A Desiccant Instruction Module for HVAC Courses

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Abstract

An instruction module covering introductory aspects of desiccant dehumidification for space conditioning is described. The module is self-contained and is suitable for use in university-level heating, ventilating, and air conditioning (HVAC) courses. It contains information that can be tailored by an instructor for a particular class, an extensive bibliography for additional information, and page-sized figures from which overheads can easily be made. Experiences in incorporating desiccant material into the Mississippi State University HVAC technical elective course are related.

Background

Desiccants, substances which extract water vapor from a moist air stream either by adsorption or absorption, have been available for a number of years, with the most familiar being silica gel. Likewise, HVAC desiccant systems have had niche markets for a number of years, but have been largely unknown outside of specialty HVAC applications. However, HVAC desiccant systems appear poised to make a substantial penetration into more conventional HVAC applications. A number of reasons exist for this increased interest in HVAC desiccant systems; among them are:

1. ASHRAE 62-l 989 which prescribes significantly increased ventilation requirements for buildings,
2. the prevalence of "sick building" syndrome,
3. demand for more efficient dehumidification of air,
4. CFC/HCFC/HFC issues,
5. flexibility in separating latent and sensible loads.

Most commonly-used textbooks in university-level air conditioning courses contain very little information on desiccants or desiccant systems (e.g. McQuiston and Parker, 1994, Clifford, 1984). Hence, there exists a need to provide to engineering educators a user-friendly, introductory-level module that can be easily inserted into an HVAC course.

Module Organization

The module is organized as a stand-alone package, complete with references and full-size figures suitable for overheads or slides. It is assumed that the students will have already covered basics of thermodynamics and of psychrometric and air conditioning processes. An effort was made to provide maximum flexibility to the instructor in adapting the material to the needs of a particular course. Thus, the module is divided into seven (7) topics. An instructor might use material from a just few of the sections to introduce the idea of desiccant dehumidification to the class or use material from all of the sections and from the bibliography to provide a more in-depth coverage. A description of each of the topics follows. Examples of the figures (reduced to half-size for this paper) from the module are included for each topic.

A. Motivation

This section briefly introduces some of the history, motivation, and typical applications of desiccant dehumidification. Figure 1 presents some current and traditional applications of desiccant dehumidification. The effect of relative humidity on comfort level is discussed. Potential health concerns associated with high humidity and condensation are described. Examples of some negative impacts and product degradation due to high humidity in service and process industries are included and discussed. Specific quantitative effects are shown for a few cases.

B. Sub-cooling Systems vs. Desiccant Systems

The principles of "cold-coil" dehumidification are reviewed. An example is described qualitatively and quantitatively and is shown on a psychrometric chart, included here as figure 2. Advantages and disadvantages of this approach to dehumidification are discussed. The general principles of desiccant dehumidification are then introduced. The dehumidification cycle is described and illustrated. Figure 3 shows the basic components of any desiccant dehumidification system. One model of the detailed function of a desiccant material is mentioned. The approximate path of process air through a desiccant device is shown on a psychrometric chart along with the earlier example from a cold-coil system. Several common desiccant system configurations are discussed and illustrated with system schematics and psychrometric charts.

C. Considerations in Choosing a Desiccant System vs. a Sub-cooling System

Capital and operating costs of systems which include desiccant dehumidification are discussed. Two published comparisons between costs of conventional systems and desiccant systems are cited and described. Several examples of other costs associated with poor humidity control such as odors and customer discomfort are described. Some of these are summarized in figure 4. The advantages of the additional flexibility inherent in independent control of temperature and humidity are discussed. An example comparing the annual latent and sensible cooling loads at a given location is cited and described. Finally, a detailed description of a "graphical evaluator" proposed by Harriman (1996) is given. This qualitative survey of the characteristics of a potential application provides a quick way to assess whether a desiccant-based system ought to be considered in more detail. Six areas are considered: economic benefits of low humidity, latent vs. sensible load, ventilation air requirements, installed cost of using exhaust air for post-cooling, site-specific utility costs, and economic benefit of dry duct work. These six areas are each described briefly.

D. Types of Desiccant Systems

Adsorption and absorption are explained, and factors important to the commercial utility of desiccant materials are discussed. Figure 5 summarizes this discussion. Characteristics of several solid adsorbents are mentioned, and several desiccant and air stream configurations for solid desiccant based systems are discussed and illustrated. Liquid absorbent systems are discussed briefly. Characteristics of several liquid absorbents are mentioned, and one basic system configuration is described. This section concludes with a short discussion of potential sources of regeneration energy.

E. Example Exercises and Analyses

Several sample exercises with solutions are included to illustrate some aspects of using the previously-presented material. These exercises range from simply plotting points on a psychrometric chart to performance analyses of desiccant dehumidification systems. One of the exercises is included below.

Exercise 2. Given that a Munters HCD-1125 dehumidification system can remove 30 lbs of water per hour from an air stream at 75 °F, 50% RH, 1125 CFM, determine the humidity ratio of the outlet air in grains/lbm_{da}.

solution: From a psychrometric chart, at the stated air condition, the humidity ratio is w=65 grains/lbm_{da} and the specific volume is 13.7 ft^3/lbm_{da}.
The mass flow rate of air is:

$$\frac{1125 ft^3/min}{13.7 ft^3/lbm_{da}} = 82\ 1\ \frac{lbm_{da}}{min}$$

The mass flow rate of moisture leaving the unit can be calculated as follows:

$$82.1\,\frac{lbm_{da}}{min} * 65\,\frac{grains}{lbm_{da}} * 60\,\frac{min}{hr} = 320{,}190\ \frac{grains}{hr}$$

$$320{,}190\,\frac{grains}{hr} - 30\,\frac{lbm}{hr} * 7000\,\frac{grains}{lbm} = 110{,}190\sim$$

The outlet humidity ratio is:

$$\frac{110,190\sim}{(82.1\frac{lbm_{da}}{hr})*(60\frac{min}{hr})} = 22.4\frac{grains}{lbm_{da}}$$

F. Equipment and Manufacturers

This section lists a representative sample of companies (with addresses and telephone numbers) which supply desiccant dehumidification equipment. Some limited information about product lines from each of the listed companies is included to give a feel for the range of capacity and performance that is available.

G. Case Studies

Two case studies of facilities that have recently included desiccant dehumidification in space conditioning applications are provided. The first study describes a 670,000 sq. foot warehouse where the original HVAC design specified 1,600 tons of cooling at a cost of $1.6 million. The redesigned system included natural gas-fired desiccant dehumidification units with a total capacity of 64,000 cfm resulting in a reduced cooling load of 650 tons. The installed cost of the redesigned system was $1.2 million. In addition, significant savings in utility costs were projected for the redesigned system.

The second study describes the renovation of a 40,000 sq. foot commissary. The renovation included adding a desiccant dehumidification system to address recurrent humidity problems in the building. The system was connected to the existing air conditioning system, and provides a total of 9600 cfm to the conditioned space. A psychrometric chart illustrating conditions for air passing through the desiccant system is included as figure 6. According to personnel in the commissary, the system has performed extremely well in the time that it has been in operation.

References and Bibliography

References for the material presented in the text are included, as well as references to several additional resources for broader or deeper information. In addition, an extensive bibliography contains 180 citations to recently published material on desiccant dehumidification ranging from general interest to applications to current scientific research.

Experiences and Conclusions

The basis of the module was developed in the Spring 1996 offering of the MSU air conditioning course. A two-week segment on desiccant dehumidification was incorporated into the course schedule. This segment included an introduction and discussion of applications, explanation of performance indices, and consideration of selection and specifications of desiccant devices. A case study was used in the class, and a design project was assigned to the students. Software from a desiccant system manufacturer to predict performance of a desiccant device based on inlet conditions of the process and regeneration air was made available for student use. Student response was favorable, and the faculty involved assessed the desiccant materials to be a useful addition to the course.

In addition to the material developed for the curriculum module, future improvements for the desiccant segment of the course will include a hands-on laboratory experience. An instrumented test cell for desiccant devices is currently being developed by the Global Center for Desiccant Technology. This laboratory will be available for student use in connection with the air conditioning course.

Module Availability

As part of the activities of the Global Center for Desiccant Technology (GCDT), copies of the module have been sent to all mechanical engineering programs in the United States. Interested parties may obtain a copy of the curriculum module by contacting one of the authors.

References

CLIFFORD, G.E., Heating. Ventilating. and Air Conditioning, Reston Publishing Co., Reston, VA, 1984.

HARRIMAN, L., "Applications Engineering Manual for Desiccant Systems," American Gas Cooling Center, Arlington, VA, 1996.

MCQUISTON, F.C., and PARKER, J.D., Heating. Ventilation. and Air Conditioning, John Wiley Inc., 1994.

lithium battery production	prevent corrosion and improve production
computer and electronic equipment protection	prevent condensation and corrosion on metal surfaces
plastic molding	improve product finish by preventing condensation on mold surfaces
archives and museums	increase longevity of books, artwork, and artifacts
seeds and grain storage	optimize seed moisture level and minimize microbial deterioration
confectionary and pharmaceutical packaging	keep products from deteriorating
confectionary manufacturing	improve product appearance and production

Figure 1. Examples of traditional applications of desiccant dehumidification from section A.

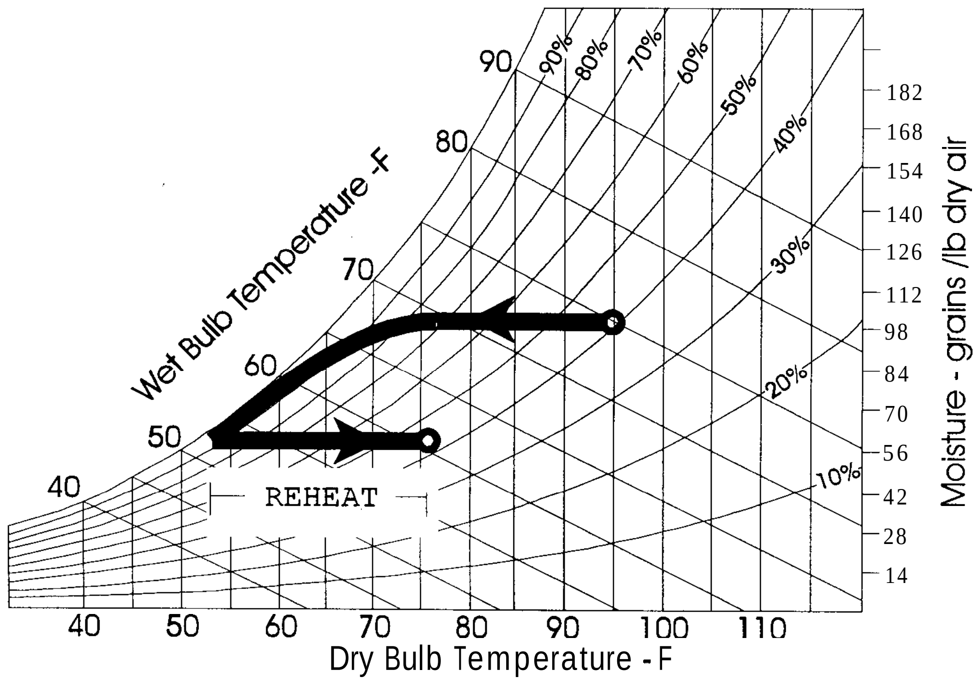

Figure 2. Illustration of the cold-coil dehumidification process on a psychrometric chart from section B.

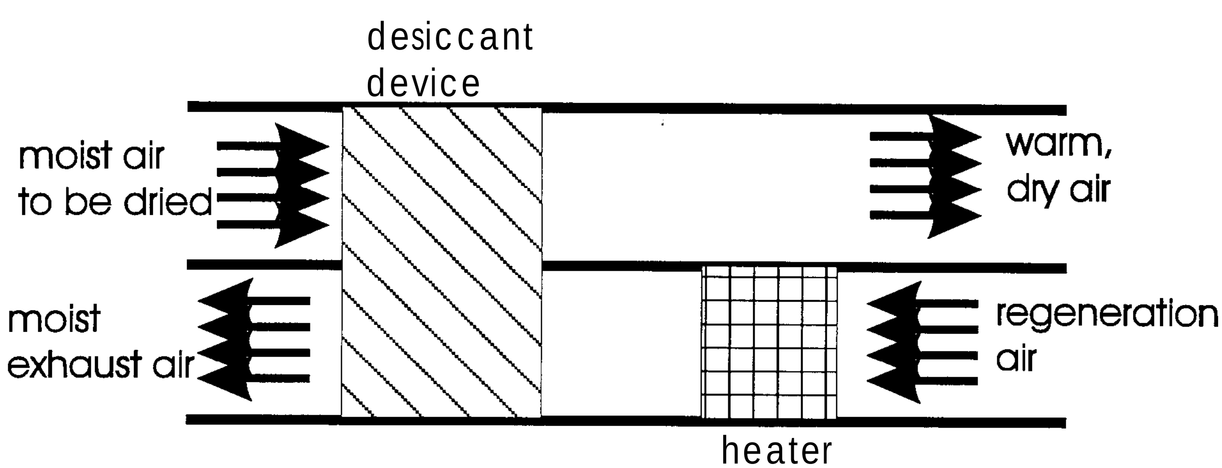

Figure 3. Illustration of the basic components of a desiccant dehumidification system from section B.

Examples of Peripheral Costs:

Retail Establishments -- customer discomfort, musty or unpleasant odors

Hospitals and Nursing Homes -- microbial growth and propagation

Grocery Stores -- customer discomfort, frost buildup on display cases

Ice **Rinks --** poor ice quality, fogging, condensation

Figure 4. Examples of peripheral costs associated with high or uncontrolled humidity from section C.

Factors in the Utility of Desiccant Materials:

- ► **cost**
- ► **long term stability**
- ► **moisture removal characteristics** (rate, capacity, saturation conditions, suitable temperatures)
- ► **regeneration requirements** (rate of moisture surrender as a function of temperature and humidity)
- ► **availability**
- ► **manufacturing considerations**

Figure 5. Listing of factors which influence the utility of desiccant materials from section D.

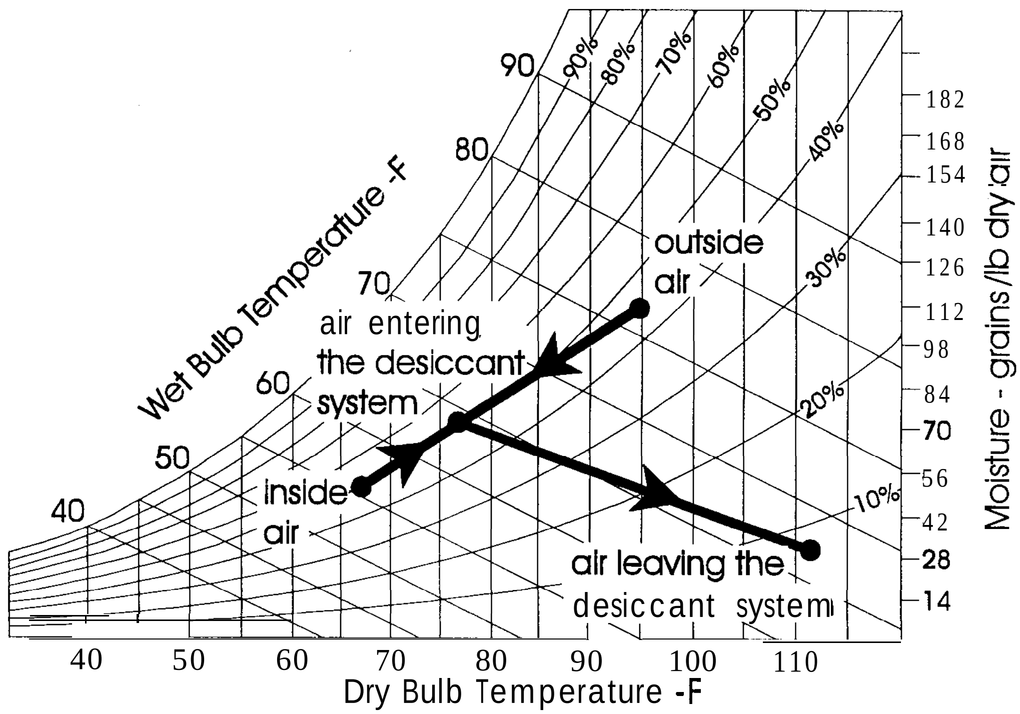

Figure 6. Psychrometric chart showing conditions of the process air in the desiccant system installed in a commissary from section G.