Vapor Retarders to Control Summer Condensation

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ABSTRACT

Prior work by the CRREL has determined that vapor retarders are needed in cold regions to avoid detrimental accumulation of moisture in walls whenever the winter wetting potential exceeds 0.6 in. of Hg•month (2.03 kPa•month). In the hot, humid regions of the United States the summer wetting potential ranges up to 0.9 in. of Hg•month (3.04 kPa•month).

Summer wetting potentials of 0.4 through 0.9 in. of Hg•month (1.34 through 3.04 kPa•month) have been mapped. The zone south of the "0.6" isoline (i.e., a portion of the coasts of Texas and Louisiana and much of southern Florida) may be a reasonable representation of where air-conditioned buildings need vapor retarders to defend against summer wetting from outside air. However, feedback is solicited on which isoline best corresponds to the collective expertise of designers and builders.

Problems associated with summer condensation are often related to wetting of exterior cladding and subsequent solar heating, not just simple vapor drive. Nonetheless, in some hot humid areas, vapor retarders may be used.

INTRODUCTION

In cold regions it is common to install vapor retarders near the inside (warm) surface of building envelopes to prevent moisture in indoor air from condensing within cold portions of the building envelope. The need for a vapor retarder in cold regions is dependent on outdoor climate and the temperature and relative humidity maintained indoors. There is great potential for driving harmful water vapor into the fabric of buildings with high indoor relative humidities in very cold regions (e.g., an enclosed swimming pool in Fairbanks, AK). Such buildings need well-made vapor retarders capable of resisting both diffusion and air infiltration.

A typical office building in Chicago also may need a vapor retarder, but it has a far lower potential for experiencing condensation problems since its indoor relative humidity is lower than that of a swimming pool (approximately 40% vs. 70%) and Chicago's winters are less intense than Fairbanks's winters.

As one progresses south in the United States, the winters become shorter and the summers longer. The potential for condensation in building envelopes in cold weather decreases significantly. However, the potential for condensation in summer increases. Then, indoor moisture is not moving outward through walls and roofs toward cold surfaces. Instead, moisture in the outdoor air is moving inward toward the air-conditioned (i.e., cool) interior. As shown in Figure 1, the direction changes but the problem is still there.

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If it is hot and humid outside and cool inside for a long period, enough moisture can condense in the building envelope to cause problems. In such cases the envelope needs a vapor retarder to prevent warm outside air from reaching the cool inner portions of the building envelope.

Portions of the Gulf Coast and much of southern Florida may be hot and humid long enough to create the need for such vapor retarders in air-conditioned buildings.

GUIDELINES FOR CONTROLLING WINTER CONDENSATION

Various maps of the United States are available that define where vapor control measures are needed in buildings. Anderson and Sherwood (1974) map the 35°F (1.7°C) average January outdoor air temperature and the National Roofing Contractors Association (NRCA) (1989a) uses the 40°F (4.4°C) average January outdoor air temperature. ASHRAE (1985) defines three "condensation zones" bounded by winter design temperatures of about 20°F (-6.7°C), 0°F (-17.8°C) and -20°F (-28.9°C).

Some guidelines also consider the relative humidity indoors. The NRCA (1989a) recommends that the relative humidity within buildings be 45% or more before vapor retarders are installed in roofs. This seems to work well in places like Kansas, Ohio, and Massachusetts. However, in the northern tier of states, experience indicates that buildings with winter relative humidities of about 35% need vapor retarders. Also, in the South, buildings with winter relative humidities well above 45% can survive without vapor retarders.

In an attempt to improve upon these quidelines, Tobiasson and Harrington (1985) generated a series of vapor drive maps of the United States, each map representing a different winter vapor drive. When that work was presented at the Thermal Performance of the Exterior Envelopes of Buildings III conference, feedback was solicited from designers and builders. Feedback obtained since that time has been directed toward the map shown in Figure 2. The isolines on that map represent the relative humidity of 68°F (20°C) indoor air at which the winter vapor drive equals 0.6 in. of Hg•month (2.03 kPa•month). If the indoor relative humidity is above the mapped value, a vapor retarder is needed. In northern Alaska, the indoor relative humidity for buildings without vapor retarders is limited to 20%. In the northern tier of states vapor retarders are needed in buildings with indoor relative humidities in excess of around 35%. Further south the indoor relative humidity can increase to 60%, 70% even 80% before vapor retarders are needed.

This map is gaining acceptance in the United States. It appears in the NRCA Energy Manual (1989b). Tobiasson and Harrington (1985) also present a graph for correcting the mapped value for indoor air temperatures other than 68°F (20°C).

MAPPING SUMMER VAPOR DRIVE

Weather Records

The method used by Tobiasson and Harrington (1985) to map winter wetting potential has been used to map summer wetting potential. The same National Weather Service (NWS) and USAF Air Weather Service (AWS) records used to generate the winter wetting maps were used to generate the summer wetting maps. The mean monthly outside air temperature and relative humidity were used to calculate outdoor vapor pressures according to tables and equations in ASHRAE (1985).

Indoor Conditions

The only way that the indoor vapor pressure can be below that outdoors is if the indoor air is dehumidified. Air conditioners reduce the indoor vapor pressure by condensing out moisture in the outdoor air as it is cooled for use indoors. In so doing, a vapor drive develops that can create a condensation problem in the building envelope.

For the summer maps, the temperature of the inside surface of the building envelope is taken as 68°F (20°C). This is lower than the 75°F (24°C) commonly used when designing air-conditioned buildings in hot, humid regions. I chose 68°F (20°C) since many air-conditioned buildings in such regions are kept that cool. Those that are kept warmer are less likely to develop condensation problems.

The vapor pressure at the inside surface of the building envelope is assumed to be at saturation (i.e., 0.691 in. of Hg; 2.34 kPa) due to the presence of a vapor retarder there. If the interior of the building envelope is relatively permeable, the amount of moisture that accumulates within the wall will be reduced. Thus these temperature and permeability assumptions result in a worst case prediction of summer wetting.

Vapor Drive

Figure 3 shows the variation in mean monthly outside vapor pressure for Galveston, TX. The horizontal line in Figure 3 represents the saturation vapor pressure for 68°F (20°C) indoor air. From mid-May to late September vapor drive is to the interior of a building air-conditioned to 68°F (20°C). During that period, outside moisture tends to accumulate within the building envelope. The total amount of moisture that could accumulate (i.e., the summer wetting potential) is a function of the vapor drive (i.e., inches of mercury, or kPa, vapor pressure difference) and the length of the wetting period. Graphically it is represented by the wetting area in Figure 3. For Galveston that area equals 0.56 in. of Hg•month (1.89 kPa•month).

If the indoor temperature had been 75°F (24°C) instead of 68°F (20°C), the horizontal "inside" line in Figure 3 would have been at a vapor pressure of 0.88 in. of Hg (3.0 kPa), and the wetting area would have been eliminated. This illustrates the significant increase in wetting potential caused by lowering the indoor temperature.

For Galveston, with an indoor temperature of 68°F (20°C) the <u>drying</u> potential totals 1.34 in. of Hg•month (4.52 kPa•month). This greatly exceeds the 0.56 in. of Hg•month (1.89 kPa•month) summer wetting potential; thus, there is ample potential to dry out wet insulation to the exterior during the rest of the year. Progressive wetting, as described by Tobiasson and Harrington (1985), occurs when the wetting potential exceeds the drying potential. Since the drying potential also greatly exceeds the summer wetting potential for all other weather stations in hot, humid regions of the United States, only seasonal wetting needs to be considered.

Maps

Figure 4 shows isolines of summer wetting potential that range from 0.4 through 0.9 in. of Hg•month (1.34 through 3.04 kPa•month). From what I have heard of summer condensation problems within building envelopes, I expect that the zone south of the 0.6 isoline in Figure 3 is where buildings may need vapor retarders to avoid summer condensation problems when they are air-conditioned to 68°F (20°C). However, I would greatly appreciate the same sort of feedback from readers on this map that I received on the winter wetting maps.

As shown in Figure 2 in the hot, humid regions in question, only buildings having very high indoor relative humidities (above about 80%) need vapor retarders near their <u>inside</u> surface to resist winter wetting. Thus most building envelopes in hot, humid climates that are equipped with a vapor retarder near their outside surface to resist summer wetting would not contain a deliberate vapor trap. I am not worried about such traps, which tend to remain dry (Tobiasson 1981, 1986) but others are (Griffin 1982; Baker 1980, and ASHRAE 1985).

<u>CAVEATS</u>

Buildings in cold regions can also suffer summer condensation problems when their cladding is improperly designed or built. If the exterior surface of walls allows driving rain to enter the building envelope, subsequent solar heating of that wall can create very high vapor pressures within it and condensation on the cooler inner portions of the wall.

Wilson (1965) describes test huts constructed to study summer condensation in Ottawa and concludes that summer condensation can be avoided by using exterior cladding resistant to wetting by rain or by ventilating behind absorptive cladding such as bricks and concrete blocks.

In the United Kingdom, the Building Research Establishment (1989) advises that walls facing east-southeast to west-southwest be protected on the exterior, or contain a cavity ventilated to the exterior, to avoid summer condensation on the outside surface of the vapor retarder. Omitting the vapor retarder is not considered an acceptable solution since summer condensation can also occur behind low-permeability internal finishes.

Anderson (1985) describes summer condensation problems in Denmark, which has a climate similar to Connecticut. He advises use of water-repellent cladding, or incorporation of a ventilated space between brick facings and the insulation behind them. Alternatively, an asphaltic felt can be installed between the bricks and the insulation to avoid summer condensation.

While ventilating outer portions of the building envelope may be beneficial, the infiltration of hot, humid outdoor air into cooler portions of the envelope can cause problems. Building envelopes everywhere, even those that are ventilated, should be designed to resist air leakage through the envelope, since air leakage is most often the vehicle that transports water vapor to unwanted places where it can cause problems.

Exposure tests in Beaumont, TX (Mei 1986; TenWolde and Mei 1986) indicate that vapor retarders near the outside of walls are probably only needed in that hot, humid location if a vapor retarder is present near the inside surface of the wall. They also indicate that a single vapor retarder located near the center of the wall can work well. The Beaumont studies also reinforce the importance of waterproofing hygroscopic sheathing, especially on south-facing walls.

CONCLUSIONS

All buildings in all areas need to resist rain penetration and air leakage, whether or not they need vapor retarders.

The potential for summer condensation exists for air-conditioned buildings in southern Florida and along portions of the Gulf Coast to such a degree that vapor retarders may be justified.

A map has been developed to define where buildings that are air-conditioned to 68°F (20°C) need such vapor retarders. The 0.6 in. of Hg•month (2.03 kPa•month) isoline on the Figure 4 map "calibrates" best to my current, but limited, knowledge of condensation problems in that region. I would appreciate feedback from readers on which isoline best fits their experiences.

It is likely that problems associated with summer condensation are related more to air leakage, rain penetration, and solar heating than classic vapor drive. In most cases, the installation of vapor retarders is not the solution to such problems, but in some areas vapor retarders may be needed.

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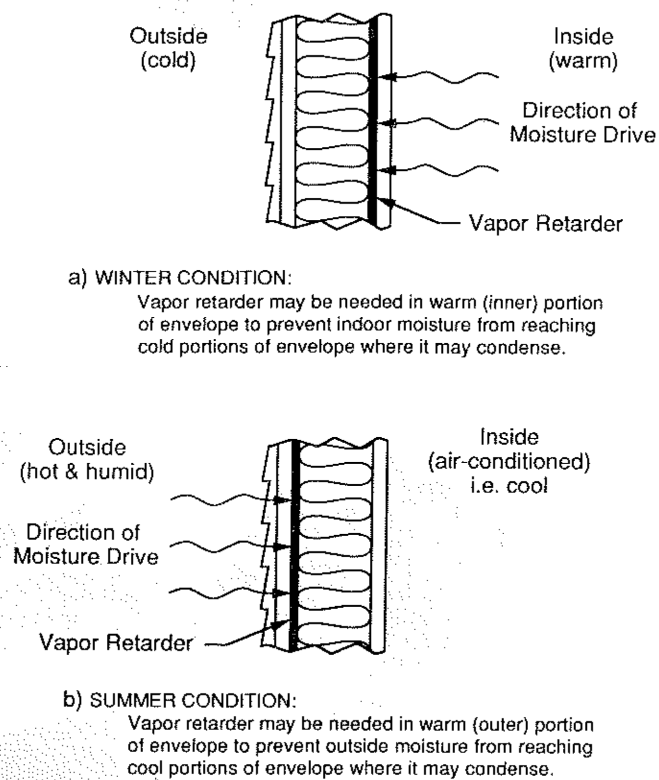

Figure 1. Winter and summer vapor drives

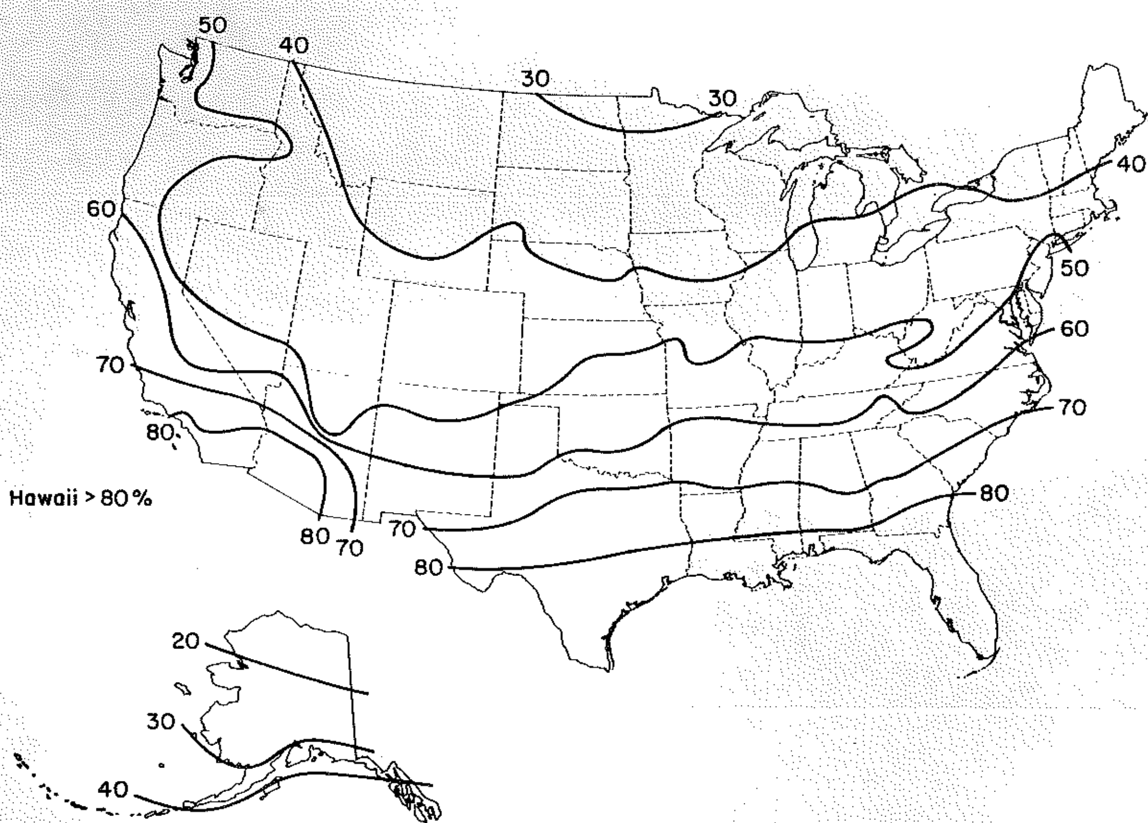

Figure 2. Indoor relative humidities above which buildings with an indoor temperature of 68°F (20°C) need vapor retarders to prevent winter wetting of the building envelope

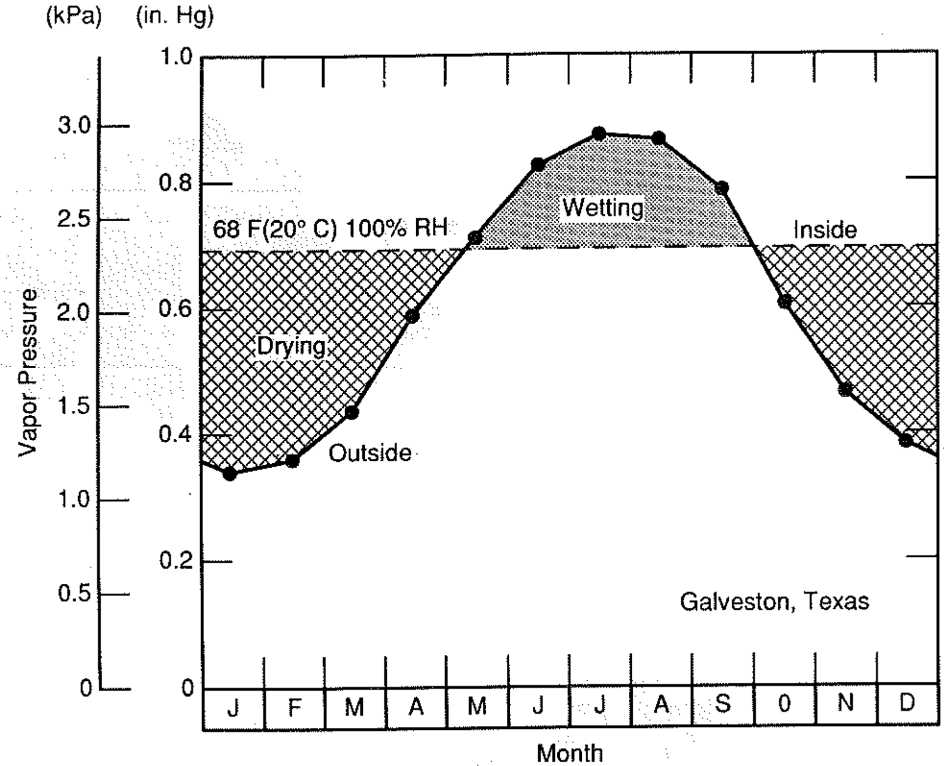

Figure 3. Wetting and drying potentials for an air-conditioned building in Galveston, Texas with an indoor temperature of 68°F (20°C)

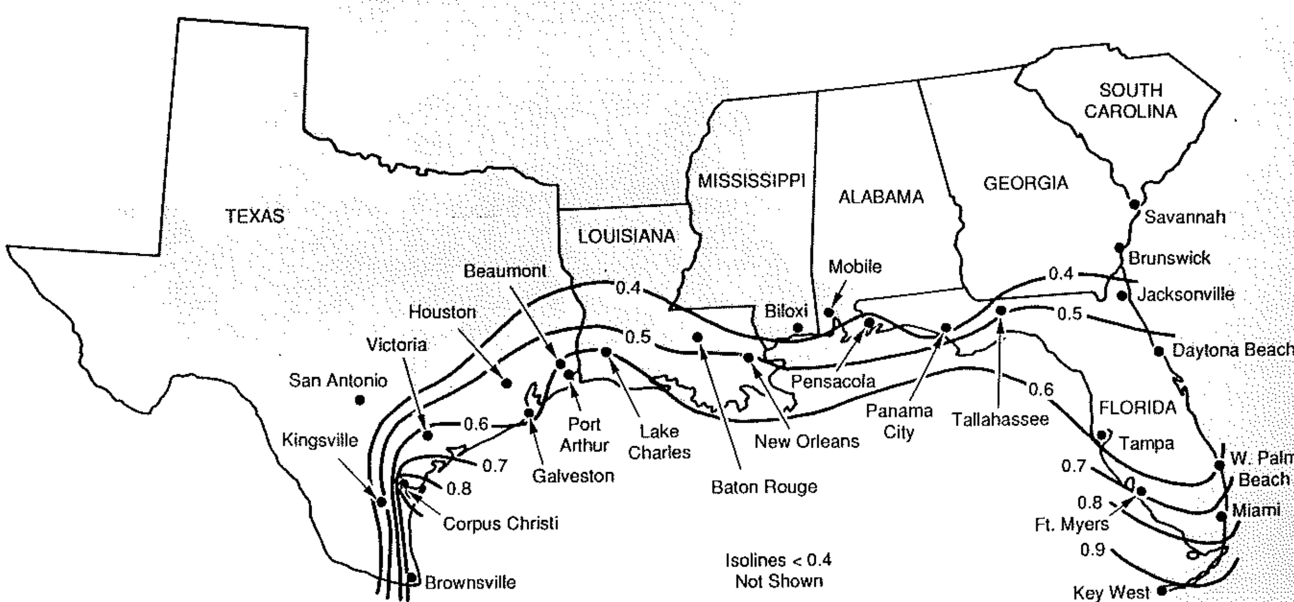

Figure 4. Isolines of summer wetting potential from 0.4 through 0.9 in. of Hg·month (1.4 through 3.0 kPa·month)