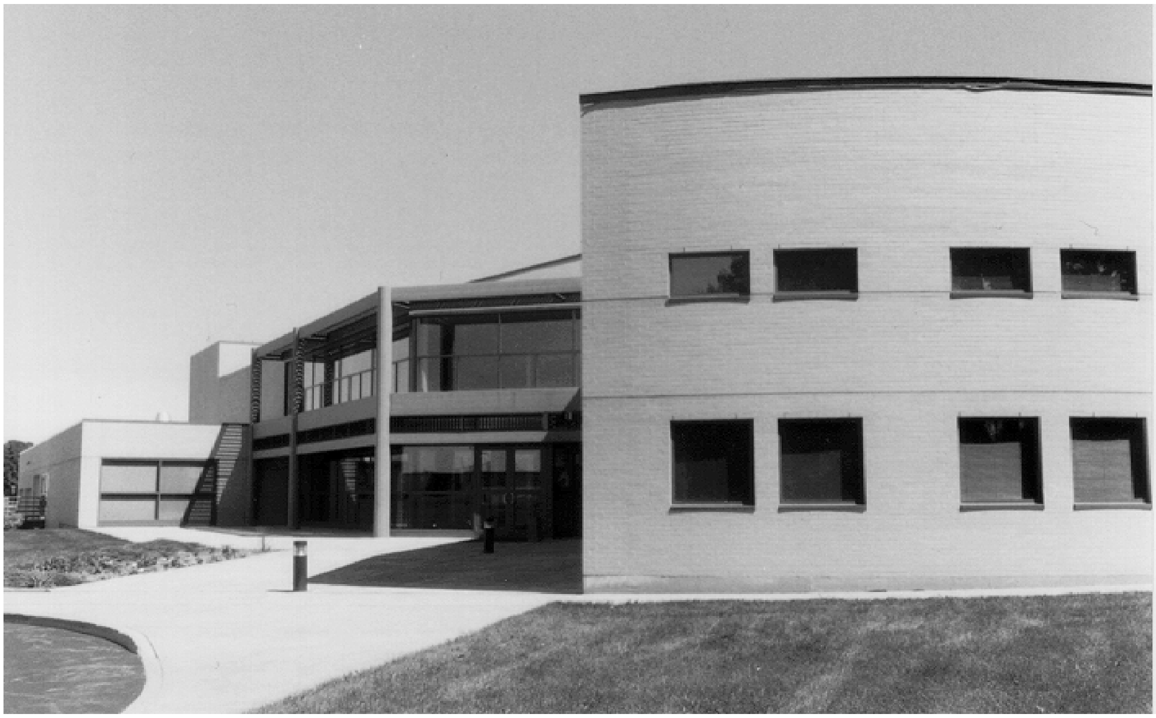

Figure 3.15 Entrance of office building with window shading. **{** TC "Figure 3.15 Entrance of office building with window shading. " \l 5 **}**
The photograph was taken just before noon.

Some of the zones in the building are open to other zones, allowing circulation of zone air among them. This can occur in some zones that have no walls between them, such as in offices that border a central office pool and have doors that are always open. The circulation of air among these zones is modeled using coupling terms in the multizone building component model, TYPE 56. These terms are not known with any precision - estimates of 100 to 200 cfm were used depending on the size of the openings connecting the zones. Because the set point in all of the zones were set the same, any error induced by the over-estimation or under-estimation of these terms is small. A sensitivity study showed that changing these values by 100 or 200% had no effect on the predicted annual energy use of the buildings.

The occupancy schedules of the office building were estimated as being constant for weekdays over the course of the year. The building was taken to be fully occupied from 7AM to 6PM every weekday and unoccupied on the weekends. This occupancy schedule was used to hourly control heat and humidity gains due to lights, office equipment and people. The only exception to the occupancy schedule is a dispatch area that is occupied 24 hours/day. The gains in this zone were treated as constant.

The occupancy schedules were applied to the gains from people and equipment in each zone. The gains used for each are shown in Table 3.8 below on a per unit basis.

Gain	Convective [W]	Radiative [W]	Humidity [kg/hr]
People† [per person]	80	50	0.0864
Metal Halide	35	140	0
Fluorescent	32	128	0
Compact Fluorescent	4	16	0
Computers	450	50	0

†(ASHRAE Fundamentals, 1993)

Table 3.8 Internal Gains for People and Equipment{ TC "Table 3.8 Internal Gains for People and Equipment" \l 6 }

An inventory of the existing lights in the building was conducted based on the as-built drawings of the building. The gain in each zone was found by multiplying the number of units or people in each zone by the gain and the occupancy (zero or one). The Type 56 building component does this calculation on an hourly basis when the model is run.

The building component model accounts for the added heating or cooling load due to outdoor air used for ventilation. The ventilation rate for the whole building was known to be 2500 cfm, from the equipment nameplate data at the site. However, the flow rates in each zone were not known. The ventilation to each of the zones was estimated as a fraction of the total rate. The heating capacity of each zone was used to estimate the fraction of the total ventilation used in each zone. The flow rate to each zone was thus the heating capacity of the zone divided by the overall heating capacity in the building.

The office building model also accounted for some infiltration in each of the zones. ASHRAE estimates infiltration rates from 0.1 to 0.6 air changes per hour (ACH) for recently constructed commercial buildings (ASHRAE, 1993). An infiltration rate of 0.2 was used in the building model. This level was found to provide the best agreement between the energy use predicted by the model and the data from utility bills.

The office building model was also used to estimate the energy use in four climates outside of Madison. For these locations the equipment models had to be modified to reflect the different sizes of heat pumps that would be used there. The heat pump sizes for locations outside of Madison were found by determining the ratio of peak heating and cooling loads at those locations relative to peak loads in Madison. The ratio of the loads was used to scale the size of heat pumps in the building. The ratios used to scale the capacity of the heat pumps are shown in Table 3.9.

City	Heat Pump Heating Capacity	Heat Pump Cooling Capacity
Miami	0.22	1.61
Phoenix	0.30	1.31
Seattle	0.35	1.07
Washington DC	0.60	1.47

Table 3.9 Ratio of heat pump sizes in four cities{ TC "Table 3.9 Ratio of heat pump sizes in four cities" \l 6 }, relative to base case in Madison.

3.4.4 Office Building Model Validation{ TC "3.4.4 Office Building Model Validation" \l 3 }

Monthly utility bills were used to validate the results of the office building simulation. Figure 3.16 shows the simulation results as compared to the actual energy use billed for 1994. The energy use is put on a daily basis so that the energy use between the different months can be compared directly.

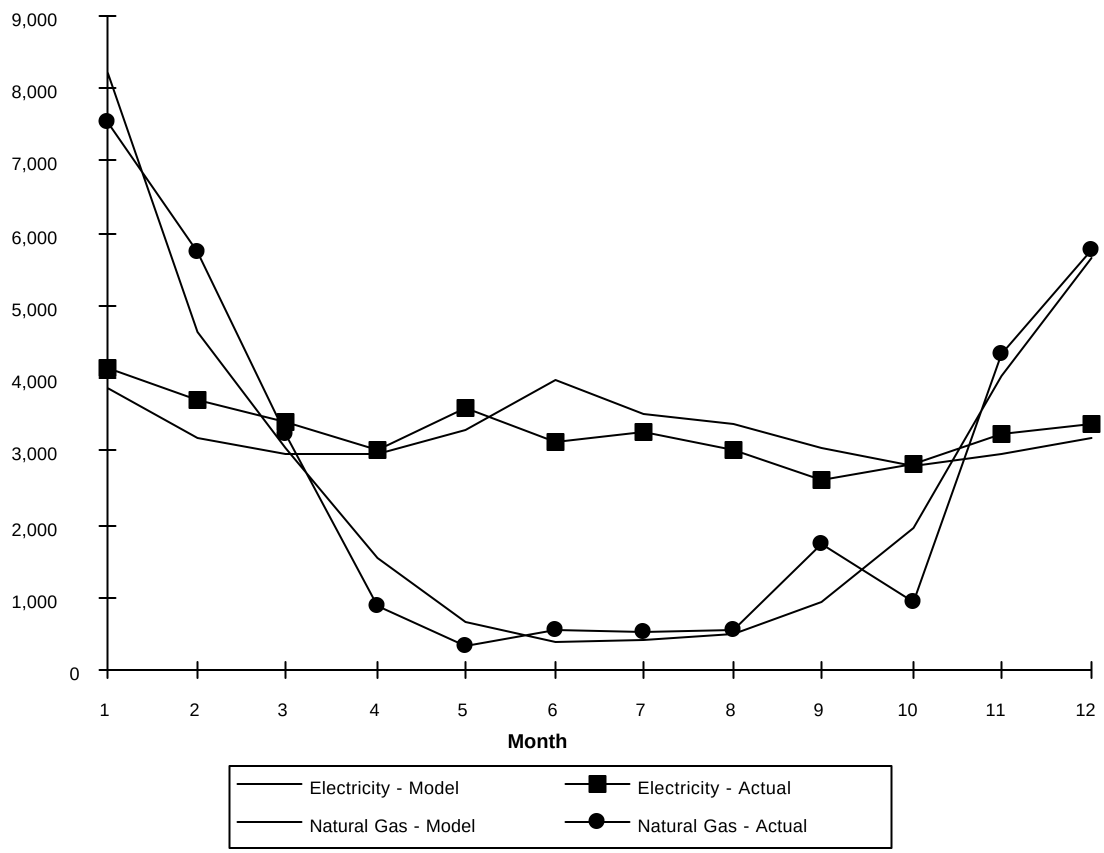

Figure 3.16 Office building model agreement with actual energy use.**{** TC "Figure 3.16 Office building model agreement with actual energy use." \l 5 **}**

The office building shows good agreement with the actual energy use for the building. There are significant differences between the natural gas use predicted by the model and the actual energy use of the building in September and October. These differences must be due to the some occupant behavior change such as a change in set point temperatures or unusual building occupancy during the period. There is nothing in the weather data for the year that would explain the heating load decrease between September and October. The overall energy use predicted by the model for the entire year agrees very closely with the actual annual energy use total for the building.

3.5 Conclusion{ TC "3.5 Conclusion" \l 2 }

Simulations were created for the office and retail buildings using TRNSYS and the Type 56 building model component. The simulations were based on construction data from two existing buildings and were developed to provide estimates of energy used to heat, cool and light the buildings.

The building simulations were very detailed in scope. The building models were divided into multiple zones for each building. The thermal characteristics of each wall, window, floor and roof element in the buildings were included in the models. Detailed equipment models were developed including performance that depended on outdoor air conditions and the fraction of full load. Internal loads from people and lighting were scheduled based on information from the building occupants. The shading of some building elements was also modeled in a dynamic manner for each hour of the simulation. All of these factors created models that reflected the interactive nature of separate building elements.

A new TRNSYS component was written to model the water-loop heat pump system in the office building. The component includes separate sub-modules that model the performance of a cooling tower, heat pumps and boilers. The control of this system is somewhat complicated because there is a high degree of interaction among the performance of the system components, and outdoor conditions. Further study of the optimal method for controlling this type of system would be a good opportunity for further research.

Both of the building models were validated using monthly utility data from 1994. Energy use estimates from the models showed good agreement with actual billing data from the two buildings. It was concluded that the models were adequate for estimating the energy use implications of changes in the building designs.