#6944

Introduction to Hotel Mold/Moisture Problems in Warm, Humid Climates

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ABSTRACT

Mold, a symptom of excess moisture in hotels, is costly in terms of hotel maintenance, renovation, and loss of revenue when guests reject rooms because of musty smells and discoloration. Recognizing the contribution of moisture from the external environment to hotel mold problems led to the incorporation of psychrometrics and weather data into tables and figures to better demonstrate the relative sensible and latent air-conditioning loads associated with infiltrating or makeup air. The latent load must be dealt with to produce the interior environment least likely to support mold growth. Terms for sensible cooling and latent infiltration loads were designed, calculated, and plotted against months of the year for three locations in the state of Florida. This series of figures provides new insights into the demands for sensible cooling and latent heat removal that can be applied to meet local conditions. Comparisons of other U.S. areas are also included.

INTRODUCTION

It has been reported by the American Hotel and Motel Association that mold and musty odors cost their members over $68 million every year in lost revenue and repair costs (AH&MA 1991). Historically, Florida hotels and motels are known to develop mold problems within a few years after opening. Hotels and motels in warm, humid climates are more likely to have problems with excess moisture and mold than similar hotels and motels in drier parts of the country. Summer mold and moisture-problem conditions in northern states last for only a few weeks a year and will not cause as severe a problem when dry weather and heating follow. The major source of moisture that causes mold problems inside buildings in warm, humid climates is outside air.

Mold has been linked to instances of subclinical, acute, and chronic respiratory diseases (Bernstein et al. 1983). A survey has also indicated that 12.5% of Florida homes have a person who is allergic to mold (Peart 1989). These people are likely to refuse to stay in rooms with musty odors or visible mold.

Mold, an important indicator of excess moisture, has the capacity to decompose cellulose, lignin, and other organic materials and may therefore ruin paper, cloth, wood, and other cellulosic products that are not protected from it. Mold spores and mold nutrients are impossible to completely eliminate from a hotel environment. The slightest smear from sticky fingers or oil from the palms of hands will support mold growth. The optimal growth range for molds is 77°F to 86°F and between 62% and 93% relative humidity (Frazier 1958). Mold is incapable of obtaining moisture for development directly from the atmosphere (except at 100% relative humidity) but derives it from the substrate that obtains the moisture from the air (Block 1953). Mold secretes enzymes that attack the substrate and digest it to maintain mold growth and development. The temperature-humidity range that supports the growth of mold overlaps the human comfort temperature-humidity range. Humidity control is accepted as the most practical method of controlling mold growth. Mold can be very slow to start growing, but if conditions are right for long enough (the right temperature, the right humidity level, and just a little nutrient to feed upon), mold spores, always available, will germinate, grow, and spread quickly.

Moisture, identified as a problem for hotels, comes from both outdoor and indoor sources. Indoor sources include hotel guests, housekeeping practices, kitchen sources, plants, fountains, and pools. Hotel structures and HVAC systems have undoubtedly been designed to address such indoor moisture sources and can work well in drier parts of the country where outside make-up and infiltration air do not add to the latent component of the air-conditioning load.

Air conditioning plays an important role in controlling moisture and mold problems in warm weather. When air is passed over the evaporator coil of an air conditioner, the moisture content of the airstream will be reduced if the surface temperature of the coil is below the dew-point temperature of indoor air. Considering the prevalence of mold and moisture problems in hotels and motels in Florida and other coastal areas, one can speculate that the excess moisture comes from outside air, since moisture generated by hotel guests is probably not too different from that generated by guests in moderate climates.

Bathroom exhaust fans in hotels, frequently designed to operate continuously, create a negative pressure in hotel rooms, drawing in outside air through cracks and crevices in outer walls. In warm, humid climates, continuously operating exhaust fans can increase the latent air-conditioning load considerably.

Mold often appears behind vinyl wall coverings, which have a low perm rating, in warm, humid climates. Vinyl wall coverings act as vapor barriers, and moisture trapped

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behind them condenses on the back surface when the dew-point temperature behind the surface is above the room temperature. When this occurs on interior walls, the structure may not have been thoroughly cured or dried out before the vinyl was applied. When mold is behind vinyl on exterior walls, moisture that infiltrates or diffuses through exterior walls will condense on the vinyl backing if the room surface temperature is near the outdoor dew-point temperature. Mold grows readily on vinyl backing and on organic glues when conditions are right. The problem of mildew behind vinyl is not addressed in this paper.

Practices in air-conditioner use can also contribute to moisture problems. As much as 19% of the moisture removed during the "compressor on" time can be reevaporated back into the conditioned space if an air conditioner's fan has been set to operate continuously through both on and off portions of the compressor cycle rather in the "auto mode (Khattar et al. 1987a).

Moisture produced inside guest rooms and the inappropriate use of air-conditioning alone cannot account for the prevalence of moisture and mold problems in hotels in warm, humid climates. Outside air is a major contributor, as humid air infiltrates and comes in as people come and go and open doors and windows. The purpose of this paper is to explore the potential contribution of infiltration to hotel moisture and mold problems in warm, humid climates.

LITERATURE REVIEW

Until recently, southern moisture and mold problems have been neglected in research. At a national workshop on Moisture Control in Buildings (Bales and Trechsel 1984), all reports addressed moisture-related problems in northern and midwestern states. While several of these papers recognized the need to study moisture problems and building design principles in warm, humid climates, no research in this area was reported. Two reports (Sherwood 1985; TenWolde and Mei 1986) dealt with moisture migration in the exterior walls of houses in warm, humid climates. A conclusion was that some recommendations for building insulation and vapor barriers developed for cold climates should be revised for warm, humid climates.

Reports presented at symposiums on Improving Building Energy Efficiency in Hot and Humid Climates have recognized the scarcity of information about high moisture levels in structures and the need for moisture management in warm, humid parts of the country. Reports addressed concerns about dehumidification, with studies on simulation of high-efficiency air conditioners (Katipamula et al. 1988), a control for energy-efficient sensible and latent cooling (Andrews 1989), a relative humidity sensor (Lofgren and Mills 1988), moisture adsorption and desorption of internal building materials and furnishings (Fairey and Kosar 1988), airflow modulators (Crawford 1987), desiccant dehumidification (Cromer 1988; Andrews et al. 1989), and the use of heat pipes (Khattar and Kleebaugh 1987).

An important reason humid air contributes so much to mold problems is that wood, cloth, and the organic content of many building materials such as gypsum board and concrete block are hygroscopic (Martin and Veershoor 1986). When furnishings are exposed to high humidity, as they might be in hotel rooms when people leave their balcony doors open at night, the moisture absorbed can contribute to the latent cooling load for several days (West and Hansen 1988). Insufficient air conditioning can produce a cool, clammy atmosphere and promote mold growth. Guests will be uncomfortable and inclined to reduce their thermostat settings and increase energy use and costs.

THE DILEMMA

The relationship between air temperature and the amount of moisture air can hold is represented by a simplified psychrometric chart in Figure 1. The air at 75°F, 50% relative humidity, in a 300-square-foot hotel room will hold about 1.8 pints of water (Point A). On a warm day in Florida, the same amount of outside air at 95°F, 50% relative humidity, will hold about 3.2 pints of water (Point B). Each air change will require about 900 Btu to reduce air temperature from 95°F to 75°F and about 1600 Btu to reduce the moisture content of air at 95°F, 50% relative humidity, to the level of air at 75°F, 50% relative humidity.

Weather reports provided by TV, radio, and newspapers often provide the relative humidity of air. But the relative humidity changes with the temperature. During the early morning hours of a typical August day in Orlando, the temperature is at its lowest and the relative humidity is about 100% (Figure 2). As the air warms during the day, it can hold more moisture, so the relative humidity falls.

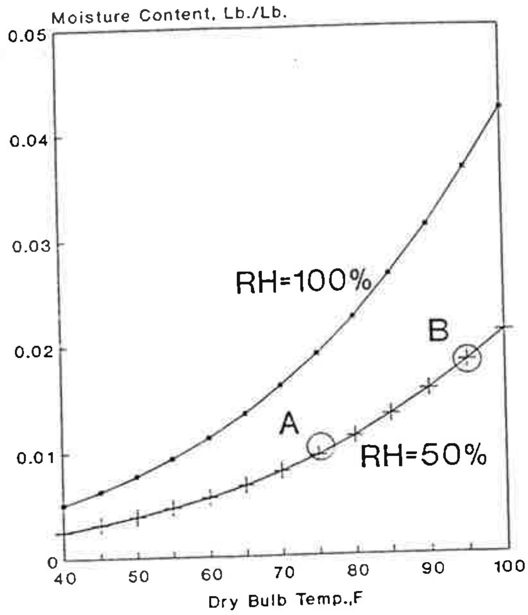

Figure 1 *Psychrometric chart.*

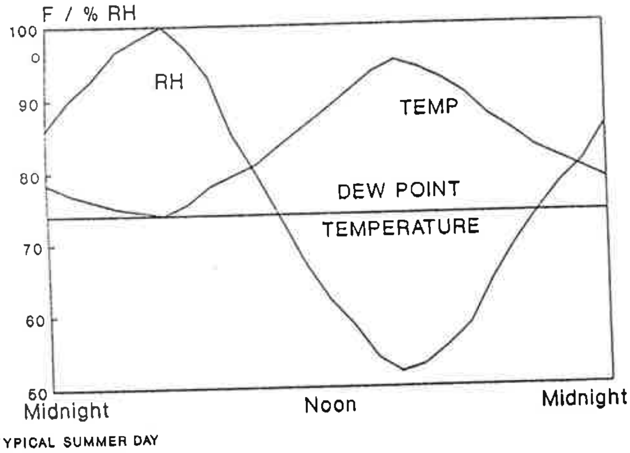

Figure 2 *Temperature, humidity, and dew-point temperature.*

The straight line across the center of the figure represents the dew-point temperature as well as the actual moisture content of air. The dew-point temperature tends to stay about the same as the nighttime low temperature all day and is a good indicator of the absolute moisture content of air for a day. When it rains or when moist air is blown in from the coast, the relative humidity and actual amount of moisture in the air will, of course, be higher. During cool, dry weather, the dew-point temperatures will be lower.

If the outside air dew point is above 55°F, air that infiltrates or make-up air that is not adequately dehumidified significantly impacts the humidity load. When the dew-point temperature of outside air is 55°F or lower, the humidity of infiltrated air will require no dehumidification assuming that the room is maintained at 75°F. At these conditions, the room's relative humidity will be 50% or lower. At this condition, the room's air conditioning can easily remove the moisture produced by hotel guests. The picture changes as the outdoor dew point gets higher. Each air exchange brings in more moisture, and a point is reached where the moisture level of the outdoor air entering through an air conditioner or other air intake vent exceeds the rate that can be accommodated by the air conditioner's dehumidification.

COMPARING SENSIBLE COOLING AND LATENT INFILTRATION LOADS

Humid outside air that enters hotels through vents, cracks, or crevices as make-up air or through open doors and windows is generally the greatest source of excess moisture in hotels in warm, humid climates. To demonstrate the magnitude of the latent content of air that infiltrates, a comparative tool has been developed by defining the sensible cooling infiltration load (SCIL) and the latent infiltration load (LIL). These values for outside air show the relative magnitudes of both the sensible cooling and latent loads for air that infiltrates.

Cooling degree-days (base of 65°F) have been used in past decades to indicate the economic impact of the sensible cooling load. Cooling degree-days vary with location and climatic conditions. There is, however, no comparable term for determining the level of the latent heat load. Not understanding the magnitude of this latent air-conditioning load can cause considerable confusion when air conditioning is sized for hotel use in warm, humid climates. Sensible cooling and latent loads of outside air have been developed to permit a comparison of energy required to condition infiltration and make-up air to a comfortable, energy-efficient, mold-safe environment of 75°F, 60% RH.

Sensible Cooling Infiltration Load

The monthly sensible cooling infiltration load has units of Btu/cfm and is defined as the sensible heat that must be removed from one cfm of outside air during a month to sensibly cool it to a room temperature of 75°F. We call this sensible cooling infiltration load (SCIL). SCIL is calculated as follows:

$$\text{SCIL} = (T_{Mo.Av} - T_i) \times D \times 24 \text{ hours/day} \times \text{SpH}_a \times 4.5 \qquad (1)$$

where

SCIL = sensible cooling infiltration load;
$T_{Mo.Av}$ = average monthly temperature;
T_i = indoor design temperature, 75°F;
D = days in month;
SpH_a = specific heat of air;
4.5 = a conversion constant, i.e., 0.075 lbs/ft^3 × 60 min/h.

Latent Infiltration Load

The monthly latent cooling infiltration load has units of Btu/cfm and is defined as the latent heat that must be removed from one cfm of outside air during the month to reduce its moisture content to a level corresponding to 75°F, 60% relative humidity. The monthly latent infiltration load is calculated as follows:

$$\text{LIL} = (W_o - W_i) \times D \times 24 \text{ hours/day} \times H_c \times 4.5 \qquad (2)$$

where

LIL = latent infiltration load;
W_o = humidity ratio of air at average outdoor dew-point per month;
W_i = humidity ratio of conditioned air at 75°F, 60% RH;
D = days in month;
H_c = heat of vaporization;
4.5 = a conversion constant, i.e., 0.075 lbs/ft^3 × 60 min/h.

Sensible/Latent Infiltration Charts

The sensible cooling and latent infiltration loads have been plotted using weather data from Orlando, Florida, and other locations in the southeastern United States, as well as for Atlanta, Georgia, and Columbus, Ohio, for comparisons. Figure 3 shows that little sensible heat removal is indicated in Orlando before May, and it drops off considerably in the last two months in the year. At maximum, the sensible cooling infiltration load is about 15,900 Btu/cfm.

As the sensible cooling infiltration load in Orlando increases, the latent infiltration load increases as well. In fact, the latent load is far in excess of the sensible cooling load for several months in the year. This shows that during summer months, all the outside air that comes into an air-conditioned hotel from make-up air and infiltration will require more energy for moisture removal than for temperature reduction. If the air temperature is reduced too rapidly and the thermostat is satisfied, the air conditioning will cycle off. Moisture will no longer be removed. Air-conditioning units with a high sensible heat ratio (SHR) will reduce air temperature too rapidly for sufficient dehumidification to occur if the latent load exceeds the sensible load. This can happen when the latent load of air that infiltrates is high, as is true in Florida in summer months. Hotels will feel clammy, furnishings will become damp, and mold can grow. In the fall months, the days become cooler. Little air conditioning is needed, but the moisture in the outside air is still very high. With no air conditioning or cooling needed, mold is likely to keep spreading.

Figures 4 and 5 show the sensible and latent infiltration loads for Tallahassee and Miami. In Tallahassee the average conditions suggest that the outside air is much drier in the winter months. In that part of the state, homes and possibly hotels can experience cold weather moisture problems if they are tightly constructed, much moisture is produced inside, and adequate ventilation is not provided. In Miami, cooling is indicated for every month, and the latent infiltration load is always equal to or greater than the sensible load. The weather data used in these figures were taken from weather stations.

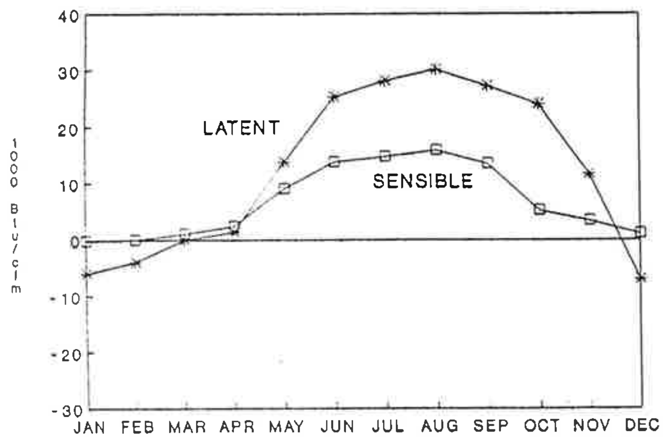

Figure 3 *Sensible and latent infiltration loads—Orlando, Florida.*

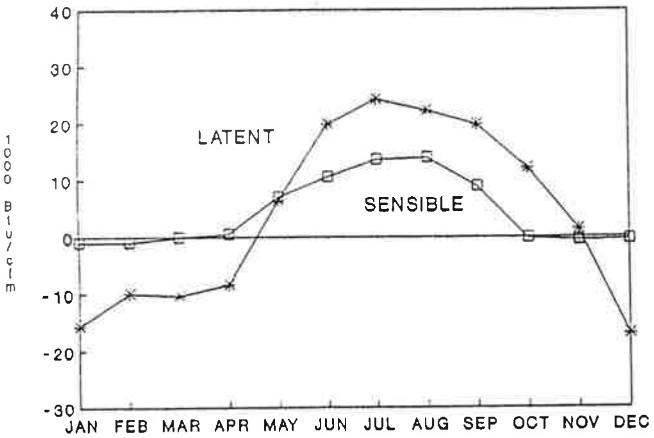

Figure 4 *Sensible and latent inflitration loads—Tallahassee, Florida.*

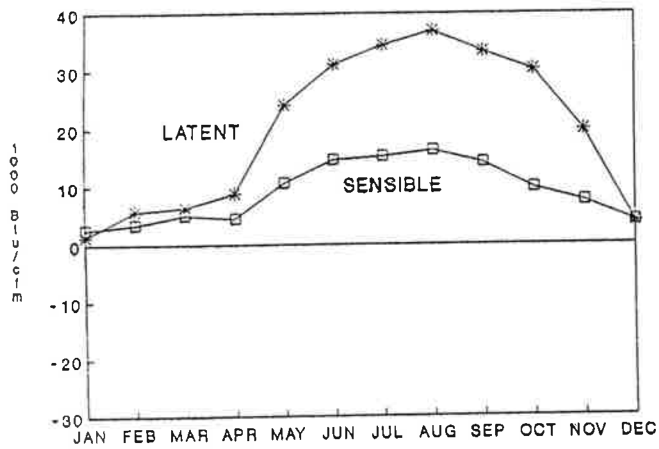

Figure 5 *Sensible and latent infiltration loads—Miami, Florida.*

The sensible and latent infiltration loads for Galveston, Texas, and Mobile, Alabama, are presented in Figures 6 and 7. Weather patterns influence the shapes of the curves but generally show a huge latent load for air that is infiltrated. The humidity level in locales adjacent to coasts and rivers will usually be higher than that shown at weather stations.

Figures 8 and 9 show the sensible and latent infiltration loads for Atlanta and Columbus. Latent loads are of short duration and not as severe as in southern coastal areas. Air-conditioning equipment may not have adequate latent heat removal capacity unless tight construction is used to restrict infiltration and make-up air is introduced at 55°F or a lower dew-point temperature. Some hotels in Florida are now using labels on balcony doors advising guests to keep the doors closed because of high outdoor humidity.

The two tables following permit a comparison of dew-point temperatures throughout Florida. The average dew-point temperatures by month for nine Florida weather

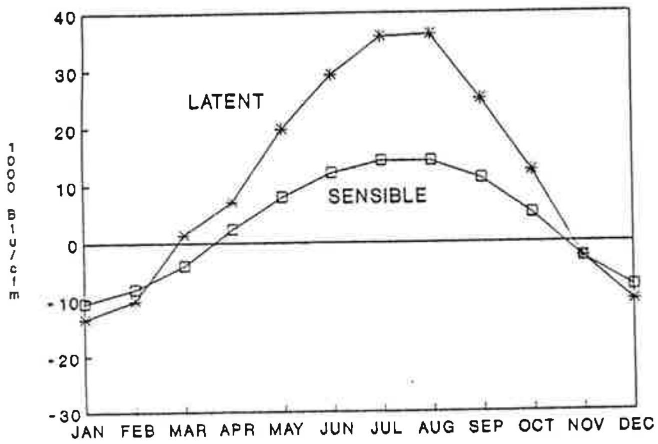

Figure 6 *Sensible and latent infiltration loads—Galveston, Texas.*

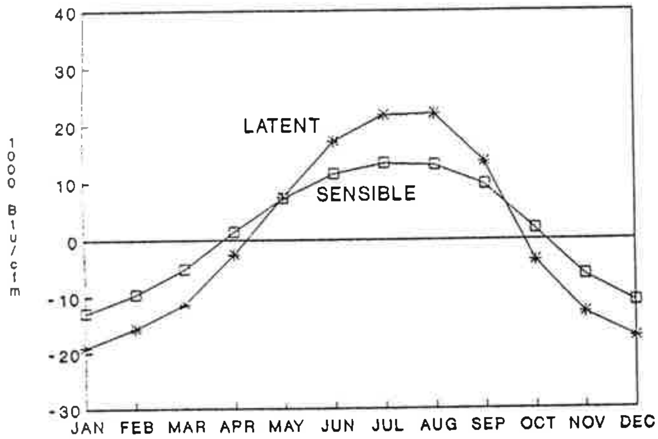

Figure 7 *Sensible and latent infiltration loads—Mobile, Alabama.*

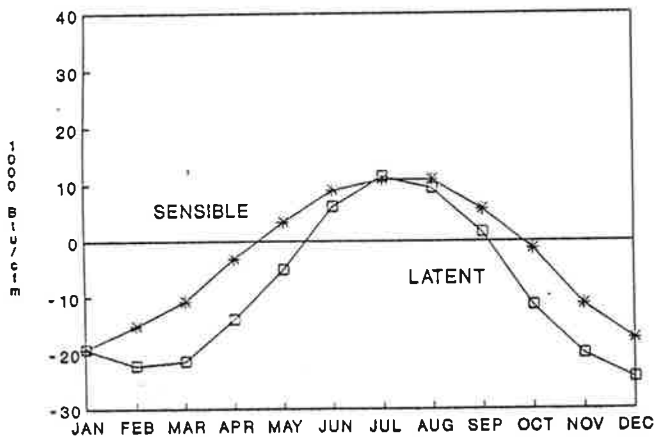

Figure 8 *Sensible and latent infiltration loads—Atlanta, Georgia.*

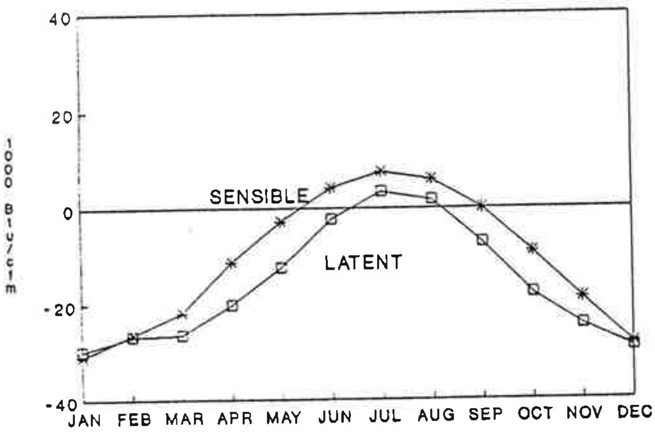

Figure 9 *Sensible and latent infiltration loads—Columbus, Ohio.*

station locations from May through November were above 55°F (Table 1). In contrast, dew-point temperatures in Atlanta and Columbus show that periods of high humidity there are much shorter and, even in summer weather, are much lower.

Average humidity levels, however, do not tell much about the day-to-day humidity levels. Table 2 shows the daily highest low temperatures and the lowest low temperatures for the same Florida weather stations. Except for January in Pensacola and Tallahassee, there will probably be days when the dew-point temperature all over Florida will be above 55°F and humid enough to promote mold growth in hotel rooms if air conditioning is not managed well.

During times of the year when hotel rooms are heated, the relative humidity indoors will be lower because of the low moisture content of the air that comes in from the outside. On the other hand, to have comfortable conditions inside when it is warm and humid outside, moisture removal is a must. Dehumidification to an appropriate level can take more energy than sensible cooling.

CONCLUSIONS

Handling hotel moisture and mold problems in warm, humid climates requires attack from all directions.

- Tight construction must be used to inhibit infiltration. Costly renovations in hotels with moisture problems will not last long if infiltration is not remedied.
- Air-conditioner sizing should realistically factor in the heavy latent cooling load in warm, humid climates. Design for a low sensible heat ratio (SHR) is a must. Where humidity is unusually high, the best option is to provide make-up air at 55°F dew point or lower. (Otherwise, air conditioners with dehumidification enhancements, such as hot gas reheat, heat pipes, or desiccants, should be considered.)
- The air conditioner's evaporator fan should be set to cycle on and off with the compressor.
- Regular maintenance checks should ensure no air leakage around air conditioners. Filters must be changed frequently to avoid blocking the intended air path.

TABLE 1
Average Dew-Point Temperatures* (°F)
(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.

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 2
Maximum/Minimum Low Temperatures* (°F)
(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.

- Bath exhaust fans should be equipped with limited timers to avoid long use. Where hotel exhaust systems run continuously, make-up air should come from a conditioned source and be delivered at a dew-point temperature of 55°F or lower. Keeping indoor air pressure high will help limit humid air infiltration.
- Housekeeping should include in daily reports any leaks or air-conditioning problems. Doors to the exterior should be kept closed when rooms are being cleaned.
- The behavior of guests that contributes to moisture problems cannot be changed, but controls can be used to turn the air conditioning off automatically when balcony doors are open. There are now technical devices that sense the presence of guests and reset the air-conditioner thermostat to a higher temperature when they leave. Humidistats may have a role in air-conditioner operation but cannot be effective if air conditioning does not have a low enough sensible heat ratio.

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