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A Psychrometric Test Facility for the Undergraduate Laboratory

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Abstract

This paper describes a laboratory test facility designed, built and tested by undergraduate students. The facility incorporates industrial hardware including electric heating coils, a cooling coil with a chiller, a rotary enthalpy recovery heat exchanger, a humidifier, a blower and three remotely controlled dampers along with instrumentation to measure airflow, various temperatures and relative humidities throughout the system. An instrumentation and control system has been integrated into the facility.

Project description

Under the ASHRAE (American Society of Heating, Refrigeration and Air Conditioning Engineers) Undergraduate Senior Project Grant Program, undergraduate students at the University of Tennessee designed and constructed a comprehensive laboratory setup for use in psychrometric studies. The local ASHRAE chapter assisted in procuring equipment. Students enrolled in a special topics class completed the design work and performed much of the actual construction over a two-year period. The first year, students designed and built a duct system incorporating a cooling coil, a two-stage heater, a variable speed fan, a humidifier and needed flow, temperature and humidity instrumentation. The second year, students modified the system for the additional testing of a rotary enthalpy recovery unit. Both groups calibrated the systems, wrote operational procedures and designed experiments for the departmental undergraduate laboratory.

The system is shown schematically in Figure 1. Room (or outside) air enters the rotary heat exchanger at flows up to 600 CFM (.283 m^3 / s) then passes through the variable speed fan, a one-ton capacity cooling coil, a two-stage 4-kW heating coil and a steam humidifier before exiting through the other side of the rotary heat exchanger. The air can be cooled to around 33 ^{o}F (0.5 ^{o}C) or heated to about 140 ^{o}F (60 ^{o}C) with relative humidities between about 15% and 95% before exhausting through the heat exchanger.

Instrumentation included six RTD type temperature transducers, five humidistats for relative humidity measurement and two pitot-type volumetric flow meters. Locations of each are shown in Figure 1. The instrumentation and control system is a SIEBE environmental system, which allows on-screen monitoring of all variables, on screen damper control and controlling certain variables to preset values.

Experiments include the following:

a. Psychrometric processes including heating, cooling , mixing, humidification and dehumidification
b. Cooling coil characteristics including bypass factor
c. Sensible, latent and total effectiveness of the rotary heat exchanger

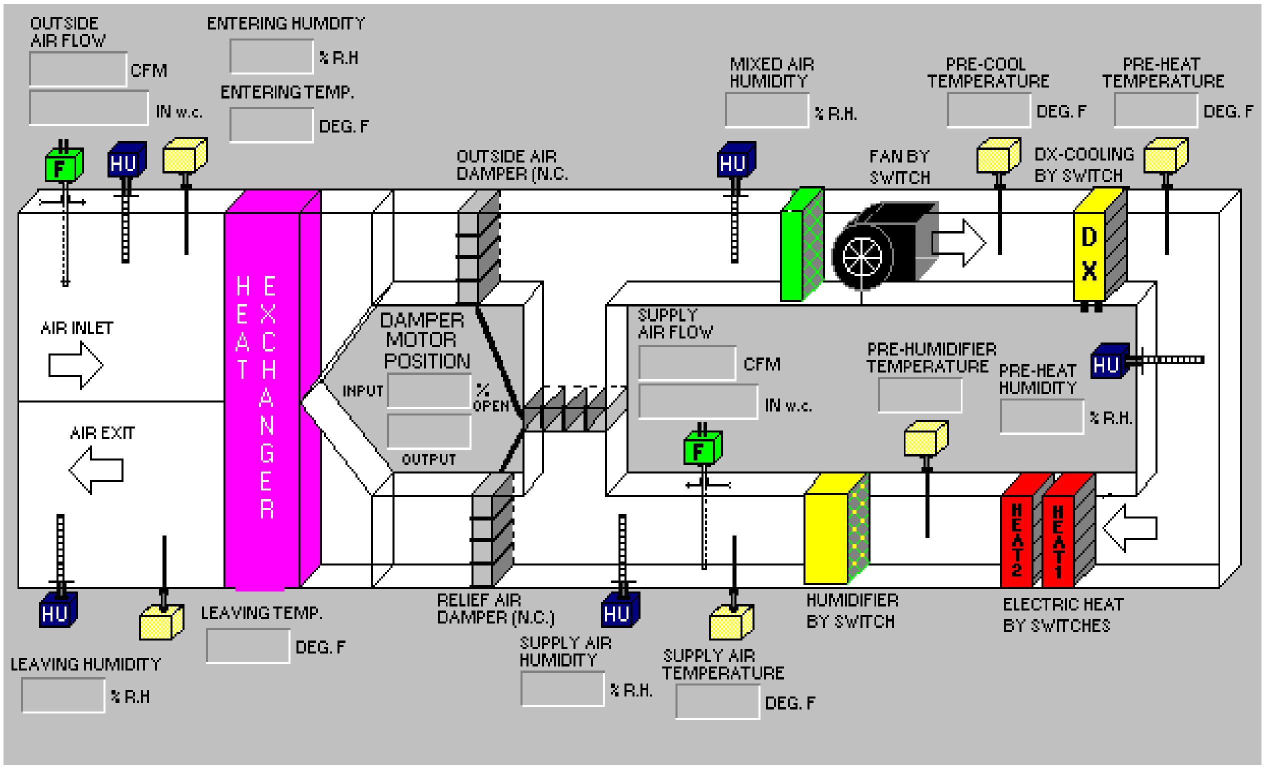
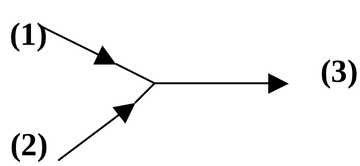


FIGURE 1
SYSTEM SCHEMATIC COMPUTER OUTPUT SCREEN

Experiment outcomes

Students have designed and carried out several experiments. Some are outlined with data and results shown below:

Mixing of two streams:



Mixing Results

STREAM	TEMP.($^oF/ ^oC$)	%RH	FLOW RATE(CFM / m^3/ s)
1 (unmixed)	70.9 (21.6)	60.7	262 / .124
2 (unmixed)	50.0 (9.9)	93.1	256 / .121
3 (mixed)	61.9 (16.6)	80	(measured)
3 (mixed)	59.9 (15.5)	78.1	(predicted)

Cooling Coil Bypass Factor

$$BF = \frac{T_{out} - T_{coil}}{T_{in} - T_{coil}}$$

Where *T* is dry bulb temperature.

INLET TEMP.	OUTLET TEMP.	COIL SURFACE TEMP	BYPASS FACTOR
62.3 ^oF (16.8 C)	37.4 ^oF (3 C)	26.3 ^oF (-3.2 C)	0.31

Effectiveness of the rotary heat exchanger

$$\varepsilon = \frac{T_{\sup ply} - T_{inlet}}{T_{return} - T_{inlet}} (sensible)$$

Where *T* is dry bulb temperature.

$$\varepsilon = \frac{h_{\sup ply} - h_{inlet}}{h_{return} - h_{inlet}} (total)$$

Where *h* is enthalpy of the air-water mixture.

Cooling mode operation:

INLET	SUPPLY	RETURN	EXHAUST	EFFECTIVENESS
69.1 ^oF (20.6 C) 63.8% RH	54.6 ^oF (12.5 C) 99%	50 ^oF (10 C) 99%	67.9 ^oF (19.9 C) 63.8%	75.9% (SENSIBLE) 62.5% (TOTAL)
Heating mode operation:				
52.3 ^oF (11.3 C)	78.1 ^oF 25.6 C)	99.8 ^oF (37.7 C)	58.0 ^oF (14.4 C)	54.3% (SENSIBLE)

A top-view photo of the system is shown in Figure 2.

FIGURE 2

Conclusion

A team of senior Mechanical Engineering students have designed, ordered equipment, constructed and calibrated a psychrometric test facility. They have designed and carried out experiments to evaluate their design. The equipment is now used regularly in the Mechanical Engineering Laboratories at the University of Tennessee.

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William S. Johnson is Professor of Mechanical Engineering at the University of Tennessee where he teaches courses primarily in instrumentation and the design of thermal systems. His current research involves direct-exchange geothermal heat pumps and he serves as manager of the University of Tennessee environmental testing facilities. These facilities involve 4 environmental chambers where testing primarily involves heating, cooling and refrigeration systems.