Project #4: Commercial Building System Design
Due Friday, 9 December 2005, 5:00 p.m.

This project is optional. If you elect to skip this project, the three previous projects will each be worth 8.33% of your final grade. If you elect to complete this project, it may be used to reduce the impact of a previous project or exam in the following ways:

- It may replace one of the previous projects. If your score on this project is greater than the lowest score of the first three projects, it can replace the lowest score project. That is, your project with the lowest score will be discarded.
- If you have performed more poorly on the exams than on previous projects, this project could reduce the impact of your worst exam score. Currently, each hour exam is worth 15% of the final grade. If your score on this project is better than your worst exam, the weighting of the exam will be reduced to 6.67% and the project will be worth the remaining 8.33%.

The selection between these two options will be automatic to give you the best final grade.

You are expected to perform the analysis in teams of up to two people. Perform the analysis for one of the following cities: San Diego, Fort Worth, Chicago, Memphis, and Washington, D.C. Pick the city whose first letter (C, F, N, S, W) is closest to the first letter of the surname (last name) of the youngest person in the group. Note: Use Sterling, VA, for Washington weather data.

Project Description

Consider a one-story small office building. You are being retained to develop a design for the building and its heating and cooling systems.

The building is a one-story office and retail building with a slab on grade foundation. The building measures 200 ft in the east-west direction and 50 ft. in the north south direction. The building has a 13 ft ceiling height. The office portion of the building is the east half of the space and the retail portion is the west half, each with a floor area of 5000 ft\(^2\). There are 32 windows on both the north wall and the south wall, evenly distributed. There are no windows on the east or west. The windows are 4 ft. wide and 6 ft. tall. There is one glass door on both the east and west walls. You should consider the building to have a basic steel construction. The walls are steel studs with stucco exterior. The roof has standard steel joists with roof insulation board above the deck and a weather barrier. The electric energy rate is $0.50 per kWh and the natural gas fuel cost is $0.70 per therm (1 therm = 100,000 Btu). The electric demand charge is $10 per kW.

Part 1: Basic Building System Design

Envelope

You are to perform a heating and cooling analysis for a base building. This base building has the following thermal characteristics.

- The walls are constructed of 2x4 steel wall framing, 16” o.c. with R-13 fiberglass cavity insulation. This wall has a U-value of 0.124 Btu/hr ft\(^2\)°F, corresponding to an overall R-value of R-8.1. In the Energy-10 program, this wall construction is described by the wall steelstud 4.
- The roof is a simple flat roof comprised of a steel pan on steel joists. Rigid board insulation and weatherproofing are installed on top of this pan, providing a continuous thermal and moisture barrier. The insulation has an R-value of 19, giving an overall roof U-value of 0.051 Btu/hr ft²°F. In the Energy-10 program, this roof construction is described by the roof \textit{flat, r-19}.

- The floor is a carpeted slab-on-grade with perimeter insulation. The \( F_2 \) factor for the floor is 0.50 Btu/hr ft°F.

- The windows are standard double-pane clear glass in an aluminum frame. The frame does not have a thermal break. While the glass has a U-value of 0.49 Btu/hr ft²°F, the overall U-value of the window assembly including frame is 0.70 Btu/hr ft²°F.

\textbf{HVAC System Design and Sizing Calculations}

The HVAC system should be a pair of packaged single zone rooftop units (RTUs), one for each half of the building. For this analysis, you should use a Carrier Model 48TM Weathermaker gas/electric rooftop unit. This model has a standard level of efficiency compliant with ASHRAE Standard 90.1. The units will be placed on the roof and all ducting will be inside.

1. Calculate the design heating load for each HVAC system. This calculation must be done by hand. That is, you may not use a computer simulation program for this task. Note that you do not need to calculation envelope U-values. Rather, you may use the values given above. Assume an infiltration rate of 0.3 ACH.

2. Use the Energy-10 program to determine the heating and cooling equipment size for each system. The Energy-10 inputs for this building are relatively straightforward. One unusual input is the infiltration. Energy-10 allows calculations of infiltration using both an air changes per hour (ACH) and an effective leakage area (ELA). For your analysis, you should change the ELA to zero and use an air change rate of 0.3 ACH.

\textbf{HVAC System Selection}

Select a pair of RTUs to meet the loads of the two building zones. For this analysis, you should assume an airflow rate corresponding to 400 cfm supply air for each ton of total cooling capacity. Assume that the electrical system is 230 V, 60 hz, single phase.

3. Using the design cooling and heating load information, select specific models of the Carrier Model 48TM Weathermaker RTU to meet the loads of the two zones. Your selection should have the basic form of 48TM\textit{mnnn}, where \( m \) is a letter D, E, or F corresponding to the level of heating capacity, and \( nnn \) is the three digit number corresponding to the cooling size. Note that the units are only available in certain sizes. Select the proper cooling size based on the comparison of the total capacity to the total cooling load.

\textbf{Part 2: Economic Assessment of Improved Design}

The building owner is interested in exploring the economic benefits of a better building design. At this point, the owner would like to consider the potential cost savings of adding more roof insulation, using better wall insulation, better windows, and adding a shading device over the south windows.

4. Design a shading system for the south windows that would be appropriate to shade the windows in the summer but allow passive solar heating in the winter. You should specify a continuous overhang along the entire wall.
5. Use the Energy-10 program to calculate the annual energy costs for the base case and for a set of improved designs with the following characteristics. Consider each option individually and then all of them together. (You should have the base case, four individual alternative designs, and one combined alternative design.)

- Add 2 in. of continuous polyisocyanurate insulation \( (\text{polyiso foam} \text{ in Energy-10}) \) on the roof. The cost of this added insulation is estimated to be $0.40 per square foot of roof area.
- Replace the wall construction with 2x6 steel framing, 16 in. o.c., with R-19 fiberglass cavity insulation and 2 in. of extruded foam insulation. In Energy-10, this wall construction is described as wall \( \text{steelstud 6 poly} \). The cost of this improved wall is estimated to be $0.60 per square foot of opaque wall area.
- Add shading for the south windows. The cost of the shading is estimated to be $2.00 per foot of projection from the building per linear foot of the building wall.
- Replace the windows with low-e double pane windows having aluminum frames with a thermal break. In the Energy-10 program, these windows are described by window \( 4060 \text{ low-e al/b} \). The cost of the improved windows is estimated as $2.00 per square foot of window area.

6. For each design alternative, select a pair of RTUs to meet the heating and cooling needs. Estimate the cost of the RTU as $500 per ton of total cooling capacity. Assume that an increase in furnace size has no significant impact on equipment cost.

7. Calculate the change in initial cost of each of the options compared to the base case. For each case, you will have to pay more for the improved envelope, but you could save initial cost if the size of the HVAC equipment is reduced. Compare the savings with the additional initial costs and evaluate whether it is worth improving the design? You might consider using the payback period for your evaluation, defined as the ratio of the additional initial costs to the annual energy cost savings.

**Deliverable:**

Prepare a brief report describing your analysis and results. The report should include the following features:

- Executive summary of results, including conclusion of the economic analysis.
- Brief description of building design and assumptions.
- Calculations and results for each of the seven identified tasks.
Design Evaluation

Designer(s): 

Presentation 
Organization 
Grammar and Writing 

Building Design 
1. Heating load 
2. Cooling load 
3. HVAC system selection 

Improved Design 
4. Shading design 
5. Energy calculations 
6. HVAC costs 
7. Economic evaluation 

Total: 

/100
### ARI* Capacity Ratings

**ARI** CAPACITY RATINGS — 48TM004-014

<table>
<thead>
<tr>
<th>UNIT 48TM</th>
<th>NOMINAL TONS</th>
<th>NET COOLING CAPACITY (Btuh)</th>
<th>TOTAL kW</th>
<th>SEER†</th>
<th>EER**</th>
<th>SOUND RATING (decibels)</th>
<th>IPLV††</th>
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**LEGEND**
- db — Dry Bulb
- EER — Energy Efficiency Ratio
- IPLV — Integrated Part-Load Values
- SEER — Seasonal Energy Efficiency Ratio
- wb — Wet Bulb

*Air Conditioning and Refrigeration Institute.
†The SEER values shown for sizes 004, 005, and 006 are for units with the optional belt drive motors. SEER rating for these units with the standard direct drive motor is 9.7.
**ARI does not require EER ratings for units with capacity below 65,000 Btuh. For these units, the EER rating at ARI standard conditions is provided for information only.
††The IPLV applies only to two-stage cooling units.

**NOTES:**
1. Rated in accordance with ARI Standards 210-94 or 360-93.
2. ARI ratings are net values, reflecting the effects of circulating fan heat.
3. Ratings are based on:
   - Cooling Standard: 80°F db, 67°F wb indoor entering-air temperature and 95°F db air entering outdoor unit.
   - IPLV Standard: 80°F db, 67°F wb indoor entering-air temperature and 80°F db outdoor entering-air temperature.
4. All 48TM004-014 units are in compliance with ASHRAE 90.1 2001 Energy Standard for minimum SEER and EER requirements. Refer to state and local codes or visit the following website: http://solstice.crest.org/efficiency/bcap to determine if compliance with this standard pertains to a given geographical area of the United States.

### Heating Capacities and Efficiencies — 48TM004-014

#### 208/230-1-60 — Single-Stage Gas Heat

<table>
<thead>
<tr>
<th>UNIT 48TM</th>
<th>INPUT CAPACITY</th>
<th>OUTPUT CAPACITY</th>
<th>TEMPERATURE RISE (°F)</th>
<th>MINIMUM HEATING AIRFLOW (CFM)</th>
<th>EFFICIENCY</th>
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#### 208/230-1-60 — Single-Stage Gas Heat — Low NOx

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<th>UNIT 48TM</th>
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#### 208/230/460-3-60 — Single-Stage Gas Heat — Low NOx

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AFUE — Annual Fuel Utilization Efficiency
# Model number nomenclature

These item required for Model specification

**Example:**

```
48 TM D 006 P M F 6 - - HA
```

## Model Number Code

- **48**: Packaged Rooftop Electric Cooling/Natural Gas Heat
- **TM**: Constant Volume, Standard Efficiency

### Heat Options:

- **49 States**
  - D: Low Heat
  - E: Medium Heat
  - F: High Heat
- **California Compliant**
  - L: Low NOx Low Heat
  - M: Low NOx Medium Heat
  - N: Low NOx High Heat

### Capacity Nominal-Tons

- 004: 3 Tons
- 005: 4 Tons
- 006: 5 Tons
- 007: 6 Tons
- 008: 7-1/2 Tons
- 009: 8-1/2 Tons
- 012: 10 Tons
- 014: 12-1/2 Tons

### Controls and Sensors

- N: None
- P: PremierLink™ DDC Control
- **Novar ETM3051 Control***

### Factory-Installed Options†

**Voltage**

- 1: 575-3-60
- 3: 208/230-1-60
- 5: 208/230-3-60
- 6: 460-3-60

**Coil Protection Options (fin/tube)**

- B: Cu/Cu Cond & Evap
- C: Cu/Cu Cond & Al/Cu Evap
- F: E-Coat Al/Cu Cond & Al/Cu Evap
- G: E-Coat Cu/Cu Cond & Al/Cu Evap
- V: Al/Cu Pre-Coat Cond Fin & Al/Cu Evap

**Indoor Motor Options**

- A: Alternate Motor
- M: High-Static Indoor Motor

**Heat Options:**

- D: Low Heat
- E: Medium Heat
- F: High Heat
- **California Compliant**
  - L: Low NOx Low Heat
  - M: Low NOx Medium Heat
  - N: Low NOx High Heat

**Quality Assurance**

Certified to ISO 9001:2000

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**Legend**

- Al: Aluminum
- Cu: Copper
- DDC: Direct Digital Controls
- FIOP: Factory-Installed Option

*Contact factory for availability and application information.
†Refer to 48TM Price Pages, Quote Builder, or contact your local Carrier representative for FIOP code table.