ENERGY-EFFICIENT ELECTRIC DEHUMIDIFICATION SYSTEM #6234

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High operating costs associated with conventional electric dehumidification have made fossil-fuel fired desiccant dehumidification technology appealing to building owners and operators. Electric dehumidification however, is more effective than desiccant dehumidification when applications exceed 40 percent relative humidity.

This paper describes an energy-efficient electric dehumidification product that integrally incorporates an air-to-air heat exchanger for energy recovery and a modulating bypass feature for variable latent/sensible cooling control. This paper also summarizes the results of development work conducted since 1985, with primary focus on the technical lessons learned. Dehumidifier system performance characteristics are discussed and the benefits of the dehumidification technology, including potential energy savings, are detailed. The final research, development and demonstration plan for the dehumidification system is also presented here.

INTRODUCTION

The new product is an energy-efficient humidity and temperature control system intended for use in applications such as supermarkets, manufacturing facilities, indoor swimming pools, health care facilities, department stores and other commercial facilities. The system has been successfully field tested in a number of applications since 1985, and has been shown to use one-half the energy of conventional electric dehumidification systems. In addition, the system has minimal air and water flow requirements and a high degree of reliability. U.S. and Canadian patents have been granted.

DESCRIPTION OF THE TECHNOLOGY

The self-regulating humidity and air temperature control system for indoor swimming pools, supermarkets and other humidity control applications comprises a circulating fan, a series of plenums and an air-to-air heat exchanger. Warm, humid air is drawn through one side of the air-to-air heat exchanger by the fan, for precooling and dehumidification by thermal exchange with cooler air prior to passage through a dehumidification and cooling coil. The dehumidified and cooled air is then drawn back through the opposite side of the air-to-air heat exchanger to be heated. A set of dampers operated by an actuator and controlled by a room temperature controller allows air to bypass the heat exchanger to regulate the amount of air that passes through the heat exchanger according to increases and decreases in room temperatures from sensible heat sources such as solar heat gain, interior lighting, and body temperature.

Figure 1 depicts conventional electric dehumidification technology which uses an ordinary vapor compression cycle to dehumidify, cool and reheat the air. Conditions entering the dehumidification and cooling coil require sufficient energy to lower air temperature by 42° Fahrenheit. The air is then reheated to room temperature through the condenser coil.

In comparison, Figure 2 depicts the new product which also uses an ordinary vapor compression cycle. However, conditions entering the dehumidifying cooling coil require cooling capacity to lower the air temperature only 16° Fahrenheit as compared with 42° Fahrenheit with the conventional dehumidifier.

Lower coil entering conditions are the result of precooling and dehumidification through the air-to-air heat exchanger which is innovatively combined with an ordinary vapor compression cycle to achieve extraordinary performance. In the conventional dehumidifier, a bypass around the cooling coil provides the balance of air needed to meet the requirements of the condenser coil which is twice that required with the new product.

Figure 3 depicts the details of the dehumidification module of the new product. This unit includes two stages of heat exchange and a damper arrangement for regulating discharge air temperature for cooling and dehumidification. All components used in this unit are commercially available.

BENEFITS

The key benefits of the energy-efficient technology are best understood when compared with conventional electric dehumidification technology. First, like conventional systems, the energy-efficient technology uses an ordinary vapor compression cycle. However, in the energy-efficient dehumidifier described in this paper, lower temperature air enters the cooling coil as a result of precooling and dehumidification through an air-to-air heat exchanger. This innovative combination of a plate type air-to-air heat exchanger and an ordinary vapor compression cycle results in reduced compressor capacity, thus the system requires only one-half the power of conventional systems when operating in the dehumidification mode.

A second key benefit can be seen through an analysis of air flow. While the air volume across the dehumidification cooling coil is the same in both the energy-efficient and conventional systems, a conventional dehumidifier incorporates a bypass around the cooling coil to provide the balance of air needed to satisfy the greater requirements of the condenser coil. The total air volume is twice that required with the energy-efficient system and results in an increase in the capital cost and size of the air duct system.

The new product improves upon conventional air conditioning systems by regulating the air conditioning discharge temperature and humidity to meet the fluctuating humidity and temperature requirements of different applications. The new product automatically adjusts to room conditions by responding to input from both room temperature and humidity, thereby providing the means for total control over comfort, while optimizing energy use.

NEEDS ASSESSMENT

Throughout North America, electric utility companies are sponsoring energy conservation incentive programs to promote the application of energy efficient lighting, motors, variable speed drives, window surface film and other techniques that reduce internal sensible heat gain and cooling loads. These techniques produce significant reduction in the operating hours of cooling equipment, which results in substantial energy savings.

However, in conventional air conditioning systems, reduced cooling operating hours lead to higher indoor humidity which is typically remedied by reheating air after it is cooled and dehumidified. This effectively forces the cooling equipment to run longer by replacing the internal sensible heat eliminated in the conservation effort.

Humidity is fundamental to human comfort, yet conventional air conditioning systems control only temperature. Conventional air conditioning systems produce excess humidity most of the time.

As the emphasis on humidity control grows, these efficient systems will allow electric utilities to compete more effectively with fossil fuel-based desiccant systems, that are more suited for controlling relative humidity below 30 percent.

The new product provides significant potential for rapid market entry because the technology is understood and accepted by the network of Air Conditioning and Refrigeration service and installation companies, currently in-place.

PRIOR RESEARCH

Air-to-air exchange has been used in humidity control applications for more than 50 years. Early applications included a low efficiency "Run-around cycle" for humidity control, which is depicted in the Trane air conditioning manual.

The conventional vapor compression cycle was one of the first commercial humidity control systems used. By cooling the air below its dew point, condensing moisture and then reheating, close humidity control can be attained. It may appear that the "free heat" produced by the compressor (heat of compression) and used for air reheating results in optimum energy effectiveness. However, when comparing conventional vapor compression dehumidifiers with the new product, it becomes apparent that what appears obvious is deceiving. Close observation reveals that the new product requires one-half the energy and air volume of comparably sized conventional dehumidifiers because the air-to-air heat exchanger recovers 50 percent of the enthalpy difference between its passes, providing precooling and dehumidification at virtually no expense.

The commercial availability of high efficiency plate type air-to-air heat exchangers in the early 1970's opened the door to their greater use in humidity control applications. The first applications used plate type air-to-air heat exchangers as a means to recover waste heat from dilution ventilation applications.

It was in the process of designing a dilution ventilation system for humidity control in a large indoor swimming pool early in the 1980's that new product's inventor developed the concepts that merged two different technologies (air-to-air heat exchangers and a vapor compression cycle) in a synergistic combination.

In 1986, a favorable evaluation of this system prototype was performed by the National Bureau of Standards under a United States Department of Energy (DOE) grant program. With respect to indoor swimming pools, the study stated "The invention has the potential to save .39 million barrels of oil equivalent per year on the national scale if 5000 pools of 4300 square feet area each are equipped with this invention." The report continued "Based on expected payback period of one year and a large existing market, commercial feasibility seems assured."

In 1989, a U.S. DOE grant was awarded to provide a pre-production prototype demonstration project. A system has been built and is awaiting installation at one of many demonstration sites under consideration. The system is designed to remove 135 pounds per hour at 82^{0} Fahrenheit and 50 percent relative humidity.

FUTURE RESEARCH, DEVELOPMENT AND DEMONSTRATION

A two year project sponsored by the New York State Energy Research and Development Authority (Energy Authority) and the Empire State Electric Energy Research Corporation (ESEERCO) to design, develop, manufacture and field test production-prototype units will begin in mid-1992. One field test is planned for dehumidification in the 40 to 50 percent range such as is found in supermarkets, while another is planned for dehumidification in the 50 to 60 percent range such as is found in indoor swimming pools (natatoriums).

Adequate supermarket dehumidification can provide significant energy savings. Lowering store humidity to the 40 to 45 percent range discourages ice buildup on refrigeration coils, and thereby reduces energy-intensive defrost cycles. Lower humidity also lessens the need for electric defrost heaters on refrigeration case doors.

According to information provided by the Electric Power Research Institute (EPRI), Supermarkets account for 4 percent of the energy consumed in the United States. Refrigeration equipment accounts for 54 percent of supermarket energy consumption. It is estimated that more than 18 percent of supermarket energy use attributed to refrigeration can be conserved through more efficient dehumidification.

Another area for energy savings is in indoor swimming pools, which typically use a water source heat pump to simultaneously heat pool water and dehumidify room air. The coefficient of performance (COP) for these heat pumps using conventional electric dehumidification technology is about 2.0, a value which is not competitive with fossil fuels. In addition, the low COP and a year-round requirement for pool water heating have made indoor pools a prime target for cogeneration systems. The new electric dehumidification technology described herein, which has a COP of 4.0 or better, will allow electric to compete with fossil fuel cogeneration.

This research project will conclude with an extensive technology transfer effort which will include the production of a video tape, an informational display, a marketing package, and a final report published by the Energy Authority.

CONVENTIONAL DEHUMIDIFIER

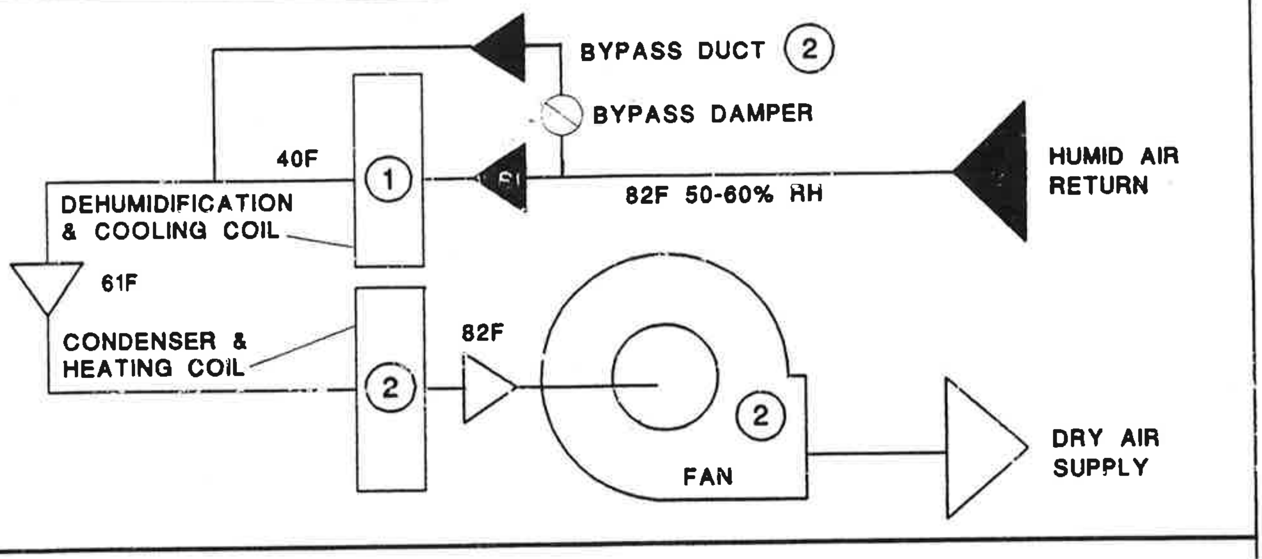


Fig. 1

(1) DEHUMIDIFICATION/COOLING COIL REQUIRES SUFFICIENT COMPRESSOR COOLING POWER TO REDUCE AIR TEMPERATURE BY 42F. THE NEW DEHUMIDIFIER REQUIRES COMPRESSOR POWER FOR ONLY 16F.

(2) SYSTEM AIR VOLUME IS DICTATED BY THE HIGH REQUIREMENTS OF THE CONDENSER/HEATING COIL. EXCESS AIR IS BYPASSED AS SHOWN. THE NEW DEHUMIDIFIER DOES NOT REQUIRE A CONDENSER/HEATING COIL.

NEW DEHUMIDIFIER

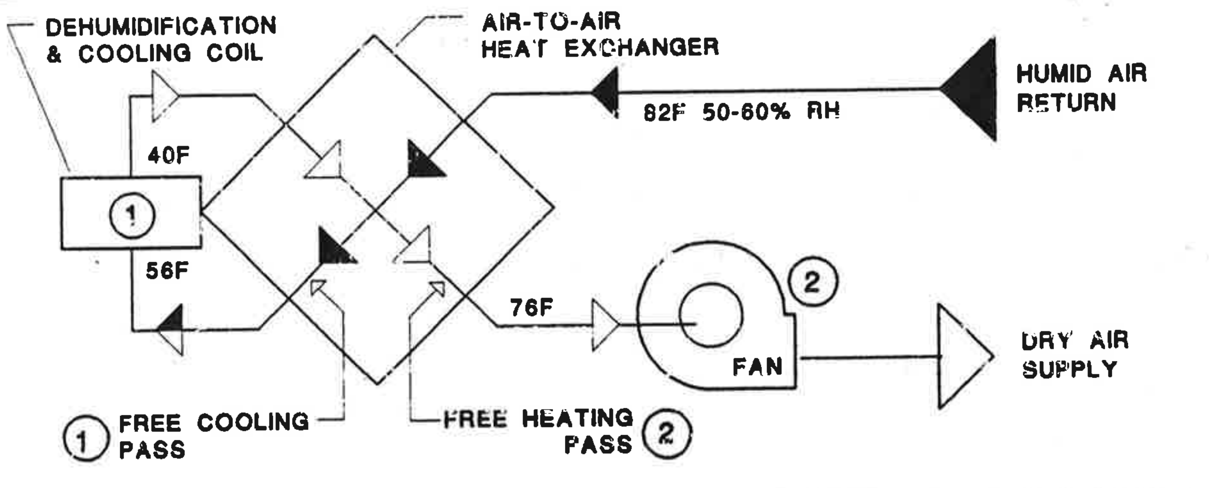


Fig. 2

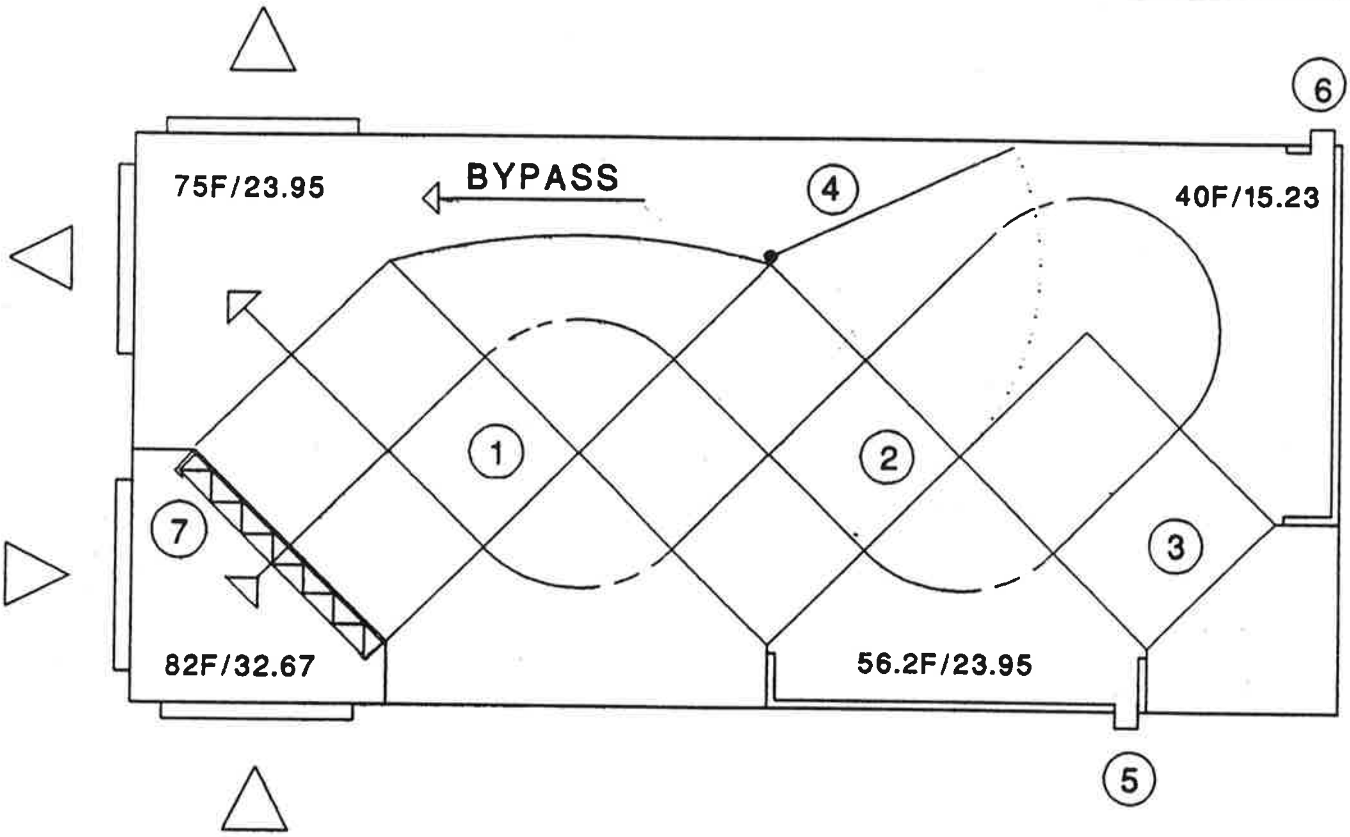
(1) FREE-COOLING FEATURE REDUCES THE DEHUMIDIFICATION/COOLING COIL LOAD AND THEREBY LOWERS COMPRESSOR COOLING POWER. CONSEQUENTLY...

ENERGY CONSUMPTION = 1/2 CONVENTIONAL

(2) FREE-HEATING FEATURE ELIMINATES THE NEED FOR A CONDENSER/HEATING COIL AND THE HIGH AIR VOLUME ASSOCIATED WITH IT. CONSEQUENTLY...

AIR VOLUME = 1/2 CONVENTIONAL

DEHUMIDIFIER MODULE



LEGEND
(1) HEAT EXCHANGER, STAGE 1
(2) HEAT EXCHANGER, STAGE 2
(3) DEHUMIDIFICATION/COOLING COIL
(4) FACE AND BYPASS DAMPER
(5) DRAIN CONNECTION, HORIZONTAL
(6) DRAIN CONNECTION, VERTICAL
(7) 2 INCH AIR FILTER

Figure 3