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Condensation on Inside Window Surfaces

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Please note

Condensation on inside window surfaces is a common wintertime complaint in most of Canada, especially in buildings in which some attempt is made at humidification. Window condensation not only reduces visibility and is psychologically irritating but it can lead to severe damage of surrounding construction from wetting. It is only one of several aspects of window performance, but it is one that can be observed directly, whereas other shortcomings may not always be so evident. Condensation between the panes of double windows is a separate problem and is not covered in this note.

Condensation occurs on inside window surfaces whenever surface temperature falls below the dew-point temperature of the room. Window construction often represents the poorest component of the building enclosure in a thermal sense, even when double windows are used, and hence has the lowest inside surface temperature. The window, therefore, determines the practical limit of humidity for the space in winter, and condensation may appear on the glass, frame, or sash, depending on the relative thermal characteristics of these three components.

Condensation on the Glass

The relative humidity in a room at which condensation will occur on the inside surface of the glass depends on the glass surface temperature, which in turn depends on all the factors affecting heat flow through glass. The principal factors are: the inside and outside air temperatures adjacent to the glass surface, the number of panes of glass, and the air flow condition over inner and outer surfaces. Additional factors affecting surface temperature of multiple pane windows are width of the air space, convection within it, and the extent of air leakage into and out of the air space. Drapes or other window coverings, width of sill and stool, and the room heating arrangement are important insofar as they affect the principal factors referred to. The thickness of the glass is usually unimportant within the range of thicknesses normally used in buildings, since glass has a relatively high thermal conductivity.

Glass surface temperatures can be readily calculated using simple heat transfer relationships, and inside humidities at which condensation will occur on glass surfaces be determined for any outside temperature condition. The results of calculations will depend on the surface heat transfer coefficients selected. Table I gives results of such calculations for single, double, and triple glazing for two wind conditions, with natural convection over the inside surface. The assumption of natural convection over the inside surface is valid unless special steps have actually been taken to blow air over the window. Merely locating the room heat supply under the window will not necessarily increase the inside surface heat transfer coefficient, but will tend to increase the air temperature adjacent to the window. Values in Table I are for periods of no solar radiation.

Table I. Maximum Humidities For No Window Condensation and Corresponding Inside Surface Temperatures

Outdoor Temp. °F	Surface Temperatures and Relative Humidities with Inside Temperature at 70°F											
	Single Window				Double Window				Triple Window			
	15 mph wind		No wind		15 mph wind		No wind		15 mph wind		No wind	
	Temp °F	R.H.	Temp °F	R.H.	Temp °F	R.H.	Temp °F	R.H.	Temp °F	R.H.	Temp °F	R.H.
40	47	44%	55	59%	59	68%	61	73%	63	78%	64	81%
20	32	24%	45	41%	52	53%	56	61%	59	68%	60	71%
0	17	12%	35	27%	45	41%	50	49%	54	57%	56	61%
-20	2	6%	24	17%	38	32%	44	39%	50	49%	52	53%
-40	-14	2%	14	10%	31	23%	38	31%	45	41%	48	46%

In multiple glazing, temperature gradients are set up in the air spaces as a result of convection. The temperature of the air space at the bottom will be several degrees lower than that at the top, and this is reflected in inside glass surface temperatures. It explains why condensation on inside surfaces of double windows usually occurs first at the bottom. Tests have shown that calculated values of surface temperature arc in good agreement with surface temperatures measured at the centre of windows. The glass surface temperature at the bottom will be lower than the calculated values and the limiting values of humidity for no condensation will be correspondingly lower. This effect may be counteracted to some extent by locating the heat source beneath the window. Thermal characteristics of double glass are little affected by increasing the air space thickness beyond ¾ to 1 inch; even reducing it to ¼ inch leads to an increase in heat loss of only 15 per cent.

The higher humidities possible with multiple glazing are evident from Table I. With single glass, humidities above 25 per cent cannot be carried with outside temperatures below 20°F without excessive condensation. For most areas in Canada windows must be designed for outdoor temperatures below 20°F; double windows are used extensively for residences, although in Eastern Canada single windows are often selected for commercial buildings in order to reduce capital costs. To overcome the limitations imposed on relative humidity by single glass, heating systems providing a degree of forced convection over the window are sometimes employed.

Table II shows the effect of forced convection over the inside surface of single glass with an outdoor wind condition of 15 miles per hour upon surface temperatures and the corresponding maximum room humidities which can, be carried without condensation. An average inside air velocity of 2½ miles per hour over the lower part of the window is probably the maximum that can be expected with typical air-conditioning units located at the window stool. Values given for an air velocity condition of 5 miles per hour correspond very closely to those for air at 80°F and a velocity of 22½ miles per hour adjacent to the inside window surface. This increase in temperature adjacent to the window is the maximum that should be expected with under-window heating systems.

Table II. Effect of Forced Convection Over Inside Surface of Single Windows

Outside Temp. °F	Surface Temperatures and Relative Humidities with Inside Temperature at 70°F and Outdoor Wind of 15 mph					
	Natural Convection		Forced Convection air velocity = 2½ mph		Forced Convection air velocity = 5 mph	
	Temp. °F	R.H.	Temp. °F	R.H.	Temp. °F	R.H.
40	47	44%	51	51%	53	55%
20	32	24%	38	31%	41	35%
0	17	12%	25	18%	29	21%
-20	2	6%	12	9%	17	12%
-40	-14	2%	-1	5%	6	7%

It may be seen from Table II that significant increases in surface temperature and maximum permissible humidity can be achieved by forced convection and increased air temperature adjacent to the window. These values are still lower than those for double windows with natural convection. It should be realized also that such forced convection and higher air temperatures result in increased heat loss of from 50 to 70 per cent through single glazing. On the other hand, the heat loss through single glass is from two to four times that through double glass, depending on the inside convection conditions. The cost of single glass, particularly with forced convection, is therefore comparatively high in terms of energy requirements for heating.

Drapes and curtains can affect both the air temperature adjacent to a window and the inside convection condition. These may increase or decrease surface temperatures and condensation, depending on their location with respect to the window and heating outlet. Window stools interfere with air flow at the bottom of the window and tend to lower temperatures in this region.

Condensation on the Frame and Sash

The surface temperatures of wood frames or sash are normally higher than those of the inside surface of the glass because of the relatively high thermal resistance of wood and the thicknesses used. For example, the thermal resistance of ¾ to 1 inch of wood is equal to that of an air space, so that condensation on wood members is usually not a problem. The thermal conductivity of aluminum, on the other hand, is about 800 to 1400 times that of wood, and mild steel 300 times that of wood. This means that the resistance to heat loss of metal members that are continuous from inside to outside is extremely low.

The inside surface temperatures of metal frames or sash, continuous from inside to outside, will depend largely on the heat transfer coefficients at inside and outside surfaces.

Thus the area exposed inside and out is a major factor in determining inside surface temperatures. The greater the surface area of sash or frame exposed inside, relative to outside, the higher will be the inside surface temperature. Unfortunately it is not unusual to provide a greater exposure to outside than to inside, at least for mullion and sill sections. Nominally, if the inside exposure is equal to the outside the inside surface temperature will be essentially that of single glass. However, this is true only if the surface heat exchange coefficients are the same for both. This coefficient is generally lower at the stool or bottom rail because of the interference with air flow at this location, but with aluminum it will be significantly lower, perhaps only one-half that for the glass, because of its high reflectivity. The lower rate of heat transfer at the surface of the metal will result in surface temperature lower than that of single glass and the humidity at which condensation will occur will be correspondingly lower. Some improvement could be effected by reducing the reflectivity of the inside aluminum surfaces. Inside surface temperatures of the frame are also affected by heat exchange with the surrounding construction, and for this reason it is desirable to make structural connections with the wall nearer the warm inner surface.

One method used to overcome the high heat conduction of metal frames or sash and to raise inside surface temperatures is to provide a break in the member with an insulating separator between inside and outside elements. This approach is not common with single sash, although it might be used to advantage where condensation on frames or sash is objectionable. Thermal breaks are absolutely necessary with multiple glazing if their advantage in permitting higher room relative humidities is to be fully utilized. Otherwise, condensation will occur on the frame at approximately the limiting relative humidities for single glass.

Ideally, a frame or sash should be designed so that the inside surface temperature of the metal is at least equal to the minimum temperature on the inside surface of the glass. The thickness of the thermal break required to achieve this ideal will depend on details of the particular frame or sash design, but two of the major determining factors are the area of inside and outside exposure and the surface heat exchange coefficients of frame or sash. Additional factors are the cross-sectional area of the thermal break normal to heat flow and its thermal conductivity; the values of both should be as low as is practical. In general, thermal break materials must be sufficiently rigid to permit the two elements of the frame or sash to act as a structural unit when bolted together. As suitable materials are unlikely to have a conductivity less than that of wood, the thickness of the thermal break required will be not less than ½ inch unless its cross-section is unusually small, even when other thermal factors are favourable; it may be 1 inch or more with some arrangements. This is in excess of the thermal separation provided in several metal windows on the market, and it would appear that these may fall short of the ideal with respect to the thermal performance of frames and sash and room humidities that can be carried without condensation.

A special problem exists with metal frames or sash for windows using factory sealed double glazing units. Since these units may be only ¾ inch thick, the space available in the member for a thermal break is limited. Furthermore, the spacer and surrounding channel of the units may contribute to lower edge temperatures. More skill will be required in the design of metal frames or sash for such units if the advantage of double glazing is to be fully utilized.

Summary

Window surfaces usually determine the maximum room relative humidity that can be carried without condensation. Condensation can occur on glass, sash, or frame, and the thermal performance of each must be separately considered. Multiple glazing permits significantly higher relative humidities than single glazing, although the humidities that can be carried with single glass can be increased to some extent by forced convection and heated air. The heat loss through single glass is at least twice that through double glazing, and is further increased when forced convection is employed.

In order to obtain the full benefit of multiple glazing in permitting higher relative humidities without condensation, metal frames and sash must incorporate thermal breaks. The thickness required to maintain frame temperatures equal to the minimum glass surface temperature will depend on the specific design of the window, but a minimum of ½ to 1 inch of material with a thermal conductivity equivalent to that of wood is usually required.