Ventilation Air Preconditioning Systems

Mukesh Khattar
Manager, Space Conditioning and Refrigeration
Customer Systems Group
Electric Power Research Institute
P.O. Box 10214
Palo Alto, California 94303

Michael J. Brandemuehl
Associate Professor
Joint Center for Energy Management
Campus Box 428
University of Colorado
Boulder, Colorado 80309

Abstract

Increased outside ventilation air requirements demand special attention to how that air will be conditioned. In winter, the incoming air may need preheating; in summer, the mixed air may be too humid for effective dehumidification. Part-load conditions pose greater challenges: systems that cycle on and off allow unconditioned air into the building during compressor off-cycles.

Introduction

The increased ventilation recommended by ASHRAE Standard 62-89 places a burden on existing HVAC equipment not sized to handle the added load. Some systems are simply too small and require extensive retrofits. Others may have sufficient capacity to meet the sensible cooling needs of the building, but cannot remove enough moisture from the incoming air, causing indoor humidity to rise above acceptable

[illegible] with manufacturers to develop dual path HVAC systems, with one path dedicated to preconditioning the outside air. This paper discusses two such systems for cooling and dehumidification applications: one with a separate preconditioning unit and one with separate ventilation and return air paths in a single unit. Both deep-cool and deep-dry the incoming air before mixing it with the return air, thereby eliminating the latent load on the primary cooling coil. As unitary packages, they are easy to install in new and retrofit applications. Also, their excellent energy efficiency cuts electric energy consumption, providing significant operating savings.

exacerbated when condensate from the cooling coil or drain pan re-evaporates and is delivered to occupied space during compressor off-cycles. Although heat recovery between the exhaust air and ventilation air can reduce the impact on the HVAC system, many buildings do not have central exhaust, making heat recovery impractical. Part-load conditions pose even greater challenges, as systems that cycle on and off bring moisture-laden, unconditioned air into the building during compressor off-cycles.

These difficulties can be solved simply and cost-effectively with a dual path arrangement that treats and controls the ventilation air independently of the recirculation air. The Electric Power Research Institute

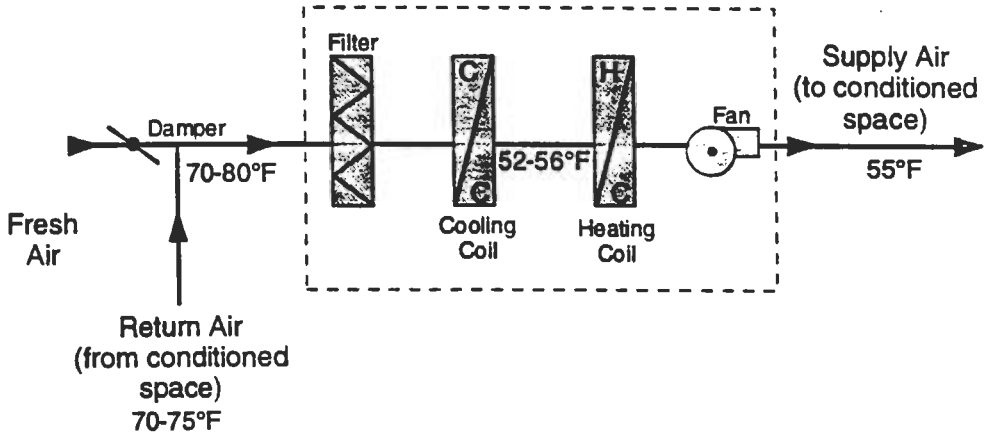
(EPRI)—the nonprofit R&D arm of the electric utility industry—is working with several manufacturers to develop variations of this concept. This paper describes two such sytems. These unitary-package designs are especially suited to larger commercial applications that would normally require built-up systems.

Advantages of Dual Path Cooling

Conventional HVAC systems treat the ventilation air and return air in a "single path"—i.e., the ventilation air is mixed with the return air prior to conditioning by the same set of equipment (coils, fans, etc.), as shown in Figure 1. Dual path systems add a second equipment path for separate treatment of the ventilation air, which can then be mixed with the return air or delivered directly to the occupied space (see Figures 2 and 3).

dry return air before entering the cooling coil, which lowers the average humidity level and makes it more difficult for the cooling coil to extract the moisture. With ASHRAE Standard 62-89 tripling or even quadrupling the ventilation load and more than doubling the latent load, conventional equipment is generally not able to remove enough moisture from the mixed air stream to maintain desired humidity levels without overcooling the building. As a result, the HVAC equipment must be oversized to meet dehumidification requirements, and reheating is often needed to overcome the excess sensible cooling. Some researchers have suggested that additions to conventional systems—such as indirect evaporative coolers, heat pipes, and sensible recovery exchangers—have the potential to reduce humidity without increasing total capacity, but even these devices will have difficulty meeting ASHRAE's new standard without requiring more capacity and energy. In dual path systems, the moisture is removed directly from the humid outdoor air, allowing

Figure 1. Conventional Single Path System



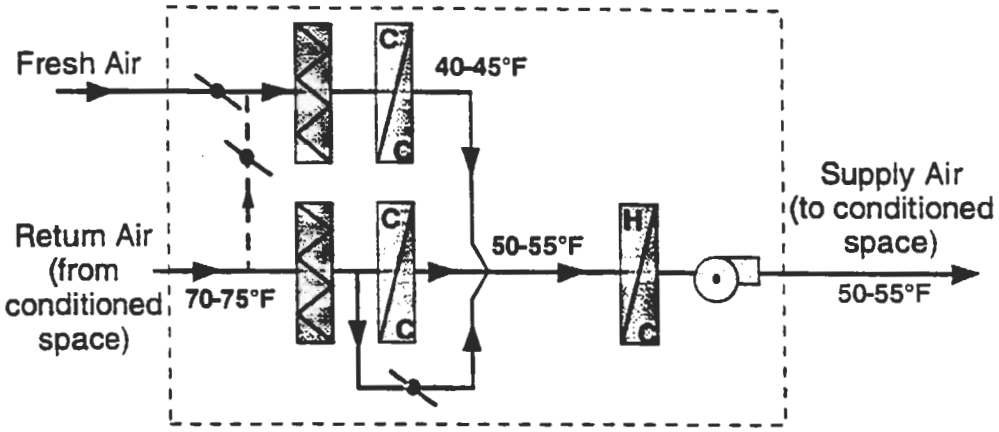
The dual path arrangement offers improved efficiency and humidity control, by removing moisture from a humid air stream rather than from a dry air stream. In conventional systems, the humid outdoor air is mixed with

inherently higher efficiency, reduced overall equipment size, and reduction or elimination of reheat requirements. Further, the separate coils can be specifically designed for their individual functions, with the ventilation coil

optimized for moisture removal and the primary coil for sensible cooling.

Naturally, the comparative benefits of a dual path vs. single path system depend on the specific application. However, a general idea

Figure 2. Dual Path System



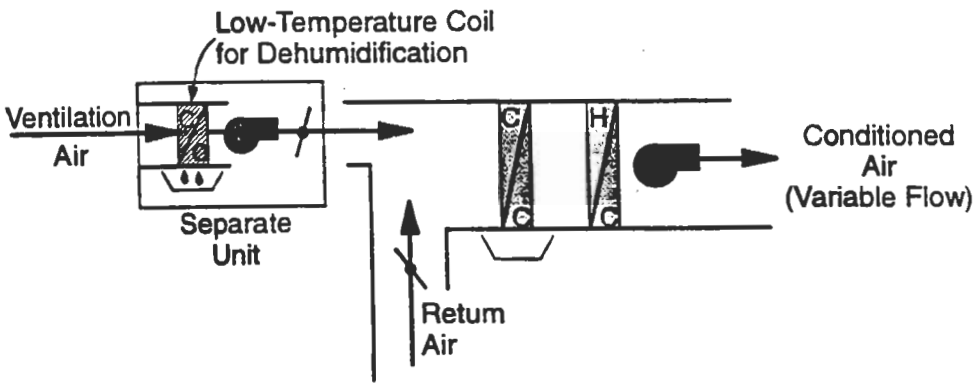
can be gained from Table 1 and Figures 4 and 5, which show simulation results for generic systems in a typical large retail store in four cities with humid climates. In all examples, the dual path system saved 15-27% in installed cooling capacity, electrical demand, and energy consumption.

A dual path configuration, such as the systems described later in this paper, offers several important advantages:

Direct Control of Ventilation Air Quantity

Conventional variable-air-volume systems may reduce the amount of ventilation air when the overall building load is low (e.g., mornings and evenings, spring and fall), despite the air quality needs of occupants. In contrast, a dual path system—with separate fans for the ventilation and recirculation air—can introduce the required amount of ventilation air regardless of the primary VAV unit's total air volume. Thus, even at low flow rate, the system can provide 100% of the ventilation air requirement. Ventilation air volume can be controlled by various

Figure 3. Alternative Dual Path Configuration



means—a timer, occupancy sensors, CO_2 sensors, or other IAQ sensors—to ensure plentiful fresh air during occupied periods and avoid unnecessary conditioning during unoccupied periods.

Improved IAQ—Reduced Mold, Bacteria, and Other Contaminants

Separating the latent load also improves air quality by eliminating standing water in the drain pans of both the ventilation and recirculation coils. The intensive moisture removal of the ventilation coil creates abundant condensate that washes the incoming air and constantly flushes the ventilation drain pan, avoiding stagnant water. And because the incoming air has been thoroughly dehumidified at the source, the air entering the primary unit is quite dry, so that condensation on the primary coil is virtually eliminated. Thus, the primary drain pan also remains dry and free of mold, mildew, and bacteria.

Table 1. Comparison of Single and Dual Path Systems (Conventional Design)[1]

		Dallas	St. Louis	Washington D.C.	New Orleans
Installed Capacity (tons/1000 sq. ft.)	Single Path	2.74	2.92	2.78	3.18
	Dual Path	2.32	2.28	2.15	2.70
Electrical Demand (W/sq. ft.)	Single Path	3.73	3.83	3.61	4.09
	Dual Path	2.83	2.72	2.54	3.22
Annual Energy Use (kWh/sq. ft.)	Single Path	15.29	12.56	9.69	18.53
	Dual Path	11.72	9.18	8.29	15.37
Sizing Parameter	Single Path	1.0 cfm/sq. ft.	1.0 cfm/sq. ft.	1.0 cfm/sq. ft.	1.0 cfm/sq. ft.
	Dual Path[2]	500 cfm/ton	500 cfm/ton	500 cfm/ton	500 cfm/ton

[1] Simulation performed with component-based HVAC models developed by the University of Colorado. Assumes large retail store with internal lighting load of 1.32 W/ft^2, equipment load of 0.3 W/ft^2, occupancy of 150 ft^2/person, and ventilation of 0.2 cfm/ft^2. Cooling loads were determined using DOE2.1D building simulation program. Indoor conditions of 75°F and 50% RH maintained by typical packaged DX equipment, with thermostat and humidistat.

[2] Primary air-handling unit.

Excellent Humidity Control

Moisture is always removed at the source, regardless of the building load, so that only dry air is mixed with the return air. In contrast, a single path system may allow untreated air to enter under part-load conditions, creating humidity swings and associated problems.

Electrical Demand and Energy Savings

By shifting the dehumidification load to a dedicated ventilation coil, dual path systems maximize system efficiency. Spared the latent load, the primary coil can be set (or sized) to a lower temperature for energy and demand savings. The ventilation coil operates more efficiently as well, since it is easier to remove moisture from the more-saturated outside air than from the mixed air stream.

The dual path configuration also facilitates intensive air treatment: The ventilation air-handling unit can be designed to incorporate high-efficiency filters or monitoring instruments.

Figure 4. Comparison of Equipment Sizes

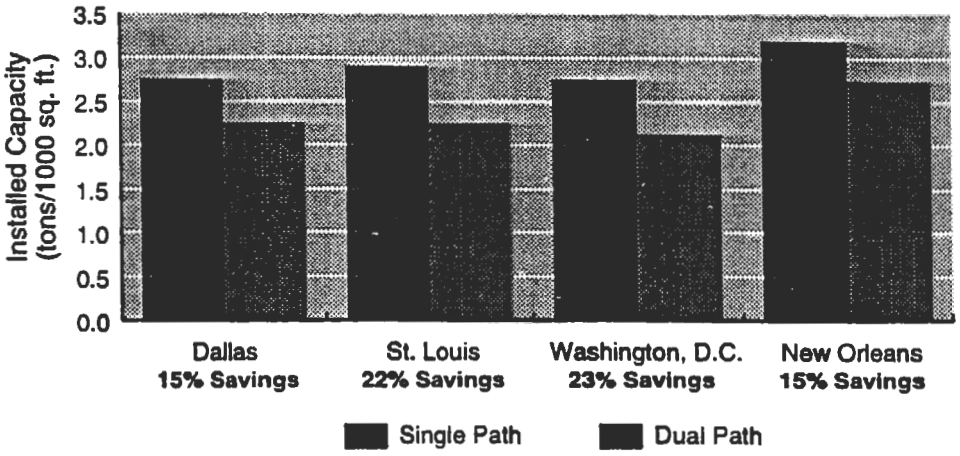
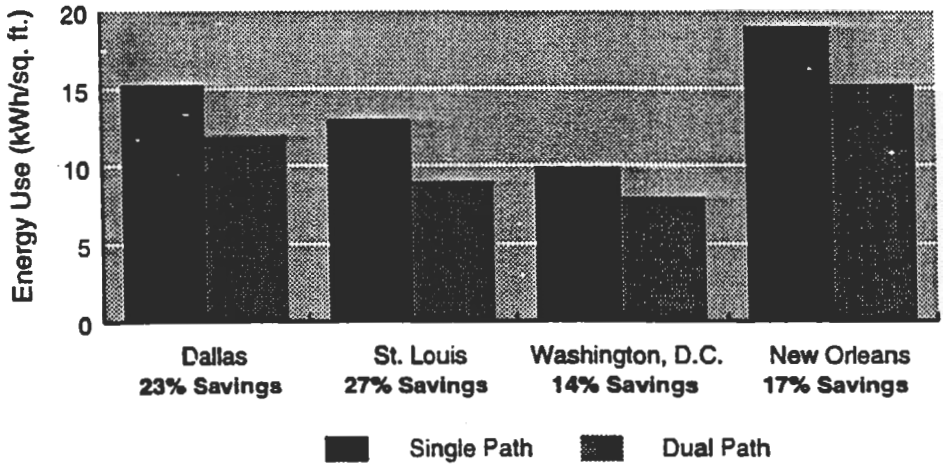


Figure 5. Comparison of Annual Energy Use

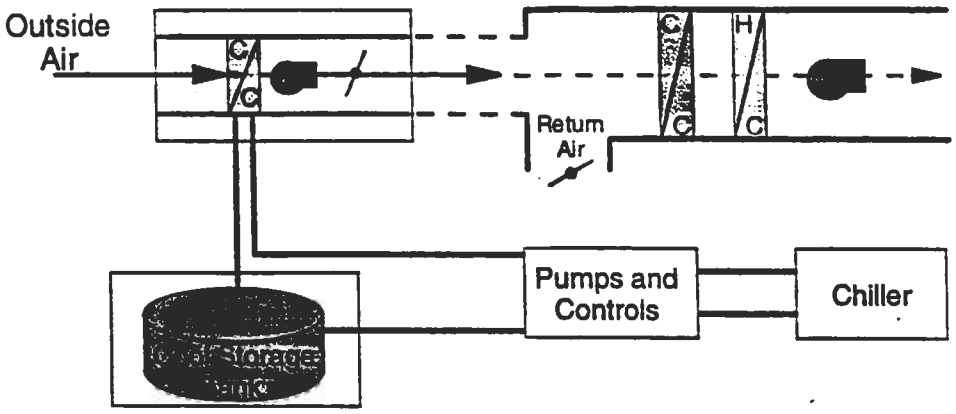


Simple, Low-Cost Installation

Prefabricated and pre-engineered, unitary dual path systems can be easily specified by design and consulting engineers or facilities managers, eliminating the need for custom design. Unlike desiccant systems, the dual path technology lends itself to great flexibility in size and shape—simplifying retrofits and saving space in new construction. On-site labor costs are drastically reduced, cutting the overall installed cost.

Additional benefits can be obtained by optimizing the system for a particular type of application. EPRI is developing variations of the dual path concept to meet different retrofit and new construction markets.

Figure 6. Ventilation Air Conditioner as a Separate Unit



EPRI/CALMAC System: Separate Unit for Ventilation Air Conditioning

EPRI is teaming with a major manufacturer to develop dedicated "ventilation conditioners," which deep-cool and deep-dry the incoming air before it is mixed with the return air and sent through the primary air-handling unit. A small liquid chiller cools the incoming air well below the dewpoint, providing such thorough dehumidification that little, if any, latent load remains for the primary coil. As shown in Figure 6, a small ice storage tank can be incorporated to shift the ventilation load to off-peak hours for added energy savings. Because they handle only the fresh-air load, the chiller and storage tank can be quite small. This application thus slashes the capital costs that have traditionally kept ice storage from finding a wider market, despite its proven advantages.

The system comprises the following modules:

- A packaged liquid chiller (the current prototype has a nominal capacity of about 25 tons)
- One or more small air-handling systems that attach directly to the outdoor air intake(s)
- A mechanical package—suitable for outdoor installation—that incorporates pumps, valves, interconnecting piping, accessories, and controls
- An optional ice storage tank (the current prototype has a nominal capacity of 165 ton-hours)

These modules will be offered separately rather than as a single skid-mounted package. This maximizes design and "fit" flexibility, and allows specification of individual parts to optimize site operating efficiency.

In addition to all the advantages of a dual path approach, the system offers a number of benefits:

Sole-Source Responsibility

The manufacturer fully supports operation of all modules, including controls.

Design Flexibility

Besides reducing installed costs, the small, modular nature of the system allows great flexibility for fitting into retrofit geometries

and saves space in new construction. Moreover, a single chiller can serve multiple air-handling units—in stark contrast to packaged desiccant systems, which require a separate unit at each air intake.

Simple Controls

Unlike direct expansion (DX) systems, this system (with or without ice storage) can easily accommodate changing weather conditions without complex controls. The chilled water loop introduces a thermal capacitance or flywheel effect, which simplifies capacity control.

Optional Cool Storage for Additional Demand and Energy Savings

If used with the ice storage option, this high-efficiency system provides even greater energy and demand savings. The ice can be made overnight, when electric rates are lowest and a high ΔT generally reduces the overall energy required for cooling.

Avoidance of Electrical Service Upgrade

In existing buildings, electrical service may be at or near capacity. The ice storage option transfers the ventilation load to night, when the overall building load is low. The need for increased ventilation air can thus be met without increasing the building's electrical service capacity.

Optional Morning Warm-Up

If connected to a liquid condenser bundle, the icemaking chiller can serve as a heat recovery heat pump. The chiller can freeze ice in the early morning to provide heat for morning warm-up, and use the ice in the afternoon for free ice cooling.

This system is applicable to all types of commercial buildings, including hospitals, libraries, offices, retail outlets, restaurants, and supermarkets, with particular benefit to buildings that need to maintain very low humidity. For buildings where existing electrical service is saturated, the off-peak ice storage allows owners to avoid a costly electrical upgrade to meet ventilating requirements.

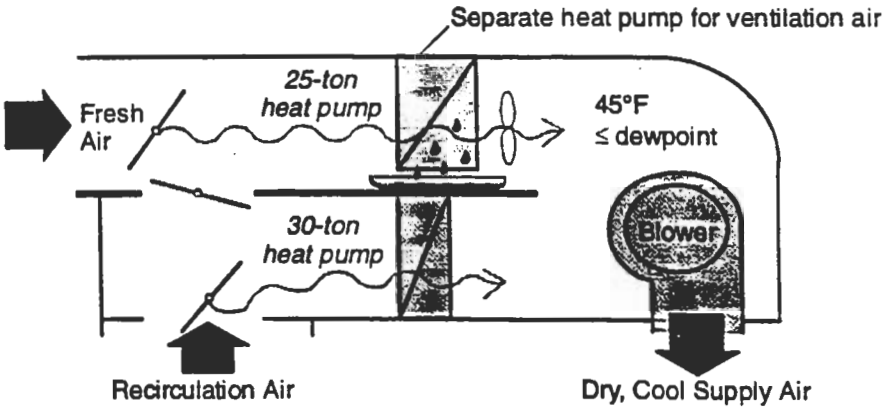
A prototype unit—with a 25-ton chiller and an ice storage tank with a capacity of 165 ton-hours—is currently being tested, and commercial units are expected to be available soon. EPRI and sponsoring electric utilities plan to quantify the energy and IAQ benefits for a variety of buildings.

EPRI/ClimateMaster System: Separate Paths in a Single Unit

Another variation of the preconditioning concept has been developed by EPRI and a major manufacturer in conjunction with Oklahoma Gas & Electric and WalMart Stores. This dual path system combines both paths in a single unit, using a water-cooled DX system for the ventilation path and a water-source heat pump for the recirculation path (see Figure 7).

These units can either be installed separately or integrated with additional HVAC or refrigeration equipment. They are being initially demonstrated in the new WalMart in Moore, Oklahoma, which opened in the fall of 1995. The store—which includes a complete supermarket as well as the usual array of household goods—features a novel HVAC&R system that combines all space conditioning, refrigeration, and water heating systems on a single water loop. As in all high-volume, low-margin merchandising operations, the reliability and cost of all these functions are vitally important. EPRI anticipates that this integrated approach to building management will prove less costly to design, purchase, install, and maintain than current composite systems. WalMart has agreed to use this store as a test site for

Figure 7. Separate Ventilation and Return Paths in a Single Unit



. . .RH indirectly controlled, typically below 45% RH
. . .Excellent part-load control

EPRI to monitor the performance of these HVAC units as well as the store-wide HVAC&R system.

Special features of this system include the following:

Efficient Ventilation Air Control
The ventilation air flow is controlled by dampers that bring in only the amount of air actually required by the building. As the damper opening changes, the fan motor adjusts to the lowest speed needed to deliver the exact amount of outside air required to maintain high IAQ. This approach is more efficient that typical economizers, which often allow more inlet air than is necessary to maintain IAQ.

Excellent IAQ and Zone Control
Each building zone is typically equipped with a single unit, which is controlled by sensors that detect humidity, temperature, and CO_2 levels. Zones can thus be individually conditioned; for example, the core areas may be cooled at the same time that perimeter areas are being heated. The quantity of ventilation air delivered to each zone is based on need; the system has the flexibility to be controlled by schedule, occupancy sensors, CO_2 sensors, or other means. It also can meet rigorous IAQ specifications, maintaining excellent control of temperature and humidity within each zone. Filter racks are 4" deep to accommodate a wide range of high-efficiency filters.

Tempering Outside Air in Winter
In winter, the recirculation air can be heated rather than cooled with the water-source heat pump. The hot return air can then be mixed with outside air as cold as 15°F to provide an acceptable mixed-air temperature for the occupied space.

Avoids Winter Heating
Where heat recovery from refrigeration is available, as in the WalMart superstore, these units can handle ambient temperatures as low as 15°F without any additional heat. In other applications, where refrigeration waste heat is not available or where the ambient temperature is lower than 15°F, the system can be augmented with a boiler or geothermal ground-coupled system.

Superior Energy Efficiency

The system boasts a heating COP of 4.0 and a cooling EER of 13.0 or higher, compared to competitive systems with average heating efficiencies of 3.0-3.8 and cooling efficiencies of 9.0-10.0. The novel WalMart configuration is expected to save on peak electricity demand compared with conventional systems involving gas desiccant dehumidification, air-source vapor compression air conditioning, and air-cooled refrigeration racks. Simulation of the WalMart superstore application of these units showed a potential cost savings of 22.6% over conventional HVAC&R systems.

Zero-ODP Refrigerant

The ventilation chiller uses R-407C, an environmentally acceptable refrigerant with zero ozone depletion potential.

Most cost-effective in new construction, the system is suitable for a wide variety of commercial buildings, including offices, retail outlets, supermarkets, hospitals, health care facilities, and schools. As rooftop units, they are ideal for applications where height or other restrictions prevent ceiling installation.

Conclusion and Future Directions

By separately conditioning the ventilation and return air streams, dual path systems achieve both improved air quality and operating savings. What's more, dual path technology can be easily offered in prepackaged units for low installed costs. Working with HVAC&R equipment manufacturers, the Electric Power Research Institute has developed innovative unitary systems that can be easily specified and installed in a variety of new and retrofit commercial applications.

EPRI is continuing to develop packaged dual path systems that improve air quality and increase energy efficiency. Work to date has focused on effective cooling and dehumidification designs; the Institute is now investigating practical ways to integrate heating functions more efficiently. EPRI is currently looking into:

- Air-handling units with a heat recovery heat exchanger for buildings with central exhaust (e.g., schools, theaters, assembly halls)
- Heat pump units capable of preheating the ventilation air

EPRI welcomes new ideas and invites interested manufacturers and end-users to join in development of advanced HVAC systems.

References

[1] Mitchell, John, *Analysis of Supermarket Dehumidification Alternatives,* Electric Power Research Institute TR-100352, 1992.

[2] Bradford, J. D., *Optimal Design of Air Conditioning and Dehumidification Systems,* MS thesis, Department of Civil, Environmental, and Architectural Engineering, University of Colorado at Boulder, 1995.