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Condensation between Panes of Double Windows

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Please note

It is well known that double windows are of value in reducing heat transmission through glass areas and in permitting substantially higher relative humidities in winter than are possible with single glass without excessive condensation on inside glass surfaces. Condensation between the panes, on the inside surface of the outer glass, occurs with most types of double windows under some conditions of use. Windows fitted with factory scaled glazing units are a possible exception, but they may not be without problems, as will be discussed. A small amount of condensation on the outer panes of non-sealed double windows is generally accepted as inevitable; when it begins to obstruct seriously the view through the window for long periods, or when run-off contributes to the deterioration of surrounding materials, there is reason for concern.

Condensation will occur on the inside surface of the outer pane whenever the temperature of that surface at any point is below the dew-point temperature of the air space. The surface temperature of the outer pane is always above outside dew-point and usually below room dew-point under winter heating conditions. The dew-point of the air space will be between room and outside dew-point at a level at which the moisture removal from the space balances the moisture gain. It follows that in designing a window free of condensation under given conditions, consideration must be given to the factors that affect moisture flow to and from the air space between panes.

Factors Affecting Moisture Flow

Water vapour can move into and out of air spaces of double windows under two forces. It moves through cracks and some materials in window assemblies by diffusion, as a result of differences in partial pressure of water vapour, and it is transported as a component of the air which flows through window cracks under total pressure differences.

It can be demonstrated that vapour flow by diffusion is important as a factor in window condensation or its control only when total pressure differences are zero or very small, except perhaps for extremely tight windows. Under most conditions of exposure vapour transmission by air flow is several times that by diffusion, and the latter can be neglected.

Condensation on the outer pane is unlikely when the flow of air is from outside to inside through the window space, since outside air has a dehumidifying effect and will result in an air space dew-point close to outside dew-point. On the other hand air flow from the room to the air space has a humidifying effect and will lead to condensation unless counteracted in some way. Figure 1 represents the variations in air pressure with height across a double window subjected to a temperature gradient, with air flow from inside to outside. Pressure differences from top to bottom, which are greatly exaggerated for purposes of illustration, result from the changes in air pressure with elevation and differ from inside to outside because of differences in temperature.

Figure 1(a) represents pressure conditions when the resistances to flow around both panes are equal. The air space pressure is approximately mid-way between inside and outside pressures and flow is from inside to outside through all openings. Figure 1(b) represents the pressure distribution when resistance to flow through openings around the inner pane is much greater than that through openings around the outer pane, these being evenly distributed above and below the mid-height of the window. Under these conditions, pressure at the top of the air space is greater than that outside and the pressure at the bottom is less. Thus air can flow into the air space from, outside through lower openings around the outer pane, even though there is an over-all flow from the building to the outside. All outflow passes through the upper openings around the outer pane under pressure difference created by chimney action between the air space and outside.

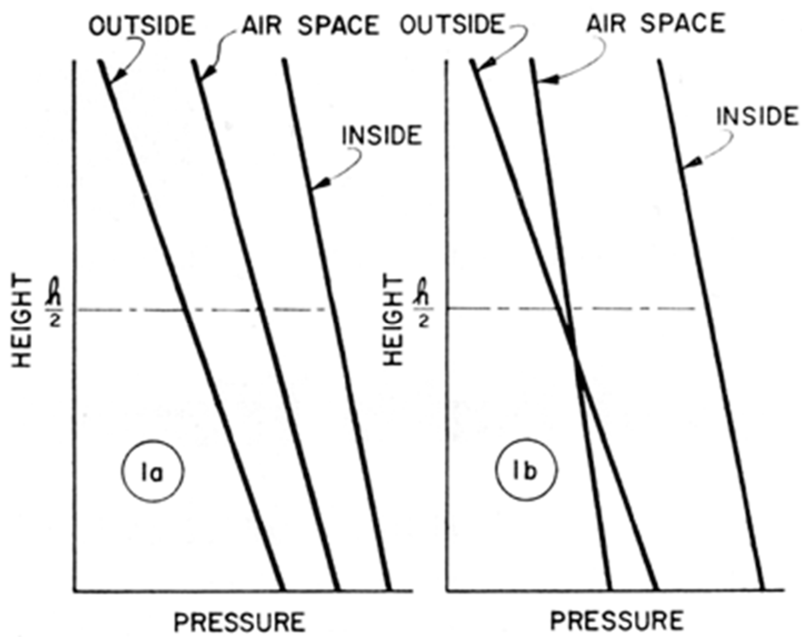

Figure 1. Pressure Distribution Across Double Windows With Air Flow From Inside to Outside

Values of the minimum ratio of outside to inside air flowing to the air space that are required to prevent condensation on the outer pane are given in Table I. These are based on room and air space dew-point temperatures equal to the surface temperatures of inside and outside panes, respectively, with outside air at 100 per cent relative humidity. The amount of air flow from outside to the air space must be several times that from the building to avoid condensation, the ratio increasing with decreasing outside temperature.

Table I. Ratio of Air Flows to Air Space for No Condensation

Outside Temp. °F	Minimum Ratio of Outside to Inside Air Flow to Window Space

40	7
20	9
0	16
-20	25
-40	41

It follows that the inner pane assembly must be much tighter than that of the outer. Unless the inner pane assembly is extremely tight openings past the outer pane assembly must be located both above and below the mid-height of the air space in order to induce air flow into the air space by chimney action. It will often be necessary to provide intentional openings between the air space and outside. The area of vents required will depend on the total air pressure difference across the window.

Total Air Pressure Differences

Several factors may contribute to total air pressure differences across windows, Wind action induces air flow from outside to inside on windward walls and from inside to outside on leeward walls. It is commonly observed that condensation occurs between the panes on leeward windows, while on the windward side of the building windows are clear. Information on the actual pressure differences around buildings owing to wind is relatively sparse.

Chimney action induced by temperature differences between air in a building and the outside is a second major factor contributing to total pressure differences across windows. As a result, air tends to flow into a building through lower openings and leave through upper openings.

With no other forces acting, there is a neutral zone somewhere between at which inside and outside pressures are equal. Unfortunately, information on neutral zone locations is very limited, although windows above it are more likely to exhibit condensation, since flow, from the building to outside occurs only above this level. In multi-story buildings it is common to observe severe condensation on the upper stories, while windows at lower levels are clear. This effect may be noted even in two-story houses. In practice the pressure differences across the walls of buildings depend on both wind and chimney effect acting together and are also influenced by the action of air supply and exhaust systems.

Venting Requirements

The venting required in an outer sash to prevent condensation between panes can be calculated for selected values of temperature and humidity provided the air leakage characteristics of the inner pane and the design pressure difference across the window are known. Selection of appropriate design pressure differences is the main problem and requires sound judgment based on field experience with window condensation. Air leakage can be measured at any desired pressure difference. For comparative purposes the air leakage characteristics of windows are often expressed in terms of the air flow per foot of crack at a pressure difference of 0.3 inch of water, the dynamic pressure of a 25 mph wind. A double window 3 feet wide by 2 feet high, with an inner glazing assembly having an air leakage characteristic on this basis of 0.075 cfm, per foot requires venting equivalent to twenty ¼-inch diameter holes at both top and bottom of the outer pane when the total pressure difference across the window is 0.004 inch of water. This is for conditions of O°F and 85 per cent relative humidity outside, and 70°F and 25 per cent relative humidity inside. The same window requires 60 such vents top and bottom. at a total air pressure difference of 0.014 inch of water. These pressure differences of 0.004 and 0.014 inch of water correspond to the pressure difference expected across leeward windows at wind velocities of 5 and 10 mph.

Venting to outside of the air space between panes will lower the temperature of the air space and inside surface and thus increase over-all heat transmission. At the temperature and humidity condition referred to above the venting required at a pressure difference of 0.014 inch of water results in an increase in heat transmission of about 2.5 per cent for a window with an air leakage characteristic of 0.075 cfm per foot of crack. The increase is about 16 per cent for a window having an air leakage characteristic of 0.5 cfm per foot (pressure difference of 0.3 inch of water), a value commonly accepted as the maximum allowable for vertical or horizontal sliding windows.

Control of condensation by venting would appear to be a practical approach when inner sash have low air leakage rates. In such cases neither the vent area nor the penalty in heat loss need be considered excessive. For inner pane assemblies having leakage rates of 0.5 cfm per foot of crack and above, the very extensive venting required will lead to corresponding increases in heat loss and will probably not be acceptable as an alternative to some condensation between panes.

Sealed Glazing Units

Attempts are often made to seal two panes of glass in a single wood sash in order to avoid storm sash and limit the number of surfaces to be cleaned. These arrangements are invariably unsuccessful, since it is impossible to achieve perfect sealing with wood. Changes in air space temperature produce substantial total pressure differences between the air space and outside, and air flow is induced through even very small openings by this pressure. This "breathing" action during normal temperature fluctuations is an important mechanism for moving water vapour into and out of the air space of a semi-sealed double window, although it has only a minor effect on windows having movable inner or outer sash.

A temperature change of only 50°F corresponds to a pressure change of almost 40 inches of water in a sealed space. Pressure changes that occur when rain strikes a warm tightly sealed window can draw water into, the space between the panes through very small openings, in extreme cases filling the air space to a depth of several inches. At best, water vapour will be drawn into the space by breathing action and some condensation will later develop on the outer pane. Wetting and drying brings alkali in the glass to the surface where it forms a cloudy film. This is sometimes referred to as scumming and is a common source of glass soiling. When it is accessible for cleaning, this film is readily washed away, but such soiling of inaccessible glass surfaces is a serious form of window failure, since eventually it leads to clouding so serious that it can no longer be tolerated.

Factory sealed double glazing units have been available from, two or three sources for several years and the availability of new sealing compounds has encouraged a number of other manufacturers in Canada to take up the production of such units. In factory sealed units the objective is to seal hermetically the space between the panes and maintain the dew-point of the air space sufficiently low to prevent condensation on inaccessible glass surfaces. A hermetic seal is extremely difficult to achieve, however, and even more difficult to maintain. Pressure changes due to fluctuations of temperature and barometric pressure distort the glass and stress the seal. The seal is thus subjected to flexing and cyclical variations in temperature and pressure as well as to water and sunlight. Though tight initially, it may be broken down slowly over several years.

If leaks exist or develop the dew-point of the air space will rise at a rate depending on the extent of seal failure and on the conditions to which the unit is exposed. Ultimately, wetting and drying will occur on inaccessible glass surfaces as a result of condensation and scumming will develop. In extreme cases the units may fill with water. Desiccant, intended in the first instance to remove moisture left in the air space during manufacture, will retard the rise in dew-point of leaky units for a limited time, but it will be unable to cope with serious seal leakage. The useful life of the unit will, in general, be limited by the time required to cause seal failure and the development of scumming on inaccessible glass surfaces.

Accelerated laboratory testing to determine the probable life of sealing arrangements in use is greatly needed. Such tests are under development, but like all accelerated service tests they must ultimately be correlated with actual field performance extending over many years. In the meantime, it is necessary to rely on such evidence of quality and probable satisfactory performance as can be obtained, keeping in mind the difficulties which can arise.