DISCOVERING THE UNEXPECTED THROUGH THE USE OF THE DOE-2.1 BUILDING ENERGY SIMULATION PROGRAM

Mark R. Davenport
Heery Energy Consultants, Inc.
880 West Peachtree Street, NW
Atlanta, Georgia 30367

Lung-Sing Wong
Jones Nall Davis, Inc.
Suite 900, Flatiron Building
84 Peachtree Street, NW
Atlanta, Georgia 30303

ABSTRACT

only through the use of mainframe building energy simulation programs can some opportunities for reductions in energy and construction cost be uncovered. Case studies showing how surprising results from DOE-2.1B simulations led to the discovery and subsequent implementation of " non-standard practice" design strategies in two different large commercial building projects are presented. One project is a 250,000 sq. ft. speculative office building in Orlando, Florida, and the other is a 300,000 sq . ft. corporate office building in Atlanta, Georgia.

INTRODUCTION

Despite the great potential that mainframe building energy simulation programs hold for optimizing building energy use, it is often difficult for designers and clients alike to justify the extra time and expense that their use entails. Some of the most compelling arguments for more widespread use of these programs in the design process come to light in applications where they have enabled the discovery of cost savings opportunities which depart from accepted design practice.

Following are case studies of two commercial office projects where results of DOE-2.1B simulations uncovered opportunities for reducing construction expenditures by eliminating planned energy efficiency measures which were mistaken as being cost-effective. Specific benefits accruing to the building owners and others involved in these projects are also discussed under the Conclusions section of the paper.

This paper is based upon work performed while both authors were employed by Heery Energy Consultants, Inc.

CASE STUDY #1: LANDMARK CENTER, ORLANDO

Landmark Center in Orlando, Florida is a six story, 250,0000 s.f. atrium office building developed as a joint venture of Capital Holding Company and The Landmarks Group. Heery Energy Consultants, Inc. was engaged by the client, the developer, in the latter stages of the Construction Documents Phase to identify and analyze potential energy cost reduction measures. The building, as of the end of Design Development, represented what was considered good, energy cost-efficient design for speculative office buildings in the Orlando area.

Analysis of Single versus Double Glazing

A DOE-2.1B simulation model was developed based on construction drawings and projected occupancies and other operational data provided by the developer. From a review of energy end use figures in the DOE-2.1B BEPS report, it was found that energy use in the base building design was dominated by year-round cooling and connected lighting loads. Together, these two constituted 65% of annual building energy consumption. Heating energy was the smallest energy use component at 13% of total annual consumption.

Because estimated heating loads were so low for this building, single glazing was identified as a possible alternative. It was hypothesized that if a glazing with a shading coefficient equal to or less than that of the specified double glazed units was used, heating energy use would rise substantially, but cooling energy use would remain approximately the same. Any resulting energy cost penalty could then be compared against the sizeable $41,000 savings in construction material costs that would be available by substituting single glazing for double glazing.

Analysis of base case energy use also revealed high electric demand in the milder winter months. This reflected interaction between chiller, cooling tower, supply fans and electric reheat coils. Air cooled by chilled water, from either the chiller or cooling tower strainer cycle, was reheated by electric reheat coils in perimeter VAV boxes to meet the building's minimum cooling load and heating load. In addition, fan energy use suffered because supply fans had to move more air than was required for cooling under low load conditions. From these observations, it became apparent that a secondary air distribution system using fan-powered induction boxes would minimize reheating of previously cooled air at the building perimeter and reduce fan energy consumption during heating periods.

Because they would be able to "track" perimeter heating loads (i.e. modulate cooled supply air quantities to zero) more closely than VAV reheat terminal units, the fan-powered induction units were selected for the simulation comparison of single glazing versus double glazing. This strategy would minimize the heating penalty incurred by the single glazing.

Simulations were conducted for the base glazing, 1" Solarcool Gray (U = 0.55/0.57, SC = 0.33) to 1/4" TS-20 (U = 0.94/0.96, SC = 0.30). Both simulations assumed perimeter air distribution through fan-powered induction units.

Analysis Results

When applied to the Florida Power & Light commercial electric rate schedule, DOE-2.1B simulation results indicated an annual energy cost savings of $1,950 dollars attributable to the single glazing strategy. Peak electric billing demand for the highest month was reduced by 21 Kw, and total consumption was reduced by 42,000 KwH. A more in-depth review of DOE-2.1B report output was undertaken to determine what different energy use characteristics of the single glazing design led to the savings.

In reviewing the DOE-2.1B Monthly Peak and Total Energy Use report, it was discovered that the building summer electric peak had shifted from early morning to the afternoon. Apparently, the single glazing reduced the morning pull-down cooling load by allowing building internal heat to escape more readily during the night. Additionally, the BEPS report indicated that although heating energy nearly doubled, cooling energy was reduced by a comparable amount. Some of this reduction, though, was attributed to the single glazing's slightly lower shading coefficient.

Based on simulation results, the owner elected to use single glazing in lieu of the originally specified double glazing. By making this substitution, the developer was able to offset much of the additional cost of the more efficient fan-powered induction units with the first cost savings on the glazing system.

CASE STUDY #2: LIFE OF GEORGIA HOME OFFICE

The Life of Georgia Home Office is a new, 300,000 s.f. corporate headquarters project located in suburban Atlanta, Georgia. The building is scheduled for occupancy in September, 1985. Energy consulting and analysis services were provided by Heery Energy Consultants, Inc. to the client, the Life Insurance Company of Georgia, from the Predesign Phase through Construction Documents. A major goal for the project was to achieve the most cost-effective level of energy use, with a minimum 25% Internal Rate of Return as the economic selection criteria for energy conservation measures.

Analysis of Waterside Economizer Cycle

Trade-off studies of a number of energy-related alternatives for architectural, mechanical and electrical systems were conducted throughout design. One such study, conducted during Design Development, was intended to measure any additional energy cost savings that an airside economizer cycle might offer over the base condition of a waterside economizer cycle for providing "free cooling". If the savings were significant, then an argument might be made for moving the fan rooms from the center of the building to the building perimeter, where access to 100% outside air would not require large vertical shafts or horizontal duct runs.

Simulations calculated a $3,700 annual savings for the airside economizer over the waterside economizer. This was less than anticipated. Knowing that airside economizer was generally more effective than waterside economizer, attention turned to to investigating whether a waterside economizer was itself an economically justified as a base design feature.

Waterside economizer cycle is by far more common than airside economizer in Atlanta area office projects with chilled water systems. Depending on engineering preference, either a direct or indirect economizer cycle may be used. Direct economizer cycle provides direct distribution of condenser water to cooling coils whenever the economizer cycle is activated. In this mode, condenser water is typically filtered to remove corrosive and biological elements picked up in the open cooling tower. An indirect system employs a flat plate heat exchanger to transfer heat between condenser and chilled water flow - a more certain method of reducing the possibility of system corrosion and contamination.

The base mechanical system design for the Life of Georgia project included an indirect waterside economizer cycle. The DOE-2.1B program, however, can only simulate a direct waterside economizer, or "strainer cycle" in DOE-2.1B terminology. An indirect waterside economizer cycle will incur a savings penalty in the range of 10% to 20%, depending on the heat exchanger's performance, or "approach". Therefore, it was acknowledged that the savings predicted via the DOE-2.1B computation would be optimistic when applied to Life of Georgia's indirect waterside economizer.

With a waterside economizer, the savings obtainable are directly proportional to the number of hours during which waterside economizer can operate. The number of hours, in turn, is a function of the chilled water temperature required to cool and de-humidify the building. A chilled water temperature at the air handling units of 55° F was selected for cooling purposes during simulated operation of the waterside economizer. Two speed cooling tower fans were also assumed.

Analysis Results

Energy cost savings predicted by the DOE-2.1B computer simulation with waterside economizer were only $690, due to 17,200 ton-hours of chiller operation avoided. Several factors were found to contribute to this surprising result. First, much of the electrical savings from the offset chiller operation were consumed by additional operation of the cooling tower fans to produce the colder water leaving the cooling tower.

The very efficient (0.60 Kw/ton) centrifugal chillers assumed in the simulations were also partially responsible for the diminished dollar savings of the waterside economizer. In the scenario of no waterside economizer, when outdoor temperatures were suitable for economizer operation, the 300 ton base-loaded chiller operated at high part loads. Thus, the efficiency of the one chiller during the 17,200 ton-hours avoided by the economizer cycle was extremely high, and corresponding energy use relatively low. Finally, the use of waterside economizer did not affect peak electric billing demand - a significant component of the total electric bill under Georgia Power Company's commercial rate structure.

Given the above results, the waterside economizer cycle was deleted from the mechanical systems design for the Life of Georgia Home Office. It should be noted that although the airside economizer cycle yielded much greater energy cost savings than the waterside economizer, fan room access to 100% outside air proved too costly to implement architecturally.

CONCLUSIONS

The foregoing case studies discuss the discovery and subsequent implementation of design strategies which countered local standard architectural and engineering practice. Without the use of the DOE-2.1B or similar large energy simulation program, it is doubtful that the "discoveries" would have been made. As a result, individuals and firms which were involved in the two projects, as well as the owners, have benefitted in several important ways.

First, performing DOE-2.1B energy simulations has increased the individual users' level of understanding of building energy performance, helped them to better identify potential cost saving measures, and improved their ability to effect a truly integrative approach to energy conservative design. Even on projects where DOE-2.1B simulations have not been part of the scope, DOE-2.1B simulation experience has enabled program users to achieve higher quality results. In this light, DOE-2.1 has been very much a tool for individual education and professional advancement.

The skills gained by the individuals involved in the example projects, and the success of these projects, have served to enhance the reputation of the firms where they work. These firms have also been successful in using the "discoveries" described in this paper as marketing devices to gain further commissions.

The owners of the above projects benefitted from their consultant's use of DOE-2.1B by being able to reallocate the budget for two marginally effective conservation techniques, double glazing and waterside economizer, to other measures which proved to be more cost-effective. This more prudent use of capital, and the associated reduction in building operating expenses, have also served to enhance the owners' images in the local marketplace.

Others have also benefitted as a result of the more cost-effective building designs discussed above. For example, the misapplication of conservation techniques and lost opportunities for effective cost-saving measures on previous projects had cost the developer/owner (Case Study #1) thousands of dollars every year. Most of these costs were passed directly through to the developer's tenants. Through the refinement of energy efficient building designs enabled in part by DOE-2.1B, tenants in this developer's buildings have enjoyed passed-through energy costs lower than that of similar office buildings in the area.

ACKNOWLEDGEMENTS

The work described in this paper was performed under contract with The Landmarks Group and the Life Insurance Company of Georgia.