings varied from 100 to over 200 kBTu per square foot.

Secondly, each selected energy conserving measure (ECM) was then varied to determine the isolated effect for that measure. A combined simulation that represented all the ECMs was then used to determine an aggregated effect.

Five energy conservation measures were analyzed to determine the base-case conditions: 1) Two low-E glazing types were simulated for the as-built case. Single-pane bronze glazing was used for the base-case condition. 2) For the HVAC system, the REJ’s simulated system was varied between a VAV and a constant volume dual duct system. 3) Lighting power densities were varied to represent efficient T8 lighting versus the standard T12 lighting, and 4) lighting motion sensors were evaluated. Finally, 5) the chiller efficiency was varied from 0.5 kW/ton (measured efficiency of the new chiller) to 0.75 kW/ton (measured efficiency of standard chillers [Haberl et al., 1997]), to represent the impact of the new, efficient chiller.

The results show that the low-E glazing and the VAV system have the greatest impact on the energy saving of the building, with the VAV heating and cooling system having the greatest energy reduction of all the ECMs analyzed. In contrast, the motion sensors, high efficiency lighting, and the 0.5 kW/ton chiller had smaller impacts, with the motion sensors having the least energy savings of the measures evaluated. The lighting motion sensors had the least effect.

Overall, the building’s annual energy use was reduced by 34,752 MMBtu or 45.0% when
compared to similar buildings. The monthly peak electric load was reduced as well, varying from a reduction of 483 kW (23.6%) in July and August to a reduction of 681 kW (34.3%) in February.
ACKNOWLEDGEMENTS

This work was funded by the Texas State Energy Conservation Office and the General Service Commission of Texas through an inter-agency agreement. Special thanks are due to the Pam Groce, Felix Lopez, and Dub Taylor at SECO, and Denis Feary at GSC for their efforts in providing timely information and review of this report. Special thanks are also due to the numerous people that helped install, calibrate and maintain sensors, and gather, clean and archive the data from the data logger, including Shelly Price (SiTEX, Inc.), Kim Carlson (ESL), Kelly Milligan (ESL), Jim Sweeney (ESL), and Peter Klima (ESL).

DISCLAIMER

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1 INTRODUCTION

The number of performance contracts and energy service agreements by U.S. businesses and institutions is continually growing. To estimate the potential savings as well as to help verify savings from retrofits actually installed, energy simulation programs have also become a growing part of this effort. As a result, ASHRAE has recently developed Guideline 14P Measurement of Energy and Demand Savings (ASHRAE 2001) for determining the appropriate methods for analyzing energy savings from energy conservation retrofits. This guideline defines the measurement and characterization of energy savings, which includes calibrated simulations. The U.S. DOE has also developed the International Performance Measurement and Verification Protocols (IPMVP) for measuring savings from energy retrofits and for measuring the performance of new designs (NEMVP 1996; IPMVP 1997; IPMVP 2001). This report uses calibrated simulation methods that are consistent with Guideline 14P and the new building performance measures methods described in the 1997 IPMVP, as well as the methods reported in other published studies (Bou Saada and Haberl 1995a,b; Clarke et al., 1993; Haberl et al., 1993; Haberl et al., 1995; Hsieh 1988; Kaplan et al., 1990; Manke and Hittle 1996; and Soebarto 1996) to evaluate the performance of the Robert E. Johnson (REJ) State Office building in Austin, Texas.

1.1 Project Background

The Robert E. Johnson State Office building is a 5-story, 303,389 square foot office building for state legislative support staff, such as House Committees, Legislative Council, State Auditor, the Legislative Reference Library, the Senate Print Shop and the Sunset Commission.
Overall, the building is divided into three sections with divisions created by a ground-level breezeway and vehicular access area. Upper floors extend above these areas. The building’s northern facade is approximately 14 degrees west of north, which exposes it to direct sunlight during the late afternoon hours. It is also important to note that the building contains over 50% glazing in the façade consisting of two types of glazing and that deciduous trees line a significant portion of the south façade up to the 3rd level. Figure 1 through Figure 31 are photos of the building and its heating, cooling and lighting systems.

To develop and calibrate the energy simulation the following interview procedures were conducted:

- Meet with the systems’ engineer and review the buildings design intent and actual operation.

- Meet with the architect and review the building’s intent and actual material specifications, especially glazing.

- Review the DOE-2 design simulation.

- Conduct building walk-throughs to verify the existing architecture and systems.

- Conduct targeted systems audits to determine the actual operation and parameters of selected systems.

- Acquire relevant building documentation such as the construction documents, change orders, systems specifications, relevant metered and sub-metered hourly data, and the building’s utility bills.

- Identify and verify systems and their performance.

- Document systems through photographs for review by other personnel.
1.1.1 Site Visits and Meetings

During the project the building was visited several times to meet with the project architects and systems engineers. During the first visit in 2001, a tour of the exterior of the building was conducted to photograph the architecture of the building and the systems. Attendees on tour were Dr. Jeff Haberl (Co-Principal Investigator), Dr. Keith Sylvester (Co-Principal Investigator), and Mr. Dale Norton (Project Manager). See Appendix A for details concerning this site visit.

Figure 1. Entrance View of the Robert E. Johnson building From the Southwest Corner.
Figure 2. South and West Façade Above the Entrance.

Figure 3. South and West Façade at the Entrance.
Figure 4. West and South Façade Above the Entrance.

Figure 5. West and South Façade at the Entrance.
Figure 6. West Façade at the Entrance.
Figure 7. West Façade Above Street Level.

Figure 8. West Façade at Street Level.
Figure 9. West Façade at Northwest Corner of the Penthouse Level.

Figure 10. West Façade at Northwest Corner at Street Level.
Figure 11. South Façade.

Figure 12. Detail of Window With Blinds Partially Open in Clerestory Glazing.
Figure 13. Detail of Window With Blinds Closed in Clerestory Glazing.

Figure 14. View of Conference Center, Cooling Towers, and the REJ’s Garage
Figure 15. East Façade Showing 90% of the Blinds Closed During Morning Hours.

Figure 16. North Façade With 100% of the Blinds Closed in Clerestory Window (Afternoon).
To bring clarity to the information documented during the tour of the building, several additional meetings were held to verify the installed energy saving features, including the installation of sensors. Numerous issues had to be resolved to assure that the sensors were measuring the right electrical circuits. Temperature, flow and solar sensors had to be calibrated, installed and verified before the data could be used.

Overall, there are two types of spaces in the building - open office spaces and individual offices. The building also contains a large computer center and a senate print shop. At this meeting, the attendees were Dr. Jeff Haberl, Dr. Keith Sylvester, Mr. Dale Norton (Project Manager), Ms. Shelly Price (Metering Subcontractor), Mr. Kearie Franklin (Building Maintenance), Ms. Pam Groce (Program Administrator), and Ms. Kimberly Carlson (TAMU Systems' Engineer). Field documents dated 9/11/97 were provided at this meeting.

A second meeting was conducted and attended by Dr. Jeff Haberl, Dr. Keith Sylvester, Mr. Dale Norton, Ms. Shelly Price (Metering Subcontractor), Mr. Kearie Franklin (Building Maintenance), Ms. Pam Groce (Program Administrator), and Mr. Robert Hill (Project Architect) to attempt to ascertain information not included in the 1997 REJ documents. See Appendix A for additional details about this meeting.
Figure 17. Typical South Facing Window With Light Shelf.

Figure 18. Detailed View of Light Shelf.
Figure 19. View From Interior Hallway Showing Glare Produced by Light Shelf at 2:24 p.m.

Figure 20. Typical Interior Window Design Throughout the Building to Allow Light to Penetrate to Inner Offices.
Figure 21. Typical Light T8 Fixture with Dimming Ballast and Light Sensor.

Figure 22. Corner Office Used For Solar Sensor Location.
Figure 23. Typical South-facing Open Office Plan Showing Mismatch of Office Furniture and Daylighting Features.

Figure 24. Library with Northern View Showing use of Lights During Periods When Sensors Could have Dimmed Fixtures.
Figure 25. Typical Southern View of Open Office Plan with Light Shelves
(Note the mismatch in the modular office furniture and the light shelves. Also, the modular furniture blocked the access to the control of the Venetian blinds, which meant they stayed in one position (i.e., permanently down)).

Figure 26. Typical Open Office Plan in the Center of the Building for a South Facing Façade.
(Note. Light From the Light Shelf was Supposed to Penetrate Into These Cubicles via the Slanted Ceiling Tiles Above. Light Shelf Visible at Right of Photo.)
Following this meeting, a tour of the interior of the building was conducted to verify the systems and document what was constructed. The group visited a 4th Floor, corner office where the solar sensors were to be located, viewed typical office spaces, HVAC systems located on the roof, and the power management systems. Photos of each of these spaces were also taken. One of the observations made during this meeting was that the placement of many of the light sensors was inconsistent with the as-built documents. Furthermore, there appeared to be little coordination between the selection and installation of office furniture and the light shelves.

Using the data collected during this preliminary review process, the measured hourly data, weather data from the National Weather Service, and the simulation input file from the previous study conducted by Eley and Associates (1998), the analysis of the newly constructed Robert E. Johnson building was begun by an Energy Systems Laboratory research team.

\footnote{The as-built drawings specified that the lighting sensors be placed in such a way that they dim the lights nearest to the windows. However, a site inspection of wiring of the lights revealed that some of the lights had been improperly wired to accomplish this. Furthermore, several of the lighting sensors had failed and had had to be wired out of the control circuit.}
Figure 27. Eastward View of the REJ Roof.

Figure 28. Cooling Tower on the Roof of the Cooling Plant.
Figure 29. Main Mechanical Room.

Figure 30. Variable Frequency Drives (VFDs) in the Mechanical Room.
Figure 31. Chilled Water VFW on the Secondary Loop.
1.2 Energy Conservation Design Measures

Despite the many building systems and components that were supposed to be energy efficient, many were not easy to quantify without a simulation effort that exceeded to scope of this project. In some instances, additional sub-metering of the building’s systems would have been necessary. Therefore, it was decided that the analysis would be limited to the most important energy conserving features, which could be simulated within the allotted project resources. Therefore, for this research, the following energy conserving measures were studied: 1) selected features of the main HVAC system, 2) high efficiency chillers, 3) T-8 fluorescent lamps for lighting, 4) motion sensors for lighting control, and 5) low-E window glazing. Since this decision excluded several features, which have been shown to be effective in other buildings, but could not be analyzed, it is safe to say that the building is saving more than the energy savings reported in this report.

A review of the mechanical equipment indicated that the building contained high efficiency centrifugal chillers, an oversized cooling tower, and two 20 horsepower pumps used to circulate water through the tower. Primary-secondary chilled water loops are used to distribute the chilled water to the building. Variable frequency drives are installed on the secondary chilled water loop. In addition, the building contained a low-NOx boiler providing hot water for the HVAC system during the winter season. For the majority of the conditioned area, the air distribution system is a dual-duct, variable air volume (VAV) system, which utilizes a pre-conditioning system for outside air that contains a run-a-round coil (before and after the pre-conditioning coil). VAV systems are used in all areas except the basement, which

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3 Energy efficient design features which were identified but not included in this report include: enthalpy-based heat recovery for print shop, low-head pumping for the cooling system, a low-NOx boiler, daylighting-dimming system, dual-path pre-conditioning systems, the building’s shape, the building’s high albedo roof, the run-around-loop on the fresh air system, which serves as an energy efficient economizer for the whole-building, and several other HVAC control options that were simulated in the Eley report but could not be verified.
has a constant volume system for the senate print shop, which contains an enthalpy heat recovery system.

The building included a specially designed daylighting system, with dimmable ballasts, which were installed in about 15-18% of the offices. Light shelves were installed on the south façade of the building to project daylight into offices located in the interior of the building. Unfortunately, on-site inspections revealed that window blinds were in use on all glazed surfaces, negating the effect of the daylighting-dimming equipment. Therefore, the electric energy savings associated with the dimmable lighting system were not considered.
2 METHODOLOGY

The International Performance Measurement and Verification Protocol (IPMVP), developed by the Department of Energy (DOE), provides best practice techniques available for verifying results of energy efficiency, water efficiency, and renewable energy projects (IPMVP 2001). Also included in the 2001 IPMVP is general advice about how to verify the performance of newly constructed buildings. The methods used in this study were designed to be compatible with the 2001 IPMVP, and utilize the simulation calibration methods contained in the 1997 IPMVP, and ASHRAE Guideline 14P (ASHRAE 2001).

![DOE-2 Data Processing Structure](image_url)

Figure 32. DOE-2 Data Processing Structure.

To analyze the sustainability of the Robert E. Johnson Building, this study: 1) created a calibrated energy simulation (Figure 32) that was matched to the hourly measured whole-building energy consumption, 2) compared the annual energy consumption of the Robert E.
Johnson building with selected similar state buildings in the LoanSTAR database (Haberl et al., 2001), and 3) evaluated the energy savings of the selected efficient components of the building using simulation. Specific tasks included the following:

- Task #1 – Simulate the as-built building, which assumes the inclusion of all energy conservation measures (ECMs).
- Task #2 – Calibrate the as-built simulation to the measured hourly data.
- Task #3 – Identify ECMs to Simulate.
- Task #4 – Modify the calibrated as-built simulation to: 1) create the effect of the individual ECMs by replacing efficient equipment with standard equipment or parameter operations, and 2) to create an aggregated effect by excluding all simulated ECMs representing the base-case or standard building.
- Task#5 – Compare the energy use indices (EUIs) of the Robert E. Johnson building with similar buildings.
Figure 33. DOE-2 Simulation Model
3 AS-BUILT SIMULATION

In this report, the as-built simulation refers to the existing building conditions, including all energy efficient features. To create the simulation model, the as-built energy simulation was based on pre-construction data provided by the previous study by Eley and Associates (Eley and Tathagat 1998) and adjusted to match the system data of the constructed building. TMY2 weather data for Austin, Texas was used in all simulations.

After the interview process, the collected data were entered in the DOE-2 program and the dimensions checked with the DrawBDL (Huang 1993) viewing program (Figure 33). In Figure 33a the building is shown as viewed from the southeast, which shows the simulated trees along the south side, as well as the auditorium, parking garage, and shading provided by other buildings on the north side. Figure 33b shows the building as it appears at street level from the south side. Figure 33c shows the building in a plan view. An analysis of the measured sub-metered data of a typical floor was then conducted and used to determine the lighting and equipment schedules of the entire simulated building. To further calibrate the model, the whole-building electricity use was analyzed and used to adjust equipment schedules and to account for variance in system operation.

Lastly, the simulation was adjusted to match the selected energy saving features. In some cases, the DOE-2 model was simplified due to the program’s limitations, which include: 1) a lack of program coding to simulate the exact features of certain air-handling systems, 2) codeword limitations of the DOE-2 program (i.e., enthalpy heat recovery for the Senate Print shop), which also limits the number of windows, walls, and zones, etc., and 3) incomplete data from the as-built drawings.

---

4 The overlapping tiles on the roof are an artifact of the DOE-2 program, which only allows rectangular roof segments.
3.1 Measuring the Energy Use of the Building

This section presents the monitoring of the Robert E. Johnson State Office building. In addition, selected data plots of the monitored data are also presented. Finally, electric and gas costs are also presented. Table 1 shows the monitoring channel descriptions and their equations for: 1) the whole-building electricity use of the building including chiller and miscellaneous pump energy, 2) the electricity performance of the two chillers, 3) the weather-independent electricity use of the building (excluding the chillers and miscellaneous pump energy), which provided a means for comparison and calibration of the DOE-2 building electricity use, 4) the temperature of the supply chilled water and the condenser water, which provided operational parameters for input into the DOE-2 program, and 5) the receptacle and lighting electricity use of the fourth floor, which was used to determine the typical performance of the building. Figure 34 provides a diagram of the metered data points, which includes the metered energy for the whole-building electricity and sub-loads (Figure 34a), metered data from the Motor Control Center (Figure 34b), metered data from the chillers (Figure 34c and Figure 34d), metered data from the boiler, (Figure 34e), and solar data collected to verify the low-E glazing (Figure 34f).
### Table 1. Monitoring Channel Description

<table>
<thead>
<tr>
<th>NAME</th>
<th>DESCRIPTION</th>
<th>UNIT</th>
<th>EQUATION</th>
<th>CHANNELS</th>
</tr>
</thead>
<tbody>
<tr>
<td>WBE</td>
<td>Whole-building Electricity Use</td>
<td>KwH</td>
<td>The combination of those channels would represent the WBE</td>
<td>Building Electricity 1 Phase A (ch4497)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Building Electricity 1 Phase B (ch4498)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Building Electricity 1 Phase C (ch4499)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Building Electricity 2 Phase A (ch4500)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Building Electricity 2 Phase B (ch4501)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Building Electricity 2 Phase A (ch4502)</td>
</tr>
<tr>
<td>Chiller #1 Efficiency</td>
<td>Chiller #1 performance (Kw/Ton) at the Certain Capacity (Ton)</td>
<td>Kw/Ton</td>
<td>Chiller Elec * 12/ Q(kBtu)</td>
<td>Chiller 1 Electricity Phase A (ch4478)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Chiller 1 Electricity Phase C (ch4479)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Chiller 1 Chilled Water Flow (ch4487)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Chiller 1 Supply Temperature (ch4485)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Chiller 1 Return Temperature (ch4486)</td>
</tr>
<tr>
<td>Chiller #2 Efficiency</td>
<td>Chiller #2 performance (Kw/Ton) at a certain capacity (Ton)</td>
<td>Kw/Ton</td>
<td>Chiller Elec * 12/ Q(kBtu)</td>
<td>Chiller 2 Electricity Phase A (ch4480)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Chiller 2 Electricity Phase C (ch4481)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Chiller 2 Chilled Water Flow (ch4489)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Chiller 2 Supply Temperature (ch4490)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Chiller 2 Return Temperature (ch4491)</td>
</tr>
<tr>
<td>Building Electric Use</td>
<td>Whole-building Electric Use is break down into end use such as motor control (MCC), Chiller electric use by direct measurement</td>
<td>KwH</td>
<td></td>
<td>WBE</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>MCC</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>Chiller Electricity</td>
</tr>
<tr>
<td>Chiller Temperature</td>
<td>This plot would represent the supply chilled water temperature and return chilled water temperature based on direct measurement</td>
<td>Degree F</td>
<td>Chiller #1 Supply and Return Temp. Chiller #1 Supply and Return Temp.</td>
<td>ch4485, ch4486, ch4490, ch4491</td>
</tr>
<tr>
<td>Condenser Temperature</td>
<td>This plot would represent the supply condenser water temperature and return condenser water temperature based on direct measurement</td>
<td>Degree F</td>
<td>Condenser Supply and Return Temp.</td>
<td>ch4495, ch4496</td>
</tr>
<tr>
<td>4th Floor Electric use</td>
<td>This plot would represent the 4th floor electric energy consumption, receptacle energy, and lighting energy use</td>
<td>KWh</td>
<td></td>
<td>4th Floor Total Electricity Use</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Receptacle Electricity Use</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Lighting Elec. Use</td>
</tr>
</tbody>
</table>


**Texas General Services Commission**

**Texas State Energy Conservation Office**

**Energy Systems Laboratory**

**Texas Engineering Experiment Station, Texas A&M University**
Figure 34. Monitoring Diagrams for the REJ Building
3.2 Simulation of the Window Properties

This section discusses the methods used to evaluate the in-situ window properties and the exporting of these data for use by the DOE-2 software. In this study, low-E insulated glazing manufactured by Varicon was evaluated to determine the solar transmittance and to simulate the spectral properties of the window for input into the DOE-2 program for the existing building construction. In general, two types of energy efficient, low-E glazing were used in the building - the upper clerestory and the lower window area. Because the optical data of the low-E and clear glazed window systems were previously tested and reported by Lawrence Berkley Laboratory, this study used the previously published data after verifying it against the on-site solar measurements (LBL, 2001). In the DOE-2 energy software, these solar transmission coefficients were then used to describe the relationship between transmittance of the window and the incidence angle of the sun. In addition to the physical description of the window, the thermal properties such as conductance, spectral properties, emissivity, and the solar heat gain coefficient were input into the software. Using the Window 4.1 program (LBL 1997), this study created window library entries for each window type and appended the existing window library file of the energy software. See the Appendix for additional details about the window library entries.

3.3 Review of the Pre-simulation Report

This section reviews the Energy Analysis Report of the R. E. Johnson State Office Building in Austin Texas, which was developed by Charles Eley and Associates (Eley and Tathagat 1998). The stated purposes of the Eley report were to reduce the peak load and to qualify the building for rebate under the City of Austin’s “Commercial New Construction
Program”, which required a comparison simulation of the proposed building with a reference building.

Table 2 contains the name and description of various DOE-2 simulations produced by Eley and Associates. These files are of three basic types: 1) error files which are the reported errors in the input code, 2) input files which are the LOADS, SYSTEMS, and PLANT descriptions, and 3) output files which are the results of the simulation runs. Six different simulations were provided by Eley and Associates:

- Alt1-DualDuct+VAV
- Alt2-ASHRAE 90.1
- Alt3-DualDuct-DualFan
- Alt3-DualDuct-DualFan-2
- Base-case, 6: -ASHRAE 90.1 CASE
- ASHRAE 90.1 Case

In the Eley report, the reference building, also referred to as the prototype building, is defined by the Austin Energy Code, based on ASHRAE Standard 90.1-1989. As stated by Eley, the principal purpose of the report is to determine peak load reduction. In the Eley analysis, DOE 2.1e, release 114 was used to create the simulation reports. Specifically, internal shading devices, daylighting, and HVAC features were used in the proposed building. Figure 35 shows graphical views of the simulation input file by Eley and Associates. When one compares this figure to Figure 33 it is clear that the building that was submitted to the City of Austin was similar, but not the same as what was eventually built. For example, the Eley building did not include the shading effect of the trees on the south side of the building, or the shading effects from the parking garage, and other geometric differences in the building shape.\(^5\)

\(^5\) One of these differences can be seen in Figure 35c, which shows the effect of using a floor multiplier command that creates the appropriate thermal load by multiplying the loads from one floor times the number of floors with the same shape. Unfortunately, when viewed with the DrawBDL program, this causes the floor to visually float about the lower floors.
Other differences include: equipment descriptions, zoning, treatment of daylighting, and assumptions about occupancy and equipment schedules.

Table 2. List of DOE-2 Files from the Report by Eley and Associates (Eley and Tathagat 1998).

<table>
<thead>
<tr>
<th>DATE</th>
<th>TIME</th>
<th>SIZE</th>
<th>NAME</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
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<td>599.552</td>
<td>JOHNSON7.80</td>
<td>Error File for Alt1-DualDuct+VAV</td>
</tr>
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<td>64,996</td>
<td>JOHNSON7.81</td>
<td>Error File for Alt2-ASHRAE 90.1</td>
</tr>
<tr>
<td>02/21/97</td>
<td>04:20p</td>
<td>292,435</td>
<td>JOHNSON7.82</td>
<td>Error File for Alt3-DualDuct-DualFan</td>
</tr>
<tr>
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<td>JOHNSON7.83</td>
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<tr>
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<td>299,085</td>
<td>JOHNSON7.84</td>
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</tr>
<tr>
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<td>64,305</td>
<td>JOHNSON7.85</td>
<td>Error File for 6-ASHRAE 90.1 CASE</td>
</tr>
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<td>69,938</td>
<td>JOHNSON7.86</td>
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<td>dooe2e JOHNSON7.B2 AUSTINTX.bin</td>
</tr>
<tr>
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<td>05:13p</td>
<td>716,549</td>
<td>JOHNSON7.GPH</td>
<td>Could not open with text editor - Program dependent</td>
</tr>
<tr>
<td>02/19/97</td>
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<td>165,454</td>
<td>JOHNSON7.B0</td>
<td>Input File for Alt1-DualDuct+VAV</td>
</tr>
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<td>37,513</td>
<td>JOHNSON7.B1</td>
<td>Input File for Alt2-ASHRAE 90.1</td>
</tr>
<tr>
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<td>166,645</td>
<td>JOHNSON7.B2</td>
<td>Input File for Alt3-DualDuct-DualFan</td>
</tr>
<tr>
<td>02/19/97</td>
<td>01:36p</td>
<td>166,320</td>
<td>JOHNSON7.B3</td>
<td>Input File for Alt3-DualDuct-DualFan-2</td>
</tr>
<tr>
<td>Not Provided</td>
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<td></td>
<td>JOHNSON7.B4</td>
<td>Input File for Base Case</td>
</tr>
<tr>
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<td>37,271</td>
<td>JOHNSON7.B5</td>
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</tr>
<tr>
<td>Not Provided</td>
<td></td>
<td></td>
<td>JOHNSON7.B6</td>
<td>Input File for ASHRAE 90.1 Case</td>
</tr>
<tr>
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<td>176,581</td>
<td>JOHNSON7.B8</td>
<td>Output File for Alt1-DualDuct+VAV</td>
</tr>
<tr>
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<td>86,772</td>
<td>JOHNSON7.B9</td>
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<td>944,777</td>
<td>JOHNSON7.B10</td>
<td>Output File for Alt3-DualDuct-DualFan</td>
</tr>
<tr>
<td>Not Provided</td>
<td></td>
<td></td>
<td>JOHNSON7.B11</td>
<td>Output File for Alt3-DualDuct-DualFan-2</td>
</tr>
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<td>JOHNSON7.B12</td>
<td>Output File for Base Case</td>
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<td>JOHNSON7.B13</td>
<td>Output File for 6-ASHRAE 90.1 CASE</td>
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<td>86,790</td>
<td>JOHNSON7.B14</td>
<td>Output File for ASHRAE 90.1 Case</td>
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<td>JOHNSON7.ZIP</td>
<td>Compressed Archive of the original files</td>
</tr>
</tbody>
</table>
Figure 35. BDL From Eley Report - Filename (*.10)
3.4 Measured Energy Use

In this section the monthly utility costs and the measured hourly energy use are shown. In Table 3 and Figure 36 the Monthly Electricity Utility bills from the City of Austin are shown. Table 4 and Figure 37 show the monthly natural gas usage and costs. Portions of these utility billing data were used to help verify the measured data, and were used as a final check for the simulation program. However, as will be discussed, direct comparison of these monthly utility costs with similar building was of limited use because of the high internal loads in the REJ building due to the Senate print shop and computing center.

The spike in the monthly gas utility billing data represents excess gas use due to a malfunctioning temperature-pressure valve on the building’s boiler, which was not captured by the measured whole-building heating loads\(^6\).

![Figure 36. Monthly Electric Utility Billing Use From the City of Austin for January 2000 to December 2000 (kWh/Mo.)](image)

---

\(^6\) This observation was confirmed by conversations with the building administration.
Table 3. Monthly Electricity Utility Billing Data Received From the City of Austin.

<table>
<thead>
<tr>
<th>Billing Date</th>
<th>Month #</th>
<th>Day</th>
<th>Year</th>
<th>Reading Date</th>
<th>Days/Mo</th>
<th>Total/Mo kWh/Mo</th>
<th>Tot/Day kWh/day</th>
<th>Demand kWh/Mo</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nov</td>
<td>12</td>
<td>18</td>
<td>98</td>
<td>12/18/98</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Dec</td>
<td>12</td>
<td>23</td>
<td>98</td>
<td>12/23/98</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Jan</td>
<td>1</td>
<td>26</td>
<td>99</td>
<td>01/26/99</td>
<td>34</td>
<td>2,000</td>
<td>59</td>
<td>400</td>
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<td>24</td>
<td>99</td>
<td>02/24/99</td>
<td>29</td>
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<td>220</td>
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<td>29</td>
<td>99</td>
<td>03/29/99</td>
<td>33</td>
<td>128,000</td>
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<td>400</td>
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<td>Apr</td>
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<td>27</td>
<td>99</td>
<td>04/27/99</td>
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<td>174,000</td>
<td>6,000</td>
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<td>26</td>
<td>99</td>
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<td>99</td>
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<td>99</td>
<td>07/27/99</td>
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<td>27</td>
<td>99</td>
<td>08/27/99</td>
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<td>09/28/99</td>
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<td>980</td>
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<td>1220</td>
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<td>100</td>
<td>06/30/00</td>
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<td>706,000</td>
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<td>26,645</td>
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</tr>
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<td>Sep</td>
<td>9</td>
<td>29</td>
<td>100</td>
<td>09/29/00</td>
<td>29</td>
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<td>Oct</td>
<td>10</td>
<td>31</td>
<td>100</td>
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<td>714,000</td>
<td>22,313</td>
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<td>101</td>
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<td>32</td>
<td>724,000</td>
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</tr>
<tr>
<td>Feb</td>
<td>2</td>
<td>28</td>
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<td>02/28/01</td>
<td>28</td>
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<tr>
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<td>30</td>
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<td>716,000</td>
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<tr>
<td>Apr</td>
<td>4</td>
<td>30</td>
<td>101</td>
<td>04/30/01</td>
<td>31</td>
<td>768,000</td>
<td>24,774</td>
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</table>
Figure 37. Monthly Gas Consumption From June 2000 Through May 2001

Table 4. Monthly Gas Utility Billing Data

<table>
<thead>
<tr>
<th>Billing Date</th>
<th>Month #</th>
<th>Day</th>
<th>Year</th>
<th>Reading Date</th>
<th>Days/Month</th>
<th>Total/Month MCF</th>
<th>Tot/Day MCF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apr</td>
<td>4</td>
<td>5</td>
<td>100</td>
<td>04/05/00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jun</td>
<td>6</td>
<td>3</td>
<td>100</td>
<td>06/03/00</td>
<td>59</td>
<td>158.0</td>
<td>2.7</td>
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<tr>
<td>Jul</td>
<td>7</td>
<td>1</td>
<td>100</td>
<td>07/01/00</td>
<td>28</td>
<td>236.9</td>
<td>8.5</td>
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<tr>
<td>Aug</td>
<td>8</td>
<td>1</td>
<td>100</td>
<td>08/01/00</td>
<td>31</td>
<td>42.9</td>
<td>1.4</td>
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<tr>
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<td>1</td>
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<td>09/01/00</td>
<td>31</td>
<td>65.7</td>
<td>2.1</td>
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<tr>
<td>Oct</td>
<td>10</td>
<td>1</td>
<td>100</td>
<td>10/01/00</td>
<td>30</td>
<td>46.2</td>
<td>1.5</td>
</tr>
<tr>
<td>Nov</td>
<td>11</td>
<td>1</td>
<td>100</td>
<td>11/01/00</td>
<td>31</td>
<td>0.3</td>
<td>0.0</td>
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<tr>
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<td>12</td>
<td>1</td>
<td>100</td>
<td>12/01/00</td>
<td>30</td>
<td>1,153.7</td>
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<td>01/01/01</td>
<td>31</td>
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<tr>
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<td>1</td>
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<td>93.8</td>
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<td>3</td>
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<td>03/01/01</td>
<td>28</td>
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<tr>
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<td>1</td>
<td>101</td>
<td>04/01/01</td>
<td>31</td>
<td></td>
<td>0.0</td>
</tr>
<tr>
<td>May</td>
<td>5</td>
<td>1</td>
<td>101</td>
<td>05/01/01</td>
<td>30</td>
<td>1,687.8</td>
<td>56.3</td>
</tr>
</tbody>
</table>
Figure 38 to Figure 50 show the measured hourly data for the period January 1, 2001 through October 22, 2001. These data revealed much about the building and were very useful in calibrating the as-built simulation. In Figure 38 the whole-building electricity use is shown along with the electricity use of the motor control center in the main cooling plant, which includes the chiller electricity use and the electricity use of the associated equipment. The daytime peak for the whole-building electricity use of the REJ building can be seen varying from a low of about 1,000 kW\textsuperscript{7} in the winter months to a summertime high of over 1,300 kW. Evening electricity use of the REJ building varied from a low of 750 kW in the winter months to a high of about 950 kW in the summer months. This variation is due to the load from the cooling plant, as seen in Figure 39.

A closer inspection of the electricity use of the cooling plant (i.e., the motor control center) reveals that there were two distinct loads in the cooling plant, the loads caused by the chillers (Figure 40), which varied significantly from day to day and with temperature, and the loads from the pumps, and cooling towers (i.e., the lower line in Figure 39), which varied little throughout the year\textsuperscript{8}.

Figure 41 and Figure 42 show the measured heating and cooling energy use, respectively. Figure 41 shows the measured whole-building heating energy use, which was obtained from a Btu meter that was installed to measure the heating produced by the building’s boiler. Clearly, several periods of use can be seen in Figure 41, the high heating use in the winter months, the reduced heating use from May through July, followed by a

\textsuperscript{7} These electric demand values are based on the measured hourly data, which may be lower than the 15-minute hourly demand as measured by the City of Austin.

\textsuperscript{8} This lack of variation in the electricity use of the pumps and cooling tower may be indicating a potential to reduce energy use since the plant contains variable speed pumping, which has not been optimized.
further reduction in August. Later in this report it will be shown that this second drop in heating energy use was caused by an operational change, which was implemented by GSC to reduce the temperature of the hot water in the building (an example of the value of

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**Figure 38. Measured Whole-building and Motor Control Center Electricity Use**

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**Figure 39. Measured Motor Control Center Electricity Use**
Figure 40. Measured Chiller Electricity Use

Figure 41. Measured Whole-building Heating
the value of informed-feedback to the building operators). Figure 42 shows the cooling energy use measured with a Btu meter located in the chiller water line leaving the cooling plant. A comparison of Figure 41 and Figure 42 indicates the striking 4:1 difference between the building’s heating and cooling loads, which was one of the driving forces behind the careful selection of energy conserving design features.

Figure 43 to Figure 45 show the measured hourly solar radiation data that were used to evaluate the effectiveness of the low-E glazing. Figure 43 shows the global horizontal solar radiation that was measured on the inside of the west-facing window. Figure 44 shows the global horizontal solar radiation that was measured on the south-facing glazing, and Figure 45 shows the exterior, global horizontal solar radiation. Several features are evident in the comparison of these graphs. First, as expected, the magnitude of the peak solar radiation from the interior horizontal solar measurements for both exposures is about 200 W/m², which is a clear indication that the low-E glazing is working as expected. However, the time of occurrence of the peak loads for the south-facing glazing and west-facing glazing are in different seasons, with the west-facing peaks occurring in the summer, and the south facing loads, occurring in the spring and fall.

Figure 46 shows the measured supply and return temperatures for the building’s hot water supply. Measurement of these temperatures along with the flow rate of the water is used to calculate the building’s thermal heating load. These temperatures were also useful for setting the hot water supply temperatures inside the simulation program. In general, the wider the variation in the difference between the supply (i.e., the upper line) and the return

---

9 The thermal loads shown in Figures 41 and 42 represent the cooling and heating demand, which is measured in millions of Btu. These plots do not include the efficiency of the boiler or chillers.
10 Data for Figure 45 represents coincident global horizontal radiation measured at the Langford solar test bench located in College Station, Texas, for the period January 1st, 2001 through October 22nd, 2001.
temperatures the larger the heating loads. Also of note are the two periods where the supply temperature was reduced in August.

Figure 42. Measured Whole-building Cooling Energy Use
Figure 43. Measured Solar Radiation (Interior of West Façade)

Figure 44. Measured Solar Radiation (Interior of South Façade)
Figure 45. Measured Global Horizontal Solar Radiation at Texas A&M University
This was caused by the GSC building operators lowering the hot water temperature from 180 F to 150 F and then to 130 F to reduce energy use. This is followed by a return to about 145 F, which was caused by the need for increased heating for humidity control\textsuperscript{11}. These drops correspond to the previously observed drops in the building’s heating load shown in Figure 41.

Figure 47 and Figure 48 show the measured condenser water supply and return temperature, which were also used to calibrate the DOE-2 simulation. The figures also indicate several opportunities for reducing energy use. There are three periods of distinctly different operation. In the first period, during January, the building’s cooling was supplied by Chiller #2, which is indicated by the equal supply and return temperatures that track ambient conditions around the sensors. In the second period, the condenser tower was operated at an efficient return temperature of about 75 F, which lasted through March. Then, beginning in April and lasting until September, the cooling towers returned a constant 80 F temperature. This presents an opportunity for improving the efficiency of the chiller by developing control strategies that reduce the condenser return temperature. In Figure 49 and Figure 50 the drybulb temperature and relative humidity are shown, which were retrieved and translated from the NWS weather station at the airport in Austin, Texas.

\textsuperscript{11} Heating is often used in the summer in certain systems for dehumidification. This is because the cooling coil temperatures that are required to remove the moisture in the building’s air are too cold for certain parts of the building, which then need to have the air reheated to maintain comfort conditions.
Figure 46. Measured HW Supply and Return Temperature

Figure 47. Measured Condenser-1 Water Temperature
Figure 48. Measured Condenser-2 Water Temperature

Figure 49. National Weather Service (NWS) Ambient Temperature
Figure 50. National Weather Service (NWS) Relative Humidity
3.5 Developing Typical Building Data

One of the tasks that needed to be performed to calibrate the simulation was the development of input data that accurately reflected the “as-built” conditions. One of the first tasks that needed to be accomplished was the development of lighting and receptacle profiles that represented the measured lighting and receptacle profiles for the building. This task was an important step in capturing the efficiency of the lighting systems, and accurately profiling the electricity use of the receptacle loads, which are input to the DOE-2 program as internal electrical loads. To accomplish this task metering was installed on the electrical feeders to the fourth floor to capture the lighting+receptacles, and the receptacles transformer. Then, using subtraction, the lighting loads were obtained. The fourth floor represents approximately 44,100 square feet of conditioned space. The data collected from the fourth floor is shown in Figure 51a, Figure 51b, and Figure 51c.

These data were analyzed with the ASHRAE 1093-RP diversity factor calculation procedures (Abushakra et al., 2001), which yielded the profiles shown in Figure 52 to Figure 57, and the accompanying statistics shown Table 5, Table 6, and Table 7. In general, these profiles show low nighttime electricity use and low weekend electricity use when compared to diversity factor profiles for the nearby state office buildings (Haberl et al., 2001).

Several other features are also worth noting in the lighting and receptacle profiles. First, there is a significant difference in the evening profiles of the lights versus the receptacle loads during the weekdays. In the case of the lighting profiles, the lighting loads reach their peak level at 10:00 a.m., and gradually decrease beginning about 4:00 p.m., and continuing until about 3:00 a.m., which indicate the presence of cleaning crews. Receptacle profiles rise all
Figure 51. 4th Floor Electric Energy Use for Lighting and Receptacles
Figure 52. Typical Load Shapes of the Weekday types: 4\textsuperscript{th} Floor Lights & Receptacles

The dates that are excluded from the weekday profile are as follows:
11/23/00, 11/24/00, 11/27/00, 12/11/00, 12/18/00, 12/27/00, 1/1/01, and 4/13/01.

Figure 53. Typical Load Shapes of the Weekend Day types: 4\textsuperscript{th} Floor Lights & Receptacles
Figure 54. Typical Load Shapes of the Weekday types: 4th Floor Lights
The dates that are excluded from the weekday profile are as follows: 11/23/00, 11/24/00, 11/27/00, 12/11/00, 12/18/00, 12/27/00, 1/1/01, and 4/13/01.

Figure 55. Typical Load Shapes of the Weekend types: 4th Floor Lights
Figure 56. Typical Load Shapes of the Weekday types: 4th Floor Receptacles

The dates that are excluded from the weekday profile are as follows:
11/23/00, 11/24/00, 11/27/00, 12/11/00, 12/18/00, 12/27/00, 1/1/01, and 4/13/01.

Figure 57. Typical Load Shapes of the Weekend types: 4th Floor Receptacles
morning, peaking at noon, begin decreasing at 4:00 p.m., and reach their evening levels at about 7:00 p.m.

Weekend profiles are also different for the lights and receptacles. Lighting profiles on the weekends show some activity beginning at 9:00 a.m., and continue sometimes until 3:00 a.m., with significant variation. Receptacle profiles show almost no activity on the weekend. Finally, noticeably absent are the expected daytime reductions that are characteristic of lighting systems supplemented with daylighting and automatic dimming circuits\(^\text{12}\). Other electrical loads, which are served by the building, such as the parking lights, exterior lights, and the

---

\(^{12}\) Further evidence that additional effort is needed to activate the daylighting systems and train the building staff and occupants how to use the system.
Legislative Computer Center were identified, manually measured and added to the DOE-2 simulation.

### 3.6 As-built Calibration

To consider the simulation calibrated, good agreement between the measured and simulated data had to be obtained. The comparisons that were used to obtain the calibrated simulation consisted of:

- The whole-building hourly electricity energy use,
- The whole-building cooling energy use,
- The whole-building heating energy use, and
- The measured chiller efficiency (kW/ton vs. tons).

Figure 58 to Figure 63 show the measured and simulated energy use of the REJ building. Figure 60 shows good agreement between the measured whole-building, weather-independent electricity use for the REJ\(^{13}\) and the simulated, whole-building electricity use.

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\(^{13}\) This weather-independent, whole-building electricity use represents the whole-building electricity use minus the electricity use of the cooling plant, and the electricity use of the exterior lighting (including the parking lot lights).
Figure 58. Comparison of Measured and DOE-2 System Electricity Use for the As-built Building

Figure 59. Comparison of Measured and DOE-2 Whole-building Cooling Energy Use for the As-built Building
Figure 60. Comparison of Measured and DOE-2 Whole-building Heating Energy Use for the As-built Building

Figure 61. Comparison of Measured and DOE-2 Annual Heating Energy Use for the As-built Building
Figure 62. Time Series Comparison of Measured and DOE-2 Whole-building Cooling Energy Use for the As-built Building

Figure 63. Comparison of Measured Chiller Efficiency and DOE-2 Chiller Efficiency for the As-built Building
Figure 59 and Figure 62 show good agreement in the daily cooling loads\(^ {14}\) during peak periods, with significant variations in the measured part-load conditions, which most likely reflect unknown changes to the building operation during the 10 month measurement period. Figure 60 and Figure 61 show good agreement between the measured and simulated heating loads for the REJ building\(^ {15}\). Significant variation can also be seen in the part-load heating periods, which also include the previously mentioned changes to the hot water delivery temperatures.

Finally, Figure 63 shows the measured and simulated performance of the building’s chillers, which performed as expected at 0.5 kW/ton. The slight bifurcation in the measured data in the 200 to 500 ton range indicates periods when one (i.e., the lower, more efficient group) or both chillers (the upper group) were in operation. This grouping was not evident in the DOE-2 simulation, which simulates only the optimal loading on the chillers.

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\(^{14}\) These daily cooling loads represent the cooling produced by the chillers, which was measured with Btu meters in the chilled water lines.

\(^{15}\) These loads are also the building’s thermal loads as measured with Btu meters in the hot water lines. Variations in the time series plots are to be expected since the simulated data reflect the weather contained in the TMY2 weather file, and the measured data reflect the weather conditions that occurred during measurement period.
4 RESULTS OF THE ANALYSIS

To determine the building’s sustainability, results of the calibrated simulation were first compared to similar buildings within the LoanSTAR database. Second, each selected energy conserving measure (ECM) was varied to determine the individual effect for each condition and then all ECMs were combined to determine an aggregated effect that is considered to be the base-case building (i.e., a building with the same shape, that performs the same functions, but does not contain the identified energy conserving design features).

4.1 Comparison with Similar Buildings

As a first step in the analysis, the simulated annual energy use of the REJ was compared with similar office buildings (Haberl et al., 2001) as shown in Figure 64, and Table 8. In general, these buildings represent similar buildings in Austin, Texas, that were assembled from measured LoanSTAR data. Of importance to this research the buildings:

11 - John H. Reagan Building,
12 – Insurance Building,
13 – Archives building,
14 – W.B. Travis Building,
15 – L.B. Johnson Building,
16 – Price Daniels Building,

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16 Additional information about the LoanSTAR program can be found in Turner et al. 2000.
17 The simulated energy use of the REJ was used instead of the actual energy use since 12 months of utility billing data were not available at the time this report was written. Also, it was felt that the simulation was probably more representative of the as-built building since the building was still undergoing unknown commissioning procedures throughout the 2001 measurement period.
18 The buildings presented in this table are from a study performed for the Federal Reserve Bank in Dallas to assist with benchmarking the energy use of the bank against similar buildings. In this study data from 27 buildings were analyzed and Energy Use Indices (EUIs) prepared for heating, cooling and electricity use. These buildings were organized into CBECs size classification: Large (L) > 100,000 ft², Medium (M) > 10,000 ft² and < 100,000 ft², and Small (S) < 10,000 ft². In Figure 64 the EUIs are shown for those buildings that contained data for electricity, cooling and heating use (i.e., buildings that did not contain electricity, heating and cooling data are shown as zero).
17- Tom C. Clark Building,
20 – Capitol Building,
21 – Sam Houston Building,
23 – James E. Rudder Building,
24 – Insurance Annex building,
25 – Central Services Building,
26 – Supreme Court Building.
In comparison, the total Energy Use Index (EUI) for the Robert E. Johnson Building was calculated to be 148.26 kBtu per square foot, which compares well with the Supreme Court Building (26).

Table 8. Index of Typical Buildings in Texas (Haberl et al., 2001)

<table>
<thead>
<tr>
<th>No.</th>
<th>Building</th>
<th>Location</th>
<th>Building Area (sqft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>USDOE Forrestal Building</td>
<td>Washington D.C</td>
<td>1,200,000</td>
</tr>
<tr>
<td>2</td>
<td>Judicial Building</td>
<td>Minneapolis, MN</td>
<td>200,829</td>
</tr>
<tr>
<td>3</td>
<td>State Office Bldg.</td>
<td>Minneapolis, MN</td>
<td>281,850</td>
</tr>
<tr>
<td>4</td>
<td>Capitol Building</td>
<td>Minneapolis, MN</td>
<td>366,805</td>
</tr>
<tr>
<td>5</td>
<td>Centennial Building</td>
<td>Minneapolis, MN</td>
<td>317,286</td>
</tr>
<tr>
<td>6</td>
<td>Ford Building</td>
<td>Minneapolis, MN</td>
<td>57,047</td>
</tr>
<tr>
<td>7</td>
<td>Veterans Building</td>
<td>Minneapolis, MN</td>
<td>87,664</td>
</tr>
<tr>
<td>8</td>
<td>Criminal Apprehension Bld</td>
<td>Minneapolis, MN</td>
<td>77,630</td>
</tr>
<tr>
<td>9</td>
<td>Butte Courthouse</td>
<td>Butte, MT</td>
<td>100,000</td>
</tr>
<tr>
<td>10</td>
<td>Government Center</td>
<td>Dallas, TX</td>
<td>473,800</td>
</tr>
<tr>
<td>11</td>
<td>John H. Reagan</td>
<td>Austin, TX</td>
<td>169,746</td>
</tr>
<tr>
<td>12</td>
<td>Insurance Building</td>
<td>Austin, TX</td>
<td>102,000</td>
</tr>
<tr>
<td>13</td>
<td>Archives Building</td>
<td>Austin, TX</td>
<td>120,000</td>
</tr>
<tr>
<td>14</td>
<td>W.B. Travis</td>
<td>Austin, TX</td>
<td>491,000</td>
</tr>
<tr>
<td>15</td>
<td>L.B. Johnson</td>
<td>Austin, TX</td>
<td>308,080</td>
</tr>
<tr>
<td>16</td>
<td>Price Daniels Building</td>
<td>Austin, TX</td>
<td>151,620</td>
</tr>
<tr>
<td>17</td>
<td>Tom C. Clark Building</td>
<td>Austin, TX</td>
<td>121,654</td>
</tr>
<tr>
<td>18</td>
<td>Pittman Atrium</td>
<td>Dallas, TX</td>
<td>100,000</td>
</tr>
<tr>
<td>19</td>
<td>Brazos County Courthouse</td>
<td>Bryan, TX</td>
<td>100,000</td>
</tr>
<tr>
<td>20</td>
<td>Capitol Building</td>
<td>Austin, TX</td>
<td>282,499</td>
</tr>
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<td>21</td>
<td>Sam Houston Building</td>
<td>Austin, TX</td>
<td>182,961</td>
</tr>
<tr>
<td>22</td>
<td>Records Complex</td>
<td>Dallas, TX</td>
<td>323,232</td>
</tr>
<tr>
<td>23</td>
<td>James E. Rudder</td>
<td>Austin, TX</td>
<td>80,000</td>
</tr>
<tr>
<td>24</td>
<td>Insurance Annex</td>
<td>Austin, TX</td>
<td>62,000</td>
</tr>
<tr>
<td>25</td>
<td>Central Services Building</td>
<td>Austin, TX</td>
<td>97,030</td>
</tr>
<tr>
<td>26</td>
<td>Supreme Court Building</td>
<td>Austin, TX</td>
<td>72,737</td>
</tr>
<tr>
<td>27</td>
<td>Administration Building</td>
<td>Dallas, TX</td>
<td>42,385</td>
</tr>
</tbody>
</table>
However, this type of comparison falls short of providing an accurate assessment of the REJ building’s energy performance since it does not separate out the energy intensive Senate Print Shop and Computing Center that are housed in the REJ, which consume significant amounts of electricity. Hence, an accurate assessment can only be achieved for the REJ building using a simulation that is calibrated to the as-built building, and then used to measure the performance of the energy conserving design features by subtracting the features one-at-a-time until the base-case building, or standard office building is represented.
4.2 Analysis of ECMs

In order to evaluate the performance of the REJ building the energy savings of the individual energy conservation measure (ECMs) were analyzed with the calibrated, as-built simulation. For each measure the as-built DOE-2 input file was modified to reflect the condition that would have existed without the ECM. The energy savings were then calculated by comparing the simulated consumption of the as-built building (i.e. this reflects the reduced energy use with the ECM) to the simulated consumption of the building with the ECM removed. The analysis showing all the ECMs removed was then the base-case, or standard building. Table 9 provides a list of the building components that were affected by the identified ECM, and lists the assumptions about the ECMs for the as-built, base-case building, as well as the primary DOE-2 variable that was changed to produce the intended effect.

<table>
<thead>
<tr>
<th>Building Component</th>
<th>As-built</th>
<th>Base-case</th>
<th>DOE-2 Variable Name</th>
</tr>
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<tbody>
<tr>
<td>Motion Sensors</td>
<td>On</td>
<td>Off</td>
<td>Lighting schedule</td>
</tr>
<tr>
<td>Lighting</td>
<td>T-8 fluorescent bulbs</td>
<td>T-12 fluorescent bulbs</td>
<td>lighting-w/sqft</td>
</tr>
<tr>
<td>Chiller</td>
<td>0.5 kw/ton</td>
<td>0.75 kw/ton</td>
<td>elec-input-ratio</td>
</tr>
<tr>
<td>Window Glazing</td>
<td>Low-E Insulating Glass</td>
<td>Single Pane Bronze Tinted</td>
<td>glass-type-code</td>
</tr>
<tr>
<td>Air Handling</td>
<td>Variable Air Volume</td>
<td>Constant Volume</td>
<td>min-cfm-ratio</td>
</tr>
</tbody>
</table>

As indicated earlier in this report, five energy conservation measures were analyzed to determine the base-case conditions. Motion sensors were simulated by varying the lighting schedules to reflect the reductions observed in the measured lighting profiles. Two types of
low-E glazing were simulated for the as-built building and compared to single-pane, bronze glazing, which was used for the base-case building. To simulate REJ’s energy efficient HVAC system, a variable-air-volume (VAV) system was compared against a constant volume system. Finally, to evaluate the chiller ECM the kW/ton performance of the chiller was varied from a measured as-built value of 0.5 kW/ton to 0.75 kW/ton, which reflects the performance of a standard chiller (Haberl et al., 1997).

4.2.1 Motion Sensor Analysis

To analyze the savings attributed to the lighting motion sensors, the measured data from the fourth floor was used to determine the as-built internal loads. For the base-case (i.e., no motion sensors), the whole-building equipment and lighting used was used to determine the occupancy use of the building. In the base-case simulation (i.e., no motion sensors), these data were used to develop typical weekend and weekday lighting schedules for the sensor analysis (Figure 65, Figure 66). The DOE-2 simulation revealed that the lighting motion sensors reduced the annual lighting load by 19.2%, the cooling load by 3.5%, and the fan energy by 2.9%. However, the building’s heating load increased by 10.9%, yielding a total savings of 1,257 MMBtu/year or 2.81% (Table 10 and Figure 67).
Figure 65. Typical Lighting Schedules for As-built Simulation

Figure 66. Typical Lighting Schedules for Base-case Lighting Simulation
Figure 67. Comparison of As-built (w/sensors) and Base-case (w/o sensors) Simulated Electricity Use

Table 10. Building Energy Performance (BEPS) Comparison for Motion Sensor ECM

<table>
<thead>
<tr>
<th></th>
<th>As-built (MMBtu)</th>
<th>Sensors (MMBtu)</th>
<th>% Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area Lights</td>
<td>8327</td>
<td>10312</td>
<td>19.2%</td>
</tr>
<tr>
<td>Misc. Equipment</td>
<td>13625</td>
<td>13625</td>
<td>0.0%</td>
</tr>
<tr>
<td>Space Heat</td>
<td>10531</td>
<td>9500</td>
<td>-10.9%</td>
</tr>
<tr>
<td>Space Cool</td>
<td>6172</td>
<td>6393</td>
<td>3.5%</td>
</tr>
<tr>
<td>Heat Reject</td>
<td>1097</td>
<td>1115</td>
<td>1.6%</td>
</tr>
<tr>
<td>Pumps &amp; Misc.</td>
<td>424</td>
<td>424</td>
<td>0.0%</td>
</tr>
<tr>
<td>Vent Fans</td>
<td>2149</td>
<td>2213</td>
<td>2.9%</td>
</tr>
<tr>
<td>Dom. Hot Water</td>
<td>82</td>
<td>82</td>
<td>0.0%</td>
</tr>
<tr>
<td>Total</td>
<td>42407</td>
<td>43664</td>
<td>2.9%</td>
</tr>
</tbody>
</table>

NOTE: This table represents the values provided in the DOE-2 BEPS report that represent the electricity and natural gas use of the building’s energy consuming systems, as measured at the utility meter. SPACE HEAT is the sum of electricity and natural gas for space heating. SPACE COOL is the electricity used by the building’s chillers.
4.2.2 Lighting Analysis

To analyze the savings attributed to the energy efficient lighting, the measured data from the fourth floor was again used to determine the as-built condition. First, the maximum lighting kW for the fourth floor was determined and adjusted with a 5% increase to account for the emergency lighting that were not within the metered fourth floor channel. Then, using the area of the fourth floor, the lighting consumption was calculated in Watts per square foot (Table 11), yielding a 1.31 W/sq.ft. lighting density. To determine the Watts per square foot for the base-case, which assumed T-12 lamps, the lighting density was increased to 1.74 W/sq.ft., a 25% increase over the energy efficient T-8 lamps (Table 12). The lighting used per square foot was then varied in the DOE-2 simulation to determine the change in energy use between the as-built simulation and the base-case simulation.

The results of the change can be seen in Figure 68, and Table 13. In contrast to the savings from the lighting motion sensors, the savings from the efficient T8 lighting reduced the building’s lighting load by 16.1%, the cooling load by 5.2%, and the ventilation and heat rejection loads by 5.6% and 2.2%, respectively. Since there was no increase in heating load, which is due in part to the HVAC system schedule, the total savings was 2,090 MMBtu or 4.7%.

Table 11. Measured Lighting Power Density for T-8 Lamps (4th Floor)

<table>
<thead>
<tr>
<th>Lighting</th>
<th>Emergency Maximum kW</th>
<th>Emergency Lighting (kW)</th>
<th>Area w/sq. ft.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lighting</td>
<td>54.85</td>
<td>2.74</td>
<td>44,100.00</td>
</tr>
</tbody>
</table>

Table 12. Lighting Power Density for T-8 and T-12 Lamps

<table>
<thead>
<tr>
<th>Lamps</th>
<th>kW/sq.ft.</th>
</tr>
</thead>
<tbody>
<tr>
<td>T8</td>
<td>1.31</td>
</tr>
<tr>
<td>T12</td>
<td>1.74</td>
</tr>
</tbody>
</table>
Figure 68. Comparison of As-built (w/efficient lighting) and Base-case (w/o efficient lighting) Simulated Electricity Use

Table 13. Building Energy Performance (BEPS) Comparison for Lighting ECM

<table>
<thead>
<tr>
<th></th>
<th>As-built (MMBtu)</th>
<th>Lighting (MMBtu)</th>
<th>% Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area Lights</td>
<td>8327</td>
<td>9924</td>
<td>16.1%</td>
</tr>
<tr>
<td>Misc. Equipment</td>
<td>13625</td>
<td>13625</td>
<td>0.0%</td>
</tr>
<tr>
<td>Space Heat</td>
<td>10531</td>
<td>10532</td>
<td>0.0%</td>
</tr>
<tr>
<td>Space Cool</td>
<td>6172</td>
<td>6511</td>
<td>5.2%</td>
</tr>
<tr>
<td>Heat Reject</td>
<td>1097</td>
<td>1122</td>
<td>2.2%</td>
</tr>
<tr>
<td>Pumps &amp; Misc.</td>
<td>424</td>
<td>424</td>
<td>0.0%</td>
</tr>
<tr>
<td>Vent Fans</td>
<td>2149</td>
<td>2277</td>
<td>5.6%</td>
</tr>
<tr>
<td>Dom. Hot Water</td>
<td>82</td>
<td>82</td>
<td>0.0%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>42407</strong></td>
<td><strong>44497</strong></td>
<td><strong>4.7%</strong></td>
</tr>
</tbody>
</table>

NOTE: This table represents the values provided in the DOE-2 BEPS report that represent the electricity and natural gas use of the building’s energy consuming systems, as measured at the utility meter. SPACE HEAT is the sum of electricity and natural gas for space heating. SPACE COOL is the electricity used by the building’s chillers.
4.2.3 Chiller Analysis

The analysis of the performance of the energy efficient chillers was accomplished by entering the measured REJ chiller efficiency into the DOE-2 program for the as-built simulation, and comparing it against measured chiller efficiency for similar buildings in the LoanSTAR database (Haberl et al., 1997) as shown in Figure 69, Figure 70, and Table 14. The as-built chiller performance was measured to be approximately 0.5 kW/ton. The chiller performance for a standard building was 0.75 kW/ton. Figure 69 shows the simulated chiller performance kW/ton curve for the as-built chiller (i.e., the lower group of points), and the standard chiller (i.e., the upper group of points). The simulated results of this ECM show a 33.6% savings in the electricity used by the chiller, which amounts to a 3,228 MMBtu (7.1%) annual energy savings.

![Chiller Performance Curve](image)

Figure 69. Comparison of As-built (w/efficient chiller) and Base-case (w/o efficient chiller) Simulated Chiller Efficiency
Figure 70. Comparison of As-built (w/efficient chiller) and Base-case (w/standard chiller) Simulated Cooling Electricity Use

Table 14. Building Energy Performance Comparison for the Chiller ECM

<table>
<thead>
<tr>
<th></th>
<th>As-built (MMBtu)</th>
<th>Chiller (MMBtu)</th>
<th>Difference (MMBtu)</th>
<th>% Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area Lights</td>
<td>8327</td>
<td>8327</td>
<td>0.0%</td>
<td></td>
</tr>
<tr>
<td>Misc. Equipment</td>
<td>13625</td>
<td>13625</td>
<td>0.0%</td>
<td></td>
</tr>
<tr>
<td>Space Heat</td>
<td>10531</td>
<td>10623</td>
<td>0.9%</td>
<td></td>
</tr>
<tr>
<td>Space Cool</td>
<td>6172</td>
<td>9292</td>
<td>33.6%</td>
<td></td>
</tr>
<tr>
<td>Heat Reject</td>
<td>1097</td>
<td>1107</td>
<td>0.9%</td>
<td></td>
</tr>
<tr>
<td>Pumps &amp; Misc.</td>
<td>424</td>
<td>424</td>
<td>0.0%</td>
<td></td>
</tr>
<tr>
<td>Vent Fans</td>
<td>2149</td>
<td>2157</td>
<td>0.4%</td>
<td></td>
</tr>
<tr>
<td>Dom. Hot Water</td>
<td>82</td>
<td>82</td>
<td>0.0%</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>42407</strong></td>
<td><strong>45635</strong></td>
<td><strong>7.1%</strong></td>
<td></td>
</tr>
</tbody>
</table>

NOTE: This table represents the values provided in the DOE-2 BEPS report that represent the electricity and natural gas use of the building’s energy consuming systems, as measured at the utility meter. SPACE HEAT is the sum of electricity and natural gas for space heating. SPACE COOL is the electricity used by the building’s chillers.
4.2.4 Glazing Analysis

The analysis of the energy efficient low-E glazed window systems manufactured by Varicon were accomplished using data published by Lawrence Berkley Laboratory (LBL, 2001), which are included in the Window 4.1 library, as well as new library entries (LBL, 1997). The window library of the DOE-2 program was then appended, and the simulations using the standard glazing and energy efficient glazing were compared. The resultant values for the glazing are reported in Table 15\(^{19}\), and are shown graphically in Figure 71, Figure 72, and Figure 73.

Figure 73

Figure 74, Figure 75 and Table 16 show the simulated annual savings from the use of the low-E glazing. The use of the energy efficient, double-pane, low-E glazing reduced the annual heating energy use by 41.9%, the annual cooling energy use by 23.1%, the energy used by the building’s fans by 23.6%, and the heat rejection energy use by 9.9%, which accounted for a total energy reduction of 10,231 MMBtu, or 19.4%.

<table>
<thead>
<tr>
<th>Glazing</th>
<th>U-value(^{a}) Btu/hr-ft(^2)-F (W/m(^2)-C)</th>
<th>SC(^{b})</th>
<th>SHGC(^{c})</th>
<th>Vt(^{d})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Bronze Clear</td>
<td>1.12 (6.38)</td>
<td>0.71</td>
<td>0.61</td>
<td>0.51</td>
</tr>
<tr>
<td>REJ Upper Window</td>
<td>0.56 (3.18)</td>
<td>0.47</td>
<td>0.40</td>
<td>0.60</td>
</tr>
<tr>
<td>REJ Lower Window</td>
<td>0.39 (2.19)</td>
<td>0.33</td>
<td>0.28</td>
<td>0.35</td>
</tr>
</tbody>
</table>

\(^{a}\)U-value is the total heat transfer coefficient for the window system (W/m\(^2\)-C : Btu/hr-F-

\(^{b}\)SC is the shading coefficient for the total window system representing the ratio of the solar heat gain through the window system relative to that through 3 mm (1/8") clear glass at normal incidence.

\(^{c}\)SHGC is the solar heat gain coefficient of the total window system representing the solar heat gain through the window system relative to the incident solar radiation.

\(^{d}\)Vt is the total window system’s visible transmittance at normal incidence.

\(^{19}\) The Window 4.1 input files are also included in the appendix to this report.
Figure 71. Transmissivity vs. Angle of Incidence for Upper Window Clerestory

Tsol is the solar transmittance percentage.
Rsol is the solar reflectance percentage of the front and back (outward and inward) surfaces.
Tv is is the visible transmittance percentage.
Rv is is the visible reflectance percentage of the front and back (outward and inward) surfaces.

Figure 72. Transmissivity vs. Angle of Incidence for Lower Window System

Tsol is the solar transmittance percentage.
Rsol is the solar reflectance percentage of the front and back (outward and inward) surfaces.
Tv is is the visible transmittance percentage.
Rv is is the visible reflectance percentage of the front and back (outward and inward) surfaces.
Figure 73. Transmissivity vs. Angle of Incidence for Base-case Building
Tsol is the solar transmittance percentage.
Rsol is the solar reflectance percentage of the front and back (outward and inward) surfaces.
Tvis is the visible transmittance percentage.
Rvis is the visible reflectance percentage of the front and back (outward and inward) surfaces.

Figure 74. Comparison of As-built (w/ Low E) and Base-case (w/ single pane bronze) Simulated Cooling Energy Use.
Figure 75. Comparison of As-built (w/ low-E) and Base-case (w/ single pane bronze) Simulated Heating Energy Use.

Table 16. Building Energy Performance (BEPS) Comparison for the Glazing ECM

<table>
<thead>
<tr>
<th></th>
<th>As-built (MMBtu)</th>
<th>Glazing (MMBtu)</th>
<th>% Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area Lights</td>
<td>8327</td>
<td>8327</td>
<td>0.0%</td>
</tr>
<tr>
<td>Misc. Equipment</td>
<td>13625</td>
<td>13625</td>
<td>0.0%</td>
</tr>
<tr>
<td>Space Heat</td>
<td>10531</td>
<td>18124</td>
<td>41.9%</td>
</tr>
<tr>
<td>Space Cool</td>
<td>6172</td>
<td>8025</td>
<td>23.1%</td>
</tr>
<tr>
<td>Heat Reject</td>
<td>1097</td>
<td>1218</td>
<td>9.9%</td>
</tr>
<tr>
<td>Pumps &amp; Misc.</td>
<td>424</td>
<td>424</td>
<td>0.0%</td>
</tr>
<tr>
<td>Vent Fans</td>
<td>2149</td>
<td>2814</td>
<td>23.6%</td>
</tr>
<tr>
<td>Dom. Hot Water</td>
<td>82</td>
<td>82</td>
<td>0.0%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>42407</td>
<td>52638</td>
<td>19.4%</td>
</tr>
</tbody>
</table>

NOTE: This table represents the values provided in the DOE-2 BEPS report that represent the electricity and natural gas use of the building’s energy consuming systems, as measured at the utility meter. SPACE HEAT is the sum of electricity and natural gas for space heating. SPACE COOL is the electricity used by the building’s chillers.
4.2.5 Air Handling System Analysis

To vary the simulation of the air-handling system to reflect the energy efficient, variable volume system, the minimum CFM ratio in the DOE-2 program was varied between zero and one – zero being a variable volume system and one being a constant volume system. During the calibration process, it was discovered that the best fit to the data occurred at 0.6, therefore, this value was used to represent the minimum CFM ratio for the as-built building\(^{20}\). As a result, this analysis used a minimum CFM ratio of 0.6 for the as-built simulation and 1.0 for the standard air-handling simulation. Figure 76, Figure 77, Figure 78, and Table 17 show the results of the simulated comparison.

In Table 17 the results show that the energy efficient HVAC system reduced the heating energy use by 43.9\%, the cooling energy use by 16.8\%, the energy use of the building’s fans by 52.6\%, and the energy use associated with heat rejection by 8.4\%, resulting in a total energy use reduction of for a total energy reduction of 11,970 MMBtu, or 22.0\%.

\(^{20}\) Clearly, this presents an O&M opportunity for the REI, since lower values of the minimum CFM can be obtained which would reduce cooling energy use further. However, to obtain these lower values usually requires a careful analysis of the HVAC system, such as is accomplished in a Continuous Commissioning\(^{SM}\) process. Additional information about Continuous Commissioning\(^{SM}\) can be found in Claridge et al. 1996.
Figure 76. Comparison of As-built (w/constant volume) and Base-case (w/variable volume) Simulated Electricity Use.

Figure 77. Comparison of As-built (w/constant volume) and Base-case (w/variable volume) Simulated Heating Energy Use.
Figure 78. Comparison of As-built (w/constant volume) and Base-case (w/variable volume) Simulated Heating Energy Use.

Table 17. Building Energy Performance (BEPS) Comparison for the HVAC ECM

<table>
<thead>
<tr>
<th></th>
<th>As-built</th>
<th>HVAC (MMBtu)</th>
<th>% Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area Lights</td>
<td>8327</td>
<td>8327</td>
<td>0.0%</td>
</tr>
<tr>
<td>Misc. Equipment</td>
<td>13625</td>
<td>13625</td>
<td>0.0%</td>
</tr>
<tr>
<td>Space Heat</td>
<td>10531</td>
<td>18769</td>
<td>43.9%</td>
</tr>
<tr>
<td>Space Cool</td>
<td>6172</td>
<td>7417</td>
<td>16.8%</td>
</tr>
<tr>
<td>Heat Reject</td>
<td>1097</td>
<td>1197</td>
<td>8.4%</td>
</tr>
<tr>
<td>Pumps &amp; Misc.</td>
<td>424</td>
<td>427</td>
<td>0.7%</td>
</tr>
<tr>
<td>Vent Fans</td>
<td>2149</td>
<td>4533</td>
<td>52.6%</td>
</tr>
<tr>
<td>Dom. Hot Water</td>
<td>82</td>
<td>82</td>
<td>0.0%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>42407</td>
<td>54377</td>
<td>22.0%</td>
</tr>
</tbody>
</table>

NOTE: This table represents the values provided in the DOE-2 BEPS report that represent the electricity and natural gas use of the building’s energy consuming systems, as measured at the utility meter. SPACE HEAT is the sum of electricity and natural gas for space heating. SPACE COOL is the electricity used by the building’s chillers.
4.3 Base-case (Standard) Analysis

As a final analysis, all five ECMs\textsuperscript{21} were combined and compared against the calibrated as-built simulation. To produce the simulation of the standard or base-case building, all ECMs were replaced with standard equipment, which creates a building that represents the energy use of a standard building that has the same shape and functions as the REJ building, but does not contain the specific ECMs that were modified with the simulation program. Table 18, Table 19, Table 20, and Figure 79, Figure 80, Figure 81, and Figure 82 show the results of the comparison of the as-built simulation versus the standard building.

The results show that combined ECMs reduced the building’s lighting energy use by 32.9\%, space heating use by 61.7\%, space cooling use by 59.5\%, and fan and energy use associated with heat rejection by 67.0\% and 21.1\%, respectively. Overall, the building’s annual energy use was reduced by 34,752 MMBtu or 45.0\%. In Table 19 the reduction in monthly peak electric load is given, which shows that the ECMs reduced the building’s peak electricity use, varying from 483 kW (23.6\%) in July and August to 681 kW (34.3\%) in February.

\textsuperscript{21} This includes: 1) the lighting motion sensors, 2) the energy efficient lighting, 3) the energy efficient chillers, 4) the low-E glazing, and 5) the energy efficient variable-volume HVAC system.
Figure 79. Comparison of As-built (w/all ECMs) and Base-case (w/o ECMs) Simulated Electricity Use.

Figure 80. Comparison of As-built (w/all ECMs) and Base-case (w/o ECMs) Simulated Cooling Energy Use.
Figure 81. Comparison of As-built (w/all ECMs) and Base-case (w/o ECMs) Simulated Heating Energy Use.

Figure 82. Comparison of As-built (w/efficient chiller) and Base-case (w/standard chiller) Simulated Chiller Efficiency.
Table 18. Building Energy Performance (BEPS) Comparison for the Base Case (all ECMs)

<table>
<thead>
<tr>
<th></th>
<th>As-built (MMBtu)</th>
<th>Base-case (MMBtu)</th>
<th>% Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area Lights</td>
<td>8327</td>
<td>12406</td>
<td>32.9%</td>
</tr>
<tr>
<td>Misc. Equipment</td>
<td>13625</td>
<td>13625</td>
<td>0.0%</td>
</tr>
<tr>
<td>Space Heat</td>
<td>10531</td>
<td>27464</td>
<td>61.7%</td>
</tr>
<tr>
<td>Space Cool</td>
<td>6172</td>
<td>15249</td>
<td>59.5%</td>
</tr>
<tr>
<td>Heat Reject</td>
<td>1097</td>
<td>1391</td>
<td>21.1%</td>
</tr>
<tr>
<td>Pumps &amp; Misc.</td>
<td>424</td>
<td>426</td>
<td>0.5%</td>
</tr>
<tr>
<td>Vent Fans</td>
<td>2149</td>
<td>6515</td>
<td>67.0%</td>
</tr>
<tr>
<td>Dom. Hot Water</td>
<td>82</td>
<td>82</td>
<td>0.0%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>42407</strong></td>
<td><strong>77159</strong></td>
<td><strong>45.0%</strong></td>
</tr>
</tbody>
</table>

NOTE: This table represents the values provided in the DOE-2 BEPS report that represent the electricity and natural gas use of the building’s energy consuming systems, as measured at the utility meter. SPACE HEAT is the sum of electricity and natural gas for space heating. SPACE COOL is the electricity used by the building’s chillers.

Table 19. Peak Demand Reduction for Base Case (all ECMs)

<table>
<thead>
<tr>
<th>Month</th>
<th>As-built (kW)</th>
<th>Standard (kW)</th>
<th>% Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>1269</td>
<td>1901</td>
<td>33.2%</td>
</tr>
<tr>
<td>February</td>
<td>1309</td>
<td>1990</td>
<td>34.2%</td>
</tr>
<tr>
<td>March</td>
<td>1401</td>
<td>2040</td>
<td>31.3%</td>
</tr>
<tr>
<td>April</td>
<td>1477</td>
<td>2048</td>
<td>27.9%</td>
</tr>
<tr>
<td>May</td>
<td>1558</td>
<td>2050</td>
<td>24.0%</td>
</tr>
<tr>
<td>June</td>
<td>1555</td>
<td>2049</td>
<td>24.1%</td>
</tr>
<tr>
<td>July</td>
<td>1560</td>
<td>2043</td>
<td>23.7%</td>
</tr>
<tr>
<td>August</td>
<td>1562</td>
<td>2045</td>
<td>23.6%</td>
</tr>
<tr>
<td>September</td>
<td>1546</td>
<td>2050</td>
<td>24.6%</td>
</tr>
<tr>
<td>October</td>
<td>1552</td>
<td>2041</td>
<td>24.0%</td>
</tr>
<tr>
<td>November</td>
<td>1479</td>
<td>2043</td>
<td>27.6%</td>
</tr>
<tr>
<td>December</td>
<td>1276</td>
<td>1915</td>
<td>33.4%</td>
</tr>
</tbody>
</table>
5 SUMMARY

The results of the calibrated simulations show that the use of low-E glazing and the VAV system had the greatest impact on the energy savings of the building, with the VAV system having the greatest single effect. The lighting motion sensors having the least effect.

Table 20, and

Figure 83 give a summary view of the impact of the ECMs, individually, and combined. Overall, the building’s annual energy use was reduced by 34,752 MMBtu or 45.0%, and the monthly peak electric load was reduced as well, varying from 483 kW (23.6%) in July and August to 681 kW (34.3%) in February.

Figure 83. Simulated Building Energy Performance Summary (BEPS)
Table 20. Building Energy Performance (BEPS) Summary in MMBtu.

<table>
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<tr>
<th></th>
<th>As-built</th>
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<th>Chiller</th>
<th>Glazing</th>
<th>HVAC</th>
<th>Base-case</th>
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<td>1122</td>
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<td>1218</td>
<td>1197</td>
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<td>424</td>
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<td>2213</td>
<td>2277</td>
<td>2157</td>
<td>2814</td>
<td>4533</td>
<td>6515</td>
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<tr>
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<td>82</td>
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<td><strong>Total</strong></td>
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<td><strong>44497</strong></td>
<td><strong>45635</strong></td>
<td><strong>52638</strong></td>
<td><strong>54377</strong></td>
<td><strong>77159</strong></td>
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</tbody>
</table>

NOTE: This table represents the values provided in the DOE-2 BEPS report that represent the electricity and natural gas use of the building’s energy consuming systems, as measured at the utility meter. SPACE HEAT is the sum of electricity and natural gas for space heating. SPACE COOL is the electricity used by the building’s chillers.

This research analyzed five ECMs, and using calibrated simulation, has confirmed that the Robert E. Johnson State Office Building is a very efficient building, which uses approximately 50% less energy than a similar building which used construction practices that were documented in nearby buildings (i.e., lighting power density, glazing type, chiller performance and HVAC system). This 50% reduction compares well with the design prediction in the Eley report (Eley and Tathagat 1998), which was the basis for many of the design decisions. This reduced annual energy consumption will easily pay for the State’s investments in the energy conservation features of the REJ building many times over during the life of the building.

However, as stated earlier in the report, the full potential for reduced energy use at the Robert E. Johnson building has not been fully realized for several reasons. First, many of the ECMs either could not be simulated or could not be identified with the time constraints and resources allocated for this study. Examples include, enthalpy-based heat recovery on the Senate print shop, dual-path HVAC systems, which include run-around dehumidification coils, and the reduced pumping loads due to the location of the cooling plant.
Second, many of the design features that were identified either in the design documentation, or during discussions with the design team had been omitted or had been disabled during the construction of the building. Examples include, reduced electricity use due to the daylighting systems, thermostat settings, and other control functions in the HVAC systems that had been assumed in the original simulation.

Third, during the course of gathering the data for the analysis, numerous commissioning opportunities became apparent, which can reduce the building’s energy use\textsuperscript{22}. These opportunities vary from changing the setpoint temperature schedules of the building’s HVAC system to training the building’s occupants and custodial staff how to use the building’s daylighting system\textsuperscript{23}.

\textsuperscript{22} Most of these opportunities were discussed with the building’s operators, and in the case of the hot water delivery temperature, adjustments were made which already have reduced the REJ building’s energy use.

\textsuperscript{23} The need for the training of the building’s staff was discussed with the building’s administration, and certain measures are being considered for implementation.
6 RECOMMENDATIONS

The following recommendations are included to help improve the operation of the Robert E. Johnson building and for future high efficiency State buildings funded by the State of Texas:

6.1 Recommendations for the Robert E. Johnson Building.

- All ECMs designed and installed in the REJ building should be analyzed with calibrated simulation to ascertain how efficient the building really is. This will require additional study and data gathering beyond the scope of this study. Special attention will need to be paid to capturing and documenting the design intent from the original architects/engineers, since much of this information remained outside the grasp of this study.

- The Robert E. Johnson building should be thoroughly commissioned to make sure that all energy efficient systems are operating in an optimal fashion. This includes, but is not limited to the lighting systems, daylighting systems, and all HVAC systems.

- The REJ building should be continuously monitored and analyzed to assure the building remains efficient. Experiences with the LoanSTAR program have shown that energy savings from energy conservation measures begin to decrease when monitoring and reporting efforts cease (Turner et al., 2000).
6.2 Other Recommendations.

- All State buildings should be continuously monitored and analyzed to assure the buildings remain efficient. Additional channels should also be considered, including IAQ channels (i.e., temperature, humidity and CO and CO2), which could be used to help assure safe working conditions for the building occupants.

- The traditional design-construction-operation team needs to be expanded to include the analysis team that will be responsible for analyzing the energy conserving features of the building. Communication between team members should begin at the design stage and continue through the first few years of the building’s life to assure that all features are installed and working properly, and that questions about the design intend can be easily answered.

- The entire building design-construction-operation-analysis process needs to be reorganized to assure that the necessary information is generated, and then passed to the appropriate parties so that the energy efficient design features are properly designed, constructed, maintained, and then documented and analyzed. Special attention needs paid to any design simulations that were performed during the construction process, including the documentation of the original design intent, and the organization and details of the simulation input files.

- Payment arrangements to the design-construction-operation-analysis team should have incentives for exceeding performance goals, and penalties for not meeting design expectations. An important aspect of future contracts should include the building’s indoor IAQ, as well as pollution emission reductions from reduced energy use. Disincentives for energy efficiency should be removed whenever
possible. For example, use of low-bid purchases of equipment that may not be deemed to be energy efficient\(^{24}\).

- Emissions trading is possible for buildings that exceed the State’s new design code\(^{25}\) if careful attention is paid to the monitoring and analysis of the building’s performance. However, a number of technical hurdles remain in the way of seamlessly accomplishing this, including: how kWh and MCF savings will be converted to NOx and then Ozone reductions\(^{26}\), how a “standard” building will be defined and simulated\(^{27}\), and who would actually calculate and track emissions that are traded, which would be the basis for the financial exchange.

\(^{24}\) The Texas State Energy Code requires that standards for all equipment must meet or exceed ASHRAE Standard 90.1 1999 before considered for low bid.

\(^{25}\) In 2001 the Texas State Legislature passed Senate Bill 5, which adopts the 2000 International Energy Conservation Code (IECC) with amendments as the State energy code. This covers all types of residential and commercial buildings.

\(^{26}\) In the future this may also include carbon reductions.

\(^{27}\) For more information about the Senate Bill 5 analysis plan for emissions reductions from energy conservation measures in buildings, see the paper by Haberl et al., 2002.
7 REFERENCES


APPENDIX A

This appendix contains field notes from the tours of the REJ building during the course of this study.

Notes From Exterior Building Tour

- The building is divided into three sections with the divisions created by the ground level breezeway and vehicular access area. Please note that the building extends over these areas.
- The building’s north façade is approximately 14 degrees west of north, which exposes the north façade to direct sunlight during the afternoon hours.
- Over 50% glazing exists in the façade of the building.
- Blinds were installed in every window, including those having light shelves.
- The blinds within the light shelf windows were closed in some cases. Later it was found that the glare was too high.
- During the morning hours, approximately 95% of the blinds were closed on the East façade. It is assumed that this would be true for the west façade during the evening hours.
- Deciduous trees lined the entire south façade up to approximately the 3rd level. Because of this, according to Mr. Norton, the daylighting scheme was only implemented starting at the fourth level and up and only existed on the south façade.
- The existing building across 15th Street will shade the lower levels of the south façade during the winter months.
- Two types of glazing are used in the façade depending upon the orientation.

Notes From Meeting Two

- The final drawing sets of as-built documents are not yet complete, but would be provided once complete.
- Sample of the glazing types from VARICON located in Dallas, Texas would be acquired
- A sample of the Venetian blinds that are semi-transparent would be obtained from the New York Company.
- The Venetian blinds have small holes approximately 3/16 in. in diameter and space approximately 3/16 of an in. apart. Actual transmissivity will be
calculated using transmissivity formulas. Measurements will be made once sample is acquired.

- 3rd through 5th floors have daylighting sensors and light shelves.
- Too much light was entering the space, causing glare on computer screens. Thus, blinds were installed in the area of the light shelves as well the windows themselves.
- The material used to make the light shelf is a stainless steel with a mirror like finish on its the upper surface. See photos.
- The sensors are recessed within the light fixture and are located closest to the window. There are concerns regarding the light level reading and the dimming. That is, the sensor should be exposed to the 360-degree light to acquire an accurate light level reading. Because it is recessed, the sensor is only measuring the reflected light from the horizontal surfaces located at the tabletop or the floor.
- Average space temperatures were 73-74 degrees with a 45% humidity level and the occupants indicated that the space was too cold.

Notes From Interior Building Tour

- The dimming ballast were breaking
- The lighting sensors were going bad.
- The lamps were going out and do not work unless "burned in".
- The installation of the lighting system is incomplete and was never inspected.
## APPENDIX B

### DOE-2 Window Library File for Single Pane Bronze

This appendix contains the glazing property files that were developed with the Window 4.1 program, and used in the DOE-2 simulation to represent the different glazing systems analyzed in this report.

**WINDOW 4.1 DOE-2 Data File: Multi Band Calculation**

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</tr>
<tr>
<td>Spacer</td>
<td>1 Class1 2.330 -0.010 0.138</td>
</tr>
</tbody>
</table>

**Total Height:** 7010.4 mm  
**Total Width:** 4318.0 mm  
**Glass Height:** 6896.1 mm  
**Glass Width:** 4203.7 mm  
**Mullion:** None

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## DOE-2 Window Library Files for Lower Window Glazing

**WINDOW 4.1**  
**DOE-2 Data File : Multi Band Calculation**  
**Unit System :** SI  
**Name :** DOE-2 WINDOW LIB  
**Desc :** REJ-L-Win  
**Window ID :** 4000  
**Tilt :** 90.0  
**Glazings :** 2  
**Frame :** 1 Al no break  
**Total Height :** 7010.4 mm  
**Total Width :** 4318.0 mm  
**Glass Height :** 6896.1 mm  
**Glass Width :** 4203.7 mm  
**Mullion :** None  

### Glass and Spacers Information

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### SHGC

| SHGC | 0.278 |

### Overall and Center of Glass Ig U-values (W/m²-C)

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**Texas General Services Commission**
**Texas State Energy Conservation Office**

**Texas Engineering Experiment Station, Texas A&M University**
### DOE-2 Window Library Files for Upper Clerestory Window Glazing

**WINDOW 4.1 DOE-2 Data File: Multi Band Calculation**

- **Unit System**: SI
- **Name**: DOE-2 WINDOW LIB
- **Desc**: REJ-U-Win
- **Window ID**: 4001
- **Tilt**: 90.0
- **Glazings**: 2
- **Frame**: 1 Al no break 10.790
- **Spacer**: 1 Class1 2.330 -0.010 0.138

#### Total Height: 914.4 mm
- **Total Width**: 4318.0 mm
- **Glass Height**: 800.1 mm
- **Glass Width**: 4203.7 mm
- **Mullion**: None

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- **Abs2**: 0.048 0.048 0.049 0.049 0.050 0.051 0.049 0.043 0.030 0.000 0.047
- **Abs3**: 0 0 0 0 0 0 0 0 0 0 0
- **Abs4**: 0 0 0 0 0 0 0 0 0 0 0
- **Abs5**: 0 0 0 0 0 0 0 0 0 0 0
- **Abs6**: 0 0 0 0 0 0 0 0 0 0 0

#### Overall and Center of Glass Ig U-values (W/m²-C)
- **Outdoor Temperature**: -17.8 C 15.6 C 26.7 C 37.8 C

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DOE-2 Input File for the As-built Simulation

This part of the appendix contains the entire DOE-2 simulation input file for the as-built building. This input file represents the most accurate information available that describes the REJ building. It was used to simulate the existing REJ building and includes all the known ECMs described in this report.

**INPUT LOADS . . .**

**Title**

LINE-1 *AS-BUILT: R.E.JOHNSTON BLDG., AUSTIN *
LINE-2 *BY TEXAS A&M UNIVERSITY * . ..

**Run-Period**

JAN 1 2001 THRU DEC 31 2001 ..

**Abort**

ERRORS ..

**Diagnostic**

WARNINGS ..

**Loads-Report**

SUMMARY = (LS-D) ..

**Building-Location**

LATITUDE=30.3 LONGITUDE=97.7
ALTITUDE=610
TIME-ZONE=6 AZIMUTH=15.0 ..

$ EARTH SOIL (MAT357)

M-SOL= MATERIAL
THICKNESS= 1.5
CONDUCTIVITY= .5
DENSITY= 85
SPECIFIC-HEAT= .2 ..

$ HEAVEY WT. CONCRETE 12 IN. (MAT356)

M-COC= MATERIAL
THICKNESS= 1
CONDUCTIVITY= .3
DENSITY= 100
SPECIFIC-HEAT= .2 ..

$ STONE 10 IN. (MAT374)

M-STN= MATERIAL
THICKNESS= .8333
CONDUCTIVITY= 1.0416
DENSITY= 140
SPECIFIC-HEAT= .2 ..

$ ROOF METAL FRAME

RMF11= MATERIAL RESISTANCE = 6 ..

$ WALL METAL FRAME

WMF00= MATERIAL RESISTANCE = .61 ..

WMF11= MATERIAL RESISTANCE = 7.51 ..

$ Layer of Construction

ROO-1 =LAYERS =MAT=(BR01,IN47,CC26)
INSIDE-FLIM-RES= .61 ..

ROO-2 =LAYERS =MAT=(RMF11,IN11)
INSIDE-FLIM-RES= .61 ..

IW-1 =LAYERS =MAT=(M-STN,ALL1,IN34,WMF11,GP02)
INSIDE-FLIM-RES= 1.35 ..

IF-1 =LAYERS =MAT=(CC36)
INSIDE-FLIM-RES= .68 ..

IF-1 =LAYERS =MAT=(GP02)
INSIDE-FLIM-RES= .92 ..

CL-1 =LAYERS =MAT=(GP02)
INSIDE-FLIM-RES= .61 ..

$ CONSTRUCTION

ROOF-1 =CONSTRUCTION LAYERS =ROO-1 .. $ TYPICAL ROOF

ROOF-2 =CONSTRUCTION LAYERS =ROO-2 .. $ MEETING ROOM ROOF

WALL-1 =CONSTRUCTION LAYERS =EW-1 .. $ TYPICAL EXTERIOR-WALL

WALL-1-2 =CONSTRUCTION LAYERS =EW-2 .. $ PENTHOUSE EXTERIOR-WALL

WALL-2 =CONSTRUCTION LAYERS =IN-1 .. $ INTERIOR-WALL

FLOOR-1 =CONSTRUCTION LAYERS =IF-1 .. $ INTERIOR-FLOOR

FLOOR-U =CONSTRUCTION LAYERS =UN-1 .. $ UNDERGROUND-FLOOR & WALL
$ B U I L D I N G  S H A D E$

SHADING-SCHEDULE = WSHADE-SCH2

VIS-TRANS-SCH = TVIS-SCH1

SHADING-SCHEDULE = WSHADE-SCH2

$ BUILDING SCHEDULES$

$ OCCUPANCY SCHEDULE$

OCCUPY-1 = SCHEDULE

THRU DEC 31

(MD) (1),(24)

(0.05,0.05,0.05,0.05,0.05,0.10,0.20,0.70,0.86,0.91,0.93,0.94,
0.90,0.93,0.91,0.87,0.78,0.65,0.48,0.30,0.20,0.10,0.05,0.05)

(SAT) (1),(24)

(0.02,0.02,0.02,0.02,0.02,0.02,0.03,0.04,0.05,0.06,0.06,
0.06,0.06,0.06,0.06,0.05,0.04,0.03,0.03,0.02,0.02,0.02)

(SUN, HOL) (1),(24)

(0.02,0.02,0.02,0.02,0.02,0.02,0.03,0.04,0.05,0.06,0.06,
0.06,0.06,0.06,0.06,0.05,0.04,0.03,0.03,0.02,0.02,0.02)

$ LIGHTING SCHEDULE BASED ON Emodel analysis of the 4th floor$

LIGHT-1 = SCHEDULE

THRU DEC 31

(MD)

(1) (0.40) (2) (0.32) (3) (0.25) (4) (0.24) (5) (0.24) (6) (0.24)

(7) (0.24) (8) (0.21) (9) (0.20) (10) (0.20) (11) (0.94) (12) (0.24)

(13) (0.93) (14) (0.93) (15) (0.93) (16) (0.92) (17) (0.89) (18) (0.81)

(19) (0.76) (20) (0.72) (21) (0.66) (22) (0.60) (23) (0.55) (24) (0.51)

(WIN)

(1) (0.37) (2) (0.31) (3) (0.26) (4) (0.25) (5) (0.25) (6) (0.24)

(7) (0.24) (8) (0.26) (9) (0.28) (10) (0.30) (11) (0.33) (12) (0.36)

(13) (0.37) (14) (0.37) (15) (0.38) (16) (0.38) (17) (0.38) (18) (0.37)

(19) (0.36) (20) (0.66) (21) (0.66) (22) (0.66) (23) (0.66) (24) (0.66)

$ LIGHTING SCHEDULE for Garage$

LIGHT-2 = SCHEDULE

THRU DEC 31 (ALL) (1,24) (1)

$ EQUIPMENT SCHEDULE$

EQUIP-1 = SCHEDULE

THRU DEC 31

(MD)

(1) (0.71) (2) (0.70) (3) (0.69) (4) (0.68) (5) (0.68) (6) (0.68)

(7) (0.69) (8) (0.69) (9) (0.72) (10) (0.74) (11) (0.75) (12) (0.75)

(13) (0.75) (14) (0.74) (15) (0.74) (16) (0.74) (17) (0.74) (18) (0.74)

(19) (0.73) (20) (0.72) (21) (0.73) (22) (0.72) (23) (0.71) (24) (0.71)

(WIN)

(1) (0.71) (2) (0.70) (3) (0.69) (4) (0.68) (5) (0.68) (6) (0.68)

(7) (0.69) (8) (0.69) (9) (0.72) (10) (0.74) (11) (0.75) (12) (0.75)

(13) (0.75) (14) (0.74) (15) (0.74) (16) (0.74) (17) (0.74) (18) (0.74)

(19) (0.73) (20) (0.72) (21) (0.73) (22) (0.72) (23) (0.71) (24) (0.71)

EQUIP-2 = SCHEDULE

THRU DEC 31 (ALL) (1,24) (1)

$ INFILTRATION SCHEDULE$

INFIL-SCH = SCHEDULE

THRU DEC 31 (ALL) (1,24) (0)

$ SHADING SCHEDULE FOR TREE$

SHADE-SCH1 = SCHEDULE

THRU APR 30 (ALL) (1,24) (0.5)

THRU SEP 30 (ALL) (1,24) (0.7)

THRU DEC 31 (ALL) (1,24) (0.4)

$ SHADING SCHEDULE FOR BUILDING$

WSHADE-SCH2 = SCHEDULE

THRU DEC 31 (ALL) (1,24) (1)

$ DAYLIGHT TRANSMITTANCE SCHEDULE$

TVIS-SCH1 = SCHEDULE

THRU DEC 31 (ALL) (1,24) (0.3)

$ SET DEFAULT VALUES

SET-DEFAULT FOR SPACE FLOOR-WEIGHT = 70

SET-DEFAULT FOR EXTERIOR-WALL CONSTRUCTION = WALL-1

SHADING-SURFACE = YES

SET-DEFAULT FOR INTERIOR-WALL CONSTRUCTION = WALL-2

SET-DEFAULT FOR ROOF CONSTRUCTION = ROOF-1

SET-DEFAULT FOR UNDERGROUND-WALL CONSTRUCTION = FLOOR-U

SET-DEFAULT FOR WINDOW GLASS-TYPE = W-1 Y=2.33

WIN-SHADE-TYPE = MOVABLE-INTERIOR

VIS-TRANS-SCH = TVIS-SCH1

SHADING-SCHEDULE = WSHADE-SCH2

$ BUILDING SHADE
BSHADE1-1 BUILDING-SHADE TRANSMITTANCE=0
  X=200 Y=450 Z=0 H=120 W=240 AZ=180
  SHADE-SCHEDULE = SHADE-SCH1 .
BSHADE1-2 BUILDING-SHADE TRANSMITTANCE=0
  X=440 Y=450 Z=0 H=120 W=120 AZ=90 .
BSHADE1-3 BUILDING-SHADE LIKE BSHADE1-1
  X=440 Y=570 Z=0 H=120 W=240 AZ=0 .
BSHADE1-4 BUILDING-SHADE LIKE BSHADE1-1
  X=200 Y=570 Z=0 H=120 W=120 AZ=270 .
BSHADE2-1 BUILDING-SHADE LIKE BSHADE1-1
  X=540 Y=300 Z=0 H=70 W=140 AZ=180 .
BSHADE2-2 BUILDING-SHADE LIKE BSHADE1-1
  X=680 Y=300 Z=0 H=70 W=300 AZ=90 .
BSHADE2-3 BUILDING-SHADE LIKE BSHADE1-1
  X=680 Y=600 Z=0 H=70 W=140 AZ=0 .
BSHADE2-4 BUILDING-SHADE LIKE BSHADE1-1
  X=540 Y=600 Z=0 H=70 W=300 AZ=270 .

$ THE TREES IN FRONT OF THE BUILDING

TSHADE1-1 BUILDING-SHADE TILT=0
  X=60 Y=30 Z=32 H=20 W=20
  SHADE-SCHEDULE = SHADE-SCH1 .
TSHADE1-2 BUILDING-SHADE LIKE TSHADE1-1 Z=39 H=20 W=20 .
TSHADE1-3 BUILDING-SHADE LIKE TSHADE1-1 Z=46 H=25 W=25 .
TSHADE1-4 BUILDING-SHADE LIKE TSHADE1-1 Z=53 H=30 W=30 .
TSHADE1-5 BUILDING-SHADE LIKE TSHADE1-1 Z=60 H=28 W=28 .
TSHADE1-6 BUILDING-SHADE LIKE TSHADE1-1 Z=67 H=25 W=25 .
TSHADE1-7 BUILDING-SHADE LIKE TSHADE1-1 Z=74 H=23 W=23 .
TSHADE2-1 BUILDING-SHADE TILT=0
  X=150 Y=20 Z=10 H=20 W=35
  SHADE-SCHEDULE = SHADE-SCH1 .
TSHADE2-2 BUILDING-SHADE LIKE TSHADE2-1 Z=17 H=50 W=30 .
TSHADE2-3 BUILDING-SHADE LIKE TSHADE2-1 Z=24 H=48 W=28 .
TSHADE2-4 BUILDING-SHADE LIKE TSHADE2-1 Z=30 H=45 W=25 .
TSHADE2-5 BUILDING-SHADE LIKE TSHADE2-1 Z=37 H=35 W=22 .
TSHADE2-6 BUILDING-SHADE LIKE TSHADE2-1 Z=44 H=30 W=20 .
TSHADE2-7 BUILDING-SHADE LIKE TSHADE2-1 Z=51 H=20 W=18 .
TSHADE3-1 BUILDING-SHADE TILT=0
  X=265 Y=-10 Z=17 H=30 W=40
  SHADE-SCHEDULE = SHADE-SCH1 .
TSHADE3-2 BUILDING-SHADE LIKE TSHADE3-1 X=272 Z=24 H=26 W=48 .
TSHADE3-3 BUILDING-SHADE LIKE TSHADE3-1 X=275 Z=30 H=34 W=55 .
TSHADE3-4 BUILDING-SHADE LIKE TSHADE3-1 X=280 Z=37 H=40 W=65 .
TSHADE3-5 BUILDING-SHADE LIKE TSHADE3-1 X=275 Z=44 H=34 W=55 .
TSHADE3-6 BUILDING-SHADE LIKE TSHADE3-1 X=272 Z=51 H=26 W=48 .
TSHADE3-7 BUILDING-SHADE LIKE TSHADE3-1 X=270 Z=58 H=22 W=40 .
TSHADE3-8 BUILDING-SHADE LIKE TSHADE3-1 X=270 Z=65 H=22 W=40 .
TSHADE4-1 BUILDING-SHADE TILT=0
  X=330 Y=-10 Z=17 H=28 W=40
  SHADE-SCHEDULE = SHADE-SCH1 .
TSHADE4-2 BUILDING-SHADE LIKE TSHADE4-1 X=330 Z=24 H=40 W=35 .
TSHADE4-3 BUILDING-SHADE LIKE TSHADE4-1 X=328 Z=30 H=35 W=32 .
TSHADE4-4 BUILDING-SHADE LIKE TSHADE4-1 X=325 Z=37 H=25 W=25 .
TSHADE4-5 BUILDING-SHADE LIKE TSHADE4-1 X=325 Z=44 H=22 W=25 .
TSHADE5-1 BUILDING-SHADE TILT=0
  X=440 Y=-10 Z=12 H=28 W=40
  SHADE-SCHEDULE = SHADE-SCH1 .
TSHADE5-2 BUILDING-SHADE LIKE TSHADE5-1 X=440 Z=18 H=26 W=40 .
TSHADE5-3 BUILDING-SHADE LIKE TSHADE5-1 X=435 Z=25 H=24 W=30 .
TSHADE5-4 BUILDING-SHADE LIKE TSHADE5-1 X=430 Z=32 H=22 W=20 .

$ GENERAL SPACE DEFINITION

OFFICE =SPACE-CONDITIONS PEOPLE-SCHEDULE =OCCUPY-1
  AREA/PERSON =175
  PEOPLE-HG-SENS =230
  PEOPLE-HG-LAT =190
  LIGHTING-SCHEDULE =LIGHT-1
  LIGHTING-TYPE =SUS-FLOOR
  LIGHT-TO-SPACE =0.9
  LIGHTING-W/SQFT =1.31
  EQUIP-SCHEDULE =EQUIP-1
  EQUIPMENT-W/SQFT =1.85
  EQUIP-SENSIBLE =.75
  EQUIP-LATENT =0
  INF-METHO =AIR-CHANGE
  AIR-CHANGES/HR =0.4
INF-SCHEDULE = INFL-SCH ..

CONF-ROOM = SPACE-CONDITIONS
PEOPLE-SCHEDULE = OCCUPY-1
AREA/PERSON = 175
PEOPLE-HG-SENS = 230
PEOPLE-HG-LAT = 190
LIGHTING-SCHEDULE = LIGHT-1
LIGHTING-TYPE = SUS-FLOOR
LIGHT-TO-SPACE = 0.9
LIGHTING-W/SQFT = 1.31
EQUIP-SCHEDULE = EQUIP-2
EQUIP-KW = 84
EQUIP-SENSIBLE = 0.75
EQUIP-LATENT = 0
INF-METHOD = AIR-CHANGE
AIR-CHANGES/HR = 0.4
INF-SCHEDULE = INFL-SCH ..

CONF-ROOM = SPACE-CONDITIONS
PEOPLE-SCHEDULE = OCCUPY-1
AREA/PERSON = 175
PEOPLE-HG-SENS = 230
PEOPLE-HG-LAT = 190
LIGHTING-SCHEDULE = LIGHT-1
LIGHTING-TYPE = SUS-FLOOR
LIGHT-TO-SPACE = 0.9
LIGHTING-W/SQFT = 1.31
EQUIP-SCHEDULE = EQUIP-1
EQUIP-KW = 185
EQUIP-SENSIBLE = 0.75
EQUIP-LATENT = 0
INF-METHOD = AIR-CHANGE
AIR-CHANGES/HR = 0.4
INF-SCHEDULE = INFL-SCH ..

$ SPACE DETAILS (LOWER LEVEL)

PARKING = SPACE
ZONE-TYPE = UNCONDITIONED
AREA = 31300
VOLUME = 2369723
FLOOR-WEIGHT = 50
LIGHTING-SCHEDULE = LIGHT-2
LIGHTING-TYPE = REC-FLUOR-NV
LIGHTING-KW = 64.814
X = 320
Y = 140 ..

PARKING-EW1 = EXTERIOR-WALL
X = 0
Y = 0
H = 75.71
W = 60
AZ = 180 ..
PARKING-EW2 = EXTERIOR-WALL
X = 60
Y = 0
H = 65.5
W = 15
AZ = 270 ..
PARKING-EW3 = EXTERIOR-WALL
X = 60
Y = -15
H = 65.5
W = 220
AZ = 180 ..
PARKING-EW4 = EXTERIOR-WALL
X = 280
Y = -15
H = 65.5
W = 115
AZ = 90 ..
PARKING-EW5 = EXTERIOR-WALL
X = 280
Y = 100
H = 65.5
W = 280
AZ = 0 ..
PARKING-EW6 = EXTERIOR-WALL
X = 0
Y = 100
H = 75.71
W = 15
AZ = 270 ..
PARKING-EW7 = EXTERIOR-WALL
X = 0
Y = 85
Z = 26.66
H = 49.05
W = 85
AZ = 270 ..
PARKING-U1 = UNDERGROUND-FLOOR
AREA = 31300
CONSTRUCTION = FLOOR-U ..

PARKING-R1 = ROOF
HEIGHT = 100
WIDTH = 60
X = 60
Y = 100
Z = 65.5
AZIMUTH = 0
TILT = 0 ..
PARKING-R2 = ROOF
HEIGHT = 115
WIDTH = 220
X = 280
Y = 100
Z = 65.5
AZIMUTH = 0
TILT = 0 ..

LOWER-1-FLM = SPACE
ZONE-TYPE = UNCONDITIONED
AREA = 16280
VOLUME = 84004.8
FLOOR-WEIGHT = 5
X = 0
Y = 36.5
Z = 11.7 ..

LOWER-1-R1 = ROOF
HEIGHT = 23.5
WIDTH = 80
X = 0
Y = 0
Z = 5.16
AZIMUTH = 180
TILT = 0 ..
LOWER-1-R2 = ROOF
HEIGHT = 30
WIDTH = 50
X = 0
Y = 23.5
Z = 5.16
AZIMUTH = 180
TILT = 0 ..
LOWER-1-R3 = ROOF
HEIGHT = 135
WIDTH = 50
X = 0
Y = 53.5
Z = 5.16
AZIMUTH = 180
TILT = 0 ..
LOWER-1-R4 = ROOF
HEIGHT = 15
WIDTH = 35
X = 0
Y = 188.5
Z = 5.16
AZIMUTH = 180
TILT = 0 ..
LOWER-1-R5 = ROOF
HEIGHT = 30
WIDTH = 60
X = 140
Y = 7.5
Z = 5.16
AZIMUTH = 180
TILT = 0 ..
LOWER-1-R6 = ROOF
HEIGHT = 22
WIDTH = 90
X = 110
Y = 23.5
Z = 5.16
AZIMUTH = 180
TILT = 0 ..
LOWER-1-R7 = ROOF
HEIGHT = 58
WIDTH = 200
TILT=0    CONSTRUCTION = CLING-1..

LOWER-4    =SPACE
SPACE-CONDITIONS = CONF-ROOM
AREA = 16280    VOLUME = 181847.6
X=240    Y=150    Z=0..

LOWER-4-IW1 =INTERIOR-WALL
AREA= 9363    NEXT-TO = LOWER-2..

LOWER-4-IW2 =INTERIOR-WALL
AREA= 1388.05    NEXT-TO = PARKING..

LOWER-4-EW1 =EXTERIOR-WALL
HEIGHT = 16.33    WIDTH = 60
X=80    Y=83    AZIMUTH = 0..

LOWER-4-EW2 =EXTERIOR-WALL
HEIGHT = 16.33    WIDTH = 56.65
X=20    Y=83    AZIMUTH = 290.69..

LOWER-4-EW2-W1 =WINDOW
HEIGHT=4    WIDTH=8    X=20    Y=9.3..

LOWER-4-EW2-W2 =WINDOW
HEIGHT=4    WIDTH=8    X=40    Y=9.3..

LOWER-4-EW3 =EXTERIOR-WALL
HEIGHT = 16.33    WIDTH = 30
X=0    Y=30    AZIMUTH = 270..

LOWER-3-EW3-W1 =WINDOW
HEIGHT=4    WIDTH=8    X=10    Y=9.3..

LOWER-4-UF1 =UNDERGROUND-FLOOR
AREA = 6530
CONSTRUCTION = FLOOR-U..

LOWER-4-CL1 =INTERIOR-WALL
AREA= 6530    NEXT-TO = LOWER-1-PLM
TILT=0    CONSTRUCTION = CLING-1..

LOWER-5    =SPACE
SPACE-CONDITIONS = OFFICE
AREA = 540    VOLUME = 6031.8
X=380    Y=0    Z=0..

LOWER-5-EW1 =EXTERIOR-WALL
HEIGHT = 16.33    WIDTH = 60
X=0    Y=0    AZIMUTH = 180..

LOWER-5-EW2 =EXTERIOR-WALL
HEIGHT = 16.33    WIDTH = 90
X=60    Y=0    AZIMUTH = 90..

LOWER-5-EW3 =EXTERIOR-WALL
HEIGHT = 16.33    WIDTH = 60
X=60    Y=90    AZIMUTH = 0..

LOWER-5-EW4 =EXTERIOR-WALL
HEIGHT = 16.33    WIDTH = 90
X=0    Y=90    AZIMUTH = 270..

LOWER-5-UF2 =UNDERGROUND-FLOOR
AREA = 540
CONSTRUCTION = FLOOR-U..

LOWER-5-PLM =SPACE
ZONE-TYPE= UNCONDITIONED
AREA=540
VOLUME=2786.4    FLOOR-WEIGHT=5
X=380    Y=0    Z=11.7..

LOWER-5-CL1 =INTERIOR-WALL
AREA= 540    NEXT-TO = LOWER-5
TILT=180    CONSTRUCTION = CLING-1..

$ PLAZER LEVEL (1F)

CORE-1    =SPACE
SPACE-CONDITIONS = OFFICE
AREA = 3900    VOLUME = 42276
X=28    Y=90    Z=16..

CORE-1-IW1 =INTERIOR-WALL
AREA=1409.2    NEXT-TO= WEST-1..

CORE-1-IW2 =INTERIOR-WALL
AREA=325.2    NEXT-TO= LOBBY-1..

CORE-1-IW3 =INTERIOR-WALL
AREA=1409.2    NEXT-TO= EAST-1..

CORE-1-IW4 =INTERIOR-WALL
AREA=325.2    NEXT-TO= NORTH-1..

CORE-1-FL1 =INTERIOR-WALL
AREA= 3900    NEXT-TO = LOWER-1-PLM
TILT=180
CONSTRUCTION = FLOOR-1..

CORE-1-PLM =SPACE
ZONE-TYPE= UNCONDITIONED
AREA=7200
VOLUME= 37152    FLOOR-WEIGHT=5
X=50    Y= 90    Z= 27.17..

WEST-1    =SPACE
SPACE-CONDITIONS = OFFICE
AREA = 3005    VOLUME = 37450.4
X=28    Y=90    Z=16..

WEST-1-IW1 =INTERIOR-WALL
AREA= 195.45    NEXT-TO= NORTH-1..

WEST-1-EW1 =EXTERIOR-WALL
HEIGHT = 16    WIDTH = 22
X=0    Y=0    AZIMUTH = 180..

WEST-1-EW1-W1 =WINDOW
HEIGHT = 14.16    WIDTH=20
X=1    Y=0..

WEST-1-EW2 =EXTERIOR-WALL
HEIGHT = 16    WIDTH = 140
X=0    Y=140    AZIMUTH = 270..

WEST-1-EW2-W1 =WINDOW
HEIGHT = 14.16    WIDTH=135
X=5    Y=0..

WEST-1-EW3 =EXTERIOR-WALL
HEIGHT = 16    WIDTH = 8
X=0    Y=140    AZIMUTH = 180..

WEST-1-EW3-W1 =WINDOW
HEIGHT = 14.16    WIDTH=5
X=1    Y=0..

WEST-1-FL1 =INTERIOR-WALL
AREA= 3005    NEXT-TO = CORE-1-PLM
TILT=180
CONSTRUCTION = FLOOR-1..

WEST-1-CL1 =INTERIOR-WALL
AREA= 3005    NEXT-TO = CORE-1-PLM
TILT=0
CONSTRUCTION = CLING-1..

EAST-1    =SPACE
SPACE-CONDITIONS = OFFICE
AREA = 4200    VOLUME = 56557.5
X=80    Y=90    Z=16..
<table>
<thead>
<tr>
<th>Component</th>
<th>Shape</th>
<th>Condition</th>
<th>Area</th>
<th>Volume</th>
<th>X</th>
<th>Y</th>
<th>Z</th>
<th>Tilt</th>
<th>Construction</th>
</tr>
</thead>
<tbody>
<tr>
<td>SOUTH-1-FL1</td>
<td>INTERIOR-WALL</td>
<td>OFFICE</td>
<td>1800</td>
<td>13008</td>
<td>320</td>
<td>15</td>
<td>27.17</td>
<td>0</td>
<td>CLING-1</td>
</tr>
<tr>
<td>SOUTH-1-CL1</td>
<td>INTERIOR-WALL</td>
<td>OFFICE</td>
<td>1800</td>
<td>39024</td>
<td>200</td>
<td>30</td>
<td>16</td>
<td>180</td>
<td>FLOOR-1</td>
</tr>
<tr>
<td>CORE-1-2</td>
<td>SPACE</td>
<td>OFFICE</td>
<td>3600</td>
<td>48312</td>
<td>200</td>
<td>15</td>
<td>27</td>
<td>180</td>
<td>FLOOR-1</td>
</tr>
<tr>
<td>CORE-1-3</td>
<td>SPACE</td>
<td>OFFICE</td>
<td>1200</td>
<td>13008</td>
<td>320</td>
<td>15</td>
<td>27</td>
<td>180</td>
<td>FLOOR-1</td>
</tr>
<tr>
<td>SOUTH-2-FL1</td>
<td>INTERIOR-WALL</td>
<td>OFFICE</td>
<td>3600</td>
<td>39024</td>
<td>200</td>
<td>15</td>
<td>27</td>
<td>180</td>
<td>FLOOR-1</td>
</tr>
<tr>
<td>SOUTH-1-2</td>
<td>SPACE</td>
<td>OFFICE</td>
<td>3600</td>
<td>48312</td>
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<td>27</td>
<td>180</td>
<td>FLOOR-1</td>
</tr>
<tr>
<td>SOUTH-1-3</td>
<td>SPACE</td>
<td>OFFICE</td>
<td>1200</td>
<td>13008</td>
<td>320</td>
<td>15</td>
<td>27</td>
<td>180</td>
<td>FLOOR-1</td>
</tr>
<tr>
<td>SOUTH-2-CL1</td>
<td>INTERIOR-WALL</td>
<td>OFFICE</td>
<td>3600</td>
<td>39024</td>
<td>200</td>
<td>15</td>
<td>27</td>
<td>180</td>
<td>FLOOR-1</td>
</tr>
</tbody>
</table>

GLASS-TYPE= W-2
EAST-2-EW1-W1 = WINDOW
HEIGHT = 6.87 WIDTH = 120 X = 15 Y = 2.33
EAST-2-EW1-W2 = WINDOW
HEIGHT = 2.84 WIDTH = 120 X = 15 Y = 9.2
GLASS_TYPE = W-2

EAST-2-FL2 = INTERIOR-WALL
AREA = 4200 NEXT-TO = CORE-1-PLM
TILT = 180 CONSTRUCTION = FLOOR-1

EAST-2-CL1 = INTERIOR-WALL
AREA = 4200 NEXT-TO = CORE-2-PLM
TILT = 0 CONSTRUCTION = CLING-1

NORTH-2 = SPACE
SPACE-CONDITIONS = OFFICE
AREA = 1500 VOLUME = 18555
X = 50 Y = 220 Z = 32.33

NORTH-2-EW1 = EXTERIOR-WALL
HEIGHT = 13.66 WIDTH = 90
X = 60 Y = 20 AZIMUTH = 0

NORTH-2-EW1-W1 = WINDOW
HEIGHT = 6.87 WIDTH = 60 X = 15 Y = 2.33
GLASS_TYPE = W-2

NORTH-2-CL1 = INTERIOR-WALL
AREA = 1500 NEXT-TO = CORE-1-PLM
TILT = 180 CONSTRUCTION = FLOOR-1

NORTH-2-CL2 = SPACE
SPACE-CONDITIONS = OFFICE
AREA = 1200 VOLUME = 10200
X = 100 Y = 30 Z = 40.83

CORE2-2 = SPACE
SPACE-CONDITIONS = OFFICE
AREA = 1200 VOLUME = 10200
X = 100 Y = 30 Z = 32.33

CORE2-2-IW1 = INTERIOR-WALL
AREA = 255 NEXT-TO = WEST2-2
CORE2-2-IW2 = INTERIOR-WALL
AREA = 340 NEXT-TO = SOUTH2-2

CORE2-2-IW3 = INTERIOR-WALL
AREA = 255 NEXT-TO = SOUTH2-3
CORE2-2-IW4 = INTERIOR-WALL
AREA = 340 NEXT-TO = NORTH2-2

CORE2-2-FL1 = INTERIOR-WALL
AREA = 1200 NEXT-TO = CORE1-2-PLM
TILT = 180 CONSTRUCTION = FLOOR-1

CORE2-2-PLM = SPACE
ZONE_TYPE = UNCONDITIONED AREA = 16800
VOLUME = 86688 FLOOR_WEIGHT = 5
X = 100 Y = 30 Z = 40.83

CORE2-3 = SPACE
SPACE-CONDITIONS = OFFICE
AREA = 3600 VOLUME = 30600
X = 200 Y = 30 Z = 32.33

CORE2-3-IW1 = INTERIOR-WALL
AREA = 255 NEXT-TO = SOUTH2-3
CORE2-3-IW2 = INTERIOR-WALL
AREA = 1020 NEXT-TO = SOUTH2-4

CORE2-3-IW3 = INTERIOR-WALL
AREA = 255 NEXT-TO = SOUTH2-5
CORE2-3-IW4 = INTERIOR-WALL
AREA = 1020 NEXT-TO = NORTH2-2

CORE2-3-FL1 = INTERIOR-WALL
AREA = 3600 NEXT-TO = CORE1-2-PLM
TILT = 180 CONSTRUCTION = FLOOR-1

CORE2-3-CL1 = INTERIOR-WALL
AREA = 4200 NEXT-TO = CORE2-2-PLM
TILT = 0 CONSTRUCTION = CLING-1

CORE2-4 = SPACE
SPACE-CONDITIONS = OFFICE
AREA = 900 VOLUME = 7650
X = 380 Y = 30 Z = 32.33

CORE2-4-IW1 = INTERIOR-WALL
AREA = 255 NEXT-TO = SOUTH2-5
CORE2-4-IW2 = INTERIOR-WALL
AREA = 255 NEXT-TO = SOUTH2-6

CORE2-4-IW3 = INTERIOR-WALL
AREA = 255 NEXT-TO = EAST2-2
CORE2-4-IW4 = INTERIOR-WALL
AREA = 900 NEXT-TO = CORE1-2-PLM
TILT = 180 CONSTRUCTION = FLOOR-1

CORE2-4-CL1 = INTERIOR-WALL
AREA = 900 NEXT-TO = CORE2-2-PLM
TILT = 0 CONSTRUCTION = CLING-1

WEST2-2 = SPACE
SPACE-CONDITIONS = OFFICE
AREA = 900 VOLUME = 11713.5
X = 80 Y = 0 Z = 32.33

WEST2-2-IW1 = INTERIOR-WALL
AREA = 306.42 NEXT-TO = SOUTH2-2
WEST2-2-IW2 = INTERIOR-WALL
AREA = 170 NEXT-TO = NORTH2-2
WEST2-2-FL1 = EXTERIOR-WALL
HEIGHT = 13.66 WIDTH = 60
X = 0 Y = 60 AZIMUTH = 270

WEST2-2-EW1-W1 = WINDOW
LIKE SOUTH-2-EW1-W1
WEST2-2-EW1-W2 = WINDOW
LIKE SOUTH-2-EW1-W2
WEST2-2-PL1 = INTERIOR-WALL
AREA = 900 NEXT-TO = CORE1-2-PLM
TILT = 180 CONSTRUCTION = FLOOR-1

WEST2-2-CL1 = INTERIOR-WALL
AREA = 4200 NEXT-TO = CORE2-2-PLM
TILT = 0 CONSTRUCTION = CLING-1

SOUTH2-2 = SPACE
SPACE-CONDITIONS = OFFICE
CORE-5-PLM = SPACE LIKE CORE-2-PLM

SOUTH4-3 = SPACE LIKE SOUTH2-3 Z = 59.65

SOUTH4-3-IW1 = INTERIOR-WALL LIKE SOUTH2-3-IW1

SOUTH4-3-EW1 = EXTERIOR-WALL LIKE SOUTH2-3-EW1

SOUTH4-3-EW1-W1 = WINDOW LIKE SOUTH2-3-EW1-W1

SOUTH4-3-EW1-W2 = WINDOW LIKE SOUTH2-3-EW1-W2

SOUTH4-3-FL1 = INTERIOR-WALL LIKE SOUTH2-3-PLM

SOUTH4-3-CL1 = INTERIOR-WALL LIKE SOUTH2-3-CL1

SOUTH4-4 = SPACE LIKE SOUTH2-4 Z = 59.65

SOUTH4-4-EW1 = EXTERIOR-WALL LIKE SOUTH2-4-EW1

SOUTH4-4-EW1-W1 = WINDOW LIKE SOUTH2-4-EW1-W1

SOUTH4-4-EW1-W2 = WINDOW LIKE SOUTH2-4-EW1-W2

SOUTH4-4-EW3 = EXTERIOR-WALL LIKE SOUTH2-4-EW3

SOUTH4-4-EW3-1 = WINDOW LIKE SOUTH2-4-EW3-1

SOUTH4-4-EW3-2 = WINDOW LIKE SOUTH2-4-EW3-2

SOUTH4-4-FL1 = INTERIOR-WALL LIKE SOUTH2-4-FL1

SOUTH4-4-CL1 = INTERIOR-WALL LIKE SOUTH2-4-CL1

SOUTH4-5 = SPACE LIKE SOUTH2-5 Z = 59.65

SOUTH4-5-IW1 = INTERIOR-WALL LIKE SOUTH2-5-IW1

SOUTH4-5-EW1 = EXTERIOR-WALL LIKE SOUTH2-5-EW1

SOUTH4-5-EW1-W1 = WINDOW LIKE SOUTH2-5-EW1-W1

SOUTH4-5-EW1-W2 = WINDOW LIKE SOUTH2-5-EW1-W2

SOUTH4-5-FL1 = INTERIOR-WALL LIKE SOUTH2-5-PL1

SOUTH4-5-CL1 = INTERIOR-WALL LIKE SOUTH2-5-CL1

SOUTH4-6 = SPACE LIKE SOUTH2-6 Z = 59.65

SOUTH4-6-IW1 = INTERIOR-WALL LIKE SOUTH2-6-IW1

SOUTH4-6-EW1 = EXTERIOR-WALL LIKE SOUTH2-6-EW1

SOUTH4-6-EW1-W1 = WINDOW LIKE SOUTH2-6-EW1-W1

SOUTH4-6-EW1-W2 = WINDOW LIKE SOUTH2-6-EW1-W2

SOUTH4-6-FL1 = INTERIOR-WALL LIKE SOUTH2-6-FL1

SOUTH4-6-CL1 = INTERIOR-WALL LIKE SOUTH2-6-CL1

EAST4-2 = SPACE LIKE EAST2-2 Z = 59.65

EAST4-2-IW1 = INTERIOR-WALL LIKE EAST2-2-IW1

EAST4-2-EW1 = EXTERIOR-WALL LIKE EAST2-2-EW1

EAST4-2-EW1-W1 = WINDOW LIKE EAST2-2-EW1-W1

EAST4-2-EW1-W2 = WINDOW LIKE EAST2-2-EW1-W2

EAST4-2-FL1 = INTERIOR-WALL LIKE EAST2-2-FL1

EAST4-2-CL1 = INTERIOR-WALL LIKE EAST2-2-CL1

NORTH4-2 = SPACE LIKE NORTH2-2 Z = 59.65

NORTH4-2-IW1 = INTERIOR-WALL LIKE NORTH2-2-IW1

NORTH4-2-EW1 = EXTERIOR-WALL LIKE NORTH2-2-EW1

NORTH4-2-EW1-W1 = WINDOW LIKE NORTH2-2-EW1-W1

NORTH4-2-EW1-W2 = WINDOW LIKE NORTH2-2-EW1-W2

NORTH4-2-FL1 = INTERIOR-WALL LIKE NORTH2-2-FL1

NORTH4-2-CL1 = INTERIOR-WALL LIKE NORTH2-2-CL1

$ SPACE DETAILS (LEVEL 5F )

CORE-5 = SPACE LIKE CORE-2 Z = 73.31

CORE-5-IW1 = INTERIOR-WALL LIKE CORE-2-IW1

CORE-5-IW2 = INTERIOR-WALL LIKE CORE-2-IW2

CORE-5-IW3 = INTERIOR-WALL LIKE CORE-2-IW3

CORE-5-IW4 = INTERIOR-WALL LIKE CORE-2-IW4

CORE-5-FL1 = INTERIOR-WALL LIKE CORE-2-FL1

CORE-5-PLM = SPACE LIKE CORE-2-PLM Z = 81.81
WEST-5 = SPACE LIKE WEST-2 Z= 73.31 ..
WEST-5-IW1 = INTERIOR-WALL LIKE WEST-2-IW1 ..
WEST-5-IW2 = INTERIOR-WALL LIKE WEST-2-IW2..
WEST-5-EW1 = EXTERIOR-WALL LIKE WEST-2-EW1 ..
WEST-5-EW1-W1 = WINDOW LIKE WEST-2-EW1-W1 ..
WEST-5-EW1-W2 = WINDOW LIKE WEST-2-EW1-W2 ..
WEST-5-FL1 = INTERIOR-WALL LIKE WEST-2-FL1
NEXT-TO= CORE-4-PLM ..
WEST-5-CL1 = INTERIOR-WALL LIKE WEST-2-CL1
NEXT-TO = CORE-5-PLM..

SOUTH-5 = SPACE LIKE SOUTH-2 Z= 73.31 ..
SOUTH-5-EW1 = EXTERIOR-WALL LIKE SOUTH-2-EW1 ..
SOUTH-5-EW1-W1 = WINDOW LIKE SOUTH-2-EW1-W1 ..
SOUTH-5-EW1-W2 = WINDOW LIKE SOUTH-2-EW1-W2 ..
SOUTH-5-FL1 = INTERIOR-WALL LIKE SOUTH-2-FL1
NEXT-TO= CORE-4-PLM..
SOUTH-5-CL1 = INTERIOR-WALL LIKE SOUTH-2-CL1
NEXT-TO = CORE-5-PLM..

EAST-5 = SPACE LIKE EAST-2 Z= 73.31 ..
EAST-5-IW1 = INTERIOR-WALL LIKE EAST-2-IW1 ..
EAST-5-IW2 = INTERIOR-WALL LIKE EAST-2-IW2 ..
EAST-5-EW1 = EXTERIOR-WALL LIKE EAST-2-EW1 ..
EAST-5-EW1-W1 = WINDOW LIKE EAST-2-EW1-W1 ..
EAST-5-EW1-W2 = WINDOW LIKE EAST-2-EW1-W2 ..
EAST-5-FL1 = INTERIOR-WALL LIKE EAST-2-FL1
NEXT-TO= CORE-4-PLM..
EAST-5-CL1 = INTERIOR-WALL LIKE EAST-2-CL1
NEXT-TO = CORE-5-PLM..

NORTH-5 = SPACE LIKE NORTH-2 Z= 73.31 ..
NORTH-5-EW1 = EXTERIOR-WALL LIKE NORTH-2-EW1..
NORTH-5-EW1-W1 = WINDOW LIKE NORTH-2-EW1-W1 ..
NORTH-5-EW1-W2 = WINDOW LIKE NORTH-2-EW1-W2..
NORTH-5-FL1 = INTERIOR-WALL LIKE NORTH-2-FL1
NEXT-TO= CORE-4-PLM..
NORTH-5-CL1 = INTERIOR-WALL LIKE NORTH-2-CL1
NEXT-TO = CORE-5-PLM..

CORE5-2 = SPACE LIKE CORE2-2 Z= 73.31 ..
CORE5-2-IW1 = INTERIOR-WALL LIKE CORE2-2-IW1 ..
CORE5-2-IW2 = INTERIOR-WALL LIKE CORE2-2-IW2 ..
CORE5-2-IW3 = INTERIOR-WALL LIKE CORE2-2-IW3 ..
CORE5-2-IW4 = INTERIOR-WALL LIKE CORE2-2-IW4 ..
CORE5-2-FL1 = INTERIOR-WALL LIKE CORE2-2-FL1
NEXT-TO= CORE4-2-PLM..
CORE5-2-TOP1 = ROOF HEIGHT=30 WIDTH=40 TILT=0
X=0 Y=0 Z=13.66 AZIMUTH = 180 ..
CORE5-2-PLM = SPACE LIKE CORE2-2-PLM Z= 81.81 ..

CORE5-3 = SPACE LIKE CORE2-3 Z= 73.31 ..
CORE5-3-IW1 = INTERIOR-WALL LIKE CORE2-3-IW1 ..
CORE5-3-IW2 = INTERIOR-WALL LIKE CORE2-3-IW2 ..
CORE5-3-IW3 = INTERIOR-WALL LIKE CORE2-3-IW3 ..
CORE5-3-IW4 = INTERIOR-WALL LIKE CORE2-3-IW4 ..
CORE5-3-FL1 = INTERIOR-WALL LIKE CORE2-3-FL1
NEXT-TO= CORE4-2-PLM..
CORE5-3-CL1 = INTERIOR-WALL LIKE CORE2-3-CL1

CORE5-3-TOP1 = ROOF
NEXT-TO = CORE5-2-PLM..
X=0 Y=0 Z=13.66 AZIMUTH = 180 ..

CORE5-4 = SPACE LIKE CORE2-4 Z= 73.31 ..
CORE5-4-IW1 = INTERIOR-WALL LIKE CORE2-4-IW1 ..
CORE5-4-IW2 = INTERIOR-WALL LIKE CORE2-4-IW2 ..
CORE5-4-IW3 = INTERIOR-WALL LIKE CORE2-4-IW3 ..
CORE5-4-IW4 = INTERIOR-WALL LIKE CORE2-4-IW4 ..
CORE5-4-FL1 = INTERIOR-WALL LIKE CORE2-4-FL1
NEXT-TO= CORE4-2-PLM..
CORE5-4-CL1 = INTERIOR-WALL LIKE CORE2-4-CL1
NEXT-TO = CORE5-2-PLM..
CORE5-4-TOP1 = ROOF
HEIGHT=30 WIDTH=40 TILT=0
X=0 Y=0 Z=13.66 AZIMUTH = 180 ..

WEST5-2 = SPACE LIKE WEST2-2 Z= 73.31 ..
WEST5-2-IW1 = INTERIOR-WALL LIKE WEST2-2-IW1 ..
WEST5-2-IW2 = INTERIOR-WALL LIKE WEST2-2-IW2 ..
WEST5-2-EW1 = EXTERIOR-WALL LIKE WEST2-2-EW1 ..
NORTH-6-EM1-W2 = WINDOW LIKE NORTH-2-EM1-W2 ...
NORTH-6-FL1 = INTERIOR-WALL LIKE NORTH-2-FL1
NORTH-6-C11 = INTERIOR-WALL LIKE NORTH-2-C11
NORTH-6-TOP1 = ROOF
HEIGHT=20 WIDTH=60 TILT=0
X=-15 Y=0 Z=13.66 AZIMUTH = 180 ..
PENTH-W1 = SPACE ZONE-TYPE= UNCONDITIONED AREA=900
VOLUME=11430 FLOOR-WEIGHT=50
X=50 Y= 180 Z=100.63 ..
PENTH-W1-EM1 = EXTERIOR-WALL
X=0 Y=0 H=12.7 W=30 AZ=180
CONSTRUCTION= WALL-1-2
SHADING-SURFACE= YES ..
PENTH-W1-EW2 = EXTERIOR-WALL
X=30 Y=0 H=12.7 W=30 AZ=90
CONSTRUCTION= WALL-1-2
SHADING-SURFACE= YES ..
PENTH-W1-EW3 = EXTERIOR-WALL
X=30 Y=30 H=12.7 W=30 AZ=0
CONSTRUCTION= WALL-1-2
SHADING-SURFACE= YES ..
PENTH-W1-EW4 = EXTERIOR-WALL
X=0 Y=30 H=12.7 W=30 AZ=270
CONSTRUCTION= WALL-1-2
SHADING-SURFACE= YES ..
PENTH-W1-UF1 = INTERIOR-WALL AREA= 900 NEXT-TO= CORE-5 ..
PENTH-W1-R1 = ROOF
LIKE PENTH-W1-R1 ..
PENTH-S1 = SPACE LIKE PENTH-W1 X=230 Y=30 Z=86.97 ..
PENTH-S1-EM1 = EXTERIOR-WALL LIKE PENTH-W1-EM1
X=0 Y=0 H=9.5 W=60 ..
PENTH-S1-EW2 = EXTERIOR-WALL LIKE PENTH-W1-EW2
X=60 Y=0 H=9.5 W=30 ..
PENTH-S1-EW3 = EXTERIOR-WALL LIKE PENTH-W1-EW3
X=60 Y=30 H=9.5 W=60 ..
PENTH-S1-EW4 = EXTERIOR-WALL LIKE PENTH-W1-EW4
X=0 Y=30 H=9.5 W=30 ..
PENTH-S1-UF1 = INTERIOR-WALL LIKE PENTH-W1-UF1 NEXT-TO= CORE-6-3 ..
PENTH-S1-R1 = ROOF
LIKE PENTH-W1-R1
H=30 W=60 X=60 Y=30 Z=9.5 ..
PENTH-S2 = SPACE LIKE PENTH-W1 X=370 Y=30 Z=86.97 ..
PENTH-S2-EM1 = EXTERIOR-WALL LIKE PENTH-W1-EM1
X=0 Y=0 H=9.5 W=10 ..
PENTH-S2-EW2 = EXTERIOR-WALL LIKE PENTH-W1-EW2
X=10 Y=0 H=9.5 W=30 ..
PENTH-S2-EW3 = EXTERIOR-WALL LIKE PENTH-W1-EW3
X=10 Y=30 H=9.5 W=10 ..
PENTH-S2-EW4 = EXTERIOR-WALL LIKE PENTH-W1-EW4
X=0 Y=30 H=9.5 W=30 ..
PENTH-S2-UF1 = INTERIOR-WALL LIKE PENTH-W1-UF1 NEXT-TO= SOUTH5-5 ..
PENTH-S2-R1 = ROOF
LIKE PENTH-W1-R1
H=30 W=10 X=10 Y=30 Z=9.5 ..
END ..
COMPUTE LOADS ..
INPUT SYSTEMS ..
SYSTEMS-REPORT SUMMARY=(SS-D) ..
SOFFDW
SCHR54 = SCHEDULE
THRU DEC 31
(MD) (1,24) =
(0.05,0.05,0.05,0.05,0.05,0.05,0.05,0.05,0.05,0.05,0.05,0.05,0.05,0.05,0.05,0.05,0.05,0.05,0.05,0.05,0.05,0.05)
(SAT) (1,24) =
(0.00,0.00,0.00,0.00,0.00,0.00,0.00,0.00,0.00,0.00,0.00,0.00,0.00,0.00,0.00,0.00,0.00,0.00,0.00,0.00,0.00)
\( (\text{SUN, HOLIDAY}) (1,24) = \\
(0.05, 0.05, 0.05, 0.05, 0.05, 0.05, 0.05, 0.05, 0.05, 0.05, 0.05, 0.05, 0.05, 0.05, 0.05, 0.05, 0.05, 0.05, 0.05, 0.05, 0.05, 0.05, 0.05, 0.05, 0.05, 0.05, 0.05, 0.05, 0.05) \)

$\text{Austin Fan}$

\text{SCH202 = SCHEDULE}

\text{THRU DEC 31 (ALL) (1,24) = (1) ..}$

$\text{Austin Min Outside Air Schedule}$

\text{SCH209 = SCHEDULE}

\text{THRU DEC 31 (ALL) (1,24)}

\( (0.25, 0.25, 0.25, 0.25, 0.25, 0.25, 0.25, 0.25, 0.25, 0.25, 0.25, 0.25, 0.25, 0.25, 0.25, 0.25, 0.25, 0.25, 0.25, 0.25, 0.25, 0.25, 0.25, 0.25, 0.25, 0.25) \)

$\text{Austin him?}$

\text{SCH207 = SCHEDULE}

\text{THRU DEC 31 (ALL) (1,24) = (71) ..}$

$\text{Austin Outside Air Schedule}$

\text{SCH208 = SCHEDULE}

\text{THRU DEC 31 (ALL) (1,24) = (71) ..}$

$\text{light sch outside of building}$

$\text{ELS-1 = SCHEDULE}$

$\text{THRU DEC 31 (ALL) (1,24) =}$

\( (1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0) \)

$\text{DESCRIPTION of ZONE: LOWER-1}$

\text{LOWER-1 = ZONE}

\text{ZONE-TYPE = CONDITIONED}

\text{ HEAT-TEMP-SCH = SCH207}

\text{COOL-TEMP-SCH = SCH208}

\text{DESIGN-HEAT-T = 71}

\text{DESIGN-COOL-T = 71}

\text{THERMOSTAT-TYPE = PROPORTIONAL}

\text{THROTTLING-RANGE = 4 ..}$

\text{PARKING = ZONE}

\text{ZONE-TYPE = UNCONDITIONED}

\text{SIZING-OPTION = ADJUST-LOADS}

\text{DESIGN-HEAT-T = 71}

\text{DESIGN-COOL-T = 71 ..}$

\text{LOWER-1-PLM = ZONE}

\text{ZONE-TYPE = UNCONDITIONED}

\text{SIZING-OPTION = ADJUST-LOADS}

\text{DESIGN-HEAT-T = 71}

\text{DESIGN-COOL-T = 71 ..}$

\text{LOWER-2 = ZONE}

\text{LIKE LOWER-1 ..}$

\text{LOWER-3 = ZONE}

\text{LIKE LOWER-1 ..}$

\text{LOWER-4 = ZONE}

\text{LIKE LOWER-1 ..}$

\text{LOWER-5 = ZONE}

\text{LIKE LOWER-1 ..}$

\text{LOWER-5-PLM = ZONE}

\text{LIKE LOWER-1-PLM ..}$

\text{CORE-1 = ZONE}

\text{LIKE LOWER-1}

\text{THERMOSTAT-TYPE = REVERSE-ACTION ..}$

\text{CORE-1-PLM = ZONE}

\text{LIKE LOWER-1-PLM ..}$

\text{WEST-1 = ZONE}

\text{LIKE CORE-1 ..}$

\text{EAST-1 = ZONE}

\text{LIKE CORE-1 ..}$

\text{NORTH-1 = ZONE}

\text{LIKE CORE-1 ..}$

\text{LOBBY-1 = ZONE}

\text{LIKE CORE-1 ..}$

\text{SOUTH-1 = ZONE}

\text{LIKE CORE-1 ..}$

\text{CORE1-2 = ZONE}

\text{LIKE CORE-1 ..}$

\text{CORE1-2-PLM = ZONE}

\text{LIKE LOWER-1-PLM ..}$

\text{CORE1-3 = ZONE}

\text{LIKE CORE-1 ..}$

\text{SOUTH1-2 = ZONE}

\text{LIKE CORE-1 ..}$

\text{SOUTH1-3 = ZONE}

\text{LIKE CORE-1 ..}$

\text{SOUTH1-4 = ZONE}

\text{LIKE CORE-1 ..}$

\text{EAST1-2 = ZONE}

\text{LIKE CORE-1 ..}$

\text{NORTH1-2 = ZONE}

\text{LIKE CORE-1 ..}$

\text{MEETING-1 = ZONE}

\text{LIKE CORE-1 ..}$

\text{CORE-2 = ZONE}

\text{LIKE CORE-1 ..}$

\text{CORE-2-PLM = ZONE}

\text{LIKE LOWER-1-PLM ..}$

\text{WEST-2 = ZONE}

\text{LIKE CORE-1 ..}$

\text{SOUTH-2 = ZONE}

\text{LIKE CORE-1 ..}$

\text{EAST-2 = ZONE}

\text{LIKE CORE-1 ..}$

\text{NORTH-2 = ZONE}

\text{LIKE CORE-1 ..}$

\text{CORE2-2 = ZONE}

\text{LIKE CORE-1 ..}$

\text{CORE2-2-PLM = ZONE}

\text{LIKE LOWER-1-PLM ..}$

\text{CORE2-3 = ZONE}

\text{LIKE CORE-1 ..}$

\text{CORE2-4 = ZONE}

\text{LIKE CORE-1 ..}$

\text{WEST2-2 = ZONE}

\text{LIKE CORE-1 ..}$

\text{SOUTH2-2 = ZONE}

\text{LIKE CORE-1 ..}
<table>
<thead>
<tr>
<th>Zone</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SOUTH2-3</td>
<td>LIKE CORE-1</td>
</tr>
<tr>
<td>SOUTH2-4</td>
<td>LIKE CORE-1</td>
</tr>
<tr>
<td>SOUTH2-5</td>
<td>LIKE CORE-1</td>
</tr>
<tr>
<td>SOUTH2-6</td>
<td>LIKE CORE-1</td>
</tr>
<tr>
<td>EAST2-2</td>
<td>LIKE CORE-1</td>
</tr>
<tr>
<td>NORTH2-2</td>
<td>LIKE CORE-1</td>
</tr>
<tr>
<td>CORE-3</td>
<td>LIKE CORE-1</td>
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**SYSTEM CONTROL**

- **MIN-SUPPLY-T**: 55
- **MAX-SUPPLY-T**: 105
- **HEAT-SIZING-RATI**: 1.2
- **HEAT-SOURCE**: HOT-WATER
COIL-BF = .19
COOL-SIZING-RATI = 1

$SYSTEM AIR
OA-CONTROL = FIXED

$SUPPLY FAN
FAN-SCHEDULE = SCH202
MIN-AIR-SCH = SCH209
SUPPLY-STATIC = 4.0
SUPPLY-EFF = 0.9
SUPPLY-MECH-EFF = 0.9
MOTOR-PLACEMENT = IN-AIRFLOW
FAN-CONTROL = SPEED
NIGHT-CYCLE-CTRL = STAY-OFF

$SYSTEM TERMINAL
MIN-CFM-RATIO = 1 $ CONSTANT VOLUME SYSTEM
REHEAT-DELTA-T = 50 ..

SYSTEM-2 = SYSTEM SYSTEM-TYPE= DDS
ZONE-NAME="
(CORE-1, CORE-1-PLM,
WEST-1, EAST-1, NORTH-1, LOBBY-1,
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EAST-6, NORTH-6, PENTH-W1, PENTH-W2,
PENTH-S1, PENTH-S2)

$SYSTEM CONTROL
MIN-SUPPLY-T = 55
COIL-BF = .19
COOL-SIZING-RATI = 1
COOL-CONTROL = CONSTANT $DEFAULT
COOL-SET-T = 55 $DEFAULT
MAX-SUPPLY-T = 105
HEAT-CONTROL = CONSTANT $DEFAULT
HEAT-SET-T = 105 $DEFAULT
HEAT-SIZING-RATI = 1.2
HEAT-SOURCE = HOT-WATER

$SYSTEM AIR
OA-CONTROL = FIXED

$SUPPLY FAN
FAN-SCHEDULE = SCH202
MIN-AIR-SCH = SCH209
SUPPLY-STATIC = 4.0
SUPPLY-EFF = 0.9
SUPPLY-MECH-EFF = 0.9
MOTOR-PLACEMENT = IN-AIRFLOW
FAN-CONTROL = SPEED
NIGHT-CYCLE-CTRL = STAY-OFF

$SYSTEM TERMINAL
MIN-CFM-RATIO = 0.6 $VARIABLE VOLUME SYSTEM

..
DHW-SCH = SCH54
DHW-SIZE = 0 ..
END ..
COMPUTE SYSTEMS ..

INPUT PLANT ..

PLANT-REPORT SUMMARY=(BEPS) ..
PLANT1 = PLANT-ASSIGNMENT ..

$ This is for Domestic Hot water
DHW1 = PLANT-EQUIPMENT
TYPE = DHW-HEATER SIZE= -999 ..

$This is electric chiller #1
CHILLER00 = PLANT-EQUIPMENT
TYPE = OPEN-CENT-CHLR
SIZE = 5.58 $FROM 465 Tons of CHILLER
INSTALLED-NUMBER = 2
MAX-NUMBER-AVAILABLE = 2 ..

$Part load info. for electric chiller #1
PART-LOAD-RATIO
TYPE = OPEN-CENT-CHLR
ELEC-INPUT-RATIO = 0.151667
MIN-RATIO = .1 ..

$Fuel Hot Water Boiler #1.
BOILER00 = PLANT-EQUIPMENT
TYPE = HM-BLILER
SIZE = 5 $MILLION BTU/H
INSTALLED-NUMBER = 1
MAX-NUMBER-AVAILABLE = 1 ..

$Part load info. for fuel Hot Water Boiler #1
PART-LOAD-RATIO
TYPE = HM-BLILER
ELEC-INPUT-RATIO = 0.022
MIN-RATIO = .33 $DEFAULT
MAX-RATIO = 2 .. $DEFAULT

$Cooling Tower
TOWER1 = PLANT-EQUIPMENT
TYPE = OPEN-TWR
SIZE = 12
INSTALLED-NUMBER = 2
MAX-NUMBER-AVAILABLE = 2 ..

PART-LOAD-RATIO
TYPE = OPEN-TWR
ELEC-INPUT-RATIO = 0.0098 ..

$ (See calculation sheet in binder. Determined using design data)

PLANT-PARAMETERS

$Electric Compression Chiller
OPEN-CENT-COND-TYPE = TOWER
OPEN-CENT-UNL-RAT = .1

$Compression chiller(‘s) condenser water flow
COMP-TO-TWR-WTR = 6 $DEFAULT VALUE=
CHILL-WTR-T = 44 $USED BY DEFAULT &
$MEASURED CHILLED WATER SUP TEMP.

$Fuel Hot Water Plant Boiler.
HW-BLILER-HIR = 1.25

$Tower
TWR-DESIGN-APPROACH = 12 $DEFAULT VALUE= 7F
TWR-DESIGN-RANGE = 10
TWR-DESIGN-WETBULB = 78 $USED BY DEFAULT
TWR-SETPT-CTRL = FIXED $USED BY DEFAULT
TWR-SETPT-T = 87 $BEASED ON MEASURED CONDENSER RET TEMP.
TWR-THROTTLE = 10 $DEFAULT VALUE= 5F
MIN-TWR-WTR-T = 66 $DEFAULT VALUE= 65F
TWR-CAP-CTRL = VARIABLE-SPEED-FAN $USED BY DEFAULT
DIRECT-COOL-MODE = NOT-AVAILABLE $USED BY DEFAULT
TWR-FUMP-HEAD = 25 $DEFAULT VALUE= 60FT
$Chilled Water
CCIRC-PUMP-TYPE = FIXED-SPEED $USED DEFAULT
CCIRC-HEAD = 20
CCIRC-IMPELLER-EFF = .8
CCIRC-MOTOR-EFF = .9
CCIRC-SIZE-OPT = INST-PLANT-EQUIP

$Hot Water
HCIRC-PUMP-TYPE = FIXED-SPEED
HCIRC-HEAD = 30
HCIRC-IMPELLER-EFF = .8
HCIRC-MOTOR-EFF = .9
HCIRC-SIZE-OPT = INST-PLANT-EQUIP

$  PLANT  HOU RLY-REPORT
HR-SCH1 = SCHEDULE
THRU DEC 31 (ALL) (1,24) VALUES=(1) ..

LRB-1 = REPORT-BLOCK
VARIABLE-TYPE= PLANT
VARIABLE-LIST=(1,2,3,8,9,19,21) ..
$1:HEATING LOAD FROM SYSTEMS
$2:COOLING LOAD FROM SYSTEMS
$3:ELEC LOAD FROM SYSTEM (KW)
$8:TOTAL HEATING LOAD TO BE MET BY PLANT (BTU/HR)
$9:TOTAL COOLING LOAD TO BE MET BY PLANT (BTU/HR)
$19:NOT WATER LOOP ELEC.
$21:COLD WATER LOOP ELEC

LRB-2 = REPORT-BLOCK
VARIABLE-TYPE= OPEN-CNT-CHLR
VARIABLE-LIST=(12,13) ..
$12:ENTERING CONDENCER TEMP
$13:LEAVING CHILLED WATER TEMP

LRB-3 = REPORT-BLOCK
VARIABLE-TYPE= END-USE
VARIABLE-LIST=(6) ..
$6:COOLING ELECTRIC (KW)

REP-1 = HOU RLY-REPORT
REPORT-SCHEDULE=HR-SCH1
REPORT-BLOCK=(LRB-1,LRB-2,LRB-3) ..

END ..
COMPUTE PLANT ..
STOP ..
APPENDIX C
ASHRAE 1093 RP Diversity Factor Toolkit Analysis

This portion of the appendix contains the diversity factors that were developed from the measured data to represent the lighting, receptacles and lighting+receptacle loads from the measured data obtained from sensors installed in the 4th floor of the REJ building. It was used to represent the appropriate loads in the DOE-2 as-build simulation program. These tables are the output from the ASHRAE 1093-RP Diversity Factor Toolkit.

WEEKDAYS: 4th Floor Lights + Receptacles

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Daily Sum from Hourly: 13.90 15.31 12.49 12.77 13.31 13.96 14.71 15.29 16.60 7.08

Daily Values: The Daily results as the statistics are applied on daily data.

Daily Sum from Hourly: The aggregated Daily results as the statistics are applied on Hour-of-Day data.
### WEEKENDS/HOLIDAYS: 4th Floor Lights + Receptacles

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**Daily Values:** The Daily results as the statistics are applied on daily data.

**Daily Sum from Hourly:** The aggregated Daily results as the statistics are applied on Hour-of-Day data.
### WEEKDAYS: 4th Floor Lights

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**Daily Values**: The Daily results as the statistics are applied on daily data.

**Daily Sum from Hourly**: The aggregated Daily results as the statistics are applied on Hour-of-Day data.
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**Daily Values:** The Daily results as the statistics are applied on daily data.

**Daily Sum from Hourly:** The aggregated Daily results as the statistics are applied on Hour-of-Day data.
### WEEKDAYS: 4th Floor Receptacles

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**Daily Values:** The Daily results as the statistics are applied on daily data.

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### WEEKENDS/HOLIDAYS: 4\textsuperscript{th} Floor Receptacles

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**Daily Values:** The Daily results as the statistics are applied on daily data.

**Daily Sum from Hourly:** The aggregated Daily results as the statistics are applied on Hour-of-Day data.