Screening Tool for Desiccant Dehumidification Applications

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ABSTRACT

A state-of-the-art software tool that calculates the benefits of desiccant-based air-treatment equipment is described. The software, a Desiccant Systems Application Screening Tool, is written in the Windows™ environment to promote user-friendliness. Its graphical interface emphasizes the simplicity of using default values or, if desired, provides the user with the option of customizing the input. The program runs annual loads/energy calculations with the electric equipment selected by the user (from a library of typical systems) and compares performance of a conventional system to an alternative electric system supplemented with a commercially available desiccant dehumidifier providing the required air-conditioning performance.

The screening tool uses DOE 2.1E as the computational engine, which runs in the background and is transparent to the user. In addition, the latest TMY2 meteorological data recently released from the Department of Energy National Renewable Energy Laboratory are used by the program.

Output of the program provides the user with a clear comparison between the performance of a desiccant/electric system and conventional system installed in an identical application. Specifically, the comfort issues are emphasized by comparing the number of occupied hours when the relative humidity in the building exceeds 60% RH (or above specific RH set point, if controlled). The economics are compared based on the annual/monthly energy consumption and operating cost. A case study is presented.

INTRODUCTION

The market potential for commercial gas-fired air-conditioning equipment has increased significantly due to the emergence of a new generation of desiccant-based air-treatment equipment. Compliance with ASHRAE Standard 62-89 in the design of building HVAC systems, and the increased awareness of indoor air quality issues, are making desiccant equipment very attractive alternatives to supplement conventional air-conditioning systems. However, results quantifying the performance and economic benefits of desiccant systems are limited. This may be partly attributed to the absence of easy-to-use, educational and marketing tools that provide information on the energy and cost savings potential of desiccant systems as compared to conventional systems. Furthermore, literature from desiccant equipment manufacturers usually only provides the performance at a series of conditions that is difficult to translate into energy and cost savings and/or comfort improvement for a particular application.

To address this need, a state-of-the-art software tool that provides fast and accurate analysis of benefits of supplementing standard air-conditioning systems with desiccant-based air-treatment equipment was developed. The software, Desiccant Systems Application Screening Tool (DSAST), was developed by the Institute of Gas Technology (IGT) and sponsored by Gas Research Institute (GRI) and IGT Sustaining Membership Program (IGT-SMP) members. The program was developed in cooperation with GARD Analytics, Inc. and the University of Illinois at Chicago. The DOE-2.1E computation engine was licensed from J.J. Hirsch & Associates.

PROGRAM STRUCTURE

The software is written in the Windows™ environment and employs, DOE version 2.1E as the computational engine, which runs in the background and is transparent to the user. This approach promotes user-friendliness without compromising engineering accuracy. The program user interface is composed of three separate folders (Location/Energy Rates, Application, and Equipment) as shown in Figure 1. Each folder emphasizes the simplicity of using default values or, if desired, provides the user with the option of modifying and customizing the input.

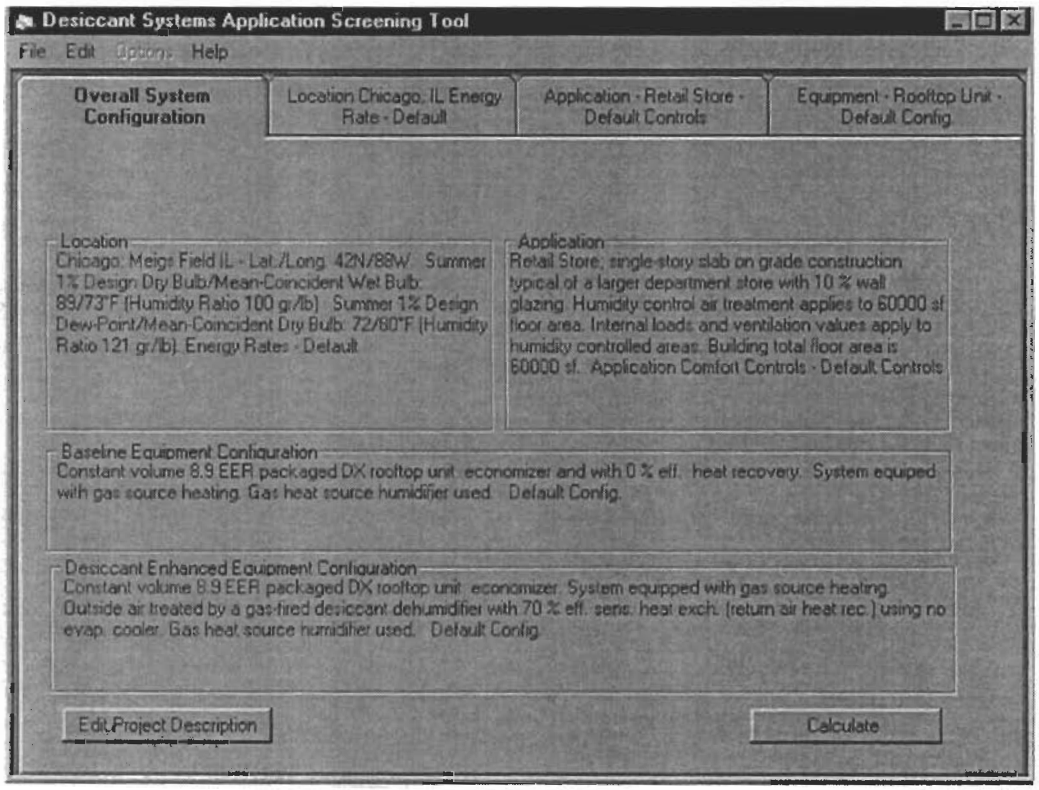

Figure 1. DSAST front end with Location/Energy Rates, Application, and Equipment folders.

Location/Energy Rates Folder

The project location and electric and gas utility information are entered on the Location/Energy Rates Folder (see Figure 2). At the present, the user can select one of the sixteen geographical locations (Atlanta, GA, Baltimore, MD, Charleston, SC, Chicago, IL, Cleveland, OH, Dallas, TX, Houston, TX, Jackson, MS, Miami, FL, Minneapolis, MN, Nashville, TN, New Orleans, LA, New York, NY, Raleigh, NC, St. Louis, MO, Tampa, FL) which offer default energy costs and electric and gas rate structures representative for that location. If appropriate, the default energy pricing information can be used without modification, however, much of information on the screen can be user defined as well. The energy pricing input options allow the user to choose between the time of use (TOU) and the stepped rate structure and its cutoff type, the rate season, the demand charges, and the application of cooling rates and ratchet charges, as well as specific monthly charges, energy cost adjustments and taxes.

In addition to the sixteen locations with the predefined energy pricing, DSAST provides the user access to 234 weather files (locations) available from NREL TMY2 database. The weather files are reformatted to be compatible with the DOE2 input data requirements. The energy costs information is not given for these additional locations and should be provided by the user in order to run the program.

In addition to the typical hourly weather data file, each geographical location has assigned a unique equipment design point weather data file. The equipment design point weather data file contains the 1% cooling dry-bulb and 1% dew-point design conditions as given in the new 1997 ASHRAE Handbook of Fundamentals (HOF). The design conditions in the 1997 HOF are calculated on a different basis compared to the design conditions published in previous editions of this handbook. Previous design conditions were based on a 4-month summer period and a 3-month winter period in the United States. The 1% annual values are about 1°F lower than the 2.5% summer design temperature in the 1993 ASHRAE HOF (see Chapter 26 of the 1997 HOF for further explanations). The design dew-point design conditions are new, and illustrate the significance of latent loads.

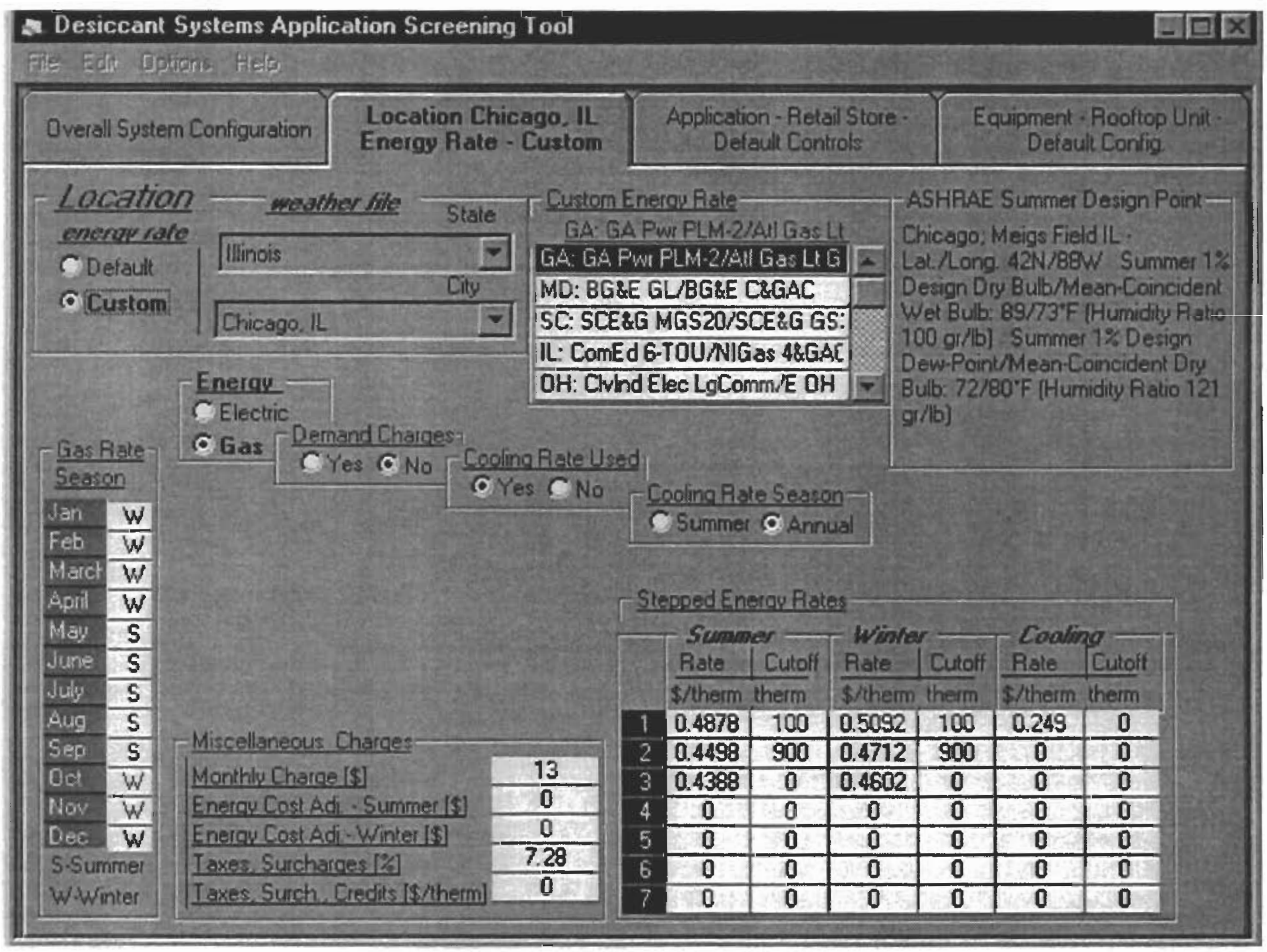

Figure 2. Location folder provides access to geographical location weather data and electric and gas energy pricing structure

Application Folder

The project building information is entered on the Applications Folder (see Figure 3). A library of eleven typical applications (hospital, small and large hotel, ice arena, movie theater, nursing home, restaurant, retail store, refrigerated warehouse, school, and supermarket) is available to the user. Each application building is pre-configured with the typical values of internal loads, ventilation, comfort controls, and schedules. For each of these variables, the user can accept the default configuration or insert user values.

The building construction parameters that can be customized include the floor area, the glazing factor, and the geographical orientation. The building heat loads that can be customized are occupancy density , lights, other electric, ventilation, and infiltration. Three 24-hour schedules can be defined separately for Weekdays, Saturday, and Sunday/holiday. These include the equipment schedule, the occupancy schedule, and the lights/other-electric schedule.

The building comfort controls are defined separately for the standard electric air-conditioning equipment configuration option and for the enhanced with desiccant dehumidifier electric air-conditioning option. The building high and low limits of heating and cooling temperatures can be setup separately during the building occupied and unoccupied hours. In addition, the application of the humidity control (humidification/dehumidification) and their set-points can be defined separately for the standard and the desiccant dehumidifier enhanced air-conditioning equipment options.

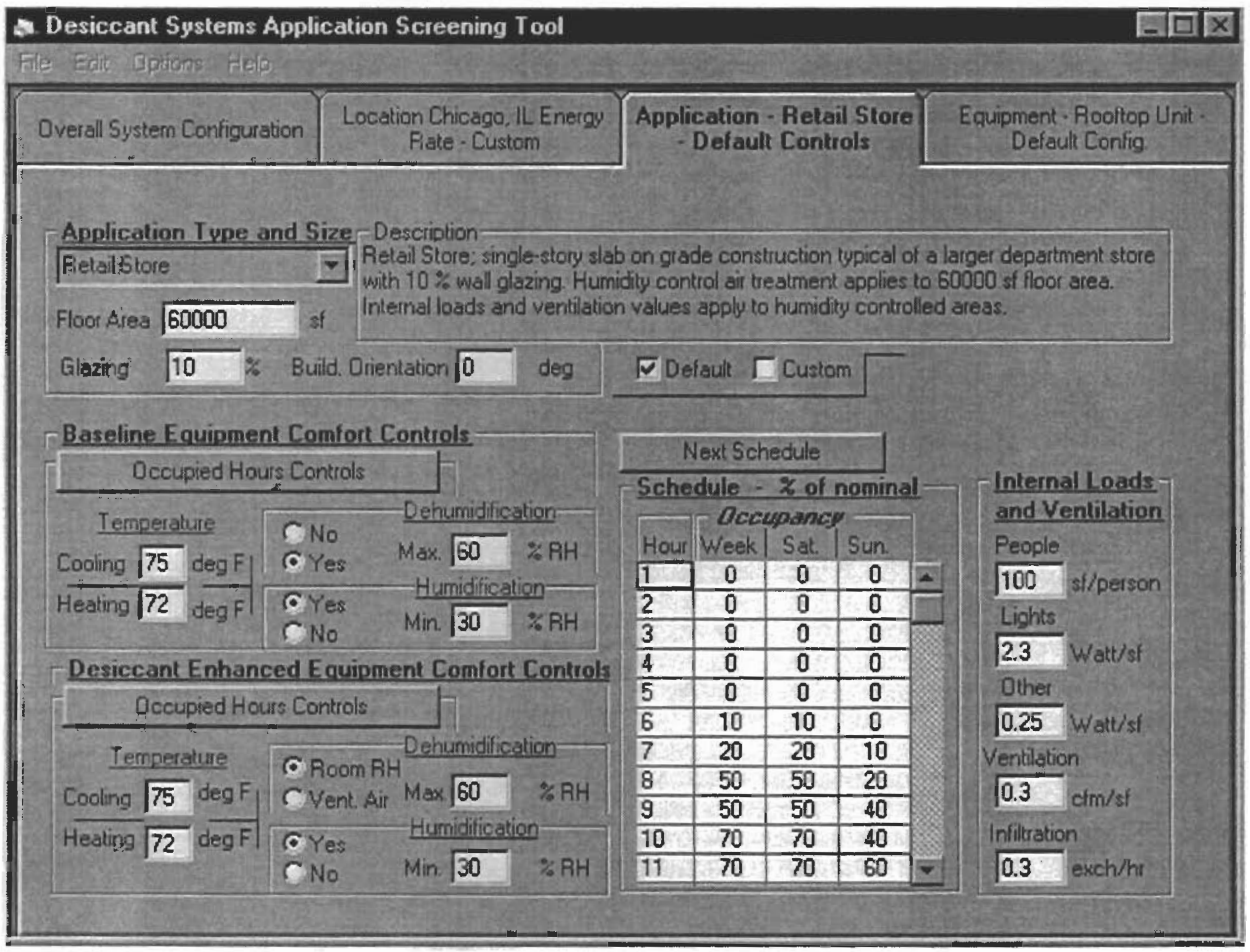

Figure 3. Application folder provides access to building type selection, internal loads, schedules, and comfort controls

Equipment Folder

The Equipment Folder opens with the selection of HVAC equipment predefined by the building type selected in the Application Folder (see Figure 4). Three basic types of the electric A/C equipment (rooftop packaged DX, packaged terminal A/C, and central chiller plant) and one type of the gas-fired desiccant wheel dehumidifier are available to the user.

The default equipment assignment can be overwritten by the user. Any of the three available A/C systems, applicable to the particular building type, can be selected. Each of the default application-A/C-system pairs has a single set of predefined equipment options. However, if needed, the user can change the type of the equipment heat recovery options (sensible, enthalpy, none), select different economizer type (sensible, enthalpy, heat pipe, none), or change the cooling equipment condenser type (air, water). Similarly, the desiccant dehumidifier equipment has a default configuration (type of regenerating air source, use of evaporative cooler) and a default value of the sensible heat recovery wheel efficiency, all of these can be modified by the user.

In addition to customizing the configuration of electric and desiccant equipment, access to the electric equipment rating point performance and its cycling point is provided. The energy source for heating/reheating and humidification is defined in the Equipment Folder as well. The user can run the program using the default configuration or select one of the two additional custom equipment configurations that can be easily changed. Only configurations of the equipment that are practical to the particular application are available for customizing.

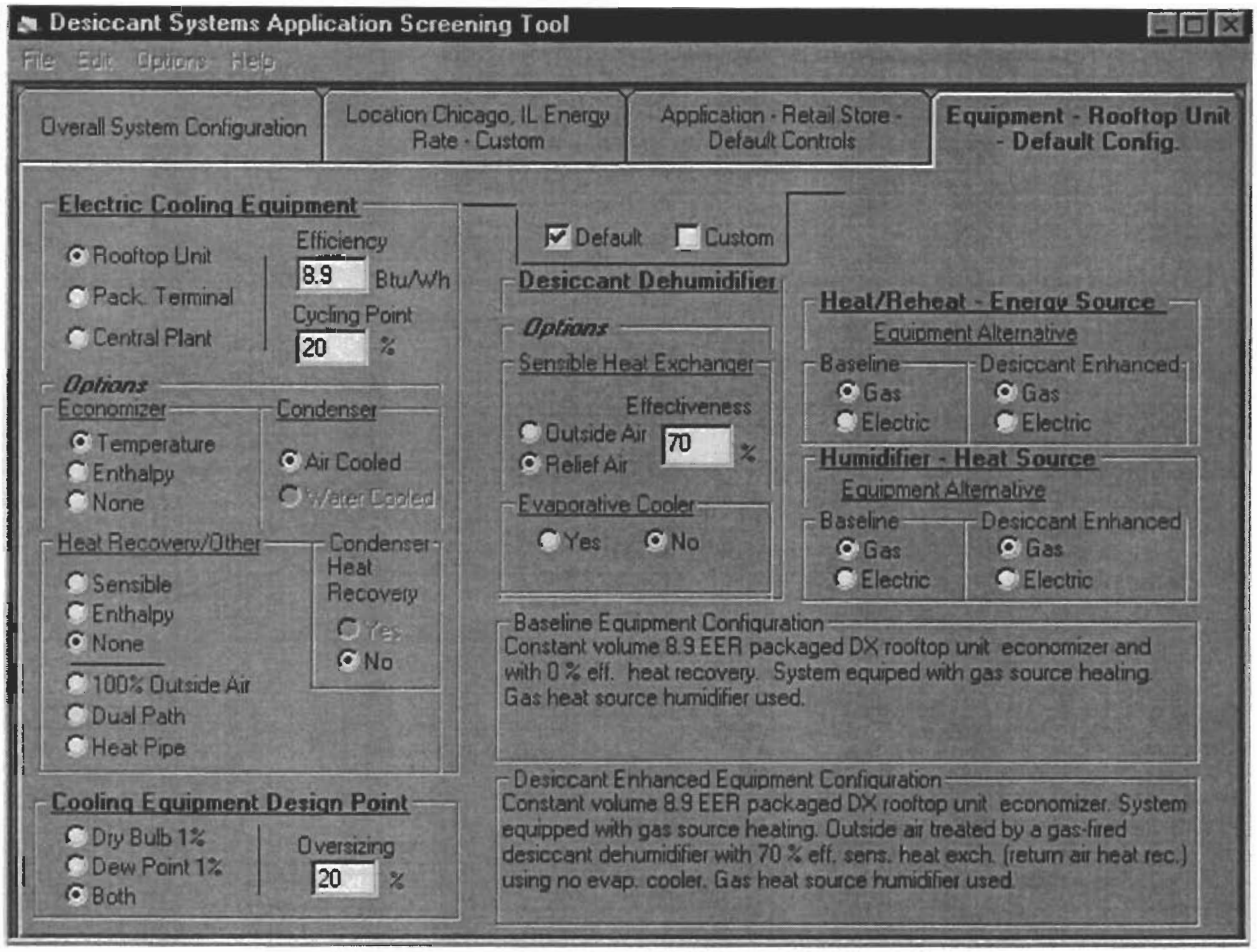

Figure 4. Equipment folder provides access to building type selection, internal loads and schedules

Program Output

Two output reports, one short and one detailed, are generated by DSAST.

The short report provides a summary of the completed calculations and a brief description of the analyzed case, based on the program default and/or the user custom input data. Cooling and heating equipment design capacity, the supply fan capacity, and the gas and electric annual energy consumption and costs are provided for both equipment options. In addition, the size and the performance of the desiccant dehumidifier is provided, along with the total annual number of hours the indoor air relative humidity stays above 60%. Any equipment configuration that would result in the conditioned space relative humidity staying above 60% for an extensive period should be considered inadequate.

The Detailed Report provides data on the monthly heating and cooling loads as well as the monthly energy consumption and costs. The electric and gas energy consumption are given separately for the various equipment types modeled. This information is provided separately for both the standard, and the desiccant enhanced equipment option, so that a direct comparison of specific equipment configurations can be made. Such comparisons are further illustrated graphically. The graphs, as well as reports, can be viewed on a computer display and/or printed to provide a hard copy. An option of saving reports in an Excel® spreadsheet format is available to the user who would like to perform a more detailed analysis of the program output.

Sample Run Case Study (Example)

A simple case study is presented, to illustrate the capability of DSAST. In this example, a 40,000 square foot movie theater in Charleston, SC was chosen to evaluate the potential benefits of supplementing a typical electric air-conditioning system with a desiccant dehumidifier to better control indoor air comfort. The building, a typical single story slab-on-grade construction had 10% wall glazing. A constant volume packaged DX rooftop unit with temperature economizer and 70% effective sensible heat recovery was used as a standard electric air-conditioning system (see Figure 5).

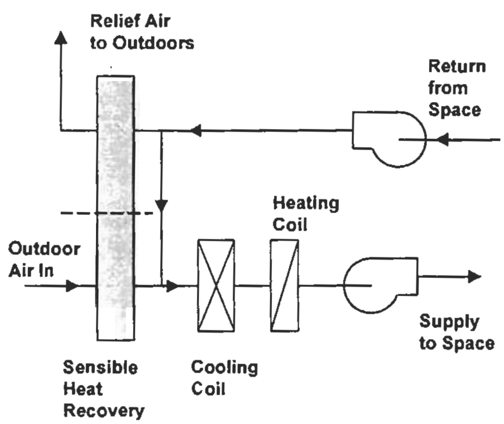

Figure 5. Standard electric AC system equipment configuration

In the desiccant enhanced configuration, the constant volume packaged DX rooftop unit with temperature economizer is supplemented with the gas fired desiccant dehumidifier with 70% efficient sensible heat recovery (see Figure 6).

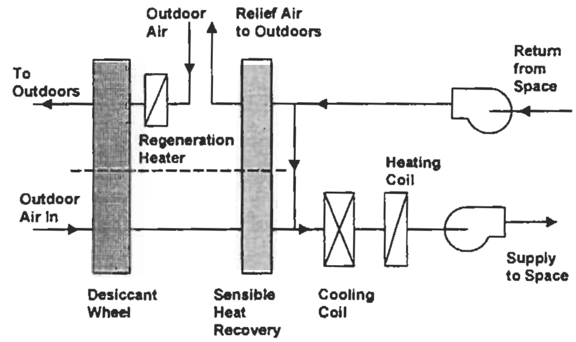

Figure 6. Electric AC system equipment enhanced with gas fired desiccant dehumidifier

The cooling and dehumidifying equipment was sized for 1% cooling dry bulb and 1% dew-point design conditions (whichever was more demanding) with an oversizing factor of 1.2. The building space heating was provided by a gas furnace in the rooftop unit. A humidifier driven by heat from the gas furnace was used to control indoors minimum humidity requirements. The theater was assumed to be occupied from 2 PM to 11 PM during the weekdays and from 10 AM until midnight during the weekends and holidays.

The assigned internal loads, infiltration and ventilation requirements are shown in Table 1. The theater comfort control set points are given in Table 2. To allow the user direct evaluation of potential advantages of each of the evaluated equipment configurations (better economics and/or comfort control), the comfort control set points are identical for the standard and the enhanced equipment configuration,

Table 1. Building Internal Loads and Ventilation

Occupancy	24.0 (sf/person)
Lighting	1.0 (Watt/sf)
Other Electric	2.0 (Watt/sf)
Infiltration	0.10 (exchanges/hr)
Ventilation	15 (cfm/person)

Table 2. Building Comfort Control Set Points

	Standard Electric	Desiccant Enhanced
Cooling Temp./Setback	75/99 (F)	75/99 (F)
Heating Temp./Setback	70/65 (F)	70/65 (F)
Maximum Humidity	60%	60%
Minimum Humidity	30%	30%

The results of applying DSAST for the two alternative equipment configurations are given in Table 3 and is shown in Figures 7 to 11.

Table 3. Equipment Sizing and Energy Use and Costs	Standard Electric	Desic. Enhanc
Design Cool. Capacity (kBtu/hr)	2,237	1,552
Design Heat. Capacity (kBtu/hr)	1,180	1,188
Supply Fan Capacity (CFM)	69,083	54,760
Dehumidifier Capacity CFM	--------	22,591
Annual Elec. Energy Use(kWh)	577,398	360,213
Annual Gas Energy Use (MBtu)	2,222	2,565
Annual Electric Energy Cost ($)	43,506	27,177
Annual Gas Energy Cost ($)	16,561	12,231
Total Annual Energy Cost ($)	60,067	39,408
Occupied Hours @ RH > 60%	1,302	113

For this example, calculations show that a significant energy cost savings and improved comfort can be achieved by supplementing standard electric air-conditioning system with the gas-fired desiccant dehumidifier. The desiccant dehumidifier enhanced system annual energy costs are only 65% of the standard electric system energy costs. In addition, the standard electric system has difficulty controlling indoor relative humidity. The theater annual number of hours with indoor relative humidity above 60% with conventional system was 1,302 while for a desiccant-enhanced electric option it was only 113 (see Figure 7)

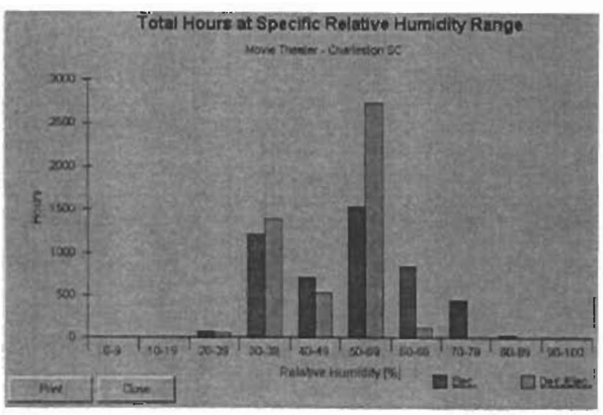

Figure 7. Quality of relative humidity control

The energy savings obtained with the desiccant-enhanced system option can be explained by analyzing monthly energy consumption and cost charts. Figure 8 illustrates how a smaller electric DX system and cooling coil latent load saves electric energy when the system includes an additional gas-fired desiccant dehumidifier. Figure 8 shows how such electric energy savings affect the monthly electric energy costs.

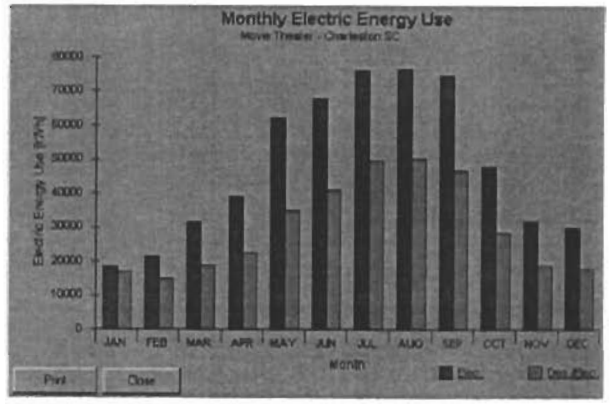

Figure 8. Monthly electric energy consumption

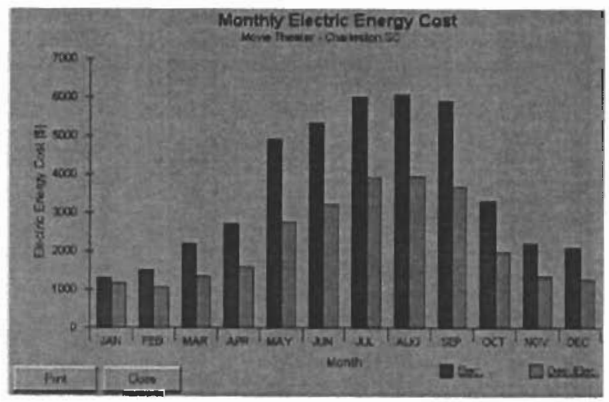

Figure 9. Monthly Electric Energy Costs

Of additional interest are the monthly profiles for gas consumption and cost shown in Figures 10 and 11, respectively. Figure 10 shows that from October to April, the gas consumption of the standard electric system is higher than that of the desiccant-electric system. During this period the standard system is forced to increase reheat gas consumption to control humidity. During the May to September period, the electric system gas consumption does not change drastically while the desiccant-electric consumes more gas. However, during this period the desiccant enhanced system effectively controls indoor air humidity, while the electric system fails to do so. Also, the gas consumption used by gas furnace for space heating is lowered in the desiccant enhanced system. This is due to the fact that the desiccant dehumidifier not only removes water from the air, but in the process of doing so increases air temperature. An additional beneficial effect that further lowers the desiccant enhanced system monthly gas energy costs results from the low gas cooling rate offered by the local utility (see Figure 11).

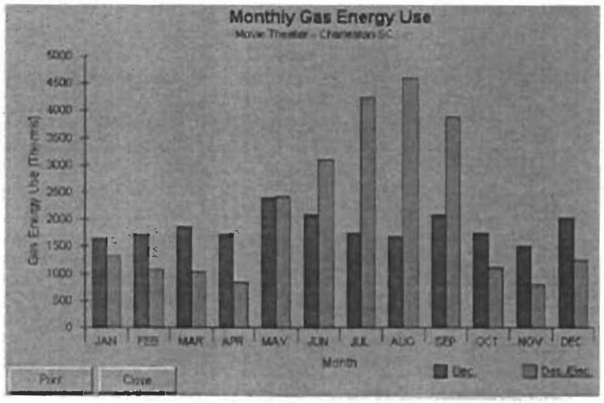

Figure10. Monthly Gas Consumption

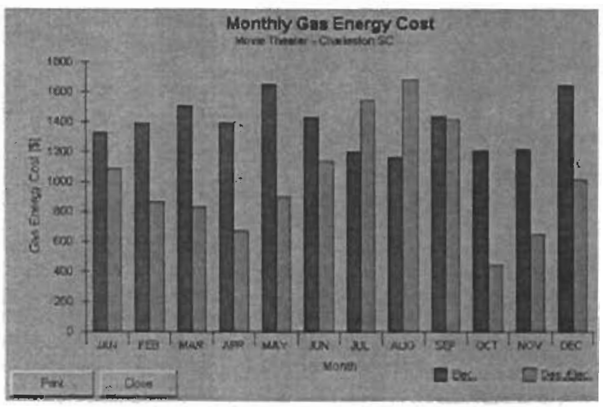

Figure 11. Monthly Gas Energy Costs

CONCLUSIONS

Analyzing the benefits of using desiccant dehumidifier technology can be complicated and time consuming. Depending upon the application, location weather data, local energy cost structure, and air-conditioning equipment configuration, the economics of using desiccants can change significantly. The DSAST program offers unique combination of a simple graphical interface with the computational sophistication of DOE2 to guide a user in the selection of the most economically viable air-conditioning equipment configuration for comfort control.

RFERENCES

American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., "1997 ASHRAE Handbook of Fundamentals," Atlanta, GA.

American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., "1993 ASHRAE Handbook of Fundamentals," Atlanta, GA.