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Thermally Activated Desiccant Technology for Heat Recovery and Comfort

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Desiccant cooling is an important part of the diverse portfolio of Thermally Activated Technologies (TAT) designed for conversion of heat for the purpose of indoor air quality control. Thermally activated desiccant cooling incorporates a desiccant material that undergoes a cyclic process involving direct dehumidification of moist air and thermal regeneration. Desiccants fall into two categories: liquid and solid desiccants. Regardless of the type, solid or liquid, the governing principles of desiccant dehumidification systems are the same. In the dehumidification process, the vapor pressure of the moist air is higher than that of the desiccant, leading to transfer of moisture from the air to the desiccant material. By heating the desiccant, the vapor pressure differential is reversed in the regeneration process that drives the moisture from the desiccant. Figure 1 illustrates a rotary solid-desiccant dehumidifier. A burner or a thermally compatible source of waste heat can provide the required heat for regeneration.

A desiccant device can operate in concert with an indirect and/or direct evaporative cooling unit to efficiently meet the sensible and latent cooling loads of a building. Studies have demonstrated the applicability of such cooling equipment to a wide range of climatic conditions. Desiccants can also be integrated with conventional (vapor compression) air-conditioning systems to independently meet the dehumidification loads and eliminate the need for an inefficient process of overcooling and reheating, which is inherent with conventional systems. Implementation of desiccant technologies are particularly attractive to health-care facilities, highly ventilated buildings in humid climates, and industrial facilities with strict humidity control requirements. Together, desiccants and other TAT for heating and cooling can meet a significant portion of the national space heating/cooling demand, which represents about one-third of the U.S. primary energy

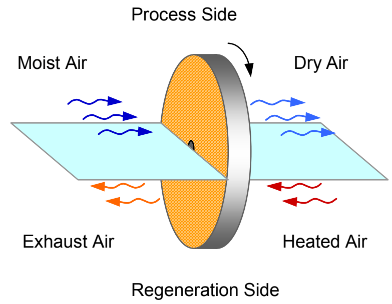

Figure 1. Rotary solid-desiccant system.

consumption for residential and commercial buildings.

When implemented in the context of combined heat and power (CHP), also known as cogeneration, TAT can significantly improve fuel efficiency/utilization through heat recovery from the on-site power generators. This thermal recovery leads to a significant reduction in emissions as well. The recent initiatives for developing output-based emission standards recognize the environmental implications of such energy efficient systems. The availability of desiccant materials with regeneration source temperatures typically ranging from about 160°F (70°C) to 300°F (150°C) reflects the compatibility of desiccant technologies with various types of on-site generators, including reciprocating IC engines, micro-turbines, and certain types of fuel cells. Cascading desiccant cooling with another compatible technology, such as absorption cooling, further enhances the overall system fuel efficiency and utilization. In general, cascading allows sequential heat recovery from a single heat source for driving two or more thermally activated systems with different operating temperatures to achieve higher first- and second-law efficiencies.

An interesting implication of CHP/TAT formation has to do with cost-effective improvement of indoor air quality. CHP systems that are primarily designed and sized to meet the entire or a significant portion of the electric demand often generate thermal output in excess of the minimum amount required to provide space air conditioning via TAT. In these circumstances, the indoor air quality and, hence, the comfort level can be enhanced in an energy efficient manner, which may not be economical otherwise.

Figure 2 depicts a CHP system installed at a Waldbaums supermarket in New York. The system incorporates a 60-kW micro-turbine for onsite power generation and a gas-to-liquid heat exchanger for heat recovery from the exhaust gas for space heating and desiccant dehumidification, depending on the season. A gas compressor is used to boost the natural gas pressure to the operating pressure of the microturbine combustor. Figure 3 illustrates the air-handling unit (AHU) incorporating a desiccant wheel, a DX cooling coil, and a heating coil. A glycol solution leaving the heat exchanger at about 180°F (82°C) preheats the regeneration air, which is further heated by a gas burner to about 275°F (135°C) for regeneration of the desiccant as needed. In the heating season, the hot liquid is circulated through the space-heating coil instead (Figure 3).

The performance of the CHP system (Figure 2) was monitored for more than 1 year. Based on the higher heating value of natural gas, the overall efficiency of the CHP system could exceed 50% on humid summer days, compared to the corresponding net electrical efficiency of about 21% to 23%. Higher efficiencies were reported for the heating season. (The efficiencies accounted for the parasitic energy use of the gas compressor and the glycol-solution circulating pump, as appropriate.) These results are reflective of the importance of TAT, without which the CHP systems reduce to power generators. (More information on CHP and related initiatives are available at http://www.uschpa.org and http://www.eere.energy.gov/de/.)

The importance of TAT extends well beyond the realms of energy conservation and environmental attributes – it also precipitates viable solutions with respect to other issues. A large-scale implementation of TAT can displace a significant portion of the electrical load induced by conventional air conditioning and refrigeration systems. This, in turn, alleviates electric grid congestion and helps end-users realize savings on electricity without having to shift the loads to off-peak periods. Whether in stand-alone or CHP installations, these technologies also provide an opportunity to utilize renewable energy, bio-fuels, and other alternative energy resources. Therefore, these technologies not only can enhance the ability of

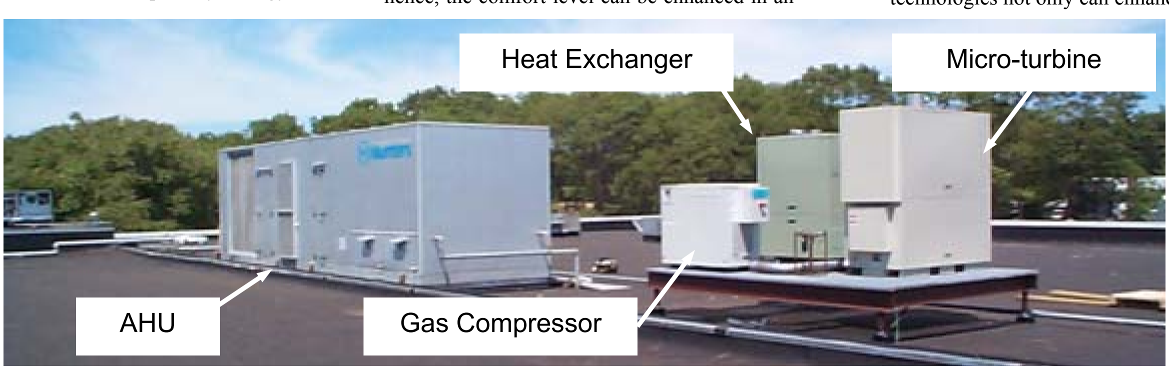

Figure 2. CHP system in Waldbaums supermarket (photograph courtesy of CDH Energy Corp.)

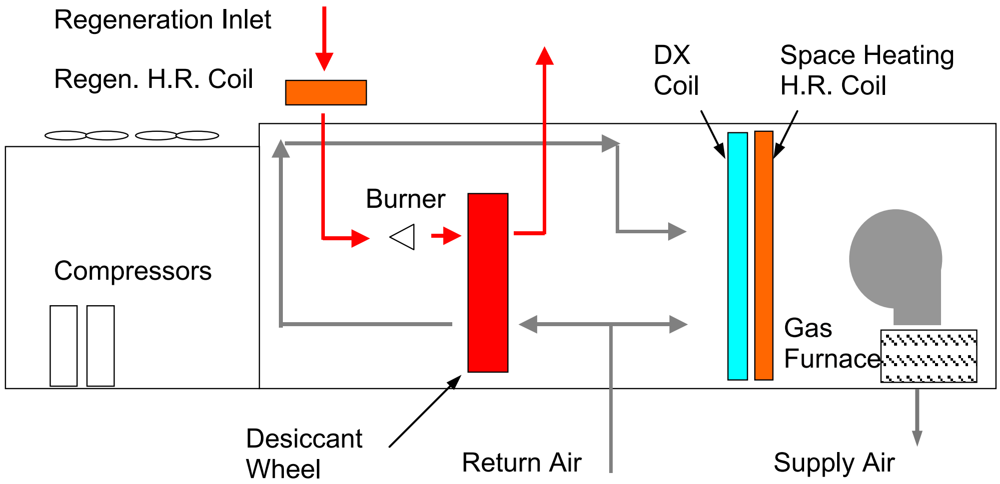

Figure 3. Schematic of air-handling unit

energy consumers in responding to energy pricing dynamics but can also enable them to proactively participate in the implementation of energy and environmental policies. These are the important attributes that constitute the market drivers for TAT.

However, in spite of their benefits, TAT are not currently in vogue, primarily because of their relatively high installation costs. To capture a larger market share, development and implementation of innovative, cost-effective, and efficient TAT is imperative. Also important is the integration of these technologies with other constituents (i.e., buildings and other energy systems) for achieving an optimum compromise between the overall energy efficiency and cost.

In pursuit of these objectives, the National Renewable Energy Laboratory (NREL) has undertaken significant R&D efforts to promote TAT, with emphasis on desiccant cooling, in collaboration with industry. Recognizing the importance of system integration, NREL has also embraced a "whole-system" approach that takes under consideration the design synergies and conflicts among key components and/or subsystems of buildings and energy systems.

For more information on related research activities at NREL, visit *http://www.nrel.gov/buildings_thermal/*.