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Thermal Characteristics of Double Windows

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Please note

Windows usually provide less resistance to heat flow than other elements of a building enclosure. In winter, therefore, the lowest inside surface temperatures will generally occur on windows, and the relative humidity that can be maintained in buildings is limited by condensation on them. For this reason double windows are widely used in Canada to reduce heat losses and to increase the allowable relative humidity (**CBD 1**and **4**).

The thermal properties of double windows depend upon the characteristics of both the air space and frames or sash. Performance in service also depends upon the amount of recessing; the location of the window in relation to the surrounding construction; the proximity of heating outlets and degree of forced convection over the inside surface, and the arrangement of blinds or drapes. In specifying windows in relation to the humidity to be maintained in winter, it is necessary to take account of the various factors that will affect their thermal performance. Similarly, in establishing the humidity to be maintained in the building, the limitations imposed by the windows must be recognized.

The method of calculating over-all heat transmission and the average temperature of the inside surface of a basic glass-enclosed air space (using average values of air space and surface conductances) is given in **CBD 52**; values of over-all heat transmission coefficients as a function of air space width are given in **CBD 46**. The maximum permissible humidity in a building for a specified outdoor temperature is often established on the basis of the average inside surface temperatures thus calculated (**CBD 4**). The actual surface temperatures of the inner glass, however, are variable with height owing to vertical variations in air space temperature and surface heat transfer conditions. With natural convection or a low degree of forced convection at the inner surface, temperatures at the bottom are significantly lower than those determined from average conductances, and condensation will occur at correspondingly lower humidities than those predicted.

Surface Temperatures for Basic Window

Figure 1 shows typical variations of temperature with height for a 5-foot high basic double window consisting of two sheets of glass in insulated construction separated by a 4-inch air space-values are for natural convection on the inside and forced convection (wind) outside. For convenience, the temperatures are expressed in terms of an index in which outside and inside temperatures are represented by O and 1, respectively. Values for real windows fall between these limits; the higher the value the higher the temperature. The actual surface temperature, T, for any values of the outside and inside temperatures To and Ti, is found from:

T = To + Index (Ti - To).

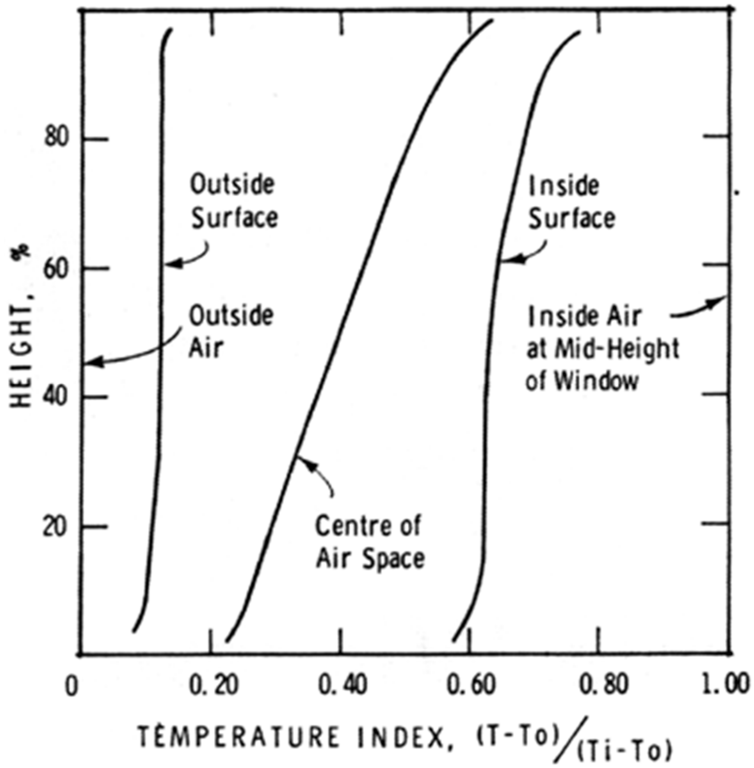

Figure 1. Temperature index values at vertical centreline of window

The temperature index is an advantage in comparing the inside surface temperature characteristics of windows, values for any point are independent of actual air temperature conditions if the surface conductances remain the same. The inside relative humidities at which condensation will occur on an inside surface for specified values of the temperature index and inside and outside air temperatures, are readily found from a psychrometric chart and have been plotted in Figure 2 for an inside air temperature of 74°F.

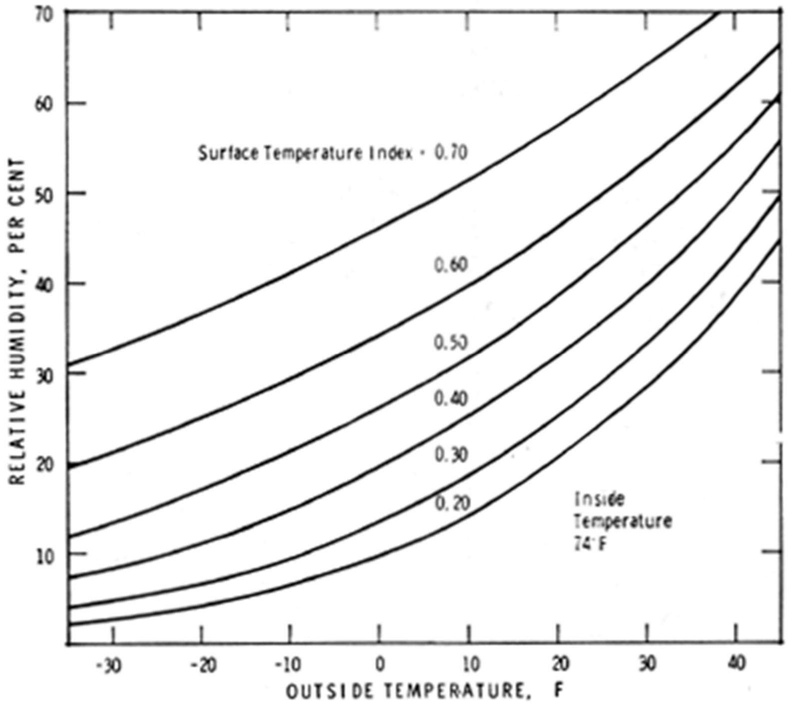

Figure 2. Relative humidity at which condensation occurs

Measurements on an idealized double glass arrangement (Figure 1) indicate that minimum inside surface temperatures are not greatly affected by air space thickness and always occur at the bottom. The corresponding minimum temperature index for a 5-foot high window is about 0.57, and that for a 2 1/2-foot one about 0.55. The index at mid-height is about 0.63 for all but very narrow air spaces, that corresponding to the average inside surface temperature is about 0.65. It may be seen from Figure 2 that at 0°F outside the relative humidity corresponding to the average inside surface temperature is about 40 per cent, that corresponding to the surface temperature at the bottom of the window is about 30 per cent. Glass temperatures at the base of the window are adversely affected if there is a stool (or recess) that interferes with natural convection heat transfer; the temperature index at the bottom may then be 0.54 or lower.

Excessive air leakage from outside into the bottom of the air space from either infiltration or intentional venting can significantly lower the minimum inside surface temperature. Laboratory measurements indicate that leakage of 1/3 to 1/2 cubic foot per minute per foot of crack will lower the minimum surface temperature index of a basic double window from 0.57 to about O.50. Actual infiltration in windows meeting current air leakage standards (**CBD 25**) is not very likely to exceed these values. A similar effect is induced in a 5-foot high window by outside venting equivalent to about three 1/4-inch diameter holes per foot of width at the top and bottom of the air space.

Metal Frames and Thermal Breaks

The foregoing temperature index values for basic double windows provide a yardstick with which to assess the thermal performance of actual window arrangements. Such windows have frames and sash; in order to develop fully the thermal advantages of double windows the inside surface temperature of these components would have to be no lower than the minimum for a basic double window. This will normally occur when frames are constructed of wood or other low-conductivity material; when constructed of metal continuous from inside to outside, the inside surface temperature will be much lower, approximating that for single glazing (temperature index of about 0.25 with a 15 mph wind). To provide surface temperatures not lower than the minimum on the inner glass, metal frames must incorporate an insulating separator, specifications for aluminum windows issued by the Canadian Government Specifications Board refer to such a separator as a "full thermal break."

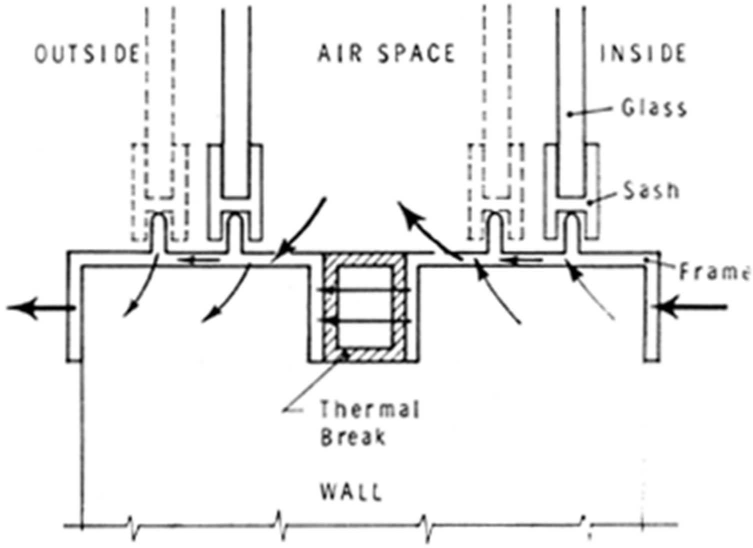

Figure 3. Heat flow through frame of double window with thermal break

It is common practice to construct metal frames in two parts that are structurally connected through a relatively rigid thermal break component (Figure 3). Similar construction is used in double glazed metal sash. As the thermal resistance of the metal is negligible, the thermal resistance of a full thermal break, as a first approximation, must be equivalent to that of the air space. The surface temperature of the glass at the bottom, however, is substantially lower than the average, thereby lowering the thermal resistance requirements. The effectiveness of the thermal break is increased by increasing its thickness or decreasing its cross-section in the direction of heat flow.

Heat flow in the vicinity of the frame is quite complex (as is indicated by arrows in Figure 3) . Reduction of resistance to heat flow into the frame at any point tends to increase the inside surface temperature, reduction of the resistance to heat flow outward has the opposite effect. Increasing the area of the frame exposed inside in relation to that exposed outside leads, therefore, to higher inside surface temperatures. From this standpoint, a wide metal stool attached to the frame is beneficial, and a wide outside sill detrimental. Heat exchange takes place between the frame and the air space, here it is desirable to minimize the exposure of the inner component to the space and to increase the exposure of the outer one.

Heat exchange also occurs with the surrounding wall. For optimum surface temperatures, it is advantageous to make structural connections, and to associate the window to the extent possible with the warm inner components of the wall. If the window is recessed into a wall that is insulated on the inside, the frame, unless separately insulated, is associated throughout with the cold outer wall components; furthermore a thermal bridge (**CBD 44**) will occur in the wall.

Characteristics of Actual Windows

Owing to the complex heat transfer the surface temperature characteristics of metal frames and sash cannot yet be calculated with accuracy. It is usually desirable to have the results of appropriate laboratory measurements. Those by DBR on a variety of residential-type aluminum windows mounted in rigid insulation to minimize the heat exchange with the supporting wall and provide a standard basis for comparison have indicated that the requirements of a full thermal break can be readily met by a variety of designs. Under these standardized conditions the temperature index corresponding to minimum inside temperatures on sash and frame usually varies between 0.55 and 0.57 with natural convection on the warm side. Box sections of rigid vinyl are commonly employed as thermal breaks, the thickness required generally varying between 1/4 and 1 inch. Wood is also used. The minimum temperature index for these windows in service may differ from the test values, depending upon the surrounding construction and other factors.

With the heavier metal windows often employed in commercial and monumental buildings, the design of thermal breaks to provide minimum surface temperatures equivalent to those of the basic double window is somewhat more difficult, though practicable; because of their greater weight and the natural tendency for differential movement between inner and outer components resulting from the large temperature difference between them, a stronger, heavier structural connection is required between the two sections if they are to act as a single unit. In addition, narrow air spaces are often used that reduce the space available for the thermal break. Where optimum surface temperatures are required, consideration might be given to two separate frames or sash utilizing a wide air space and carefully integrated with the wall design to provide the equivalent of a full thermal break.

Sealed double glazing units present a special situation because the spacer and metal edge channel (when used) constitute a relatively low resistance path for heat flow. The extent to which this affects inside glass surface temperatures will depend upon the temperature of surrounding components and the depth of bedding of the edge of the unit into the sash; there is a very sharp temperature gradient at the edges of the glass, and the temperature index at the junction of glass and sash can be as low as 0.33 while the value 1 inch above it is 0.53 (**CBD 46**). Measurements on sealed units in several window designs with thermal breaks indicate that the minimum temperature index for the glass can be as high as 0.44 to 0.48 with natural convection heating. Although not yet common practice, it is feasible to design frames and sash for sealed double glazing that provide optimum inside surface temperatures. The minimum temperature on the glass, however, will still be lower than that for a basic double window.

Temperature index values given thus far have been for natural convection on the warm side of the window, with the heating outlet remote from it. Under-window heating and forced convection will increase window surface temperatures by increasing both the air temperature adjacent to the window and the surface conductance (**CBD 52**). The results will depend upon the heating and stool arrangement and the window design. Measurements indicate that with continuous under-window heating the minimum temperature index for a double window with full thermal break might be as high as 0.60 to 0.65 with convectors; with forced air flow minimum values of 0.60 to 0.70 are practicable. The minimum index of windows with poor thermal breaks can be similarly increased, but will always fall short of what is possible with full thermal breaks. For example, the index of a frame or sash that is 0.30 with the heating outlet remote from it might be increased to 0.40 or 0.45 with underwindow heating.

Large temperature gradients at the edges of the inner pane of sealed double glazing units are increased by forced convection, and may sometimes be the cause of cracking (**CBD 46**). The gradients will usually be greater if the heating outlet is located between drawn blinds or drapes and the window.

The effect of blinds or drapes depends, in general, on the extent to which they isolate the window from the source of heat. With the heating outlet between them and the window surface temperatures are increased; with the outlet further away drawn shades can lower surface temperatures significantly unless provision is made for free air circulation between the room and the space adjacent to the window.

Heat Transmission through Frames

Over-all heat transmission through double windows may be influenced by the frames or sash. Their effect can be expressed in terms of an "application factor," which is the ratio of the total heat loss through the window to that through a basic window of the same area under similar conditions (NRC 7788).

The application factor depends on the heat transfer characteristics of the frame (or sash), the proportion of the window area that it occupies, and the surface heat transfer conditions.

Information on the application factor is limited. Measurements by DBR indicate that it has a value of about one when frames have a minimum temperature index of about 0.55, with natural convection on the inside, with sealed double glazing in metal frames and sash having a minimum index of about 0.33 and occupying 20 per cent of the total window area, the factor is about 1.3. Somewhat higher values would be expected with metal frames having no thermal breaks. Thus, thermally poor frames can lead to significantly higher window heat losses. With wood frames and sash the application factor is less than one, indicating a thermal advantage.

Increasing the temperature index by forced convection and under-window heating increases the heat loss through both frames and sash, regardless of the window construction. The percentage increase will be higher for windows with poor thermal breaks.

Conclusion

In selecting double windows for a particular application it is most desirable to have information regarding their inside surface temperature characteristics. The choice of windows may be influenced by the inside relative humidity conditions desired or anticipated and the amount of condensation that can be tolerated. The thermal limitations of double windows must be recognized in establishing building humidity. For some applications and window constructions it is necessary to determine the surface temperature characteristics by individual tests. For general-purpose rating for thermal performance the test conditions must be standardized, particularly the surrounding construction and the surface heat exchange conditions.

The information thus obtained, although comparative only, is adequate for qualifying windows for most purposes. Windows can be evaluated in terms of observations of surface temperatures or condensation, surface temperatures for a basic glass-enclosed air space under standard test conditions provide a useful yardstick. If it seems necessary to specify thermal performance under service conditions, the qualifying tests must reproduce all of the essential features of the actual installation. Such tests, however, are usually expensive and time-consuming and are justified only in special cases.

In addition to accentuating problems of surface condensation, thermally poor frames or sash can cause significant increases in heat transmission through double windows. Accurate measurements are difficult and usually this aspect of thermal performance can best be specified in terms of surface temperatures measured under standardized conditions. Ideally, the minimum surface temperature of the frame or sash should be no lower than that for a basic double window under similar conditions. This is a practicable goal for many window arrangements, but it is beyond what can be achieved by some of those in common use.