Federal Technology Alert

A publication series designed to speed the adoption of energy-efficient and renewable technologies in the Federal sector

Two-Wheel Desiccant Dehumidification System

Technology for Dehumidification and Improving Indoor Air Quality

Desiccant dehumidification technology provides a method of drying air before it enters a conditioned space. When combined with conventional cooling systems, desiccant dehumidification systems are a cost-effective means of supplying cool, dry, filtered air. These combined systems are called "hybrid" systems. This Federal Technology Alert discusses how to evaluate the cost-effectiveness of hybrid two-wheel desiccant-based cooling systems, summarizes desiccant dehumidification process, reviews field applications, and examines energy savings and other benefits.

Energy-Saving Mechanism

Desiccant systems save energy by using low-grade thermal sources to remove moisture from the air and to eliminate the overcooling and reheat step necessary in certain conventional vapor compression cooling systems. Desiccant systems often permit reductions in the size of the conventional cooling system; this saves energy and decreases electrical demand. In some applications of hybrid desiccant-based systems, the vapor compression system can be replaced with less expensive direct or indirect evaporative cooling systems. Hybrid systems can provide year-round comfort. The direct or indirect heaters used for reactivation can supply comfort heating, and the heat wheel can be used to recover energy all year.

Technology Selection

The Federal Technology Alert series targets technologies that appear to have the greatest untapped federal-sector potential. Desiccant dehumidification technology is one of the many energy-saving technologies to emerge in the

last 20 years for commercial buildings applications. The hybrid two-wheel desiccant system has the potential for federal-sector energy savings and has demonstrated satisfactory field performance and reliability in specific applications.

Potential

The technology has been shown to be technically valid and economically attractive in many applications. This Technology Alert reports on the collective experience of two-wheel desiccant system users and evaluators, and also provides guidance to future applications.

Application

Hybrid desiccant-based cooling systems can be used in any building application. However, high initial costs typically limit the use of this technology. The systems are extremely effective, and their use is well established in conditioning storage areas, ice arenas, hospital operating rooms, and supermarkets.

Site-specific conditions and differing application requirements must be understood before use of hybrid systems in a building can be justified on economic grounds. A detailed analysis is generally required to evaluate the cost-effectiveness of a hybrid system with a conventional cooling system. Typically, hybrid systems should be considered if the following conditions are met:

- low indoor humidity (below 50°F dew-point)
- high latent load fraction (greater than 25%)
- high fresh air intake (greater than 20%)
- high summer-time electric demand and energy costs, and low summer-time gas costs.

Field Experience

Detailed performance evaluations are still being conducted for two-wheel desiccant system (TWDS) technology installed in several Federal facilities. Several TWDS installations managed by U. S. Army Construction Engineering Research Laboratories (USACERL) at Defense Department sites are being evaluated; several other installations are in design stages. These systems use steam from a gas-fired boiler for their reactivation energy. In addition, the Design and Construction Division of Defense Commissary Agency (DCA) has installed over 70 desiccant-based systems in the past 10 years.

Six of the DCA units use heat recovery, and three have a TWDS design. Several facility managers for desiccant units were contacted to ascertain system performance. Only one manager was dissatisfied with the performance of the unit. This manager reported that the humidity levels in the conditioned space were still high, and the sensible cooling was inadequate. Both USACERL and DCA plan to install more desiccant systems in the future.

Case Study

Information is available from the Burger King demonstration site at Aberdeen Proving Grounds, Maryland, where some of the critical variables were monitored after the desiccant system was installed. Fast food restaurants, large dining facilities, and other common areas present a unique situation, because of the high density of occupants. The effectiveness of the desiccant-based system at the Burger King site was evaluated as a possible solution for other such facilities.

This demonstration site is open 24-hours a day, seven days a week. The dining area initially had two packaged rooftop units (a 5-ton and a 7.5-ton) supplying 700 cfm of ventilation out of a total supply flow rate of 5,000 cfm. Although the peak design load matched the equipment nominal capacity (12.5-ton) for the dining area, the components of the load (sensible and latent) did not match the equipment capacities.

At the outset of the demonstration, the nominal-capacity of the two units was reduced from 12.5 tons to 10.5 tons, and the total latent capacity was less than the required design latent capacity. This shortage was exacerbated by off-design conditions, during which the latent component of the total load did not drop off nearly as quickly as the sensible component. Because of these problems, the two packaged units were unable to dehumidify and cool the air simultaneously, resulting in frequent hot and/or humid conditions in the dining area. As a remedy, a nominal 1,600 cfm TWDS manufactured by Engelhard/ICC was installed. With this new system, the unit has operated reliably. An improvement in the space conditions was noticed by the restaurant employees and customers immediately.

Implementation Barriers

A widespread use of the hybrid desiccant cooling system is impeded by a lack of familiarity with the technology as well as a lack of knowledge about its performance and cost-effectiveness. Use of hybrid systems would be increased if there were guidance and techniques for reducing the first cost of such systems, performance documentation and confirmation, design tools such as user-friendly computer programs, and utility incentives.

Federal Technology Alert

Two-Wheel Desiccant Dehumidification System

Technology for Dehumidification and Improving Indoor Air Quality

Abstract

Desiccant dehumidification technology provides a method of drying air before it enters a conditioned space. When combined with conventional vapor compression systems, desiccant dehumidification systems are a cost-effective means of supplying cool, dry, filtered air.

In the last decade, desiccant dehumidification technology has emerged as an alternative or as a supplement to conventional vapor compression systems for cooling and conditioning air in commercial and institutional buildings. A typical hybrid system (shown above) combines a desiccant system with a conventional vapor compression cooling system.

Desiccant-based systems are cost-effective because they use low-grade thermal sources to remove moisture from the air. In general, the benefits of desiccant-based systems are greater where the thermal energy required for regenerating the desiccant is readily available, the electricity price is high, and the latent load fraction is high (>25%). If there is no difference in energy costs, the factors that influence the economy include climate conditions (humidities) and high outdoor-air requirements. In other situations, the important variables that drive the economics should be carefully evaluated. There are, however, a few applications where the technology's benefits have been so extensively demonstrated that no detailed analysis is required: storage spaces, ice arenas, most supermarket applications, military commissaries, hospital operating rooms, and as an add-on to existing air conditioning systems with inadequate dehumidification capacity.

This Technology Alert provides information and procedures that a Federal energy manager needs in evaluating the cost-effectiveness of a desiccant system. The process of desiccant dehumidification and its energy savings and other benefits are explained. Guidelines are provided for appropriate application and installation. In addition to a methodology of estimating energy savings potential from desiccant system installation, a case study is presented to give the reader a sense of the actual costs and energy savings. A listing of current manufacturers, technology users, and references for further reading is also included at the end of this report.

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About the Technology

Although there are a variety of desiccant dehumidification technologies, the primary focus of this Technology Alert is the two-wheel desiccant system (TWDS). Except when describing elements common to all desiccant-based systems, no other desiccant dehumidification processes are discussed here.

Desiccant dehumidification technology has been used in military storage and many industrial applications for more than 60 years (Harriman III 1990). Continuous desiccant dehumidification process can be achieved in a number of ways using liquid spray-tower, solid packed tower, rotating horizontal bed, multiple vertical bed, and rotating wheel. The TWDS falls into the rotating wheel category. In such a TWDS, the moist air stream, which has a high vapor pressure, passes through a rotating desiccant wheel. The desiccant, which has a low vapor pressure, adsorbs the moisture until the desiccant is saturated. Next, the saturated portion of the wheel rotates into a hot air stream, which is forced through the wheel to remove the moisture from the desiccant. The dried desiccant is rotated back into the moist air stream, and the process repeats itself. After it has been regenerated (dried), the desiccant is cooled to lower its vapor pressure.

As shown in Figure 1, a TWDS consists of a desiccant wheel, a rotary heat exchanger (sometimes referred to as a sensible heat wheel), a supply fan, an exhaust fan, and a heat source for regenerating the desiccant. The desiccant wheel is made of finely divided desiccant material, usually silica gel, titanium silicates, or some type of zeolite (a mineral containing hydrous silicates). The desiccant material is impregnated into a fibrous support structure, which looks like corrugated cardboard that has been rolled into the shape of a wheel or into a wheel-shaped rotor with a lightweight structural honeycomb core of man-made, fire-retardant material. The rotary heat exchanger, which exchanges (recovers) heat rather than moisture, resembles the desiccant wheel in appearance and design.[a] Any form of thermal energy stream (usually at 180°F or above) can be used to dry and regenerate the desiccant, including electric-resistance heaters, solar hot water coils, heat reclaim coils, hot water or steam from boilers, or natural gas burners. Most commercial applications use either direct- or indirect-fired natural gas burners. The actual desiccant cycle is explained later in this section.

The TWDS can control or lower humidity, but its ability to lower sensible heat is limited. Therefore, in most commercial applications the

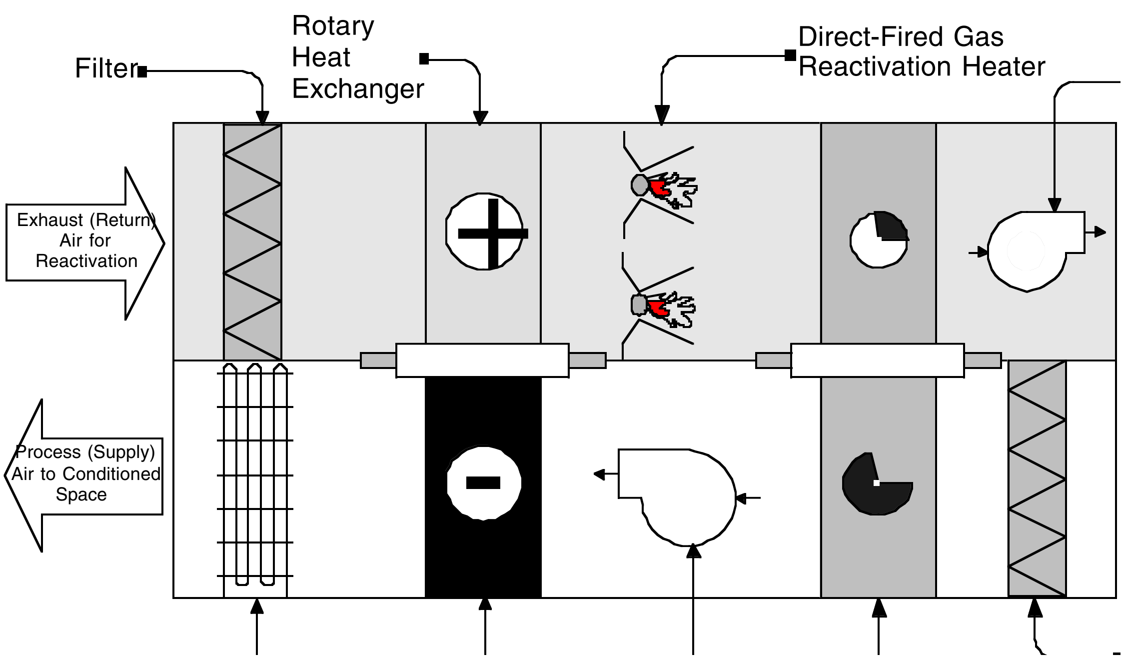


Fig. 1. Schematic of the Two-Wheel Desiccant System

(a) For some applications heat pipes are used instead of a rotary heat exchanger. The function of a heat pipe is similar to that of a rotary heat exchanger, i.e., it transfers heat from process air stream to the reactivation air stream. Although the efficiency of a heat pipe is not as high as a rotary heat exchanger, it is used in applications where the exhaust air may be contaminated. Because the heat pipe is a stationary device, particulates from one air stream do not mix with the other air stream. Desiccant systems with heat pipes are generally used in hospitals and laboratory applications.

TWDS is supplemented with either a vapor compression or an evaporative cooling system. These "hybrid" systems are described later in the Technology Alert (henceforth, much of the discussion in this Technology Alert will be focused on the hybrid systems).

Although the technology has been proven in industrial environments, there is limited field test data to evaluate the long-term performance of the TWDS in commercial building applications. The first cost of the hybrid desiccant system is generally higher than that of conventional systems, but this is offset by lower operating costs in certain applications (Manley et al. 1985; Burns et al. 1985; Cohen and Slosberg 1988; Marciniak et al. 1991; Novosel 1996). The TWDS offers many other benefits in addition to operational cost-savings. These benefits will be highlighted later in the section.

Most commercial systems are designed to maximize the energy cost savings and minimize the initial cost. To optimize the benefits of hybrid systems, an understanding of the impacts of the technology, the load being served (latent versus sensible), and the climate in which it is operating are all essential parameters. These topics are reviewed below.

Application Domain

Desiccant systems have been widely used in applications where the prime consideration is special system requirements rather than energy efficiency or competitive pricing (such as the military and industrial sectors). They have been successful in these instances because there are no practical alternative processes that are capable of providing low moisture levels (less than 30°F dew-point), low microbial growth, or improved indoor air quality. In the residential and the commercial building sectors, desiccant technology currently competes with the well-established conventional vapor compression technology. Unfamiliarity with the technology, and lack of assurance and education about the performance and cost-effectiveness of hybrid desiccant cooling systems, impede implementation of such systems (Mei et al. 1992).

Although no firm shipment numbers are available, the building sector has seen significant growth in installation of hybrid systems in the past few years. This indicates increased awareness that hybrid desiccant systems can provide both temperature and humidity control and in some applications use less energy than conventional vapor compression systems. The applications where the benefits have been extensively demonstrated include dry storage spaces, ice arenas, most supermarket applications, military commissaries, hospital operating rooms, schools, fast-food restaurants, unheated warehouses, and as an add-on to existing air conditioning systems with inadequate dehumidification capacity.

The following would encourage increased use of hybrid systems: guidance and techniques for reducing the first cost of hybrid desiccant cooling systems; performance documentation and confirmation by an agency such as the Department of Energy (to encourage government facilities' managers and their architects and engineers to objectively evaluate desiccant technology for large- and medium-sized building projects); development of design tools (such as a user-friendly computer program) to enable designers to easily evaluate economic tradeoffs and design hybrid desiccant cooling systems based on actual performance data; and utility incentives (Mei 1992).

Energy Savings Mechanism

The energy-saving mechanism of a TWDS can best be understood by comparing the dehumidification and cooling process of the conventional and the desiccant-based systems. Both systems can be operated in various modes (recirculation, pure ventilation, and mixed). These modes will be discussed later in the Technology Alert, but to illustrate the energy savings feature, it is assumed that both systems take in 100% outdoor air.

The following steps describe the psychrometric process for a hybrid desiccant dehumidification and supplemental cooling system (the letters correspond to state points on the psychrometric chart in Figure 2).

Dehumidification

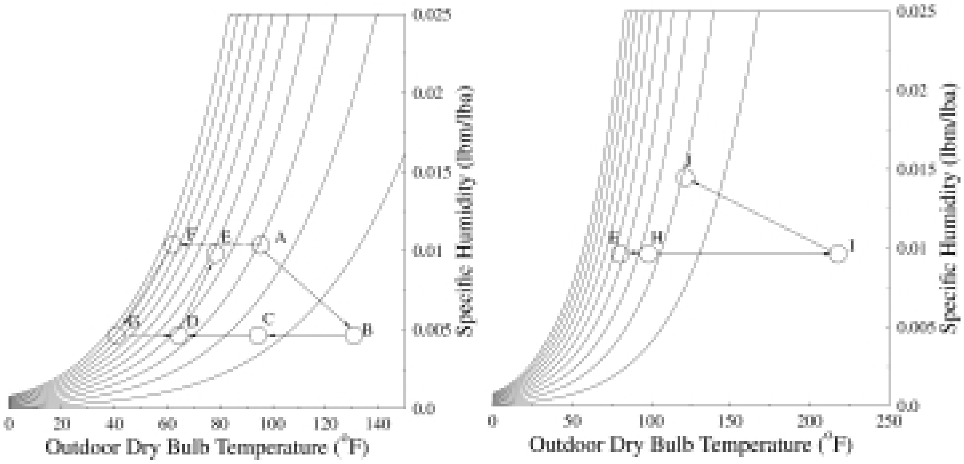
- A: Intake—hot and humid outdoor air enters the desiccant wheel at point A on the psychrometric chart (Figure 2 (a)).

- A-B: Dehumidification—as the moisture from the outdoor air is removed by sorption, the heat generated when the water is sorbed (akin to condensation) remains in the air stream, increasing the air stream's sensible load. There is a slight increase in the enthalpy (i.e., the energy content of the air stream increases), when latent heat is being converted into sensible heat. At state B, the air is hot and dry and cannot be directly used to cool the conditioned area.

Cooling

- B-C: Heat loss or post-cooling—the dehumidified outdoor air enters the rotary heat wheel, where it exchanges heat with the exhaust (return) air stream from the conditioned space. In this process, the hot and dry outdoor air cools down, and the cold exhaust air is pre-heated for reactivating the desiccant wheel.

- C-D: Supplemental cooling—the air leaving the rotary heat wheel is colder than the air leaving the desiccant wheel, but further cooling is often required before it



(a) (b)

Fig. 2. (a) Comparison of a Hybrid Desiccant-Based Dehumidification and Supplemental Cooling Process with a Conventional Dehumidification and Cooling Process (b) Desiccant Reactivation Process

can enter the conditioned space. This can be achieved by using a conventional direct-expansion vapor compression cooling system.

- D-E: Space cooling load—the exhaust air leaving the conditioned space is at state E.

Regeneration

- E-H: Heat recovery—the exhaust air stream enters the rotary heat wheel where it exchanges heat with the hot and dry air leaving the desiccant wheel. Part of the heat lost in step B-C is recovered by this process (Figure 2 (b)).

- H-I: Heat addition—the hot exhaust air is further heated to increase the vapor pressure at the desiccant.

- I-J: Reactivation—the hot exhaust air stream dries and reactivates the saturated desiccant.

For comparing the above process with that of a conventional system, the following steps for cooling and dehumidification with a conventional vapor compression system are shown on the psychrometric chart (Figure 2(a)):

Sensible cooling

- A: Intake—hot and humid outdoor air enters the evaporator coil of a conventional vapor compression system at point A on the psychrometric chart (Figure 2 (a)).

- A-F: Sensible cooling—the hot and humid outdoor air stream is cooled until it reaches saturation. At this point, the air is cold enough to be used in the conditioned space, but cannot be circulated because it is saturated with moisture. To remove moisture, the air must be cooled to below its dew-point temperature.

Latent cooling (dehumidification) and reheat

- F-G: Dehumidification—the evaporator continues to cool the saturated air stream and condenses the moisture, further reducing the dry-bulb and the humidity. If the humidity requirement is low (less than 40 grains/lb of dry air), the air must be cooled to less than 43°F in order to condense enough moisture. In this state, it is too cold to be circulated to conditioned space.

- G-D: Reheat—the cold, dry air stream is mixed with hot air or reheated to the desired circulation temperature (state D).

- D-E: Cooling load—the exhaust air leaves the conditioned space (state E).

The psychrometric processes shown in Figure 2 highlight the differences in the way dehumidification is accomplished by the two systems. The amount of energy saved depends primarily on the ability of the hybrid system to shift part of the cooling load (dehumidification load) to a low-grade thermal source and to eliminate reheat (step G-D). The fan power is slightly increased because of increased air pressure drop through the desiccant and sensible wheels. The amount of energy saved and the reduction in electric demand depend on several factors. The key factors are discussed later.

Other Benefits

Desiccant-based systems in general, and the hybrid system in particular, offer several benefits besides energy conservation.

- Desiccant systems often permit reductions in the size of the conventional system (vapor compression unit), because part of the cooling load (dehumidification load) is shifted to the desiccant system. Size reduction not only saves energy, but it also decreases electrical demand and may reduce initial capital investment.

- In some hybrid systems, the vapor compression system can be replaced with less expensive direct or indirect evaporative cooling systems.

- Hybrid systems permit independent control of both temperature and humidity. In conventional cooling systems, only temperature is controlled directly; the humidity is allowed to vary.

- Desiccant-based systems can reduce the moisture much below the 40°F dew-point temperature, while the conventional cooling systems can only dehumidify the air to temperatures above the 40°F dew-point temperature.

- Desiccant-based systems can improve indoor air quality because of precise humidity control. Where conventional systems are used in humid climates, there is potential for microbial growth in the ducts and condensate drain pans because of inadequate moisture removal. This is not a problem for a desiccant-based system because there is typically very little water on a post-desiccant cooling coil or, subsequently, in the drain pan and the air distribution ducts.

- Hybrid systems can provide year-round comfort (the boiler used for reactivation can be used for comfort heating) and the heat wheel can be used to recover energy all year.

- As Federal facilities move to replace CFC-11, CFC-12, and CFC-22 refrigerants with HCFC-123 and HCFC-134a, which only provide about 90% of the existing capacity, desiccant systems can be used to replace the capacity.

Variations in System Design and Operating Modes

Hybrid systems have several possible configurations and operating modes, some of which are discussed in this section. System configurations vary based on the type of desiccant used for humidity control, type of cooling used for temperature control, type of cooling used for pre-cooling, and method of reactivation. For the TWDS, the choice of desiccant is limited to solid desiccants embedded in a rotating wheel.

Regardless of the system configuration, some supplemental cooling will be needed in most commercial building applications. This can be achieved in several ways: conventional vapor compression (direct expansion), chilled water coils, direct evaporative cooling pads and indirect evaporative cooling coils.

- **Supplemental cooling options**: The heat wheel provides part of the sensible cooling, but in most cases is not sufficient to meet the sensible load requirements of the conditioned space. Therefore, the TWDS is usually supplemented with additional sensible cooling. Indirect evaporative cooling can be used, but the capacity of such systems is limited. The process air (air leaving the wheel) may be cooled with direct evaporative cooling pads, but this method introduces additional moisture into the conditioned spaces. A third, commonly used option is to cool the process air using conventional vapor compression cooling systems.

All the options listed above for supplemental cooling can also be used for pre-cooling the air before it enters the desiccant wheel.

- **Heat source for reactivation**: The most commonly used heat sources are direct- and indirect-fired natural gas heaters, and gas fired boilers. Direct-fired natural gas heaters burn gas directly in the reactivation air stream. Therefore, the thermal efficiency is high (90% to 95%). Indirect-fired natural gas burners burn the natural gas outside the reactivation air stream, and the combustion heat is transferred to the reactivation air stream through a heat exchanger. Because a heat exchanger comes between the flame and the reactivation air stream, heat transfer efficiency is reduced to 80% or less. Gas-fired boilers that circulate hot water or steam through heating coils can be used for both reactivation and heating during winter. Thus, one boiler can serve both heating and reactivation needs (Harriman 1996). Other heat sources used for reactivation include electric resistance heaters, solar hot water coils, heat reclaim coils, and hot water or steam.

- **Operating modes**: There are four possible operating modes: recirculation, pure ventilation, makeup, and mixed (Figure 3).

Process and regeneration air can come from two sources: outdoor air and/or exhaust air for regeneration, and outdoor air and/or return air for process. These possible sources for the process and regeneration air streams can be pure or mixed. In the recirculation mode, the source of process air is return air from the conditioned space, and outdoor air is used for regeneration (Figure 3a). In the pure ventilation mode, the source for process air (i.e., supply air) is outdoor air and exhaust air is used for regeneration (Figure 3b). In the makeup mode, the source of both process air and regeneration air is outdoor air (Figure 3c). In the mixed mode, the source for process and

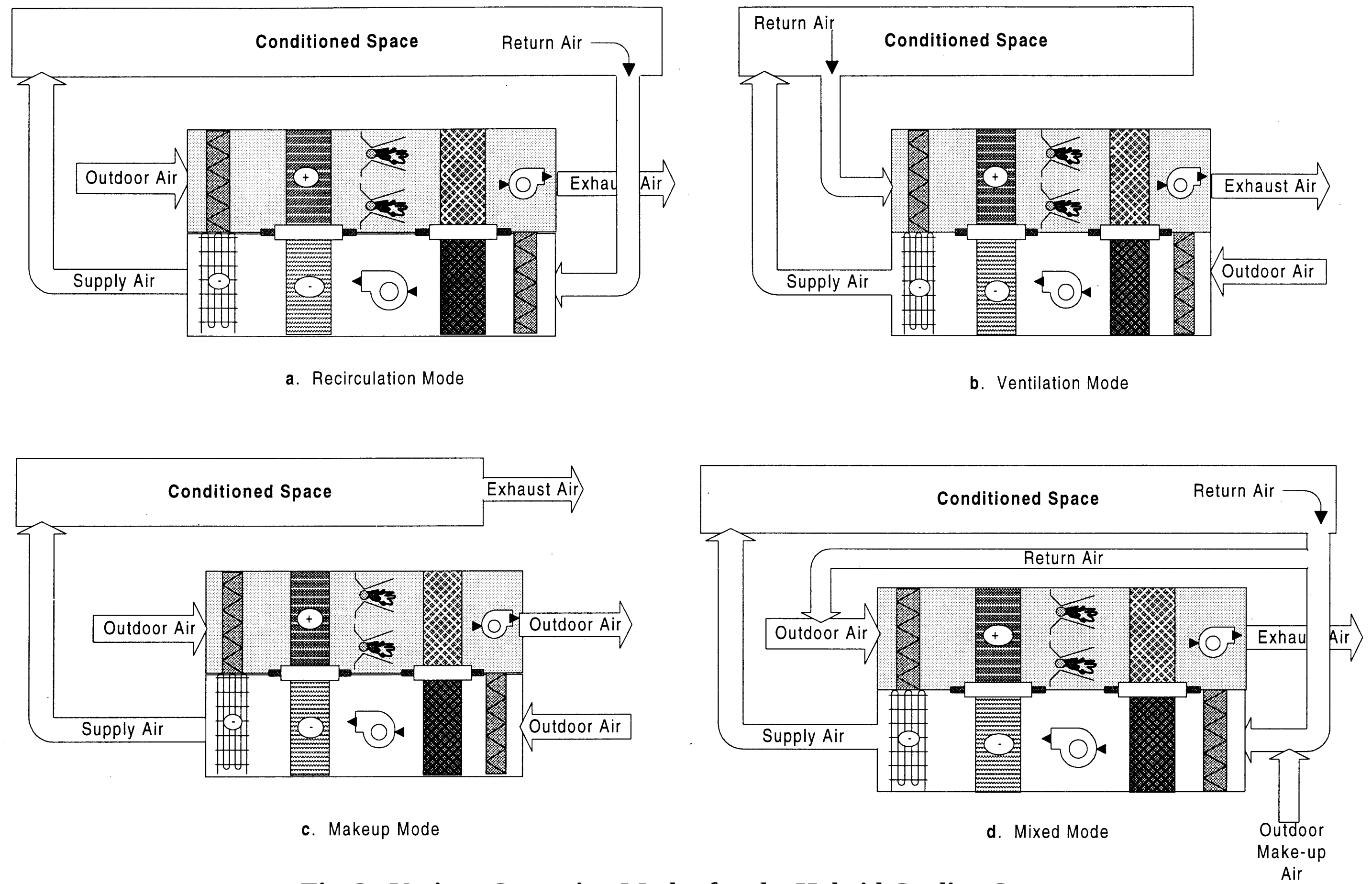


Fig. 3. Various Operating Modes for the Hybrid Cooling System

regeneration can be a combination of the other modes (Figure 3d). Site-specific conditions and application requirements will dictate or favor the choice of a given operation mode, as well as the economic viability of the hybrid desiccant system.

Variables Affecting Performance

To achieve maximum benefit from the desiccant system and for proper sizing, a clear understanding of the variables that affect the performance is essential. Among the variables that have a major impact on the sizing and effectiveness of a desiccant system are process air moisture, temperature, and velocity through the desiccant; reactivation air temperature; velocity and moisture load of air passing through the desiccant; amount of desiccant presented to the reactivation and process air streams; and desiccant adsorption properties (Harriman 1990). In any system, these variables change because of weather, and variations in moisture load. It is useful for the system designer to understand the effect of these normal variations on the performance of the dehumidifier.

- **Process air moisture**. If all other variables are held constant, the lower the moisture in the air entering the desiccant wheel, the lower the moisture will be in the air leaving the desiccant wheel. From a design perspective, if the incoming air is more moist than expected, the process air will be warmer than expected. Therefore, additional cooling will be necessary if a constant temperature in the conditioned space is critical. If the air is less moist than expected when it enters the wheel, it will be drier than expected when it leaves the system. If a constant level of moisture in the air leaving the system is critical, less air should be processed through the system.

- **Process air temperature**. If all other variables are held constant, lower process air temperatures mean less moisture in the air leaving the desiccant wheel. Higher process air temperatures mean more moisture in the air leaving the desiccant wheel.

- **Process air velocity**. The more slowly the air moves through the desiccant wheel, the drier the outlet air will be when it leaves the desiccant wheel. Low air velocity, therefore, is critical if low humidity must be maintained in the conditioned area. However, slower air velocities mean bigger and more costly desiccant wheels. The designer must install an airflow-monitoring device and control the system to avoid unplanned changes in velocity. If the moisture removal rate (pounds of moisture removed per hour) is more important than low humidity in the conditioned space, then the air can pass through the system at higher velocities, and smaller, less costly equipment can be used.

- **Reactivation air temperature**. The desiccant is dried and reactivated by a hot air stream. The hotter the reactivation air, the more easily the desiccant gives up moisture. If dry air is required in the conditioned space, high reactivation air temperatures (250°F) are generally the most economical choice. If low humidity is not a requirement, inexpensive, low-grade heat sources, such as waste heat, cogeneration heat, or heat rejected from refrigeration condensers, can be used to reactivate the desiccant at a low cost. In this case, the desiccant wheel will need to be larger than the one in a high-temperature reactivation system in order to produce the same outlet condition in the process air.

- **Reactivation air moisture**. In general, the moisture level of reactivation air does not affect solid-desiccant wheel performance. However, leakage from the reactivation air stream to the process air stream will add moisture to the process air stream. The units are designed to minimize leakage by keeping a positive pressure differential between the process and regeneration air streams and by placing seals around the rotor assembly.

- **Reactivation air velocity**. The amount of moisture removed from the desiccant wheel is a function of the reactivation airflow and the temperature difference between the reactivation air and the desiccant wheel. The faster the reactivation air flows, the greater the moisture removal from the desiccant. If the temperature of the reactivation air remains constant, it is a waste of energy to increase the airflow beyond the minimum value necessary to remove the moisture from the desiccant wheel.

- **Amount of desiccant presented to the air stream**. Increasing the amount of desiccant that is available to dry the air in a fixed period of time increases the moisture removal capacity of the wheel and the amount of energy used in reactivation. The increase can be accomplished by increasing the wheel depth or wheel rotation speed. Increasing the wheel depth increases the mass of the desiccant. This causes an increase in airflow pressure and increases the temperature of the air leaving the wheel. More energy must then be expended to cool this air before it enters the conditioned space. Increasing the wheel rotation speed increases the amount of moisture removal because the desiccant wheel moves faster between process and reactivation air streams. Again, more energy must be expended for both cooling and reactivation. In general, manufacturers design the units to optimize the relationship between energy expenditure and moisture removal capacity. Therefore, the manufacturer usually establishes the rotational speeds and wheel depth (Harriman 1990).

- **Desiccant adsorption characteristics**. At constant temperature, each desiccant has a fixed capacity to sorb moisture. In general, manufacturers design units to optimize the moisture removal capacity for specified values of other variables such as air flow rates and wheel speed.

Installation

The desiccant systems are generally designed for outdoor installation. Most commercial desiccant systems are mounted on rooftops. The units are installed on concrete pads located as close as possible to the gas and electrical interfaces. If the desiccant unit is equipped with an evaporative cooler, it will need water supply. In some large systems, a telephone hookup may be needed to remotely monitor the unit's operation. Clearance may not be an issue for rooftop-mounted units; units installed in enclosed spaces must have sufficient side access clearance for maintenance.

Federal Sector Potential

Although the desiccant technology has been employed for several decades, its use was limited to industrial and military sectors. The market potential in those sectors was estimated to be between $50 million and $60 million in the early 1990s (Mei et al. 1992). No concrete estimates are available either for the commercial buildings sector or for the Federal sector because wider applications of the technology are only now being investigated.

Application

This section addresses technical aspects of the hybrid desiccant cooling technology. The range of applications and climates in which the technology can best be applied is discussed. The advantages and limitations are enumerated. Design and integration considerations of the technology are discussed, including costs, options, and installation details. Utility incentives are also presented.

Application Screening

Hybrid desiccant cooling systems can be used in any building application because they provide precise temperature and humidity control. However, high initial costs ($5/cfm to $8/cfm) typically limit the use of desiccant technology.

Several techniques can be used to estimate the annual energy consumption of hybrid desiccant cooling systems. The most accurate are those that use computer simulations. Although they produce more reliable results than hand-calculation techniques, computer simulations are difficult and expensive to employ routinely as initial screening tools, and are therefore appropriate only when additional details are required.

The bin method is another analytical tool for screening technology applications. In general, a bin method is a simple calculation procedure that is readily adaptable to a spreadsheet-type analysis and can be used to reasonably estimate the energy consumption of a given application in a specific location (ASHRAE 1993, Chapter 28). However, the bin method underestimates the latent load by about 30%, because the methodology relies on using dry-bulb temperature bins with average coincident wet-bulb temperatures. An alternate approach is to use joint frequency tables of dry-bulb temperatures and humidity ratio. The difficulty with this approach is that hourly humidity ratios are not readily available.

Where to Use Hybrid Desiccant Cooling Systems

Site-specific conditions and differing application requirements must be understood before use of desiccant-based hybrid systems in a building can be justified on economic grounds. A detailed analysis is generally required to compare the cost-effectiveness of a hybrid system with a conventional cooling system. While it is difficult to generalize the cost-effectiveness of the hybrid systems, there are a few applications where cost-effectiveness is so well established that detailed analysis is not necessary. These include storage spaces (where the space is dehumidified in summer and heated in winter), ice arenas that operate in summer, hospital operating rooms (where humidity control and indoor air quality are critical), and most supermarkets. In a situation where the existing conventional system is unable to provide sufficient latent capacity, a TWDS can be integrated with the existing system to provide the necessary latent capacity. In such a situation, the first cost usually favors a TWDS over a conventional system.

For other situations the key variables that drive costs should be carefully evaluated. These include maximum allowable moisture level in the conditioned space, ratio of the latent cooling load to the sensible cooling load, amount of fresh air required, design outdoor dew-point temperature, availability of exhaust (return) air for post-cooling, local electric demand and energy costs, local gas cost, availability of cheap regeneration heat, and the benefits of improved indoor air quality. The following application criteria can be used (Figure 4):

- **Level of Indoor Humidity**: Desiccant-based systems are the most economical choice to dehumidify air below 40°F dew-point, because condensate often freezes on the coils of conventional cooling systems at temperatures below 40°F, thereby reducing the coil moisture removal capability. If the dew-point requirement is between 40°F and 50°F, the cost-effectiveness of desiccant-based systems depends on the other site-specific conditions and requirements. If the dew-point requirement is greater than 50°F, a conventional system is generally favored. In most commercial building applications, deep drying (dew-point <40°F) is rare. The recommended level of indoor dew-point for a typical office building is between 51°F and 57°F, while the level for libraries and museums is between 46°F and 54°F.

- **High Latent Load Fraction (>25%)**: Desiccant-based systems are more cost-effective in reducing latent loads than are conventional systems; therefore, they are more attractive when the latent loads as a fraction of the total loads are high. In most office buildings, the latent loads are a small fraction of the total load (less than 25%). However, supermarkets, movie theaters, schools, auditoriums and outside-air ventilation systems have a much higher fraction of latent loads.

- **Fresh Air Intake**: Some commercial buildings (schools, hospitals, restaurants, and retail establishments) require significant fresh air intake (greater than 20%) (ASHRAE Standard 62). If the design dew-point temperature and the frequency of high outdoor dew-point temperatures are high, desiccant-based systems may be cost-effective. ASHRAE has published 1%, 2%, and 5% occurrences of extreme dew-point temperatures and mean coincident dry-bulb temperatures (Colliver et al. 1995). It is difficult to get the actual frequency of occurrences of dew-point temperatures for various

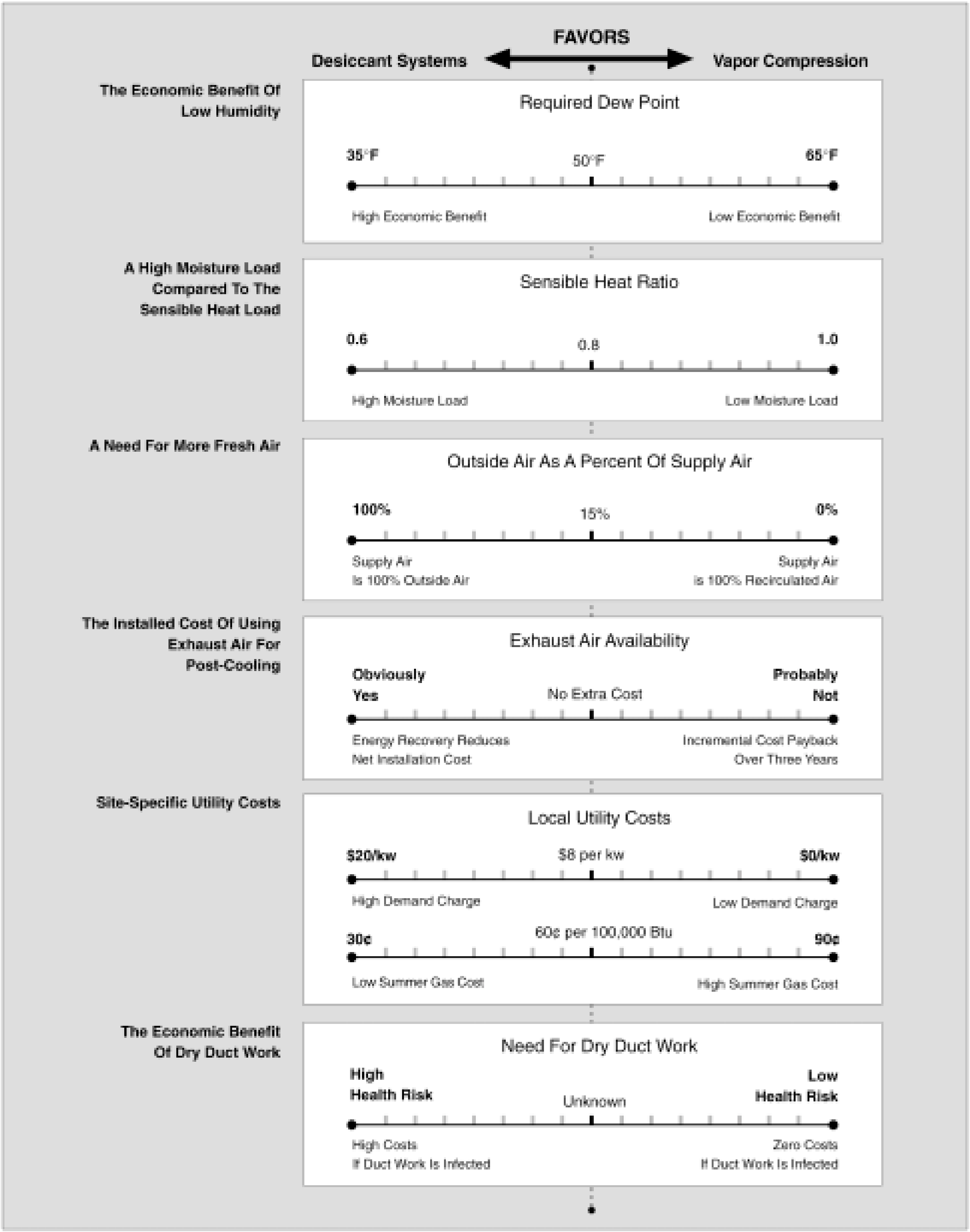


Fig. 4. Illustration of Initial Application Screening Process (Source: Harriman 1996)

climate regions, but frequency of mean coincident wet-bulb (MCWB) temperatures are readily available to most Federal energy managers (TM 5-785, 1978). However, calculations using MCWB temperatures may lead to underestimates of the latent ventilation load.

- **Availability of Exhaust (Return) Air for Post-Cooling**: If exhaust (return) air is available for post-cooling (as shown in Figure 3b), the sensible cooling requirements are reduced. If the fresh air requirements are high (greater than 20%), desiccant-based systems that use a combination of fresh and exhaust air can be more cost-effective than conventional cooling systems.

- **Demand and Energy Costs**: High summer-time electric demand and electricity cost, coupled with a low summer gas cost, can favor desiccant systems. Low gas costs alone may not make the desiccant-based systems cost-effective, and other criteria should be carefully evaluated.

- **Availability of Cheap/Free Reactivation Energy Source**: Availability of free or cheap reactivation heat will make desiccant-based systems more attractive. In general, 180°F to 220°F temperatures are required for regeneration. Some possible sources of “waste” heat are condensers, engines, and gas turbine exhaust.

- **Indoor Air Quality**: Indoor air quality is difficult to quantify in terms of economic benefit, but is essential for many buildings (e.g., hospitals and nursing homes). Desiccant-based systems improve indoor air quality because they precisely control moisture levels. Where conventional systems are used in humid climates, there is potential for microbial growth in the ducts and condensate drain pans because of inadequate moisture removal. This is not a problem for a desiccant-based system because there is typically very little water on a post-desiccant cooling coil or, subsequently, in the drain pan and the air distribution ducts.

When two or more of the key variables favor a hybrid system over a conventional system, the building manager should request a detailed analysis of the benefits of a hybrid desiccant system.

What to Avoid

The hybrid desiccant cooling system may be less attractive

- if the conditioned space dew-point requirement is higher than 50°F

- if the latent fraction of the total cooling load is less than 25%

- if the designers and installers are inexperienced. As with any heating or air-conditioning system, approved calculation procedures should be used for sizing.

Design and Equipment Integration

The purpose of this Technology Alert is to familiarize the Federal energy managers and Federal facility engineers with the benefits and liabilities of using desiccant cooling systems and their application to commercial facilities. Because any desiccant-based system needs to be optimized to a specific site condition, it is beyond the scope of this Technology Alert to fully explain the design requirements of a particular desiccant cooling system. In general, the system should be designed by an experienced designer and installer of these systems. It is, however, important that the reader know the basic steps in the design process, which are listed below:

- Determine local climatic design conditions, e.g., design dry-bulb and dew-point temperatures.

- Establish the control levels (temperature and humidity).

- Determine building heating and cooling loads (both latent and sensible) at design conditions:
  - determine number of occupants in the space
  - calculate ventilation requirements for the occupants and for appropriate building pressurization
  - calculate latent loads from ventilation, occupants, infiltration
  - size TWDS to meet the latent load
  - calculate sensible loads from internal gain (including occupants), infiltration, and ventilation
  - size conventional cooling system to meet the internal sensible load, plus the load to cool the hot dry process air to the required set point.

- Talk to several desiccant cooling system manufacturers (a list of manufacturers is provided at the end of this Technology Alert) to identify the most suitable types of equipment. Select the alternative HVAC system components, including the indoor air-distribution system type, and size the alternatives as required.

- Determine the monthly and annual building heating and cooling energy requirements.

- Estimate the cost of the hybrid system and the alternative system.

- Perform life cycle cost (LCC) analysis on the system design (or system design alternatives).

Equipment Selection. Unlike the conventional vapor compression systems, the hybrid cooling systems are selected based on the latent cooling load and not on sensible cooling or heating loads, although the equipment is capable of providing sensible cooling and heating. Having selected the system based on the latent cooling load, check its sensible cooling and heating capacity. If the sensible cooling capacity is inadequate, consider adding an external system, such as vapor compression equipment and/or a warm-air furnace, to meet the additional load. Most manufacturers of TWDS will provide additional sensible cooling equipment in a single package along with the TWDS. The units are also optimized for a small range of airflows and moisture removal capability. Operating outside these ranges may damage the desiccant wheel material or lead to unreliable performance. TWDS with a flow capacity of up to 30,000 cfm are now available in the market.

The following issues need to be evaluated before integrating the desiccant system with an existing HVAC system:

Size and Location. The desiccant system must be placed near the existing HVAC air handler. For new installations, consider the unit size, weight, and clearance required for safety, maintenance, and adequate airflow. This information is generally available in the manufacturer's literature. The actual space requirement and the weight of the unit depends on the capacity of the unit and other components required to meet the cooling and heating load of the building. Always locate the desiccant system at the fresh air intake of the existing system. Ensure that these utilities are available: electricity (for operating fans, motors, compressor), natural gas or propane (for regeneration, not required if regeneration is accomplished by using waste heat from another existing source; gas or propane connections may be desired as a reserve fuel), and water (for evaporative cooling components).

Equipment warranties. The prospective user should ask potential suppliers, contractors and installers about equipment warranties. The parts for desiccant cooling systems are generally guaranteed free from manufacturing defects for 12 to 18 months. Some manufacturers offer extended warranties for up to 5 years for the desiccant and the heat wheels. The prospective user should also ensure that the warranties of other equipment (for condensing units, etc.) are valid when a desiccant cooling system is integrated with an existing HVAC system. If the performance of the system is to be monitored, most manufacturers can install the sensors that need to be placed inside the desiccant unit before the unit is shipped. This protects the customers from potentially voiding the warranty due to damage to the equipment that could occur during installation of sensors.

Cost

Because the desiccant systems are sized based on the airflow rate (cfm), the costs are typically given in terms of $/cfm.[b] For large commercial systems the cost of a TWDS is usually about $5/cfm, while smaller units (less than 1,000 cfm) for residential application may cost up to $8/cfm. The installation costs can vary based on specific site requirements. For a hybrid system, the additional cost of vapor compression systems must be factored in. As an illustration, the following examples have been reported from a technology transfer workshop on desiccant cooling systems (Meckler et al. 1995).

- A 1,600-cfm TWDS (without additional vapor compression cooling) was installed at a cost of between $5/cfm and $8/cfm at a Burger King restaurant, Aberdeen Proving Grounds, MD.

- A 140,000-cfm TWDS was installed at a cost of about $6/cfm at the Medical College Building, Athens, GA.[c]

Utility Incentives and Support

Several utilities are currently providing incentives for installing desiccant dehumidification systems under their commercial demand-side management (DSM) program: Brooklyn Union, Metropolitan Utility District, Minnegasco Inc., and Mobile Gas Services Corp (EUN 1996). Facility managers are encouraged to check with their utility regarding the availability of any custom rebate programs. These programs are based on the energy and demand savings, not on the technology used. Other sources of information include a publication reporting current DSM programs by Electric Power Research Institute (EPRI 1993). This report identified 2,321 DSM programs from 666 utilities.

(b) A general rule of thumb of 300 cfm/ton to 400 cfm/ton can be used to compare desiccant system cost with conventional vapor compression systems.
(c) Refer to the Desiccant Technology Transfer Workshop Manual, American Gas Cooling Center, Arlington, Virginia, for more details (Meckler et al. 1995).

Technology Performance

Field Performance

The U. S. Army Construction Engineering Research Laboratories (USACERL) managed several TWDS installations at Department of Defense (DoD) sites to demonstrate the benefits of desiccant technology. Although several TWDS have been installed at DoD sites and other Federal facilities, detailed performance evaluation of the technology has not yet been performed. In the summer of 1994, USACERL participated in the installation of a desiccant system at a Burger King restaurant at Aberdeen Proving Grounds (details of the installation are provided in the Case Study section). Since then, four systems have been installed at other DoD sites and several more are in various stages of design. The units featured in the USACERL desiccant technology demonstration program are TWDS manufactured by Engelhard/ICC. The source of reactivation energy for the Engelhard/ICC units is steam from a gas-fired boiler system.

In addition to the demonstrations handled by USACERL, Design and Construction Division of Defense Commissary Agency (DCA) has installed over 70 desiccant systems in military commissaries in the United States. Of these, only three installations are of the two-wheel design, three more use a heat pipe for heat recovery, and the rest are single-wheel desiccant systems. The six units with heat recovery are targeted for direct distribution systems over frozen food aisles. All other sites have units that maintain the entire store to a design of 75°F dry-bulb temperature and 48°F dew-point temperature. The desiccant units at the DCA sites use direct-fired natural gas burners. The first installation funded by DCA was in the year 1983 at Lackland Air Force Base in Texas. DCA plans to install eight more desiccant systems with heat pipes for heat recovery in the future. DryCool division of Munters Incentive Group manufactured all systems installed by DCA.

Several facility managers were contacted to ascertain the performance of desiccant systems. Only one manager was not satisfied with the performance of the unit. This manager reported that the humidity levels in the conditioned space were still too high, and that the sensible cooling was inadequate because of improper design.

Maintenance

Maintenance costs fall into two categories:

- **General air-conditioning maintenance**. Typical yearly maintenance costs for air-conditioning systems range from $25/ton to $35/ton.

- **Maintenance of the desiccant dehumidification components**. For the desiccant and heat wheels, filters should be well maintained and changed every 2 months. The wheel can be vacuumed to remove dust from the wheel face. The other parts of the desiccant wheel that need regular maintenance are the contact seals (5-year life), the wheel drive assembly, the wheel support bearing, fan, and fan belt. No regular maintenance is required for the desiccant material. The heat wheel, like the desiccant wheel, needs very little maintenance if the filters are well maintained. The other parts of the heat wheel that need regular maintenance include the wheel drive assembly and the wheel support bearing. If the process air is post-cooled using a direct or indirect evaporative cooler, the regular maintenance for the cooler includes flushing the pads and sump frequently (every 2 months), treating the makeup water, and draining the water supply pipe during winter months (when dehumidification is not needed and freezing is likely).

Desiccant Life

Usefulness of the desiccant material depends largely on the quantity and type of contamination in the air streams. In a commercial air-conditioning environment, desiccants last between 10,000 hours and 100,000 hours before they need replacement (ASHRAE 1993, Chapter 19). Adsorbents (solid desiccants used in TWDS) tend to be less reactive chemically and more sensitive to clogging, a function of the type and particulate material in the air stream. They may also be sensitive to hydrothermal stress, which results from thermal expansion and contraction of the desiccant material due to rapid changes in desiccant moisture content (ASHRAE 1993). Because the application of TWDS in commercial air-conditioning is new, the long-term performance (over 10 years) of the desiccant wheel is not clear. According to the manufacturers, a well-maintained desiccant wheel will last for approximately 100,000 hours of operation (10 to 15 years).

Other Impacts

The usual codes and regulations for installing or servicing air-conditioning or refrigeration equipment apply. No other special code compliance issues exist. There will be a small increase in local emissions, because of the use of a fossil fuel-(gas or propane) fired heater for regeneration. However, there will also be a decrease in utility emissions, because of reduced electric energy use. Desiccant systems reduce the cooling load on the conventional system; therefore, smaller conventional systems can be used, reducing use of ozone-depleting chlorofluorocarbons (CFCs).

How to Estimate Energy Savings Potential

Estimation of energy savings from use of TWDS is an intricate task, because of the complexity involved in modeling the annual performance. A spread-sheet analysis using the ASHRAE bin method works well for the conventional system, but can not be used for desiccant systems. Several detailed energy analysis tools are available to assess the annual performance of the desiccant systems and compare it with alternative options such as conventional systems. Two such tools, DOE2.1E and TRACE,[d] are detailed programs that can model the annual performance of the solid desiccant-based systems. For details of other models, refer to the report by Mei et al. (1992). Most manufacturers have developed their own analytical models. These generally are proprietary and validation is often not clear.

Case Study

Several desiccant-based systems have been installed at DoD sites. A partial performance monitoring has been completed at one site, but no historical utility billing information is available for any of the demonstration sites. This has made even a qualitative analysis of the billing data difficult. Information is available from one demonstration site, where some of the critical variables were monitored after the desiccant system was installed. The monitoring data include outdoor dry-bulb temperature and relative humidity, process dry-bulb temperature and relative humidity (supply), process air flow rate, run time of the unit, regeneration air temperature, electricity consumption, and regeneration gas consumption. The facility, its systems, and the preliminary monitoring data are presented in the following section.

Burger King Restaurant

One of USACERL's demonstration systems was installed at a Burger King restaurant at Aberdeen Proving Ground (APG), Maryland. Fast food restaurants, large dining facilities and other common areas present a unique situation, because of high occupant density. USACERL wanted to evaluate the use of desiccant-based systems as an air-conditioning solution for such facilities.

The building is an Army-owned Burger King franchise that is representative of a typical fast food restaurant. It is open 24-hours a day, seven days a week. Several rooftop air-conditioning units serve the building (kitchen, dining area, and bathrooms). The dining area was isolated for this study, because its occupancy density is highest. Initially, the dining area had two packaged rooftop units (5-ton and 7.5-ton) supplying 700 cfm of ventilation out of a total supply flow rate of 5,000 cfm. Although the peak design load[e] matched the equipment nominal capacity (12.5-ton) for the dining area, the components of the load (sensible and latent) did not match the equipment capacities. At the design conditions, the nominal-capacity of the two units was reduced from 12.5 tons to 10.5 tons, approximately 13% below the design load (because of supply fan reheat and other losses). The total latent capacity of the units at the design conditions was also less than the required design latent capacity (Meckler et al. 1995). This shortage was exacerbated by off-design conditions, in which the latent component of the total load did not drop off nearly as quickly as the sensible component. Because of these problems, the two packaged units were unable to dehumidify and cool the air simultaneously, resulting in frequent hot and humid conditions in the dinning area. As a remedy, a nominal 1,600 cfm TWDS manufactured by Engelhard/ICC was installed in the year 1994 as a collaboration between Engelhard/ICC, APG, and USACERL to demonstrate desiccant technology under the Army's Facilities Engineering Applications Program (FEAP).

The installation of the TWDS was completed in the summer of 1994. Since then, the new system handles the latent load from ventilation and internal gains, and has operated reliably as designed. Improvements in operating conditions were immediately noticed by the restaurant employees and customers. Specifics of the system performance are given below.

Evaluation of the Two-Wheel Desiccant System Demonstration

The objective of this demonstration was to evaluate the cost-effectiveness and energy conservation potential of the TWDS as it conditioned the air to the appropriate comfort level for the dining area occupants. The design concept was to separate the sensible (internal gains) and latent (ventilation and internal latent) cooling functions. The sensible cooling was handled by the existing 7.5-ton rooftop unit[f] and the latent cooling was accomplished by installing a new TWDS, which replaced the existing 5-ton rooftop unit. By separating the cooling functions, the effectiveness of the conventional vapor compression system and the desiccant-based system was maximized.

(d) A computer model developed by Trane Commercial Systems Group for building energy modeling.
(e) A design load analysis was performed by a design engineering firm using Trane Ultra Cooling Load Program. Refer to the Desiccant Technology Transfer Workshop Manual, American Gas Cooling Center, Arlington, Virginia, for more details (Meckler et al. 1995).
(f) The ductwork was modified to distribute this capacity to the entire dining area.

The TWDS, as shown in Figure 1, combines a rotary desiccant wheel with a high-effectiveness rotary heat-exchanger wheel. This combination, described in the Energy Savings Mechanism section, transfers some of the “sensible penalty” associated with desiccant wheel over to the regeneration air stream. The unit uses a propane-fired steam boiler for the remainder of the regeneration heat, which is housed within the desiccant unit. The TWDS operates in a make-up mode, shown in Figure 3c. The outside air is passed through the desiccant-wheel where it is dehumidified and then cooled as it passes through the sensible heat-wheel. The warm dry air is directed to the conditioned space by its own concentric diffuser at ceiling level, and the return air is cooled by the existing 7.5-ton packaged rooftop unit. The dry air from the TWDS and the cool air streams only mix inside the dining area.

Preliminary Monitored Data from the Two-Wheel Desiccant System

Several variables were recorded at 15-minute data intervals from August 1994 through January 1995. The daily average outdoor air and process air dry-bulb temperatures for the cooling season are shown in Figure 5. As the outdoor air was dehumidified it became warmer. Because the source for the regeneration air stream was also the outdoor air, the process air dry-bulb temperature was higher than the outdoor air temperature (the heat exchanger effectiveness was less than 1).

The daily average moisture content for outdoor air and process air streams for the cooling season are shown in Figure 6. With the exception of the first two weeks of operation, the moisture content of the process air stream stayed between 40 and 60 grains. The daily average electric demand was around 4 kW[g] (Figure 7), and the daily average gas consumption was around 30 ft^3/h. The gas consumption in October reflects the nighttime heating energy consumption (Figure 8).

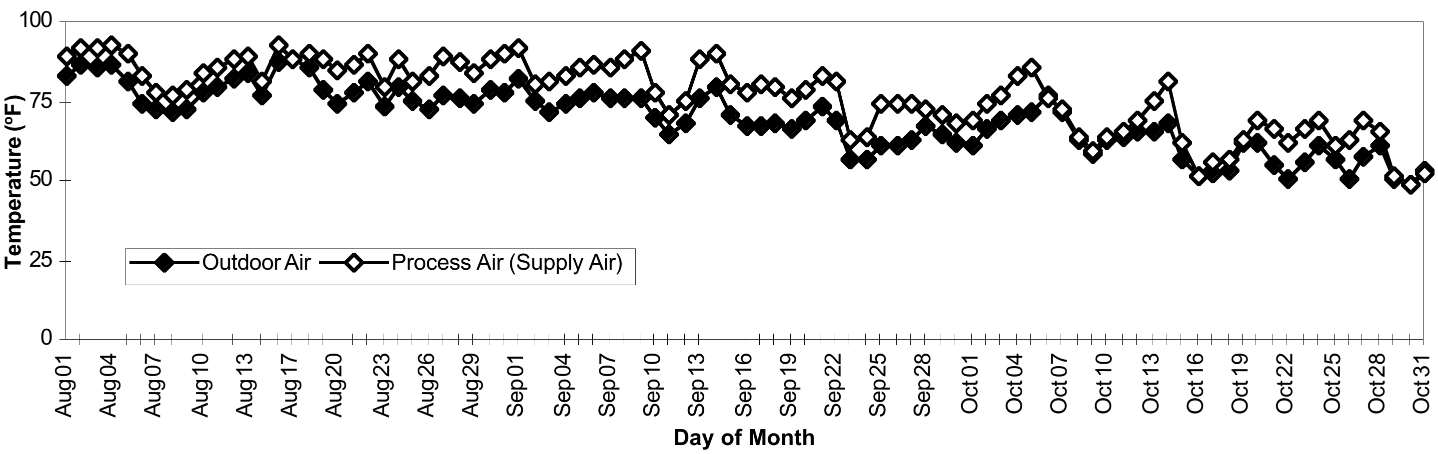


Fig. 5. Daily Average Outdoor Air and Process Air Dry-Bulb Temperatures

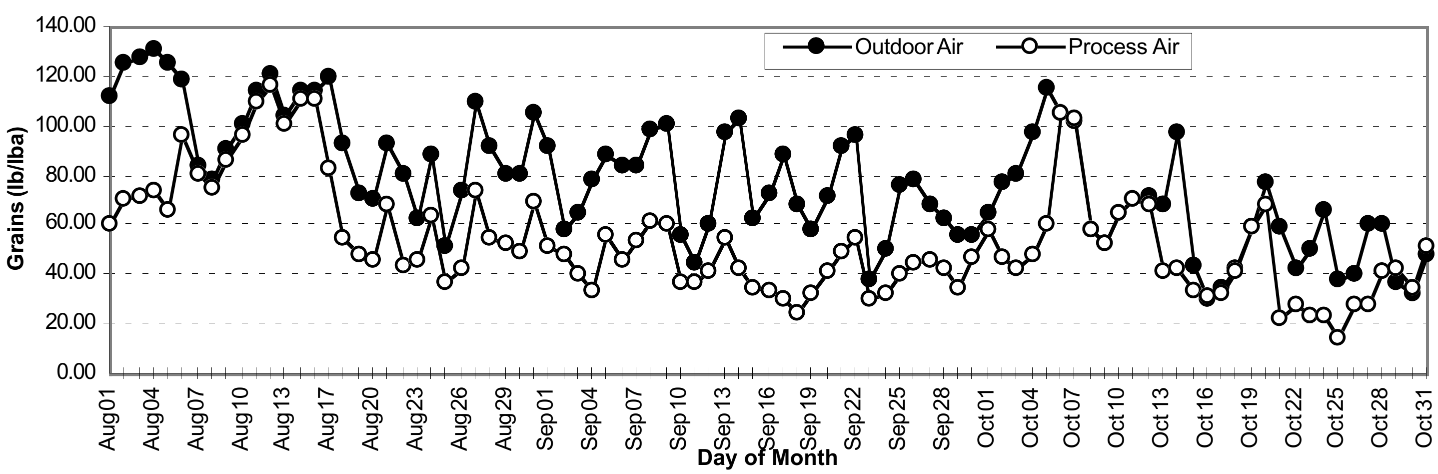


Fig. 6. Daily Average Outdoor Air and Process Air Humidity Ratios

(g) The conventional 5-ton system that was replaced with TWDS would have consumed between 6 kW and 7 kW.

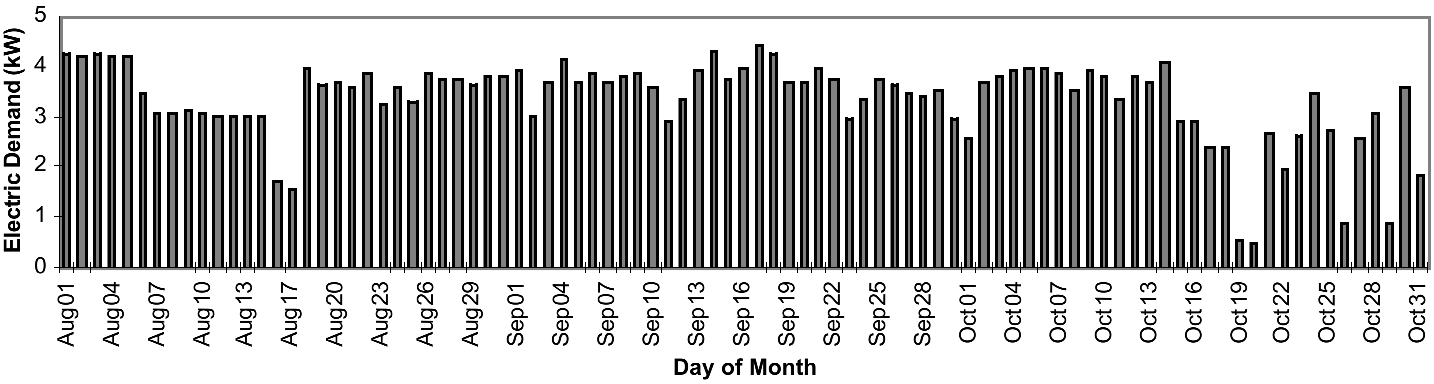


Fig. 7. Daily Average Electricity Demand Consumption

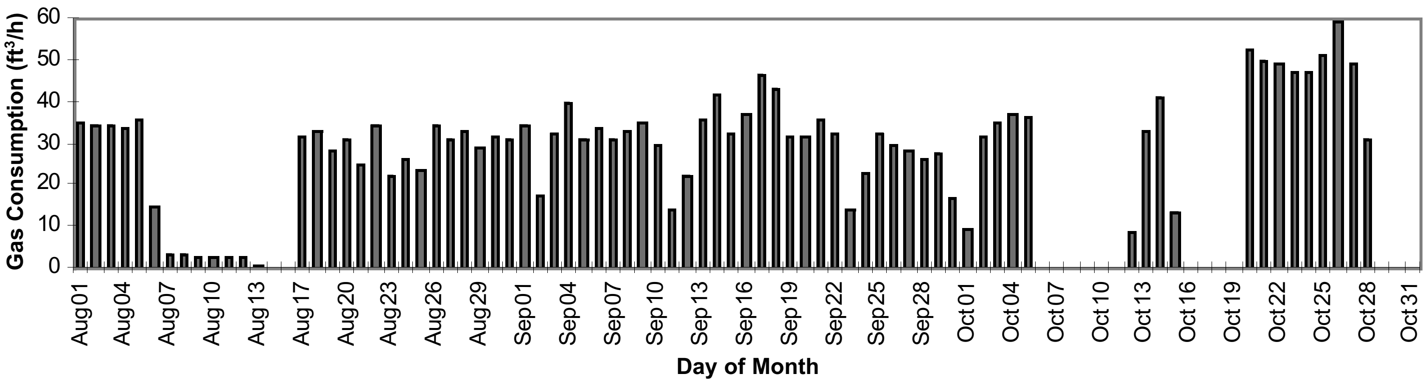


Fig. 8. Daily Average Gas Consumption

Implementation Barriers

The first cost of a desiccant system is higher than that of a conventional system. To offset this disadvantage, innovative designs using hybrid systems are often required. According to Mei et al. (1992), the impediments to use of desiccant-based systems are lack of familiarity with the technology and lack of assurance and education about the performance and cost-effectiveness of hybrid systems. This Technology Alert has addressed some of these issues. Federal energy managers who are familiar with the TWDS are listed below in the Who is Using the Technology section. The reader is invited to ask questions and learn more about the technology.

The Technology in Perspective

The desiccant technology in general and the two-wheel desiccant system technology in particular has a good potential in the Federal sector because it not only reduces operating costs but also improves indoor air quality. The technology is especially useful for conditioning storage spaces, ice arenas that operate in summer, hospital operating rooms, and most supermarkets. In a situation where the existing conventional system is unable to provide sufficient latent capacity, a TWDS can be integrated with the existing system. In such a situation, the first cost usually favors a TWDS over a conventional system. It is not economical to install a desiccant system in situations where the design space dew-point requirement is higher than 50°F, or where the latent to total capacity ratio is less than 25%.

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Manufacturers

Commercial Desiccant System

Engelhard/ICC
441 North Fifth St.
Philadelphia, PA 19123
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Munters DryCool
16900 Jordan Road
Selma, TX 78154
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e-mail: cargo@munters.com
Web Page URL: http://
www.munters.com/

New Thermal Technologies Inc.
12900 Automobile Blvd.
Clearwater, FL 34622
Phone: (813) 571-1888
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Octagon Air Systems
1724 Koppers Road
Conley, GA 30017
Phone: (404) 608-8881
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Seasons 4, Inc.
4500 Industrial Access Road
Douglasville, GA 30134
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www.smartpages.com/bryair/

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www.kathabar.com/

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Phone: (813) 828-5340

Navy Public Works Center,
Naval Air Station
Pensacola, FL
Contact: **John Geurin**
Phone: (904) 452-3127

Defense Commissary Agency,
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American Gas Cooling Center
(Gas Cooling Industry Sales & Marketing)
Contact: **Kevin McGahey**
Phone: (703) 841-8542
Web Page URL: http://
www.agcc.org/

For Further Reading

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About the Federal Technology Alerts

The Energy Policy Act of 1992, and subsequent Executive Orders, mandate that energy consumption in the Federal sector be reduced by 30% from 1985 levels by the year 2005. 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 Federal Technology Alerts (FTAs) that provide summary information on candidate energy-saving technologies developed and manufactured in the United States. The technologies featured in the Technology Alerts have already entered the market and have some experience but are not in general use in the Federal sector. Based on their potential for energy, cost, and environmental benefits to the Federal sector, the technologies are considered to be leading candidates for immediate Federal application.

The goal of the Technology Alerts is to improve the rate of technology transfer of new energy-saving technologies within the Federal sector and to provide the right people in the field with accurate, up-to-date information on the new technologies so that they can make educated judgments on whether the technologies are suitable for their Federal sites.

Because the Technology Alerts are cost-effective and timely to produce (compared with awaiting the results of field demonstrations), they meet the short-term need of disseminating information to a target audience in a timeframe that allows the rapid deployment of the technologies—and ultimately the saving of energy in the Federal sector.

The information in the Technology Alerts typically includes a description of the candidate technology; the results of its screening tests; a description of its performance, applications and field experience to date; a list of potential suppliers; and important contact information. Attached appendixes provide supplemental information and example worksheets on the technology.

FEMP sponsors publication of the Federal Technology Alerts to facilitate information-sharing between manufacturers and government staff. While the technology featured promises significant Federal-sector savings, the Technology Alerts do not constitute FEMP's endorsement of a particular product, as FEMP has not independently verified performance data provided by manufacturers. Nor do the Federal Technology Alerts attempt to chart market activity vis-a-vis the technology featured. Readers should note the publication date on the back cover, and consider the Alert as an accurate picture of the technology and its performance at the time of publication. Product innovations and the entrance of new manufacturers or suppliers should be anticipated since the date of publication. FEMP encourages interested Federal energy and facility managers to contact the manufacturers and other Federal sites directly, and to use the worksheets in the Technology Alerts to aid in their purchasing decisions.

Federal Energy Management Program

The Federal Government is the largest energy consumer in the nation. Annually, in its 500,000 buildings and 8,000 locations worldwide, it uses nearly two quadrillion Btu (quads) of energy, costing over $8 billion. This represents 2.5% of all primary energy consumption in the United States. The Federal Energy Management Program was established in 1974 to provide direction, guidance, and assistance to Federal agencies in planning and implementing energy management programs that will improve the energy efficiency and fuel flexibility of the Federal infrastructure.

Over the years several Federal laws and Executive Orders have shaped FEMP's mission. These include the Energy Policy and Conservation Act of 1975; the National Energy Conservation and Policy Act of 1978; the Federal Energy Management Improvement Act of 1988; and, most recently, Executive Order 12759 in 1991, the National Energy Policy Act of 1992 (EPACT), and Executive Order 12902 in 1994.

FEMP is currently involved in a wide range of energy-assessment activities, including conducting New Technology Demonstrations, to hasten the penetration of energy-efficient technologies into the Federal marketplace.

FEDERAL ENERGY MANAGEMENT PROGRAM

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