SOUTHERN MILDEW PROBLEMS: WEATHER AND PSYCHROMETRICS

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ABSTRACT

Mildew, a costly consequence of excessive moisture in homes, was addressed in a survey of 560 Florida families. Sixty-five percent of the participants reported they had problems with mildew. Attempts were made to correlate mildew problems with building treatments such as weatherizing (a possible cause in Northern areas) and various family living practices. The high incidence of mildew problems in this population indicates a potential gap between the dehumidification needs people have in their homes and the amount of dehumidification they are getting with their air conditioning.

Recognizing the contribution of moisture from outside the home led to the incorporation of psychrometrics and weather data into tables and graphs to assess the latent heat removal necessary to produce an interior environment that would be less likely to support mildew growth. Terms for the sensible cooling demand and the latent heat removal demand were designed, calculated, and plotted against months of the year for nine locations in the state. This series of figures provides new insights into the demands for sensible cooling and latent heat removal that can be applied to meet local Florida conditions. Comparisons of other U.S. coastal areas are also included.

INTRODUCTION:

Human comfort and energy conservation are primary concerns of this conference on "Improving Building Systems in Hot and Humid Climates." Humidity and moisture related problems are sometimes but not always considered as well. In Florida and other hot and humid areas of the country, I would submit that humidity and moisture-related problems should be a primary consideration in all summer human comfort and energy conservation efforts.

Dealing with mildew problems is costly for many Florida families. Repairing, cleaning, and replacement of mildew damaged furnishings can involve expenditures of several thousand dollars in a home. Resale value of housing drops when houses have a musty smell or when there is other evidence of mildew. Fighting mildew is time-consuming and a counter-productive activity for today's busy families. Splashing buckets of chlorine bleach and water on shower walls makes cleaning the bathroom a hazardous activity. Even after removal measures are applied, discouraged home owners report that mildew returns again and again.

Residential air conditioning is designed to dehumidify as well as to cool air; yet, the many reports of mildew problems in Florida indicate that air conditioning and heating needs may have underestimated latent heat loads. The dehumidification demands in warm, humid climates should be expanded to provide conditions that preclude conditions that encourage mildew growth.

What is mildew? What makes it grow?

Mildew is a mold. Molds such as mildew have the capacity to decompose cellulose and lignin and may therefore ruin paper, cloth, wood, and other cellulosic products that are not protected from them. The growth parameters for indoor mildew types have not been established through research; however, since mildew is a mold, it may behave in much the same way a mold does. Until more information is available about indoor mildew, the general parameters of growth for molds can be useful.

The water activity (a_w) for molds varies from 0.62 to 0.93. This corresponds to a relative humidity of 62 to 93%. An a_w would have to be below 0.62 to stop all chances for mold growth, although below 0.70 most mold growth is inhibited.

A lower a_w delays spore germination of molds, reduces the rate of mold growth, and lowers the number of cells produced. Molds are aerobic in nature. That is, they require oxygen for growth. Molds will grow at a pH of 2 to 8.5, but growth is favored by an acid (low) pH. The optimal growth temperature range for molds is 77–86°F though some growth may occur anywhere between 32° and 95°F. The nutrient requirements of molds are met by organic materials like paper, leather, wood, natural fibers, or even the slightest coating of organic matter such as food, soil, etc. on any surface. Mold growth is inhibited by mycostatic substances such as sorbic acid, proprianates, and acetates. The effects of chemical treatments with fungicides are temporary, and the most effective products on the market are currently under review as hazardous by EPA. Mold growth is slow to start, but after growth is underway, it is very rapid. Mildew growth may take several months or seasons to become established.

Only in isolated cases would it be practical to control the availability of oxygen, the acidity or alkalinity of materials or surfaces or to use mycostatic substances to treat surfaces to prevent mildew. Fungicides must be used with care as they can be unsafe or toxic to people and pets.

The most important factors for mildew growth can be explained in this mildew equation:

Mildew Growth = Spores + Nutrients + Heat + Humidity

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With normal family living, mildew nutrients are impossible to completely eliminate. We do not want to live in a sterile environment. That leaves heat and humidity to control. If we could trust a thermostat setting in a house to provide temperatures that are uniformly low throughout a house including every corner, closet, and crevice, temperature control might work. Temperatures cannot be controlled that closely. Humidity control can be expected to be more effective in controlling mildew.

A Changed Scenario.

In pre-air conditioning days, people in Florida knew they had to be very careful to avoid the appearance and spread of mildew. With the advent of air conditioning, concerns about mildew eased. The dehumidifying effects of air conditioning plus reduced temperatures allowed people to live more casually. Mildew is not as persistent at temperatures of 70 to 75°F, especially when the relative humidity is kept at 60% or lower.

The scenario in Florida has changed since energy conservation practices, that work well in cooler and drier parts of the country, have been used during the air conditioning season. Also people who have moved to Florida from the Midwest or Northeast have brought with them techniques to conserve energy and still be comfortable. Nighttime ventilation when air cools, can bring in considerable moisture. High levels of insulation reduce the sensible cooling load without reducing moisture in air. Energy efficient air conditioners efficiently reduce sensible heat, but do a poorer job of dehumidification. Setting air conditioner fans to operate continuously to provide more even cooling within a home can reintroduce into the air moisture that has been condensed on the air conditioner evaporator coils.

Are these practices contributing to moisture and mildew problems in homes in hot and humid climates?

More needs to be known about housing techniques and family living practices that contribute to mildew problems so effective solutions can be provided. The research reported here seeks to more accurately define a mildew-free environment in Florida homes that will still provide human comfort and energy conservation.

BACKGROUND:

Little research has been reported on indoor mildew problems in warm, humid climates. Most states have warm, humid/mildew-producing conditions for relatively short periods of time during the summer, or mildew-producing conditions occur regularly in only small portions of a state such as in the coastal areas. Florida represents a worst case situation because it extends further south than other states and is surrounded by bodies of water.

A literature search has indicated that research on moisture-related problems such as mildew, in hot and humid climates is practically non-existent. Two recent reports (1, 2) deal with moisture migration in the exterior walls of houses in warm, humid climates. Their conclusions were that recommendations developed for cold climates should be revised for warm, humid climates.

Reports presented at the past two symposiums on "Improving Building Energy Efficiency in Hot and Humid Climates" have recognized the information and technology scarcities about dehumidification in hot and humid climates. Reports addressed concerns about dehumidification with studies on simulation of high-efficiency air-conditioners (3), a relative humidity sensor (4), moisture adsorption and desorption of internal building materials and furnishings (5) air flow modulators (6) desiccant dehumidification (7, 8) and the use of heat pipes (9).

Other publications that deal with moisture effects in hot and humid climates include modeling combined thermal and latent transport in buildings (10), dynamic latent heat storage, (11), and a popular publication on the vagaraties of cooling load calculations (12).

An important reason humid air contributes so much to mildew problems is that wood, cloth, and other organic materials are hygroscopic. These materials possess substantial storage capacity to absorb water vapor during humid periods. This moisture will be desorbed or given up at a much slower rate. For example, the fiber saturation point occurs in most species of wood between 28 and 32 percent moisture content. That is, when the environment approaches 100% relative humidity, the amount of water wood holds will approach 30 percent of its weight. Bedding, carpet, and draperies can absorb and hold similar amounts of moisture. Based on a Department of Energy study (11) dealing with the moisture adsorption of materials, the walls, ceiling tile, carpet, and pad in a 1500 ft^2 house can take up to 75 pounds of water when natural ventilation is used and the relative humidity is high as it is likely to be at night in Florida. The study did not include upholstered furniture, bedding, and other household linens. When these are included, the amount of moisture held in housing interiors exposed to high humidity levels can be doubled or tripled depending upon the quantity and materials used. Organic soils are also hygroscopic. When they become hydrated, they emit odors. When the air conditioning operates in a humid room, the air will be cooled, but the dehumidification process can get further and further behind. The home interior will have an uncomfortable clammy feeling.

While recognition of moisture control in hot and humid climates is beginning to be taken quite seriously, research on mildew problems, as a manifestation of excess moisture in homes in hot and humid climates, has not been addressed in literature searches made.

SURVEY:

The first part of the research project was to survey Florida families about mildew problems, perceived building practices, and family living patterns including how they used air-conditioning, heating, ventilation, and ceiling fans to achieve comfort.

A survey instrument was developed and pretested to assess the extent of mildew problems in Florida homes and to identify potential contributing factors. About 1500 questionnaires were distributed to a random sample of families from 12 counties representing coastal and inland counties and northern and southern counties. Five hundred sixty usable questionnaires (36%) were returned. A Pearsonian rectangular correlation matrix was used to determine which variables were the best predictors of mildew problems. Dependent variables included the incidence of mildew, bathroom mildew, closet mildew, and bedroom mildew. Factors affecting the incidence of mildew anywhere in the home are discussed in this paper.

Significant differences in the total sample can be expected to more readily show differences than the smaller north Florida or south Florida segments of the sample. Attempts to develop regression models to predict mildew incidence for the three dependent variables failed to yield more than two predictor variables because cell sizes became to small when more variables were included.

Characteristics of the Respondents

Almost one-fifth of the sample (18.3%) were born in Florida, with New York natives accounting for the next largest group (16%). A large majority of the sample respondents were white (94.7%), and female (62.5%). Many were over 65 years of age (42.9%). Twenty-one percent were college graduates, 11.9% also had professional degrees. Both husbands and wives were employed full-time in 44.1 percent of the cases. Forty-three percent were retired. Salaries ranged from about $10,000 to more than $60,000. Ninety-one percent owned their homes. About 40% of the home owners owned their homes outright. Payments on other homes ranged from less than $200 to more than $700 per month.

Mildew Problems.

Sixty-four percent of the total sample indicated that they had mildew problems in their homes. About 1/3 of these cases were characterized as moderate or often. Most mildew problems occurred in bathrooms (48.4%), closets (31.0%), and bedrooms (12.5%). About 66% of the families in south Florida reported they had mildew problems compared to about 63% in north Florida. In 15.4% of the surveyed homes there was a person who was allergic to mildew. Most (72.1%) with mildew allergies were women.

Contributing Factors.

Although the incidence of mildew problems was about the same in the north and south parts of the state, the contributing factors differed for the two parts of the state. Table 1 shows the correlations between various contributing factors and the incidence of mildew in the total sample, in the north segment which includes Citrus, Duval, Escambia, Marion, Seminole and Volusia Counties and in the south segment which includes Collier, Hillsborough, Lee, Palm Beach, Polk, and Sarasota Counties. A positive correlation in Table 1 indicates a trend toward having mildew. A negative correlation indicates a trend away from having mildew. Plans to compare coastal to interior counties were abandoned because low population in the interior counties didn't yield a large enough sample from those counties for statistical analysis.

Age of the House. The age of the house was the single most important factor related to the incidence of mildew. Forty percent of the homes up to 5 years old had already had mildew problems. By the time homes were 15 years or older, more than 70% had mildew. This was true for all parts of the state.

Building and Design. Single family homes were more likely then apartments, condominiums, or manufactured homes to have problems with mildew.

Slab construction was related to an increase in the incidence of mildew in both the total sample and in south Florida but not in the north. Construction with poor quality or without vapor retarders can contribute to this problem in older homes, though it is believed better practices are now being used in slab construction.

Tight construction appeared to reduce mildew incidence in the north and total sample but not in the south. It seems reasonable to expect tight construction to inhibit mildew problems in a hot, humid climate during the air conditioning season.

Having an overhang was related to the increased likelihood of mildew in the total sample. Shade on houses also increased the probability of having mildew problems in the total sample and the north. Shade from trees or an overhang might reduce the sensible-to-total heat removal requirement of a house and decrease air conditioner running time and the dehumidification achieved.

Air Conditioning. Ninety-three percent of the homes in the sample had air conditioning. Having air conditioning did not have a significant effect on the incidence of mildew in homes. This was probably due to the small number of people without air conditioning, though it is possible that some of the people with unair-conditioned homes have developed techniques to inhibit mildew other than temperature and humidity control. Air conditioner temperature settings did not have a significant effect on the presence of mildew problems, nor did such practices as opening windows at night or running home air conditioner fans continuously, perhaps because few people use these practices. In the north part of the state setting the thermostat on the air conditioner higher when the family was away from the house was related to the presences of mildew.

Heating. A higher thermostat setting in the heating season did not appear to be a contributing factor in having mildew problems, however setting the thermostat lower when the family is away from the house was. This can perhaps be explained by recognizing that reducing the temperature in rooms where there is residual humidity can increase the relative humidity to the extent that mildew can grow.

Ceiling Fans. Just having ceiling fans didn't indicate a likelihood that mildew problems will occur, however, people setting their thermostats higher when using ceiling fans was strongly related to having mildew problems. A higher thermostat setting when the family is not in the home, as discussed with air conditioning, was less likely to produce mildew. However, if the family is at home, and producing moisture and opening doors allowing warm, humid air to come in, then the use of the higher temperatures with ceiling fans, can act to promote mildew problems.

Utility Bills. Although unexpected, an increased use of summer air conditioning and winter heating as evidenced by higher utility bills did not decrease the likelihood of having mildew in either the total sample or in the southern part of the state.

TABLE 1
Mildew in Florida Homes
Pearsonian Rectangular Correlation Matrix

	Total (N=)	North (N=)	South (N=)
Age of House	0.17519*** (538)	0.18933*** (217)	0.15586*** (310)
Building and Design: Single Family	0.18248*** (37)	0.17176** (217)	0.22632*** (307)
Masonry	0.01325 (468)	0.05813 (176)	-0.04914 (279)
Slab	0.11546*** (534)	0.08168 (218)	0.15232*** (304)
Tight Construction	-0.09054** (534)	-0.16357** (217)	-0.04223 (305)
Overhang	0.07746* (526)	0.09181 (215)	0.07273 (298)
Ceiling Insulation (452)	0.00338 (191)	-0.03012 (251)	0.03840
Wall Insulation	-0.08316 (352)	-0.09707 (155)	-0.05710 (191)
Shading	0.11410*** (527)	0.19959*** (215)	0.04406 (299)
Air Conditioning: Have AC	-0.04910 (543)	-0.02529 (221)	-0.07372 (309)
AC Temperature	0.06698 (463)	0.07722 (184)	0.05088 (268)
Night, Windows, Open	-0.08792 (94)	0.03091 (41)	-0.17361 (52)
AC Fan, Continous	0.03925 (328)	0.06216 (135)	0.03009 (186)
When Gone, Set AC Temp Higher	0.08952 (103)	0.31529** (45)	-0.15899 (58)
Heating: Heating Temperature	0.01790 (456)	0.03112 (188)	0.00762 (259)
When Gone, Set Heat Temp Lower	0.12747*** (513)	0.11155 (209)	0.13904*** (294)
Ceiling Fans: Have Ceiling Fans	0.08290* (536)	0.08242 (216)	0.09227 (309)
With Fans, Use Higher Temperature	0.18941*** (302)	0.16316* (126)	0.23632*** (170)
Utility Bills: Summer	0.16826*** (518)	0.06425 (210)	0.24488** (297)
Winter	0.14129*** (519)	0.06082 (210)	0.21091*** (298)

*p<.01 **p<.05 ***p<.01

If increased air conditioning, as indicated by higher utility bills, increases the incidence of mildew, one possible explanation is that people may be trying to compensate for high humidity by using lower thermostat settings. HIgher summer utility bills may also be due to leakier houses and localized high humidity. Increased winter heating costs also suggest that heat, possibly because the heating season in Florida is very short, is not providing a drier, protective period against mildew.

The low correlations between the dependent and independent variables indicates that several independent variables would be needed to explain the incidence of mildew problems in Florida homes.

MILDEW AND HUMIDITY:

There is considerable confusion about when and why mildew occurs in homes in hot and humid climates. People are comfortable at a range of temperatures and humidity levels. Mildew also thrives at a wide range of temperatures and humidity levels. Unfortunately, there is some overlap between the temperature and humidity levels at which people are comfortable and at which mildew can grow.

Humidity control is necessary for mildew control. When we bring air inside and condition it for comfort, much more attention has been paid to temperature control than to moisture control. Moisture removal in humid climates is very complex.

Moisture Sources

Indoor Sources. People produce moisture in their homes by respiration and various water-related activities.

A family of 4 might produce as much as 16 to 20 pints of water per day with these activities (Table 2). Additional water is used for such things as watering plants, scrubbing floors, or washing clothes.

Table 2
Sources of Moisture Produced Within a House

Source	Pints or Pounds
One person breathing per hour	.13 (3.2 per day)
Cooking (electricity) per day	1.84 (4.0 if gas)
Washing dinner dishes	1.00
One shower bath	.50
One tub bath	.30

Outdoor Sources. The water vapor produced by living activities in a home is added to the moisture that is brought into a house. A tight house may have one-half to one air exchange per hour. Air comes through minute cracks around windows and doors or other structural parts. In older houses, two or more air exchanges per hour are possible. If outdoor moisture is low, indoor moisture levels will be reduced by air exchange. In Florida, outdoor moisture conditions are high much of the time. In summer an air exchange might bring into a 1500 ft^2 house as much as 16 to 24 pints of water. In winter, an air exchange might contain from 3 to 6 pints which would probably be lower than what indoor air with family activities would provide.

The relation between temperatures and humidity can best be explained with a psychrometric chart (Figure 1). This simplified version shows that as temperature is increased, its capacity to hold moisture also increases. Notice that 90° air at 50% relative humidity holds the same amount of moisture as 70° air that is saturated. Considerable moisture would have to be removed from that 70°, 100% relative humidity air to produce 70° air at 50% relative humidity. (Dew point temperature would be a little more than 50°F). In a 1500 ft^2 house, eight pints of water would have to be removed (14.40 - 6.11, from Table 3).

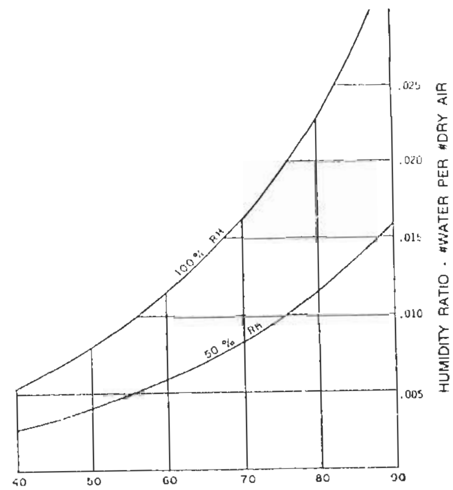

Figure 1

Table 3
Moisture Content of Air
in 1500 ft^3 House vs Dew Point Temperature

Dew Point	Moisture Content	
°	#Water/#Dry Air	#water/1500 ft^3 house
80	0.0224	20.16
75	0.0190	17.10
70	0.0160	14.40
65	0.0134	12.06
60	0.0110	9.90
55*	0.0092*	8.28*
50	0.0079	6.11
45	0.0064	5.76
40	0.0052	4.68
35	0.0038	3.42

* Conditions to produce 75°F, 50% Relative Humidity

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The temperature of saturated air can also be called the dew point temperature. On figure 1, a horizontal line drawn from any dew point temperature to the right of the chart shows the amount of moisture held in air. The dew point temperature is a good indicator of the moisture held in air.

Weather reports provided by television, radio and newspapers often provide the relative humidity of air. But, remember, the relative humidity changes with the temperature. Figure 2 shows what happens to the temperature, relative humidity, and dew point on a typical summer day in Orlando. The scale on the left of the chart is the same for temperature of air and relative humidity. The temperature drops during the night, is lowest before sunrise and rises to a high mid-afternoon. Because cool air holds less moisture than warm air, the relative humidity is highest in the early morning hours and cycles to its lowest level for the day when the temperature is the highest.

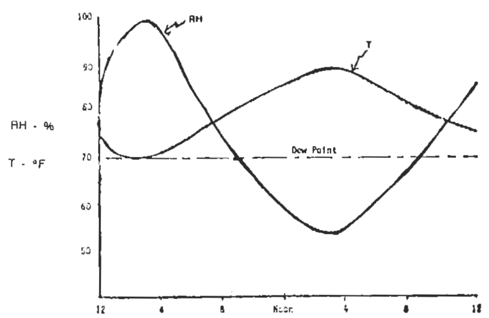

Figure 2
Temperature and Relative Humidity
Orlando - August

The dew point temperature is the temperature at which dew forms, often the lowest temperature of the day. The dew point temperature remains about the same for the whole day. The exceptions are when there is rain or a mass of cool, dry air comes in from the north.

To prevent mildew in homes, indoor temperature and humidity levels should be about 75° and at least as low as 60%. Fifty-five percent would be better. As discussed earlier, any air exchange with a dew point temperature above 55°F, will bring in some excess moisture. This underscores the importance of eliminating any unplanned air exchanges. And it shows the importance of dehumidification when air conditioning is planned and used. Natural infiltration through cracks, crevices and fireplace flues will cause some air exchange, depending on outside air movement, inside/outside temperature differentials, plus negative pressures created by exhaust fans in kitchens and bathrooms. In homes, people come and go, hold doors open, and open windows.

Sensible and Latent Heat Demand

Is outside air really so humid that we need to be concerned about infiltration and air leaks? To understand the importance of dehumidifying air for Florida and Coastal homes we need to compare sensible and latent cooling needs.

Sensible Cooling Demand. Cooling degree days (base of 65°) is a term used to indicate the sensible cooling needed for air conditioning. But there is no correlative term for latent heat removal loads. Cooling degree days can be converted to "cooling BTU days" which have been defined by calculating the BTUs that must be removed from one pound of air each day for a month to sensibly cool it from the average outdoor temperature to 65°F. We might call this value the Sensible Cooling Demand.

$$SCD = CDD \times SpH_a$$

where
SCD = Sensible Cooling Demand
CDD = Cooling Degree Days, °F
SpH_a = Specific Heat of air, BTU/lb. dry air/°F

Dehumidification Demand or Dehumidification BTU Days have been defined as the number of BTUs that must be removed from one pound of outside air each day for a month to bring it to the absolute humidity of air at 75°, 60% relative humidity. As calculated the Dehumidification Demand addresses the need for dehumidification of outside air that infiltrates. The Dehumidification Demand can be calculated by subtracting the moisture content of air at 75°, 60% relative humidity from the moisture content of air at the average dew point temperature of air for the month to get the average pounds of moisture in one pound of air to be removed. This value is multiplied by the number of days in the month and the amount of energy in BTUs required to condense the moisture in a pound of air.

$$DD = (W_o - W_i)\ D\ H_c$$

where
DD = Dehumidification Demand
W_o = Moisture in 1 lb. of air at av. DewPoint/Month
W_i = Moisture in 1 lb. of air condition air
D = Days in Month
H_c = Heat of Vaporization

Sensible Cooling and Dehumidification BTU Days have been calculated and plotted for Orlando, Florida. Figure 3 shows that little sensible heat removal is indicated before May and it drops off considerably in the last two months in the year. At maximum, the Sensible Cooling Demand is about 200 BTU days.

COOLING AND DEHUMIDIFICATION BTU DAYS
ORLANDO

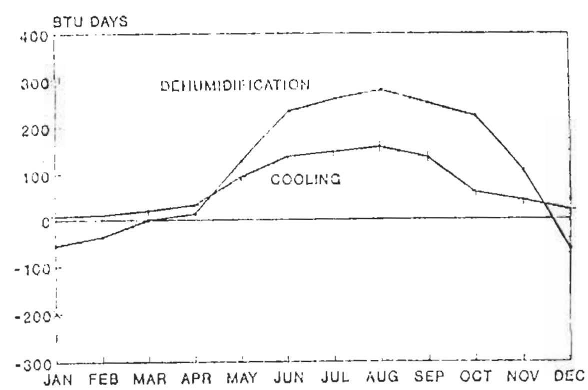

FIGURE 3

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As the sensible cooling load in Florida increases, the dehumidification load increases as well. In fact the dehumidification load is far in excess of the sensible cooling load for several months in the year. This means it is important to limit the introduction of outside air through such things as infiltration or nighttime ventilation. It also means air conditioning must be very effective in removing latent heat to prevent clamminess and mildew conditions.

In the fall months the days become cooler. Little air conditioning is needed, but the moisture in the air is still very high. With no air conditioning or heating needed, mildew problems are more likely to surface. If mildew has already started in the summer, it can get worse in the fall.

To compare moisture levels throughout Florida, Table 4 shows the average dew point temperatures at nine weather stations. The underlined numbers show the dew point temperatures that are 55°F or higher, the break point for mildew-safe humidity levels. The further south the weather station, the more months of the year will the weather be humid. Dew point temperatures are often in the 60s and 70s. Compare the dew point temperatures for Atlanta, Georgia and Columbus, Ohio. The humid periods are shorter and heating periods are longer than in Florida. There is time for homes and furnishings to dry between humid seasons.

Average dew point temperatures don't tell much about the day to day humidity levels. In Florida and other coastal areas, humidity can vary considerably from day to day. The maximum and minimum low temperatures which approximate the dew point temperature for the day show that in almost every month there are days when the dew point is above 55° (Table 5). Only during January in Pensacola and Tallahassee are there whole months with dew point temperatures below 55°F. With such frequent changes in humidity, it is difficult for families to always avoid using ventilation during humid periods. This again supports the view that when air conditioning is used, it is important that the dehumidification provided with air conditioning is more effective than is needed in drier and cooler climates.

Figures 4 to 11 show Cooling and Dehumidification BTU days for other locations in Florida, Texas, Alabama, Georgia and Ohio. In some of the Florida locations the Dehumidification Demand is two or three times the Sensible Cooling Demand. By contrast, Atlanta, Georgia appears to be fairly dry.

Homes in northern climates do not escape mildew problems, but causes in the north are related to tight construction, interior moisture production and dew point temperatures on or in walls. Ventilation can sometimes help reduce mildew and moisture problems in colder climates. In hot and humid climates, ventilation can exacerbate mildew problems.

CONCLUSIONS:

Many homes in hot and humid climates like Florida have mildew problems. By the time homes are 15 years old, 70 percent can be expected to have mildew. The unhealthy environment mildew produces, the extra money, time and effort families must spend to deal with mildew mean we need to take a closer look at this problem and seek ways to effectively deal with it. This costly condition can be managed with appropriate applications of air conditioning which can both reduce air temperatures and humidity levels. There are reasons why the air conditioning system as used now is not always effective in keeping moisture levels low enough to prevent mildew.

1. Moisture levels of outside air are very high for long periods of the year. Some ventilation may be needed but should be balanced by an air treatment system that can effectively remove excessive latent heat.

2. Housing can be so well insulated and shaded that air conditioning is oversized and does not run long enough to sufficiently remove latent heat.

3. Since most mildew occurs in bathrooms, closets, and bedrooms, we need to study building and HVAC systems that serve these areas of a house in hot and humid climates.

   ° Placement of bathroom exhaust fans often create a null-space within the tub-shower area where mildew can be most severe. Bathroom windows cannot substitute for an exhaust fan that pulls conditioned air into the bathroom. Outside air is too humid most of the time in Florida.

   ° Solid closet shelves in Florida and other hot and humid climates trap moisture in clothing. Solid doors trap moisture in closets. Heating/air conditioning registers in closets can help keep humidity low.

   ° Bedroom doors are often kept closed for privacy, but respiration moisture produced during sleeping hours can be reduced with adequate return air ducts when heating and air conditioning are being used.

4. Psychrometrics may be too complicated to use with consumers to guide them as to HVAC and ceiling fan use, but people need good guidelines. For instance, they should be advised to do such things as to limit the use of outside ventilation when the outside air dew point temperature is above 55 or 60°F. In the afternoons, when the relative humidity is low, the introduction of latent heat can be far in excess of the sensible heat that must be removed. At night, sensible heat will be low, but the high relative humidity will be soaked up by materials used in the home increasing the latent cooling demand the next day when air conditioning is turned on again.

5. Considering the long, high-humidity periods in Florida with fairly short or no heating season to dry out housing, building designs that prevent infiltration and air conditioning innovations that enhance latent heat removal should be carefully considered in the design, construction, and use of housing and air conditioning.

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6. Crawford, J.G. "Residential Humidity Control: Exciting New Opportunities with Air Flow Modulation." Fifth Annual Symposium on Improving Building Energy Efficiency in Hot and Humid Climates. 1988.

7. Pate III, M.E. and Todd, T.R. "Innovative HVAC Cycles for Severe Part Load Conditions in the Humid Climates." Fifth Annual Symposium on Improving Building Energy Efficiency in Hot and Humid Climates. 1988.

8. Cromer, J.C. "Desiccant Moisture Exchange for Dehumidification Enhancement of Air Conditioners." Fifth Annual Symposium on Improving Building Energy Efficiency in Hot and Humid Climates. 1988.

9. Khatter, M.K. and Keebaugh, D. "Direct-Expansion Air-Conditioning System Performance in Low Humidity Applications: A Case Study." Fifth Annual Symposium on Improving Building Energy Efficiency in Hot and Humid Climates. 1988.

10. Fairey, P. and Derestecioglu, A. "Dynamic Modeling of Combined Thermal and Moisture Transport Buildings: Effect on Cooling Loads and Space Conditions." Florida Solar Energy Center. FSEC-PF-81-85, 1985.

11. Martin, P.C. and Verschoor, J.D. "Investigation of Dynamic Latent Heat Storage Effects of Building Construction and Furnishing Materials." ORNL/SUB/83X-22016C. Report. Oak Ridge National Laboratory. Oak Ridge, TN. 1986.

12. Fairey, P. and Khattar, M. "Vagaries of Cooling Load Calculations." Energy Design Update. Florida Solar Energy Center. December, 1985.

COOLING AND DEHUMIDIFICATION BTU DAYS
PENSACOLA

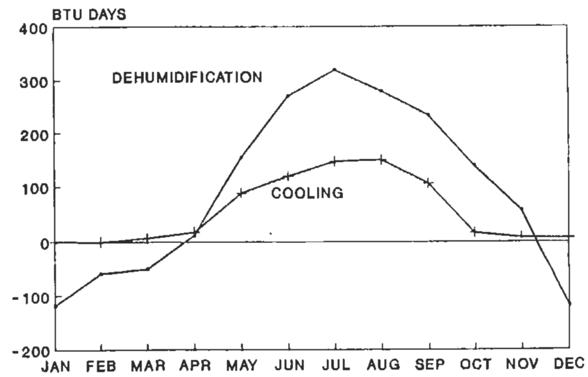

FIGURE 4

COOLING AND DEHUMIDIFICATION BTU DAYS
FT MYERS

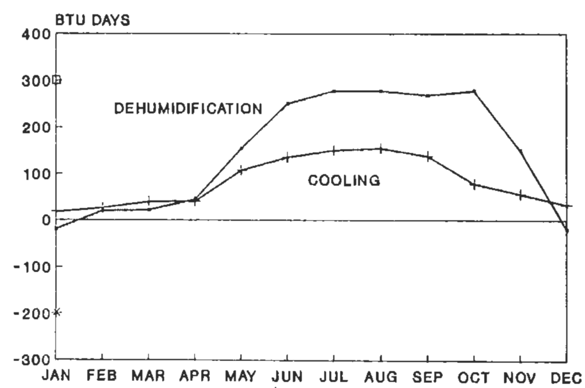

FIGURE 5

COOLING AND DEHUMIDIFICATION BTU DAYS
MIAMI

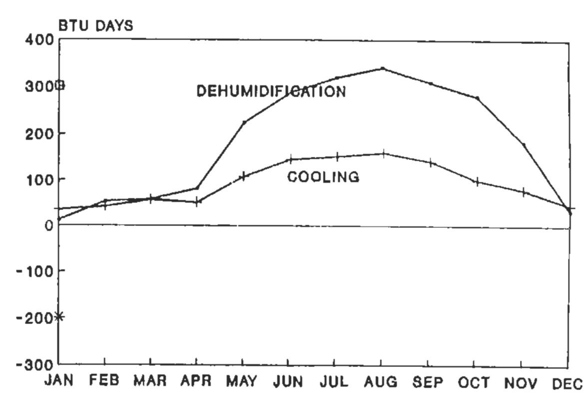

FIGURE 6

Proceedings of the Sixth Symposium on Improving Building Systems in Hot and Humid Climates, Dallas, TX, October 3-4, 1989

COOLING AND DEHUMIDIFICATION BTU DAYS
ATLANTA

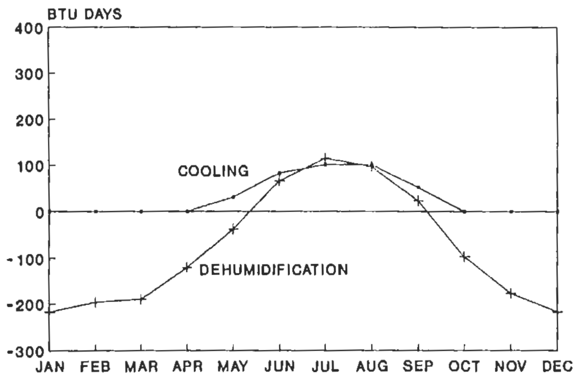

FIGURE 7

COOLING AND DEHUMIDIFICATION BTU DAYS
DALLAS

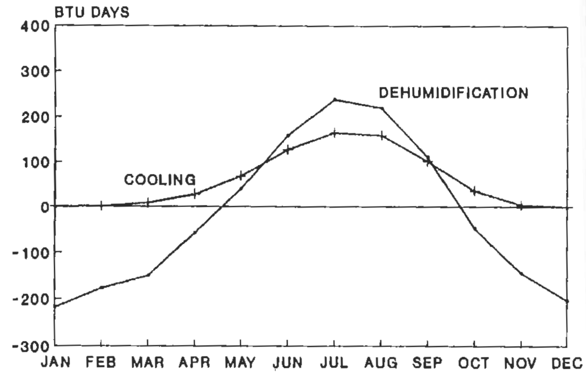

FIGURE 10

COOLING AND DEHUMIDIFICATION BTU DAYS
COLUMBUS, OHIO

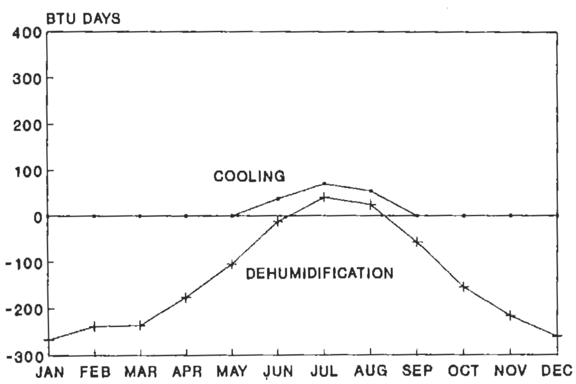

FIGURE 8

COOLING AND DEHUMIDIFICATION BTU DAYS
GALVESTON

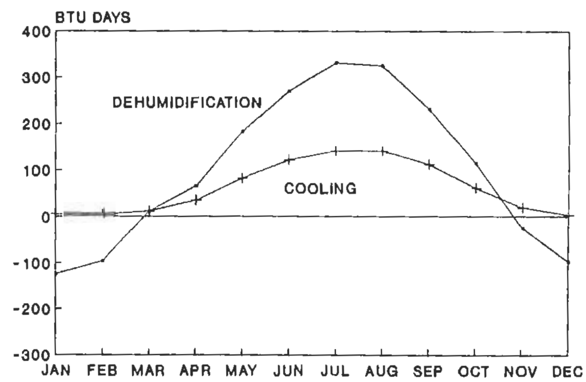

FIGURE 11

COOLING AND DEHUMIDIFICATION BTU DAYS
BOSTON

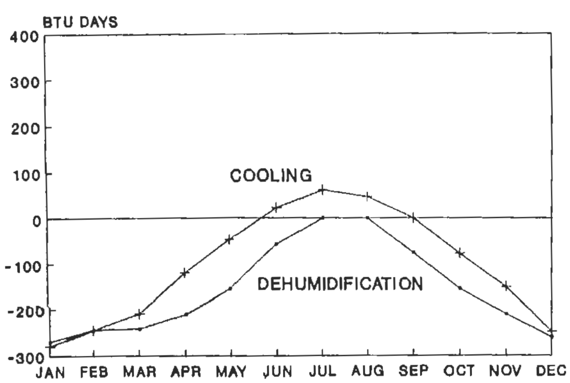

FIGURE 9

COOLING AND DEHUMIDIFICATION BTU DAYS
MOBILE

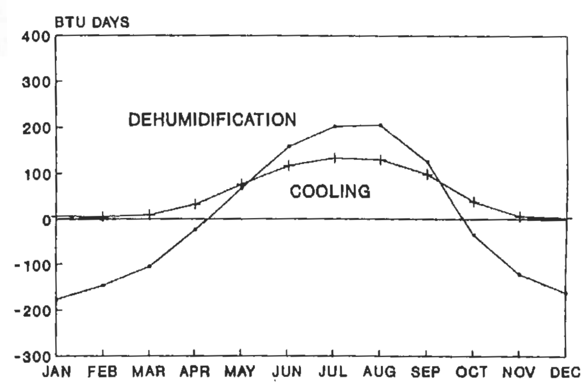

FIGURE 12

Proceedings of the Sixth Symposium on Improving Building Systems in Hot and Humid Climates, Dallas, TX, October 3-4, 1989

TABLE 4

Average Minimum Temperatures*

12 Months

9 Florida Weather Stations

	J	F	M	A	M	J	J	A	S	O	N	D
Pensacola	41	48	50	56	67	74	76	74	72	66	60	41
Tallahassee	36	43	44	46	60	69	71	70	69	64	56	34
Gainesville	43	50	48	52	62	70	71	71	70	67	61	41
Jacksonville	40	48	48	51	61	71	74	72	70	67	61	39
Orlando	49	51	55	56	65	72	73	74	73	71	64	48
Tampa	49	56	55	58	67	73	75	74	74	71	65	49
Ft. Myers	53	57	57	59	67	73	74	74	74	74	67	53
Miami	56	60	60	62	71	75	76	77	76	74	69	58
Key West	62	66	66	68	76	79	80	79	78	78	74	64

* October - December, 1985; January - September, 1986.

	J	F	M	A	M	J	J	A	S	O	N	D
Other Locations												
Atlanta, GA	34	34	39	48	57	65	68	67	62	51	40	34
Columbus, OH	23	24	30	40	50	59	63	62	55	44	33	25

TABLE 5

Minimum/Maximum Low Temperatures*

12 Months

9 Florida Weather Stations

	J	F	M	A	M	J	J	A	S	O	N	D
Pensacola	51/27	63/30	67/29	62/46	74/58	78/71	80/72	83/64	74/65	73/50	71/43	66/29
Tallahassee	53/26	63/29	65/20	59/38	67/49	73/63	76/68	78/61	73/65	72/48	72/33	63/13
Gainesville	60/17	64/29	65/26	58/48	71/52	74/67	75/70	72/69	71/65	72/51	68/38	65/19
Jacksonville	58/22	62/34	68/29	62/39	70/48	74/65	75/66	75/67	72/65	73/54	74/44	66/20
Orlando	60/26	65/39	64/35	62/47	70/58	74/70	78/70	76/73	75/70	74/61	75/46	69/25
Tampa	61/26	68/39	70/35	63/51	72/65	76/69	80/71	76/71	75/70	71/63	76/46	72/28
Ft. Myers	62/31	66/40	70/35	65/41	70/61	74/72	77/70	76/71	76/70	77/70	76/58	69/33
Miami	60/32	72/48	75/39	67/55	73/63	79/72	79/73	80/74	80/83	78/70	77/53	70/38
Key West	68/36	74/51	78/47	75/64	80/71	80/74	83/76	83/73	83/74	82/74	79/64	73/44

* October - December, 1985; January - September, 1986.