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Hutcheon, N. B.

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Humidity in Canadian Buildings

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N. B. Hutcheon

Please note

This publication is a part of a discontinued series and is archived here as an historical reference. Readers should consult design and regulatory experts for guidance on the applicability of the information to current construction practice.

This is the first issue of Canadian Building Digests - a new publication to be issued once a month by the Division of Building Research. Each Digest will be restricted to one topic and will present, as concisely and clearly as possible, a summary of the subject for the information of those who must deal with the technical and related aspects of buildings. The pattern for this kind of publication has already been well established by the Building Digests of the British Building Research Station, to whom our acknowledgement is here recorded.

Humidity is one of the most important of the topics that are of special concern in Canadian building design and operation. Low outdoor temperatures in winter give rise to condensation on and in walls and windows and tend to produce low relative humidities indoors. When even moderate humidities must be carried within buildings serious difficulties can be expected unless the designer appreciates fully what humidity is and how it relates to building performance.

It is important to realize that what is normally referred to as "humidity" is actually relative humidity. It is a measure of the amount of water vapour present in the air expressed as a percentage of the maximum amount that the air can hold at that particular temperature. When the temperature is changed, the relative humidity changes, since the capacity of the air for holding moisture increases with increasing temperature. These relationships are most conveniently represented graphically in psychrometric charts. Such a chart is shown in simple form in Fig. 1.

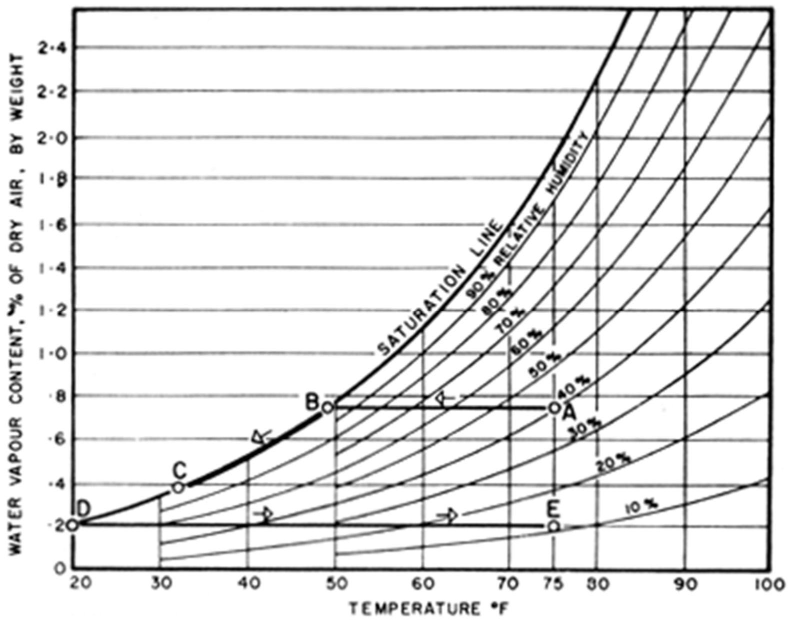

Figure 1. Heating And Cooling of Air Vapour Mixtures

The water vapour content of the air at saturation at various temperatures is shown by the saturation line of Fig. 1. When an air-vapour mixture is heated or cooled, without the addition or removal of moisture, the resulting "process" may be plotted as a horizontal line on the chart. The process ABC represents room air at 75°F and 40 per cent relative humidity being cooled in contact with a cool window surface. When cooled to 49°F the mixture becomes saturated; if cooled further, water will be removed by condensation on the window surface. This situation is typical of many that occur in buildings and when fully understood gives much insight into many humidity problems.

Humidity in Buildings

It has long been recognized that in Canadian buildings heated to comfort temperatures, the relative humidities are usually quite low in winter. Outside air which enters a building in winter has a low moisture content, and when heated provides low relative humidity unless substantial quantities of water are evaporated within the building. This may be verified by reference to the process shown by the line D E of Fig. 1, which shows that air from outside at 20°F and 100 per cent relative humidity will, when heated to 75°F, have only 12 per cent relative humidity. The moisture content will have to be increased from 0.2 to 0.74 per cent to provide 40 per cent relative humidity.

The relative humidity within a building will depend on the moisture content of the outside air, the ventilation rate, the rate at which moisture is lost through the building enclosure, and the rate at which moisture is supplied to the air within the building. These factors may vary widely from one case to another.

The average January temperature in Vancouver is 39°F while that for Ottawa is 10°F. The corresponding outdoor relative humidities at each location are about the same - 88 percent. However, when outdoor air at these conditions is warmed to 75°F the resulting humidity for Ottawa is only 5½ per cent while that for Vancouver is 25 per cent. In many public buildings having high ventilation rates and low rates of moisture supply, the relative humidities produced will be close to these values. When the ventilation rate is at the accepted minimum of 10 cubic feet per minute per person, the moisture provided by the occupants becomes quite significant and will result in humidities of 60 per cent for Vancouver and 45 per cent for Ottawa.

In dwellings the situation is somewhat different than in public buildings since ventilation rates are frequently reduced to a minimum in order to conserve fuel and there are substantial sources of moisture. The average Canadian dwelling will have a transmission heat loss of about 0.04 Btu per cubic foot of building volume per degree temperature difference between indoors and outdoors. Ventilation (or infiltration) will add to this to the extent of 45 per cent for each hourly air change. In many houses, the space provided per occupant is about 2000 cubic feet; the hourly air change required for ventilation at the accepted minimum of 10 cubic feet per minute per person will be only 0.3. The advantages in fuel economy of reducing the ventilation rate are thus apparent, when it is realized that loosely fitted windows and doors may often allow considerably more than one air change per hour.

It has been determined that the average family of four will produce by its normal activities within a house about 0.7 pounds of water vapour per hour, but that this may rise to as much as 2 pounds per hour on wash days. These quantities may be used to calculate the ventilation rates at which 40 per cent relative humidity will be maintained within the house for the average January conditions at Vancouver and at Ottawa. It is found that for Vancouver the ventilation rate must be 0.40 air changes per hour normally, and 1.1 on wash days; for Ottawa the rates must be 0.25 and 0.65 air changes per hour. Since only 0.3 air changes per hour are required for freshness it may be concluded that many houses are adequately humidified by the normal moisture sources within the house, if the ventilation rates are minimum. On days on which exceptional amounts of moisture are released within the house it may be necessary to increase the ventilation rate far above the minimum to prevent the relative humidity from rising above 40 per cent.

The cases just considered are for average modern houses, tightly constructed, and with a relatively low volume per occupant. Older, larger houses, multi-story, having many loose-fitting windows, and providing large volume per occupant will have unavoidably high ventilation rates and may have relatively small natural moisture sources. Here the extreme low humidities may approach those calculated for public buildings, for average January conditions, of 25 per cent for Vancouver and 5½ per cent for Ottawa, and may be even lower for periods of extreme low temperature. Neglecting natural moisture sources as much as 9.6 gallons of water per day will have to be added to maintain 40 per cent relative humidity at 75°F for each 10,000 cubic feet of building volume, for one air change per hour with outdoor air saturated at 20°F.

While large houses with high ventilation rates will have low humidities unless humidifiers are used, it is probable that a large proportion of the houses now being constructed have sufficient humidity provided by natural sources within the house.

Upper Limits of Humidity in Winter

The occurrence of condensation places a limit on the humidity that can be carried in Canadian buildings in winter. The occurrence of visible condensation on the room-side surfaces of windows, walls, floors, and ceilings depends upon the combination of the relative humidity maintained and the extent of the cooling produced at the surfaces in question. Visible condensation, although common on windows in winter, is not as troublesome as concealed condensation which can occur in roofs, attic spaces, and in walls. Water vapour can diffuse through interior finishes of walls and through ceilings, or may be carried by air leakage, until it encounters cold surfaces and is condensed. When the surfaces on which this condensation occurs are below freezing for long periods of time the condensation accumulates as frost. It is not impossible (in the colder areas of Canada), with poor vapour control in a wall or ceiling, to collect as much as one pound of frost per square foot of wall or roof area. This provides one gallon of water per stud space in a frame wall, which may be released over a few hours upon a rise in temperature.

There is little point in attempting to force the relative humidity in a building above the point at which visible condensation begins to occur, since the moisture added will be transferred to the cold surfaces and will accumulate there. The maximum relative humidities that can be carried in rooms at 70°F without the occurrence of condensation are as shown in Table I.

Table I. Maximum Humidities for No Window Condensation

Outdoor Temperature (°F)	Relative Humidities at 70°F			
	Single Window		Double Window	
	Wind	No Wind	Wind	No Wind
+20	24%	41%	53%	61%
0	12%	27%	41%	49%
-20	6%	17%	32%	39%
-40	2%	10%	23%	31%

It should be noted that double windows provide higher inside surface temperatures and therefore permit higher humidities to be carried without window condensation.

Houses can now be reasonably well constructed, with insulation, vapour barriers, and attic ventilation, so that it is possible to carry humidities up to those producing window condensation, without other moisture difficulties. Most public and commercial buildings are not constructed to the same standards of insulation and vapour control as wood-frame houses and cannot tolerate the same relative humidities without difficulty. Indeed much contemporary building design employing much glass and metal in walls will avoid serious condensation difficulties only if the inside relative humidities are allowed to remain at a low level in cold weather.

Humidity in older houses and in most public and commercial buildings not specially designed for proper control of water vapour should probably not exceed 20 per cent at temperatures below zero. For indoor humidities of 50 per cent at subzero outside temperature, insulation and vapour barriers must be used, low resistance heat paths that are provided by metal or solid masonry, at columns, at the edges of floor and roof slabs, and around windows must be avoided, or given special treatment to eliminate cold room-side surfaces. In addition double or even triple windows may have to be used. Industrial buildings such as textile mills in which humidities of 70 to 80 per cent must be carried require still greater precautions in design. Window may have to be eliminated, special vapour barriers will be required, and heat may have to be introduced at certain portions of the structure to maintain adequately high surface temperatures. Roofs for such conditions present a special problem. It is clear that many problems and much expense are involved when high humidities must be provided for.

Effects of Relative Humidity upon People

It has long been accepted that thermal sensations of comfort are affected by relative humidity and that for the same comfort a higher temperature is required to offset a decreased relative humidity. The research work on which these conclusions were based is under review and new evidence is being obtained. It is now evident that the conclusions drawn from the earlier work applied mainly to the thermal sensations experienced over limited periods of time after leaving one room for another at a different relative humidity. For conditions of prolonged exposure to the same relative humidity at temperatures within the comfort zone most people will experience only small changes in thermal sensations of comfort over a wide range of relative humidities so long as they are not actually sweating.

There is little conclusive evidence to show that either high or low humidities are of themselves detrimental to the health of normal people. It seems logical to assume that, in general, extremes of humidity, are undesirable and that it is desirable to keep relative humidities at values within a broad range of from 30 to 70 per cent. There is, however, no firm basis for establishing such limits so far as the health and comfort of most people are concerned.

Conclusion

Although it would be desirable to avoid high moisture contents to prevent deterioration of the building structure, and at the same time to provide constant humidity the year round to minimize dimensional and other changes in materials and furnishings within a building, this is difficult to achieve under Canadian winter conditions. Even moderate humidities inside buildings can produce wetting by condensation on and in the building structure because of the large temperature gradients within walls in winter. The best answer in many cases where higher humidities are not necessary will be to allow the humidities to fall to low levels. In buildings with large moisture sources steps may have to be taken to eliminate water vapour from them to avoid condensation. Consideration should always be given to the difficulties that may be created in any given building before humidification is added. When relative humidities in the medium to high range must be carried, the buildings must be specially designed and constructed.