DOE/EE-0273

# Demonstration and Evaluation of HVAC Controller for Lodging Facilities

***Field evaluation of hotel/motel through-the-wall HVAC systems supervisory controller***

FEMP FEDERAL ENERGY MANAGEMENT PROGRAM

Office of Energy Efficiency and Renewable Energy

Technology Installation Review

A case study on energy-efficient technologies

Prepared by the New Technology Demonstration Program

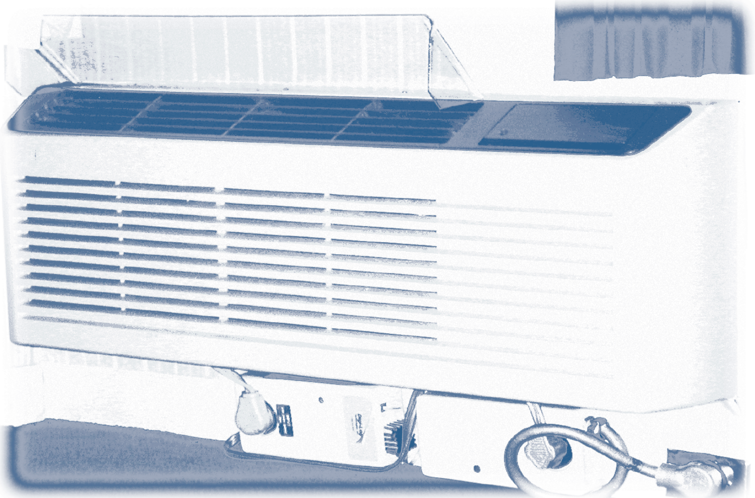
## Introduction

This *Technology Installation Review* (TIR) presents the demonstration test results of the Digi-Log supervisory HVAC (heating, ventilation, and air-conditioning) controller installed in a hotel/motel setting. Described are the technology, installation requirements, technology demonstration and performance, and energy-saving features. The demonstration was conducted by the Oak Ridge National Laboratory (ORNL) and sponsored by the U.S. Department of Energy's Federal Energy Management Program (FEMP) under its New Technology Demonstration Program.

Several potential energy-savings devices are available for through-the-wall HVAC systems but independent test data quantifying their savings are sparse. This field evaluation and demonstration study quantifies the potential energy savings and assesses the impacts on occupants and staff of using a Digi-Log supervisory HVAC controller in lodging facilities. The supervisory controller operates according to the occupancy status of each room in a hotel or motel.

The Digi-Log controller is a plug-in device installed between a wall outlet and the room HVAC unit. Preliminary tests conducted by Phillips Electronics in laboratory-simulated environmental conditions suggest that energy savings ranging from 50% to 80% are possible in unoccupied lodging rooms employing the controller (Fisher 1999). The field study objective was to quantify and verify these estimates and to identify impacts on occupant comfort. The controller was developed by Digi-Log as a tool for reducing energy consumption and lowering operating costs in the lodging industry.

The primary functions of the controller are to 1) monitor the power supply of the HVAC unit (protect it from high or low voltages), 2) respond to room temperature extremes and/or an alarming smoke detector (by generating a phone call followed by an alarm code), and 3) enable remote programming and control of various dial-up commands and functions. If a power interruption or brownout occurs, a programmable timer delays power transmission to the unit after site power is restored to prevent damage to the unit. Power to a unit can be terminated indefinitely via dial up access to the controller. If Temperature Control Mode is selected, an air-conditioning unit would be powered off if the room temperature was within the high and low temperature setpoint limits. If the room temperature was not within these limits, the controller would allow the HVAC to turn on to prevent damage to the room. The room controller also can detect a smoke alarm beeping. The controller will dial and beep if a smoke detector is alarming or if the temperature in the room is very hot or cold.



*Digi-Log controller (left), ORNL monitoring-DAS device (right)*

## Background

In 1998, the commercial sector in the United States consumed 32% of the total electrical energy, which equated to 15.4 quads of energy during that year, and by 2020, this figure is estimated to increase to 18.2 quads (DOE/BTS 2000). HVAC accounts for 31.8% of the total energy consumed in the commercial sector. Packaged HVAC systems make up 82% of the HVAC equipment being utilized in the sector. The lodging industry is 9% of the sector, and its HVAC usage accounts for 30.8% of the total energy used by the lodging industry. Phillips Electronics' laboratory tests of Digi-Log controllers in an environment simulation room indicate that energy savings ranging from 50 to 80% are possible during unoccupied periods. A one-year field evaluation of the controller was initiated in September 2000 at the Music Road Hotel in Pigeon Forge, Tennessee. A total of 163 controllers were installed in suites and single rooms, and 24 of these locations were monitored. Data downloads were conducted nightly and automatically using an on-board, dial-out modem inside the monitoring-DAS device. The Music Road Hotel was the first test site for the controller. A second test is under way at Silver Surf Gulf Beach Resort in Bradenton Beach, Florida, which allows evaluation of the controller in a more severe cooling-demand climate.

This TIR describes results of a field evaluation of the performance of a Digi-Log supervisory HVAC controller. During the test period, the HVAC energy consumption in the uncontrolled rooms averaged 2632.2 kWh monthly while in the controlled rooms it averaged 1684.6 kWh. This equates to the uncontrolled rooms' HVAC consuming an average of 947.6 kWh (56.3%) more energy than the units in the controlled rooms monthly. Due to intermittent inoperability of the controllers and other energy loads (controllers controlled approximately 50% of the hotel's conditioned space), comparison analysis of the energy cost over a three-year period for the entire hotel does not reveal any discrete savings during the test period over prior years.

## Installation and Technology Description

Digi-Log Technologies Inc. and ORNL installed Digi-Log Power Controller Units and ORNL Monitoring units in Music Road Hotel at Pigeon Forge, Tennessee, in September 2000. A total of 163 Power Control Units, one per room, and 24 ORNL Monitoring Units were installed. Of the 24 monitored rooms, 12 reference rooms were not equipped with Power Controller Units. Since the hotel had various room configurations (whirlpool tub, fireplace, kitchenette, etc., see Figure 2), rooms with controllers and reference rooms were matched based on size and orientation.

After installation, Digi-Log Technologies Inc. made several software and hardware modifications to their units during the one-year test period. Data downloads from the 24 ORNL-monitored rooms were conducted nightly and automatically using an on-board, dial-out modem inside the monitoring device. The field study test at the Music Road Hotel ended October 31, 2001.

The Power Controller Unit was developed by Digi-Log Technologies Inc. as a tool for reducing energy consumption and protecting the HVAC units in low and high voltage situations, therefore lowering operating costs in the lodging industry. The primary functions of the Power Control Unit are to 1) monitor the power supply of the HVAC unit (protect it from high or low voltages), 2) respond to room temperature extremes and/or an alarming smoke detector (by generating a phone call followed by an alarm code), and 3) enable remote programming and control of various dial-up commands and functions.


***Figure 2****. Test Site (Pigeon Forge, Tennessee).*

A communication link via telephone (computer modem or touchtone phone keypad) is established between each Power Controller Unit and the front desk, using the in room phone line and a phone line splitter. When a PC is used, Digi-Log Technologies Inc. software and Host Interface Unit are required. A desktop PC is located at the hotel front desk as shown in Figure 3. When the software is activated a dialog box appears that allows the user to enter a password that determines the managers or the front desk clerks entry level. This level permits programming and/or modification of the Power Controller's parameters and dial-up commands (Set-up Room Controller, shown in Figure 4).

After the manager has entered and completed Set-up (filling in the Room Check In or Out, Room Parameters, and Modem Setting, Room Heat Pump Enable), all rooms are programmed. The front desk clerk can now enter the Check In or Out Status by choosing the Check In or Out button on the Room Heat Pump Enable menu as hotel guest checks in or out, as shown in Figure 5.

If the temperature control mode is "on" and the "unoccupied" mode is selected, the HVAC unit will be powered off if the room temperature is within the unoccupied high and low programmed temperature limits. If the room temperature is above or below these limits, the Power Controller Unit will allow the HVAC unit to be activated to satisfy the temperature limit setpoints.

If the Temperature Control Mode is "on" and the "occupied" mode is selected, the HVAC unit will be powered off if the room temperature is within the occupied high and low programmed temperature limits. However, if the room temperature goes below the low temperature limit or above the high temperature limit the HVAC unit will be powered on to maintain the temperature limits.

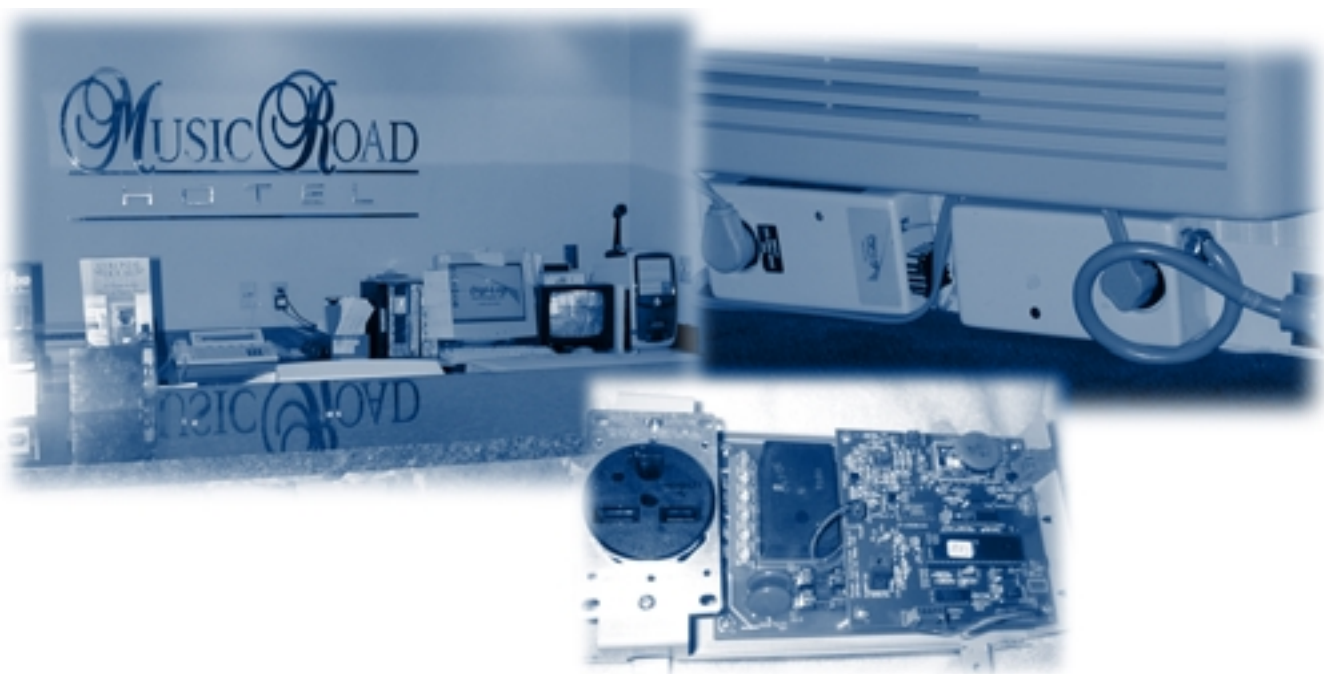



***Figure 3**. Front desk computer at front desk, installed Digi-Log unit, uncovered Digi-Log unit.*

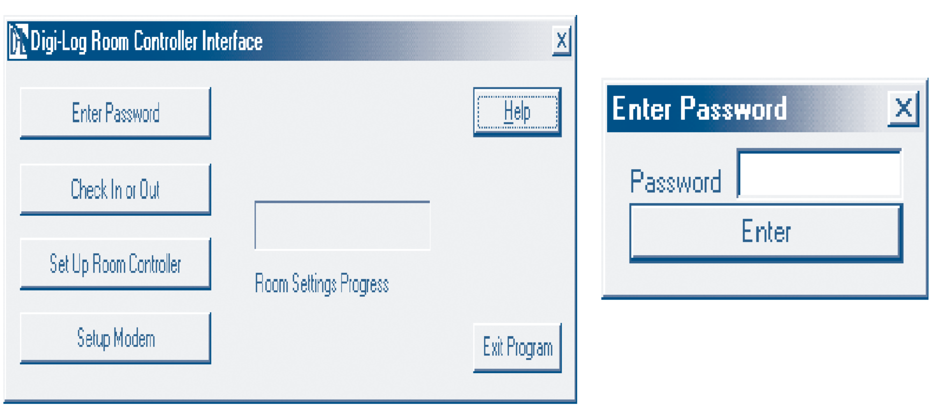



***Figure 4**. Digi-Log controller interfacing software initialization menu and password menu.*

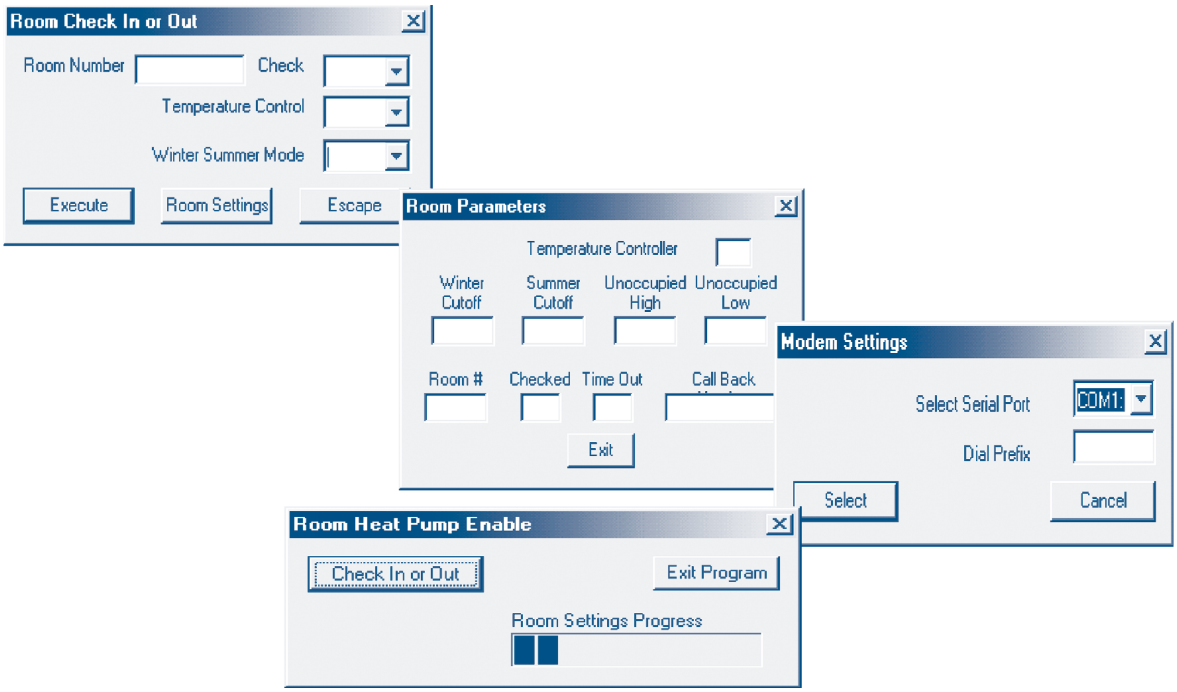



***Figure 5.*** *Check-in or out, room parameters, modem settings, and executing (heat pump enable) menus.*

The winter or summer mode is automatically selected by the Power Controller's software and will change as outside temperatures dictate. However, at a guest's request the summer/winter mode can be reversed or the temperature control mode can be turned off giving the guest complete control of the HVAC unit.

In order for the Power Controller Unit to function properly, the housekeeping staff must make sure the HVAC unit is turned to the "on" position as they leave the room. If a power interruption or brownout occurs, the Power Control Unit interrupts the power supply to the HVAC unit. The HVAC unit will not be reconnected until site power has been restored and the programmable time delay period has expired. This prevents short cycling of the compressor and prevents restart load damage.

The Power Controller Unit will call a preprogrammed call-back number, generating a dual-tone alarm code, if the temperature in the room is more than 5 degrees above or below the programmed high or low temperature limits of the unoccupied mode or if an in-room smoke detector is alarming. The recipient of the call acknowledges the alarm, causing the alarm to cease. If the recipient hangs up the phone without acknowledging the alarm, the controller will immediately call back and continue to generate the dual tone alarm codes. After the alarm has been acknowledged the alarm function will be cleared allowing another alarm to occur.

## ORNL Monitoring Method and Device

The approach that ORNL took to carry out the field evaluation study was as follows:

- Develop an instrumentation plan and data acquisition (DAS) hardware.
- Identify test sites based on climate, complex size and historical energy consumption.
- Select rooms within complex for evaluation based on occupancy, exposure, orientation, and location within the complex
- Install controller and monitoring-DAS devices (boxes beneath HVAC unit shown in Figures 1 and 3),
- Monitor room conditions and HVAC performance for one year.
- Use survey tools to determine impact on occupants and hotel staff.
- Analyze system performance and publish findings.

In conjunction with Pace Scientific, ORNL developed a monitor-DAS packaged device that was compatible with the controller. It records 1) electrical current to the HVAC unit, 2) room temperature, 3) room humidity, and 4) occupancy status/wattage to the HVAC unit. A Pace Scientific data logger was included in the packaged device, which must be preprogrammed using Pace's software prior to field installation. Data must be entered into two menus—one to program the device and the other to program the host computer, as shown in Figure 6. Data in spreadsheet format were downloaded from the 24 ORNL-monitored rooms nightly and automatically using an on-board, dial-out modem inside the monitoring-DAS device. The device facilitates collection of performance data on the HVAC controller and is shown in Figure 7. Spreadsheet utilities were used to reduce and analyze data.

## Energy-Saving Features and Benefits

The supervisory controller operates according to the occupancy status of each hotel/motel room. The controller is a plug-in device installed between a wall outlet and the room HVAC unit. The controller saves energy by allowing the room temperature to float more than is permitted by the room thermostat during unoccupied periods and prevents the room from overheating and overcooling during occupancy.

## Federal Sector Potential and Technology Application

Since the primary functions of the room controller are to: monitor power supplied to an in-space HVAC unit, verify that no power interruption or brownout occurs, and enable supervisory control of the HVAC system, the unit can be used on any brand through-the-wall HVAC system. If a power interruption or brownout occurs, power to the unit is interrupted for a programmable amount of time after site power is restored to prevent damage to the unit. Power to a unit can be terminated indefinitely via dial-up access to the controller. If the room temperature is not within the set limits (i.e., 55°F and 85°F), the controller will allow the HVAC to

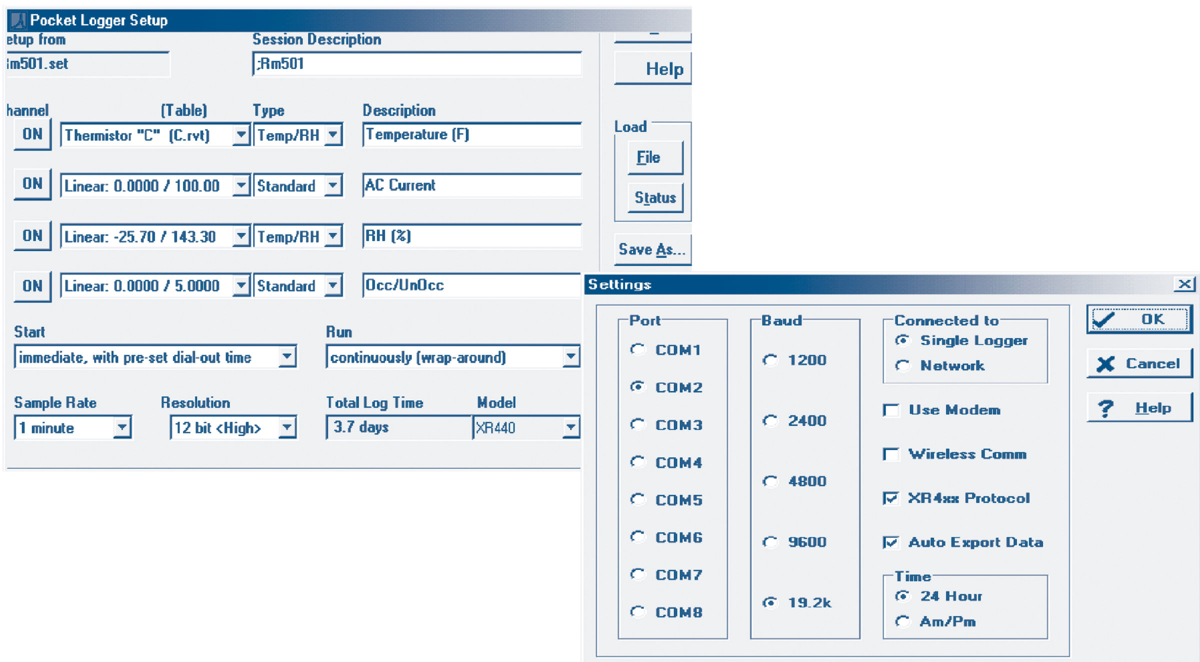



*Figure 6*. *ORNL logger setup for monitoring-DAS device and host computer (right).*

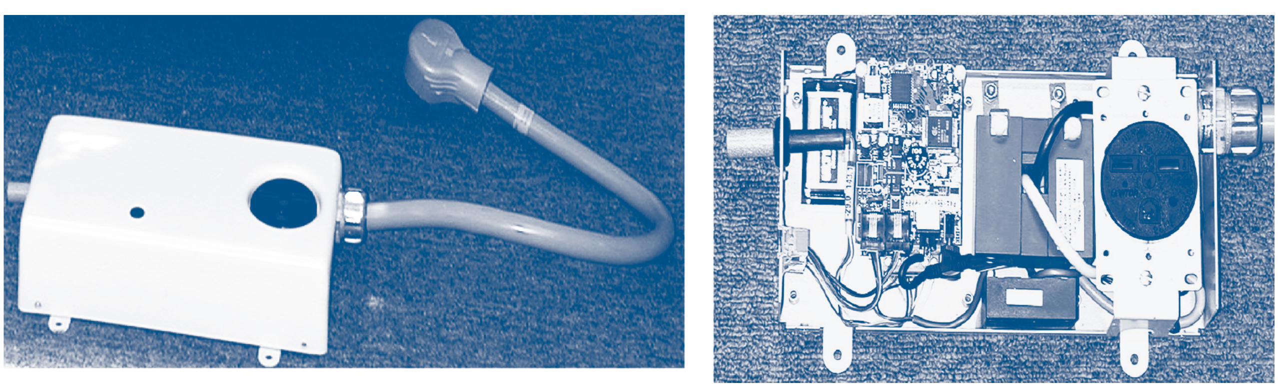


*Figure 7*. *ORNL monitoring-DAS device.*

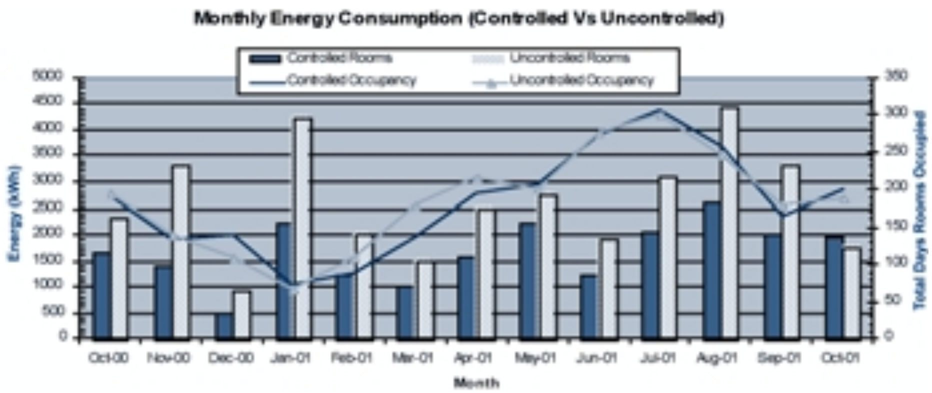



*Figure 7a. Energy consumption and occupancy of controlled and uncontrolled rooms.*

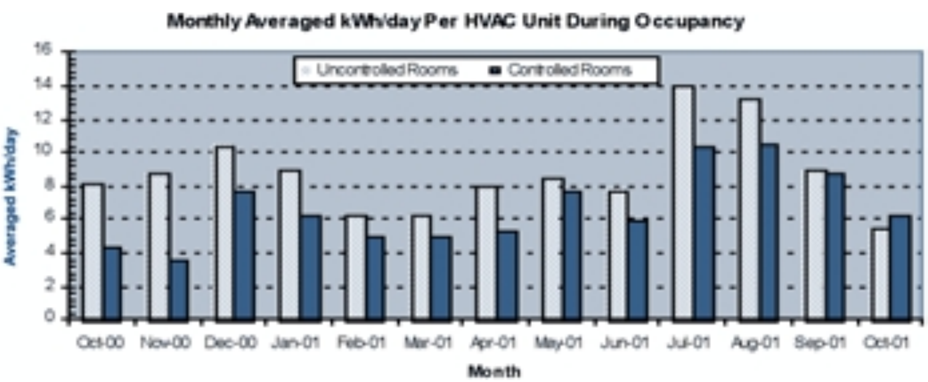



*Figure 7b. Averaged daily energy consumption per room (HVAC unit) during occupancy of rooms.*

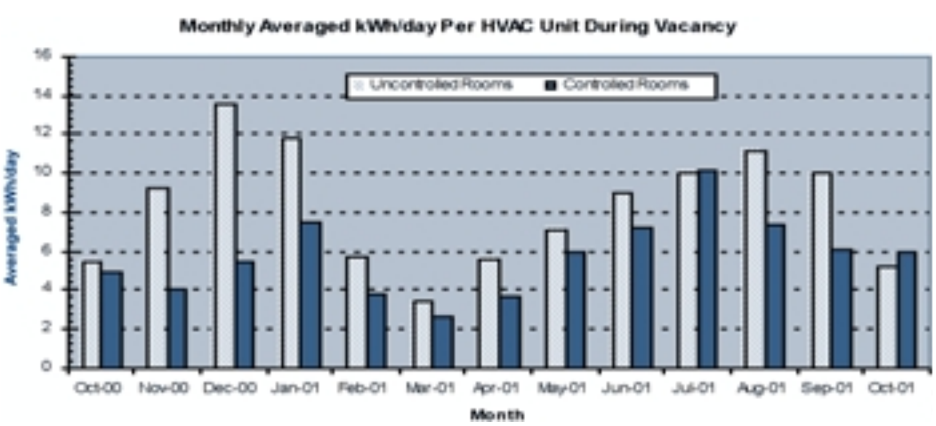



*Figure 7c. Averaged daily energy consumption per room (HVAC unit) during vacancy of rooms.*

operate to prevent damage to the room. The controller will dial and beep if a smoke detector is alarming or if the temperature in the room exceeds programmed set limits. The power interruption/brown-out, HVAC controls, and smoke detector notification can be used in any Federal building that has in-space through-the wall HVAC systems.

## Cost and Installation

The HVAC controller is a plug-in device installed between a wall outlet and the room HVAC unit. The unit cost for the power controller is $299, and the installation cost varies depending on the property. Generally, the installation cost is between $10 and $25 and is determined after a site inspection. Currently, a desktop computer that is located at the hotel front desk (seen in Figure 2) is required, but software can be incorporated into the hotel computer in future applications.

# Technology Performance and Demonstration

## Test Rooms Analysis

The yearly occupancy and energy use for the hotel rooms with Digi-Log controllers (controlled) and rooms without controllers (uncontrolled) was determined from data acquired by ORNL monitoring-DAS devices. Data illustrated in Figure 7a show that rooms equipped with controllers were occupied roughly the same number of days as those without controllers except during December 2000 and February through April 2001. The HVAC energy consumption in the controlled rooms is consistently less than that in the uncontrolled rooms. The uncontrolled rooms HVAC energy consumption averaged 2632.2 kWh monthly while the controlled rooms HVAC units averaged 1684.6 kWh, which equates to the uncontrolled rooms HVAC consuming an averaged of 947.6 kWh (56.3%) more energy than the units in the controlled room monthly during the test period. Figures 7b and 7c show the averaged daily energy consumption per HVAC unit monthly for the controlled and uncontrolled rooms during occupancy (temperature limits: 69°F minimum-summer, 76°F maximum-winter) and vacancy (temperature limits: 83°F maximum-summer, 50°F minimum-winter). When controlled rooms are occupied, the daily averaged energy consumption per HVAC unit ranges from 3.5 to 10.6 kWh/day, averaging 6.7 kWh/day, as shown in Figure 7b. Whereas during occupancy for the uncontrolled rooms, the energy use ranges from 5.5 to 14 kWh/day, averaging 8.8 kWh/day. On average, each HVAC unit in the uncontrolled rooms consumed

32.1% more energy than those in the controlled rooms during occupancy. During vacancy, the uncontrolled rooms HVAC units averaged daily energy use per unit ranges from 3.5 to 13.6 kWh/day, averaging 8.3 kWh/day as shown in Figure 7c. When the controlled rooms are vacant, the HVAC unit's energy consumption ranges from 2.7 to 10.2 kWh/day, averaging 5.8 kWh/day. Each HVAC unit in the controlled rooms consumed 43.1% less energy than the HVAC units in the uncontrolled rooms when the hotel room is unoccupied. During the test period, there were not any significant comfort differences between the controlled and uncontrolled rooms, indicating that the controller did not compromise comfort.

Figures 8 through 15 reveal the comfort conditions in both sets of rooms during the winter (December 2000–February 2001) and summer (June–August 2001) seasons. During the winter season, the temperature in the uncontrolled rooms falls primarily within a 30°F band (50°F to 80°F) with the relative humidity (RH) falling largely between 25 and 70% (see Figures 8 and 9). During the same season, as shown in Figures 10 and 11, the controlled rooms average temperature and RH ranged between 50°F–75°F and 30–70%, indicating that there were any significant comfort differences between the controlled and uncontrolled rooms. During the summer season, the monitoring-DAS devices were inoperative for about 4 weeks; therefore, the data for this period are not shown in Figures 12 through 15. Analyzed data indicate that uncontrolled room average temperature and RH ranged primarily between 68°F–80°F and 40–70%, while the controlled room conditions ranged mainly between 69°F–80°F and 45–70%. The results show that comfort conditions were very similar, indicating that using the controller did not compromise comfort.

## Hotel Analysis

All hotel rooms were equipped with supervisory controllers (163 rooms, one per room, excluding 12 ORNL-uncontrolled rooms) for the duration of the test period. The total energy impact on the hotel was

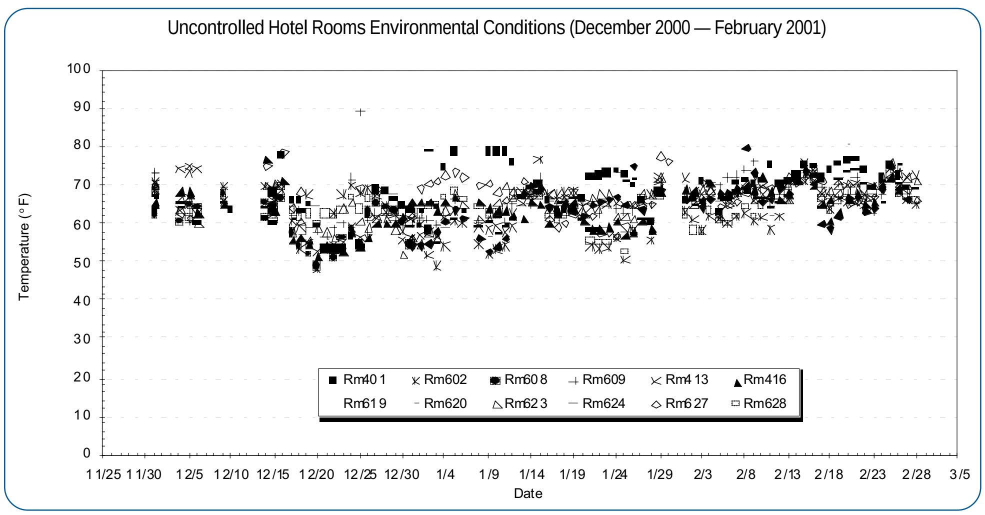



*Figure 8. Room space temperature for 12 uncontrolled rooms during the winter season.*

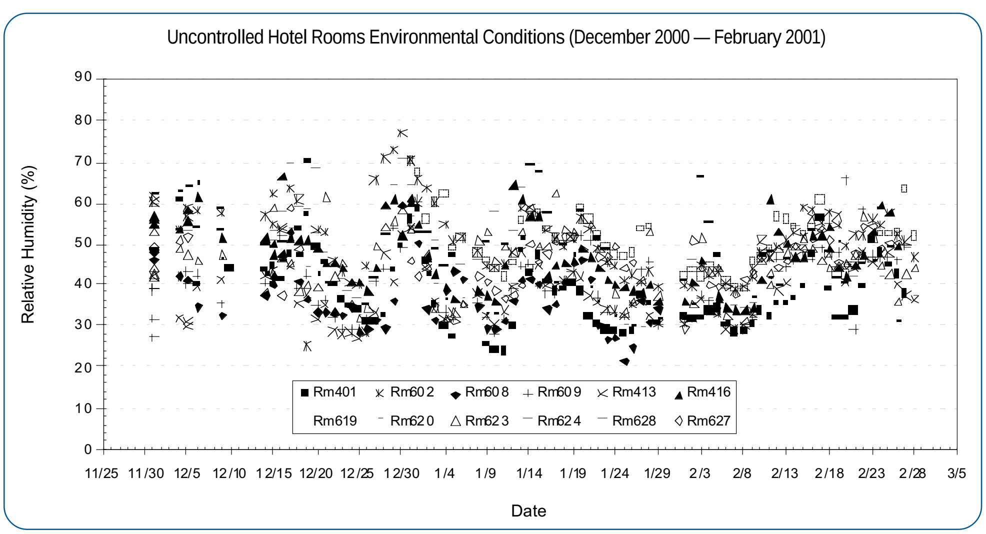



*Figure 9. Room space relative humidity for 12 uncontrolled rooms during the winter season.*

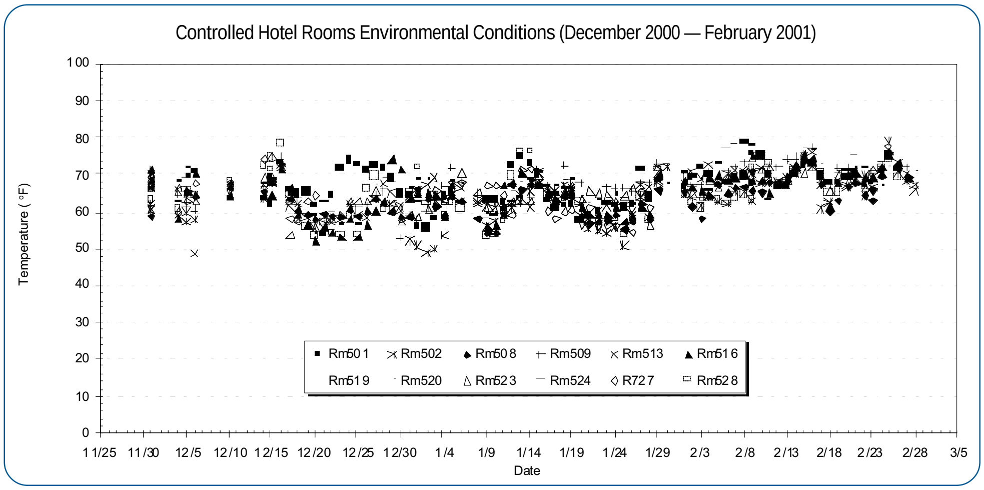



*Figure 10*. *Room space temperature for 12 controlled rooms during the winter season.*

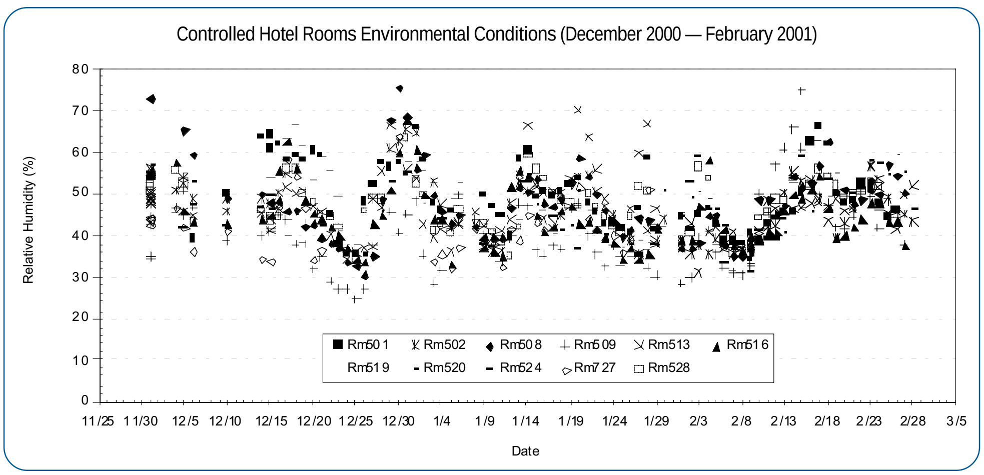



*Figure 11*. *Room space relative humidity for 12 controlled rooms during the winter season.*

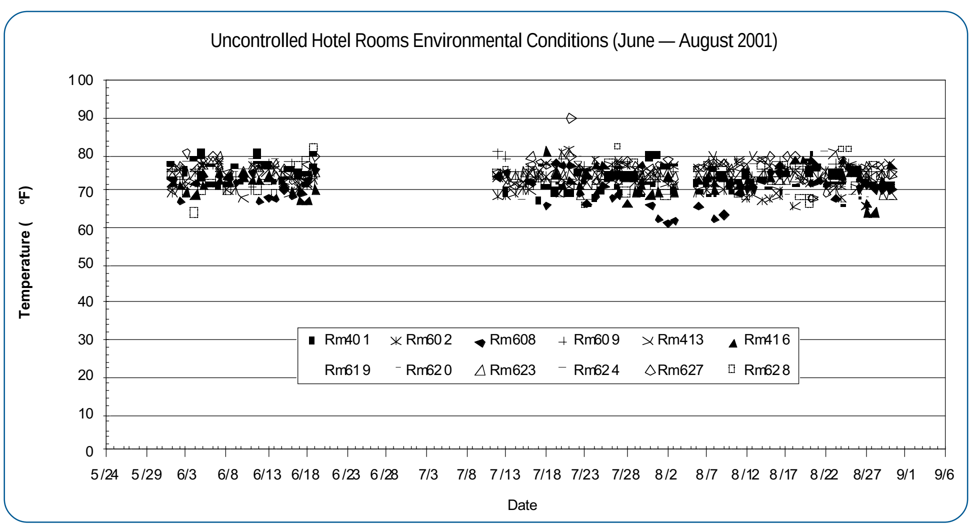



*Figure 12*. *Room space temperature for 12 uncontrolled rooms during the summer season.*

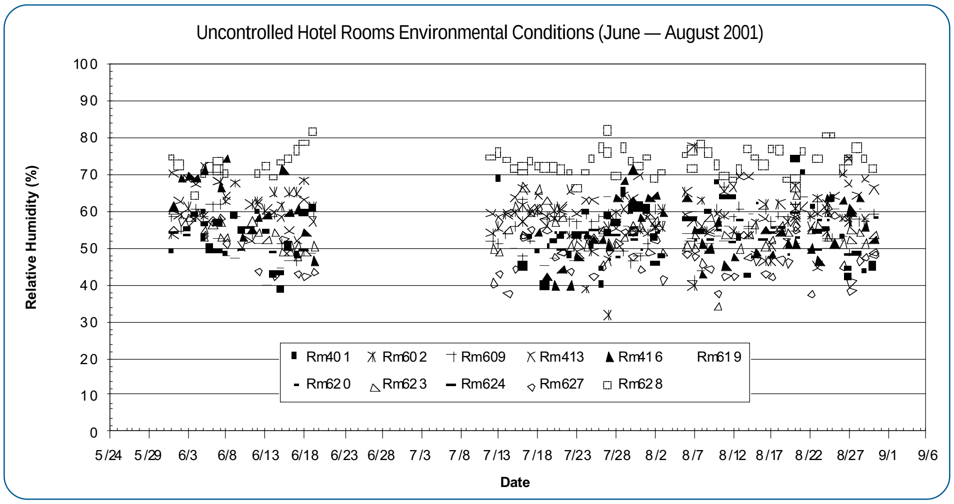



*Figure 13*. *Room space relative humidity for 12 uncontrolled rooms during the summer season.*

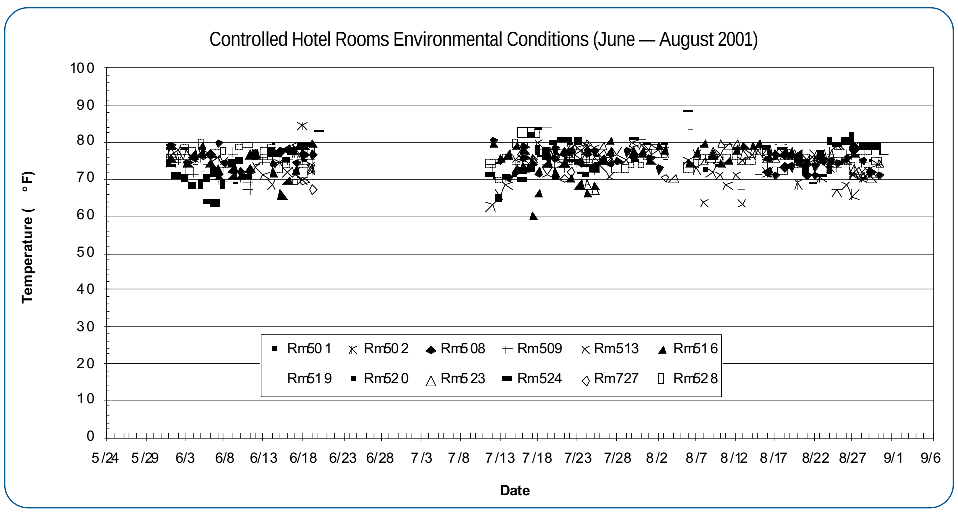



*Figure 14*. *Room space temperature for 12 controlled rooms during the summer season.*

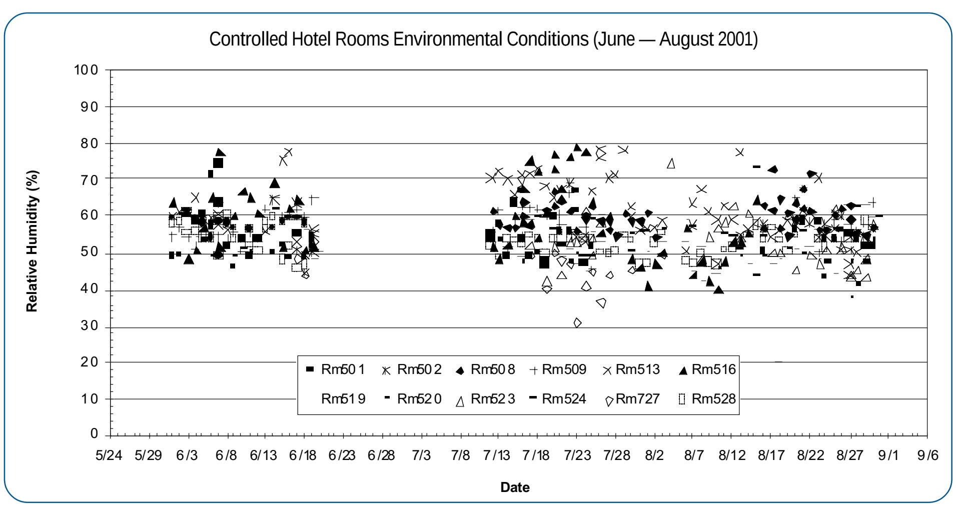



*Figure 15*. *Room space relatively humidity for 12 controlled rooms during the summer season.*

evaluated by comparing the kW usage on the electricity bills over the last three years. During the test period (2000/2001), the kW usage was lower for seven of the 12 months (January–February, May, and July–October) than the previous year (1999/2000) during the same interval, as shown in Figure 16. For the test period, the hotel consumed 30395 kW (1.5%) less energy than it used the previous year (1999/2000). During 1998/1999, the energy usage was higher five of the 12 months than that consumed during the test period (2000/2001), with comparable usage for March and May. The small energy consumption differences are partially attributable to 1) the higher number of heating degree-days (HDD), shown in Figure 17, during November 2000 through January 2001 than for previous years, 2) having supervisory controllers managing around 50% of the hotel conditioned space, and 3) the total hotel energy usage not only accounts for the HVAC energy but also for energy use of lighting and other electrical accessories and appliances. Each room is outfitted with a microwave, television, and refrigerator. The 1998/1999, 1999/2000, and 2000/2001 cooling degree-days (CDD), cited in Figure 18, are roughly within 50 CDD of each other during the core-cooling season (June–August) and appear to have minor differentiating influence on the energy usage. Table 1 shows the calculated energy cost per HDD and CDD. The averaged energy $/HDD is less during the October 2000–2001 test period than that of the previous two years. But the averaged energy $/CDD is higher during the test period than that of the previous two years.

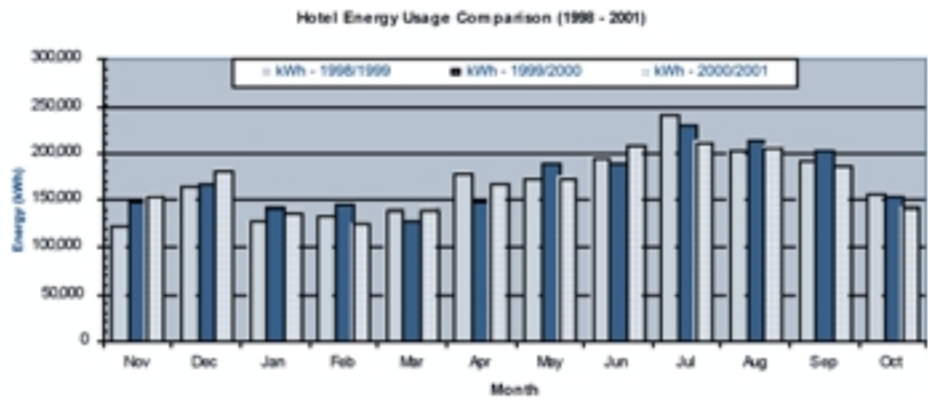



*Figure 16. Monthly kWh Usage of the Hotel (October 1998–2001)—(furnished by Hotel's CFO, Alvin Adams).*

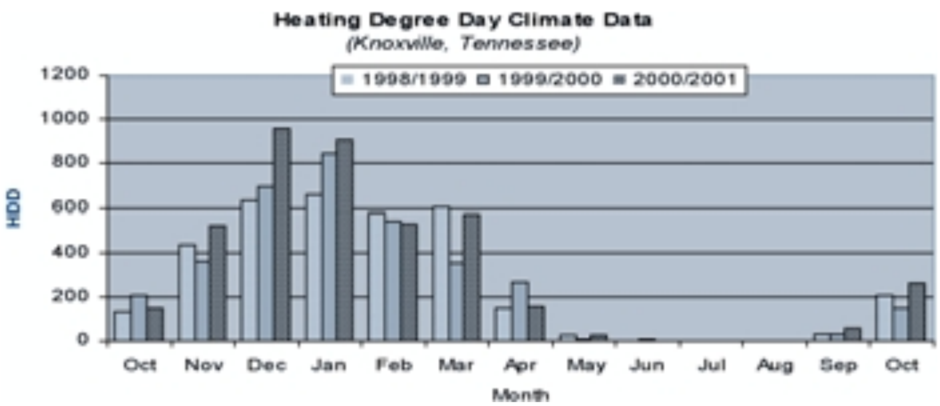



*Figure 17. Monthly Heating Degree Day for Knoxville (October 1998–2001).*

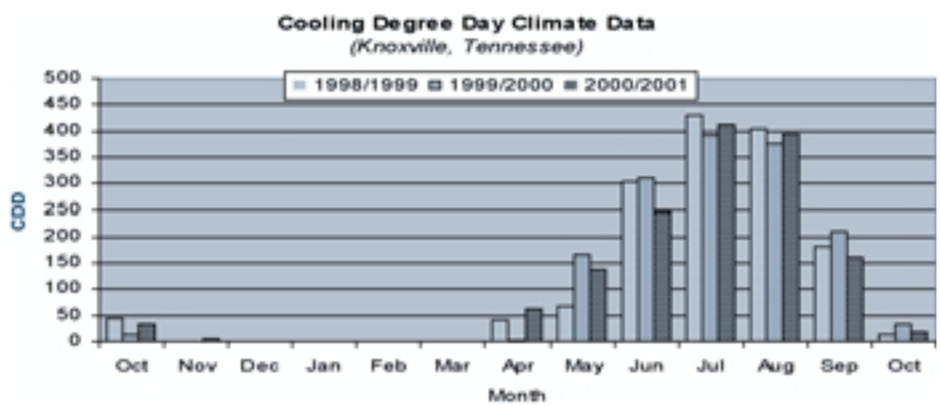



*Figure 18. Monthly Cooling Degree Day for Knoxville (October 1998–2001).*

## Discussion and Conclusions

On average, each HVAC unit in the uncontrolled rooms consumed 32.1% more energy than those in the controlled rooms during occupancy. Each HVAC unit in the controlled rooms consumed 43.1% less energy than the HVAC units in the uncontrolled rooms when the hotel room is unoccupied. The kW usage for the total hotel was reduced by 1.5% over that of the previous year. The rationale for dissimilar energy reductions between the data results for the 24 monitored rooms and that for the entire hotel is that the controllers were inoperative for several intervals of the test period. Periods when controllers were not functioning are delineated in Table 2. Inoperability that incorporated all controllers was caused by power glitches, brownouts, and software/controller adjustment. There was a direct relationship between power interruptions and occupant complaints. Initially about 5 to 6% of the hotel occupants complained after a power interruption. After modifying the software, complaints were reduced to between 3 to 5%. Subsequent to making the first

*Table 1. $/HDD and $/CDD for Music Road Hotel (Knoxville, TN, climate data . (1998 – 2001).*

| | 1998/1999 | | 1999/2000 | | 2000/2001 | |
|---|---|---|---|---|---|---|
| | $/HDD | $/CDD | $/HDD | $/CDD | $/HDD | $/CDD |
| Oct | | | | | | |
| Nov | 16.49 | | 23.45 | | 16.70 | |
| Dec | 14.97 | | 13.38 | | 10.46 | |
| Jan | 11.78 | | 10.87 | | 12.11 | |
| Feb | 15.14 | | 17.79 | | 14.14 | |
| Mar | 14.17 | | 21.16 | | 13.85 | |
| Apr | | | | | | |
| May | | | | | | |
| Jun | | 34.62 | | 33.65 | | 45.19 |
| Jul | | 28.91 | | 30.98 | | 27.98 |
| Aug | | 27.31 | | 30.77 | | 28.33 |
| Sep | | 56.11 | | 51.47 | | 64.42 |
| Maximum | 16.49 | 56.11 | 23.45 | 51.47 | 16.70 | 64.42 |
| Minimum | 11.78 | 27.31 | 10.87 | 30.77 | 10.46 | 27.98 |
| ***Average*** | ***14.51*** | ***36.74*** | ***17.33*** | ***36.72*** | ***13.45*** | ***41.48*** |

component change to the control board the occupant complaints were reduced to roughly 1%. Since the final circuit modification, there are no records of guest complaints. Random inoperability involving a limited number of controllers was hotel occupant, housekeeping, and/or maintenance staff dependent. The controllers were deactivated after room occupant complaints about the HVAC system, thereby causing inoperative intervals. The 12 monitored controlled rooms device deactivations were minimized, because the monitoring-DAS units would not call in if they were unplugged. Therefore, the status of the controllers was checked daily. Also, the controllers were inoperative when housekeeping or occupants turned the HVAC unit off. The unit must be in the 'on' position to be supervised by the controller.

*Table 2. Problems and inoperability of supervisory controller.*

| Date | Problems, Complaints, and Modifications |
|---|---|
| Nov – Dec 2000 & Jan 2001 | There were five to six complaints per month from occupants resulting from the staff's unfamiliarity with operating the system. Procedural problems occurred when front desk staff entered incorrect information (e.g., check out instead of check in, temperature controller off rather than on). These problems were more prevalent during training of a new front desk member. There were fewer complaints because there were few power interruptions. |
| Feb 2001 | This was the first month that a brownout occurred; the HVAC units went off during the brownout and most came on when the proper voltage returned. When there was a power outage of extremely short duration, approximately 5-6 percent of the units would not come on when the power returned and maintenance unplug the controllers. The power was out three to four times (up to 30 minutes per event) over a 12-hour period. No occupant complaints regarding the HVAC during the 12-hour period were received. |
| Mar – May 2001 | During this period there were approximately 12 to 15 power glitches that resulted in 2 to 10 of the controllers having to be unplugged by maintenance when interruptions occurred. Attempting to correct the problem of the HVAC not coming back on after a brownout, the software was changed and the microprocessors were replaced in the controllers. These changes were made four times, and each time the percentage of failures dropped but there were still HVAC units not coming on after a short power glitch.<br>The majority of the occupant complaints were limited to the units not coming back on after power interruptions and/or units not coming on at initial check-in to room. Both problems were a result of the microprocessor not resetting. |
| June 2001 | A circuit component problem on the control board of the controllers was discovered. The controllers were removed floor by floor, in order to take them to the shop to be repaired. All of the controllers were repaired and reinstalled by August 2001. This appeared to resolve the microprocessor reset problem that occurred during very short power interruptions. |
| Sept – Nov 2001 | During installation of controllers in another hotel test site, a different circuit component problem was discovered. It was detected because of the site uncommon transformer-wiring configuration. The total voltage of the power supply is 240 V across the line, 209 V on one leg and 107 V on the other leg. Assuming that this circuit component problem was contributing to the microprocessor-reset problem at Music Road Hotel, the site controllers were reworked again. Controllers were removed two floors at a time reworked and reinstalled. The modification was done from September through November 2001. |

## Manufacturers

Digi-Log Technologies, Inc.
600 Highway 61 East
Maynardville, Tennessee 37807
(888) 559-9498, (865) 599-5966
digilog@icx.net

Smart Systems International
3271 S. Highland Drive, #707
Las Vegas, NV 89109
(702) 734-0044, (800) 243-8762
fflower@smartsystemsintl.com

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# About FEMP's New Technology Demonstration Program

The Energy Policy Act of 1992, and subsequent Executive Orders, mandate that energy consumption in Federal buildings be reduced by 35% from 1985 levels by the year 2010. To achieve this goal, the U.S. Department of Energy's Federal Energy Management Program (FEMP) is sponsoring a series of programs to reduce energy consumption at Federal installations nationwide. One of these programs, the New Technology Demonstration Program (NTDP), is tasked to accelerate the introduction of energy-efficient and renewable technologies into the Federal sector and to improve the rate of technology transfer.

As part of this effort FEMP is sponsoring a series of publications that are designed to disseminate information on new and emerging technologies. New Technology Demonstration Program publications comprise four separate series:

**Federal Technology Alerts**—longer summary reports that provide details on energy-efficient, water-conserving, and renewable-energy technologies that have been selected for further study for possible implementation in the Federal sector.

**Technology Installation Reviews**—concise reports describing a new technology and providing case study results, typically from another demonstration program or pilot project.

**Technology Focuses**—brief information on new, energy-efficient, environmentally friendly technologies of potential interest to the Federal sector.

**Other Publications**—the program also issues other publications on energy saving technologies with potential use in the Federal sector.



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## For More Information

**FEMP Help Desk**
(800) 363-3732
International callers please use
(703) 287-8391
Web site: www.eren.doe.gov/femp

**General Contacts**

**Ted Collins**
New Technology Demonstration Program Manager
Federal Energy Management Program
U.S. Department of Energy
1000 Independence Ave., SW, EE-92
Washington, D.C. 20585
Phone: (202) 586-8017
Fax: (202) 586-3000
theodore.collins@ee.doe.gov

**Steven A. Parker**
Pacific Northwest National Laboratory
P.O. Box 999, MSIN: K5-08
Richland, WA 99352
Phone: (509) 375-6366
Fax: (509) 375-3614
steven.parker@pnl.gov

**Technical Contact**

**Evelyn Baskin**
Oak Ridge National Laboratory
P.O. Box 2008, Bldg. 3147
Oak Ridge, TN 37831-6070
Phone: (865) 574-2012
Fax: (865) 574-9329
baskine@ornl.gov

Produced for the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, by the Oak Ridge National Laboratory

DOE/EE-0273

July 2002