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DESICCANT DEHUMIDIFICATION PERFORMANCE LESSONS

Michael K. West, Ph.D., P.E.
Building Systems Scientist
Advantek Consulting, Inc.

Glenn C. Haynes, P.E.
RLWAnalytics

ABSTRACT

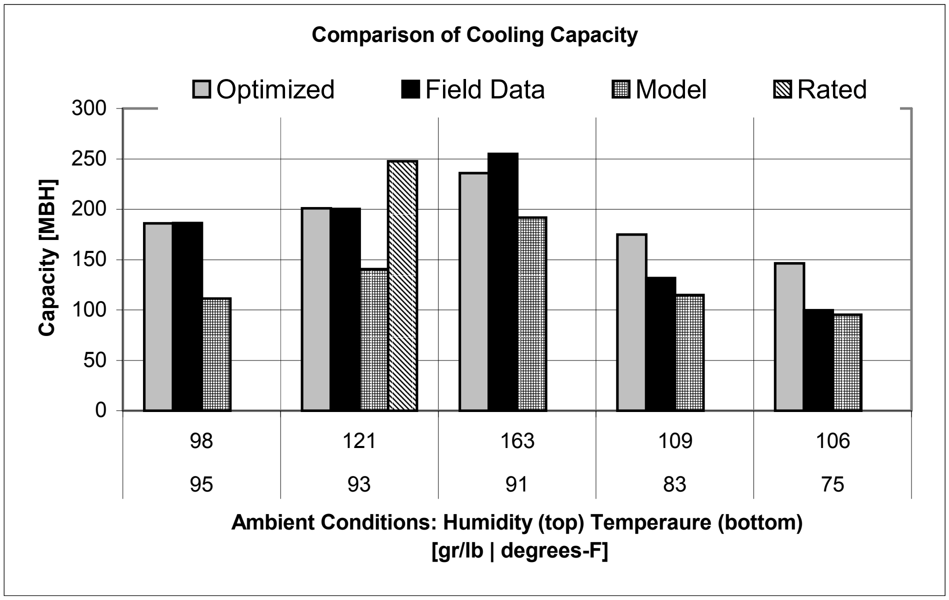
Desiccant dehumidification is primarily a non-residential end-use technology that can be important to certain commercial businesses such as restaurants, hotels, grocery stores and hospitals; in public buildings such as courthouses, jails and auditoriums; and in manufacturing sectors such as pharmaceuticals and microelectronics. This rigorous case study presents results of the field test and performance evaluation of a typical, commercially available, two-wheel gas-fired desiccant air conditioner. Field-measured performance is compared with the manufacturer's specifications, with predictions made using DOE-2 hourly modeling, with all-electric technologies, and with the theoretical limits of the technology. Comparisons were made between the manufacturer's published data, the manufacturer's site test data taken at the time of installation, the collected field data, the computer model, and theoretical best-case performance. The desiccant unit as installed delivers less cooling and dehumidification capacity than the manufacturer's rating, and much less than it would if the equipment design were optimized and the installation were commissioned. While the measured energy efficiency at peak load conditions is better than rated, the data clearly shows this rating is not representative of long-term field performance.

BACKGROUND

A field test was initiated to demonstrate and evaluate natural gas desiccant technology in the commercial market segment as a means of controlling weather-sensitive kW electric demand. The serving Florida investor owned utility, in cooperation with the local gas company, randomly selected and then recruited a commercial customer. The customer installed a new gas desiccant dehumidification system as an alternate technology to the existing electric-DX overcooling / electric reheating system. Advantek Consulting, Inc. was tasked, as an independent third party, with collecting and analyzing field performance data in light of the manufacturer's published data and the results of computer modeling. The customer paid for purchase and installation, which occurred in September-October of 1996. The manufacturer started the equipment on October 29, 1996 and it has been in continuous operation since that date.

FIELD TESTING

The dehumidification equipment, as well as key components of the building's heating, ventilation, and air-conditioning (HVAC) system were fitted with an instrumentation package to continuously monitor both overall system and sub-level component performance. The field monitoring system collects 1-hour interval data for 35 points. The most current set of data includes electric kWh and natural gas CF consumption, and ambient, space, and system temperatures and humidities. The customer integrated operation of the unit into the existing building management system, and is responsible for all maintenance and repairs.



The collected data were screened and used in the calculation of secondary quantities such as the amount of dehumidification capacity delivered, the quantity of moisture removed from the air and the energy efficiency of the equipment. These quantities were used to assess the performance of the unit as compared with the manufacturer's published performance data. The manufacturer's rated cooling capacity at the peak load condition is 248 MBH[1], however, the average as-installed capacity was measured to be considerably lower at 155 MBH.

The manufacturer's rated efficiency at the peak load condition (93 degrees-F dry-bulb / 78 wet-bulb) is COP[2] 0.73; the measured efficiency at this condition was COP 0.83. However, the average as-installed efficiency was measured to considerably lower than the rated efficiency at COP 0.53. The cooling capacity at peak load was measured to be 19% less than the manufacturer's rating. The heat input at peak load was measured to be 12% less than rated. In comparison, the optimized efficiency of this type of equipment is much higher at COP 1.0 to 1.2.

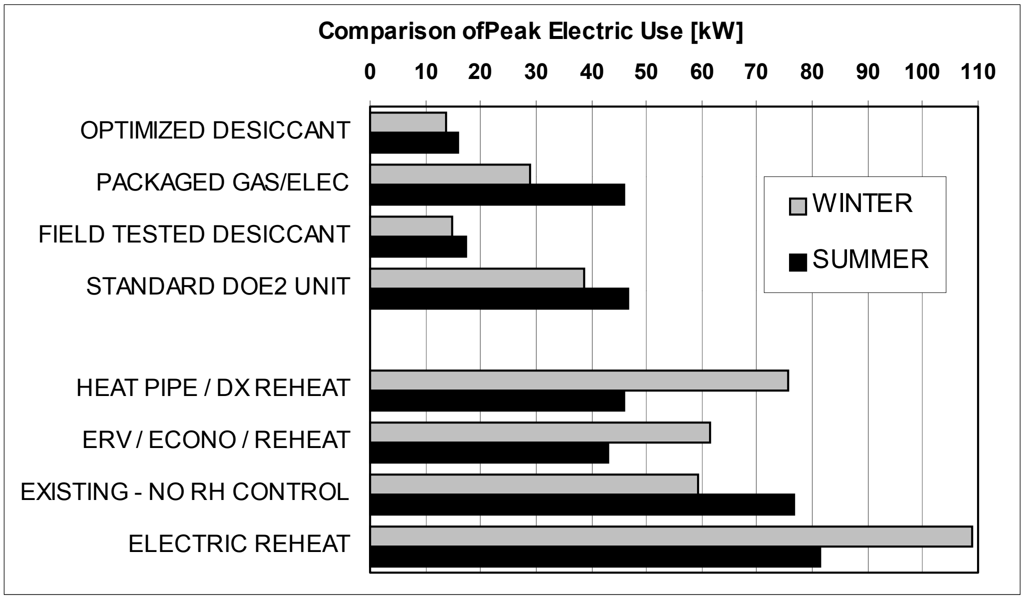
As designed and installed, the gas dehumidification unit is not optimized nor does it represent the maximum efficiency potential of desiccant equipment. Even so, it does (in our opinion) represent a "typical" commercial installation. The simple gas boiler control does not have the ability to vary heat output, and thus gas consumption, according to the need for dehumidification. The boiler is either full on or shut off, and the data clearly shows it unnecessarily operates full on almost constantly. Our data indicates that less than 60% of the natural gas energy consumed by the unit is actually utilized. Likewise, the evaporative cooler is not nearly as effective as currently available types. The analysis also indicates the possibility of moisture carry-over from the regeneration side evaporative cooler to the process side via the heat wheel.

Control of the unit is based simply on supply air temperature, and to a lesser degree humidity. The data clearly shows that control sequence does not take into account the cooling needs of the building; it aims merely to supply air at a fixed temperature regardless of whether additional mechanical cooling or reheating is necessary downstream.

COMPUTER MODELING

The most complete, representative, accurate and reliable contiguous sets of data were used to develop, calibrate and validate an hourly computer model. These sets included 55 days of hourly data from various periods of the project, a total of some 46,000 data points. Performance was evaluated using results from these sets of screened field data, and a full-year set of computer model results as driven by the serving utility company's typical 30-year hourly weather data.

[1] MBH = 1,000 Btuh = 0.083 tons
[2] COP = (Btuh Capacity) / (Btuh Gas and Electric Input)



The hourly computer model consists of a set of sub-models for each of the components of the system. These component sub-models, such as the evaporative cooler and the desiccant wheel, are assembled together to simulate the performance of the equipment as a whole. Each sub-model was used to simulate the performance of a single component for each of the 8,760 hours in the typical weather year.

As a final check, the results of the model were compared against the standard DOE-2.1e hourly simulation software developed by the U.S. Department of Energy. A static comparison and validation was also performed at the outdoor temperature / humidity conditions published in the manufacturer's equipment performance specifications. Comparisons were made between the manufacturer's published data, the manufacturer's site test data taken at the time of installation, the collected field data, the computer model, and theoretical best-case performance.

Two baseline options were developed to simulate comparable all-electric dehumidification equipment commonly used in the commercial sector. The baseline computer model simulates the existing electric-DX overcooling / electric reheating system, and alternatively, two all-electric packaged roof-top system configurations that satisfy the Florida Energy Code criteria of minimizing/avoiding the use of new energy for reheat. The first unit incorporates an energy recovery wheel (ERV) and an economizer function, and the second is equipped with wrap-around heat-pipes and condenser waste heat recovery. The results of these models were also checked against the standard DOE-2.1e hourly simulation software.

RESULTS

The desiccant unit as installed delivers less cooling and dehumidification capacity than the manufacturer's rating, and much less than it would if the equipment design were optimized and the installation were commissioned. The unit consumes less energy than rated, however, it consumes considerably more than it would with optimization and commissioning. *While the measured energy efficiency at peak load conditions is better than rated, the data clearly shows this rating is not representative of long-term field performance.* In contrast to all-electric cooling equipment, the efficiency of this type of unit tends to decrease, as conditions become less humid and cooler. Since peak load conditions are experienced only a fraction of the time, the average efficiency is considerably lower than the rated efficiency. *Furthermore, the measured decline in performance with decreasing cooling load – when dehumidification is most critical – is more severe than would be expected.*

On the plus side, the primary benefit of installing the unit to the customer has been decreased humidity and increased ventilation for building occupants. The desiccant unit has provided this improvement at annual energy & maintenance savings of about 30-percent per year as compared with achieving a similar improvement with the existing all-electric overcool/reheat equipment. The desiccant unit could provide the same level of comfort as existed before its installation (no improvement in humidity or ventilation) at annual energy & maintenance savings of about 16-percent. The peak demand of the desiccant unit is 15 kW, as compared with 77 kW for the existing equipment. The incremental cost of the desiccant installation will pay back in roughly seven years.

Two all-electric packaged rooftop system alternatives that satisfy the Florida Energy Code criteria of minimizing/avoiding the use of new energy for reheat were also compared. Peak demand during cooling mode would be about 45 kW. A gas/electric package unit (not desiccant) would have provided an annual savings of about 30 percent, and a peak demand reduction from 77 kW to 46 kW. Any of these three options would payback in about 5 years.

The potential savings available from optimization and field commissioning of the existing desiccant unit is an additional 25-percent per year, increasing the total savings to about 42-percent as compared with the baseline.

ACCURACY

Minor inaccuracies in the results of the computer modeling results mostly from the assumption of linear behavior and use of linear equations in the model. Unlike most other HVAC components, the combined heat and mass transfer occurring in the desiccant wheel experiences hysteresis and non-linear transients. For example, during relatively humid conditions the wheel can remove significantly more humidity from the process air than it expels in regeneration. The wheel "stores" moisture in this manner typically over a period that can last hours, and sometimes days. Nonetheless, the average error between the measured field data and the computer predictions is just 7%.

Minor errors in the field data propagated from a number of sources: temperature sensor calibration error of ±0.8 to ±1.3 degrees F, plus airflow measurement error of ±50 fpm, plus dimensional measurement error of ±0.5 inches, plus relative humidity measurement error of ±4 %rh. These field data errors result in a sensible cooling capacity error of 11%, dehumidification capacity error of 25%, a total unit cooling capacity error of 15%, and an energy efficiency error of 18%. These errors were inherent to the sensors and equipment used, the use of "point" type rather than "averaging" RTD sensors, the sometimes large differential between point sensor reading and bulk flow conditions, and the different data averaging / sampling rate of the K20 and CS data loggers.

CONCLUSIONS

1. The long term as-installed performance of typical desiccant HVAC equipment may be less than expected in terms of both delivered capacity and energy efficiency.

2. Engineered improvements to the design and installation of typical desiccant HVAC equipment can provide large performance and cost benefits.

3. Field monitoring and computer analysis of HVAC equipment performance can reveal many cost effective energy saving measures.

AUTHOR BIO

As Building Systems Scientist with Advantek Consulting, Michael West performs IAQ/energy investigations, and identifies and designs energy-saving solutions for commercial, industrial, and federal clients. He also directs the development and testing of cutting-edge HVAC technologies. Previously, Dr. West served on the faculty of the University of Florida for seven years; and analyzed U.S. Navy submarine environmental systems for four years. He has a degree in Mechanical Engineering from the University of Maryland, a Doctorate from the University of Florida, and is a registered Professional Engineer. Dr. West was awarded the International Project of the Year by AEE in 1994 and has authored over 50 articles. He is an active member in ASHRAE and AEE. More information on Advantek can be had at www.advantekinc.com. Dr. West can be contacted at mwest@advantekinc.com.