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Sasaki, J. R.

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by

J. R. Sasaki

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ELABORATION D'UN ESSAI NORMALISE DE COMPORTEMENT DES FENETRES A LA CONDENSATION

SOMMAIRE

Le Sous-comite 5.1 du Comite E-6 de l'ASTM travaille depuis quelques annees a l'elaboration d'un essai normalise de comportement des fenetres face a la condensation. Le Comite n'a pas encore produit une methode d'essai sanctionnee, mais il y a une methode qui recoit une certaine faveur a l'heure actuelle. Le present memoire decrit quelques aspects importants dans l'elaboration d'une telle methode d'essai. Le memoire decrit aussi le travail entrepris a la Division des recherches sur le batiment du Conseil national de recherches en vue d'evaluer la validite de cette methode d'essai.

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ANALYZED

Developing a Standard Test for Window Condensation Performance

J. R. Sasaki

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ABSTRACT: Subcommittee 5.1 of ASTM Committee E-6 has been engaged for the past several years in developing a standard test for evaluating the condensation performance of windows. This activity has not yet resulted in an accepted standard method, but one method currently is being considered as a possible standard. The article outlines some of the considerations that are important in the development of such a standard test. It also describes work undertaken by the Division of Building Research, National Research Council of Canada, to evaluate the suitability of the test method.

KEY WORDS: windows, window glass, atmospheric condensation, temperature distribution, thermal resistance, environment, conduction, performance evaluation, performance tests

Windows usually have the lowest thermal resistance of all the elements in the building envelope and, as a result, experience the lowest indoor surface temperatures in cold weather. It is important, therefore, to know the indoor surface temperature performance of windows in order to predict the conditions under which condensation will become a problem [*1*].[1]

Double windows, double glazed units, and storm units are used commonly to reduce heat loss and indoor surface condensation in regions that have low winter temperatures [2]. Many of these windows have metal sash and frame members that are continuous from the indoor to the outdoor window surface. The low indoor surface temperatures and the resulting condensation on these metal windows partly nullify one of the potential advantages offered by double glazing. The surface temperature performance of metal framed double windows can be improved by increasing the thermal resistance of the framing members. The practice with aluminum windows has been to use a low conductivity section, or a "thermal break," to provide a discontinuity in the highly conductive metal path.

The indoor surface temperature of metal frames with thermal breaks depends on the thermal resistance of the break and the ratio of the areas of metal surfaces exposed to the indoor and outdoor environments [3]. Because of the complex nature of the heat flow through a window and its frame, its temperature performance can be determined more reliably by test than by calculation.

Evaluation Tests

The detailed requirements of an evaluation test depend on the intended use of the information obtained. If the primary aim of the test is to assist a building designer to predict the thermal performance of an installed window in a specific application, all of the service conditions affecting window surface temperature must be taken into account. Service conditions affecting thermal performance include outdoor air temperature and wind velocity, incident radiant energy, air pressure difference across the window, surrounding wall construction and window mounting detail, and arrangement of heating or air conditioning terminal units.

If, however, the primary purpose of the test is to provide a basis for comparison of different windows, it is only necessary that the test rank the windows in the same order as they would behave under typical conditions of use. It would be advantageous, of course, if the test results could be used to predict actual field performance, but this is not a primary requirement for this type of test.

A test method for determining the thermal performance of windows as installed in a building cannot be standardized readily, since it must have the flexibility to simulate a variety of field conditions. A ranking or rating test, however, must be standardized in detail to ensure that different laboratories can construct an apparatus and use a technique that will give comparable results. The primary need at the moment, therefore, is to develop a standard test for rating purposes. The development of such a standard has been undertaken by Subcommitte 5.1 of ASTM Committee E-6 on Performance of Building Construction.

Test Parameters

For rating purposes, condensation performance can be defined by the minimum temperature measured on the inside glass, sash, or frame surface when the window is tested under a specified set of conditions. The test parameters affecting measured surface temperature are

1. The cold- and warm-side air and enclosure surface temperatures.
2. The air flow conditions over the cold and warm window surfaces.
3. The method of mounting the window in the supporting wall.
4. Air leakage through the window.
5. Test period.

This paper is a contribution of the Division of Building Research, National Research Council of Canada, and is published with the approval of the director of the Division.

[1] Italic numbers in brackets refer to the list of references at the end of this paper.

J. R. Sasaki, research officer, Building Services Section, Division of Building Research, National Research Council of Canada, Ottawa, Canada.

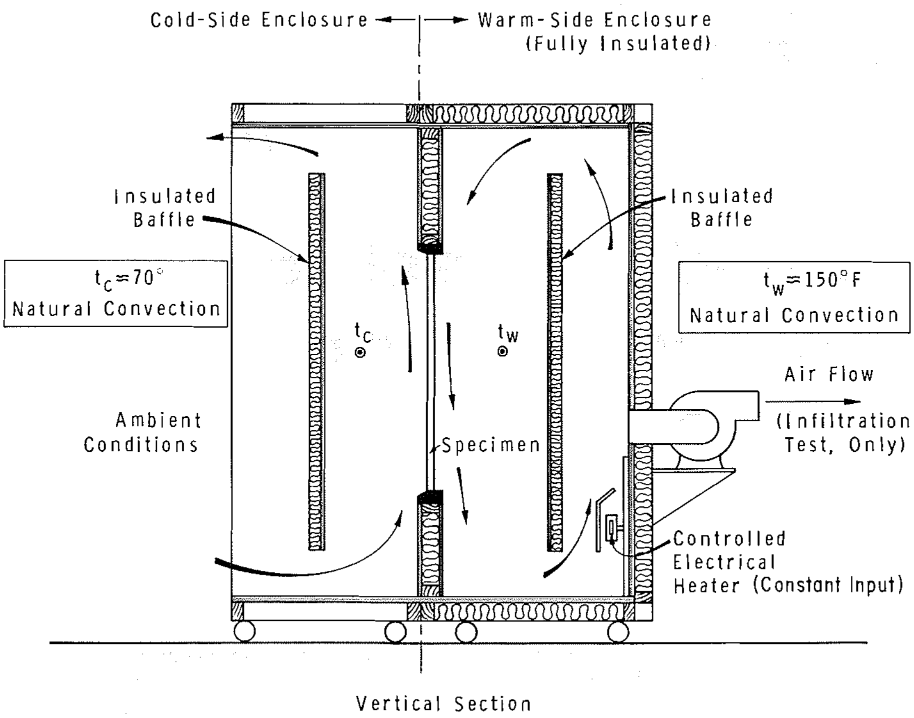

Fig. 1—*Test apparatus for Method A.*

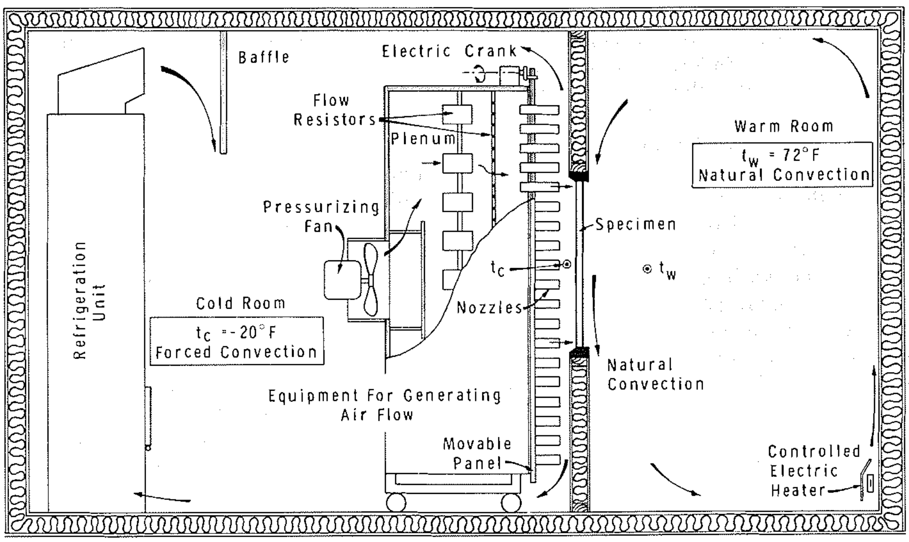

Fig. 2—*DBR/NRC cold room facility.*

Air and Enclosure Surface Temperatures/ The temperature measured on the indoor window surface is dependent directly on the air temperature and the temperature of the enclosing surfaces on both sides of the window. Because it is more convenient to describe the test conditions on each side of the window by only one reference temperature, the temperature of the enclosing surfaces should be held as close as possible to air temperature. This condition is achieved when any hot and cold surfaces, such as the heating and cooling elements, are shielded from the window.

The surface temperature performance can then be expressed independently of air temperature in terms of a temperature index *I*, defined as

$$I = \frac{t - t_c}{t_w - t_c} \times 100$$

where

t = measured surface temperature,
t_c = reference cold-side air temperature, and
t_w = reference warm-side air temperature.

The performance of different windows, expressed in terms of these indexes, can be compared even when they are not tested at exactly the same cold- and warm-side air temperatures.

Air Flow Condition/ The cold and warm window surfaces must be subjected to either natural or forced convection air flow during a test. Natural convection air flow is standardized easily because it depends on factors that can be specified, such as the geometry of the test enclosure, the location of the heating or cooling unit, and the recess of the window in the wall. The heat exchange coefficient between the window surface and the air is a minimum with this type of air flow.

Forced convection air flow is more difficult to standardize because uniform, forced convection over the whole window surface is harder to achieve. The heat exchange coefficient between the window surface and the air increases with the air speed over the surface.

Mounting of Window/ The way in which the window is mounted in the partition between the cold and warm environments affects the window surface temperature in two ways. Conductive heat exchange between the partition and window can affect surface temperature directly, thus it should be minimized in a standard rating test by insulating the window perimeter. The window recess in the partition can affect the local air film coefficient, thus it should be kept small to minimize the disturbance to the air flow.

Air Leakage/ Air infiltration from the cold to the warm side of the window cools the indoor surface adjacent to the leakage path. Similarly, air exfiltration warms the surfaces adjacent to the leakage path. The change in temperature

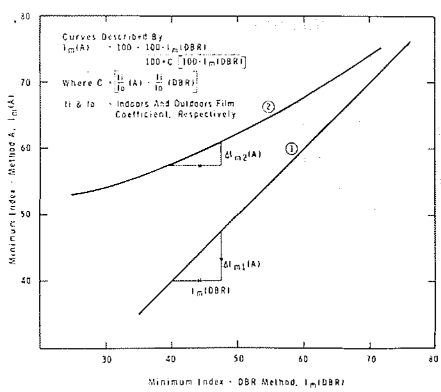

Fig. 3—*Theoretical performance rating characteristics of Method A and the DBR method.*

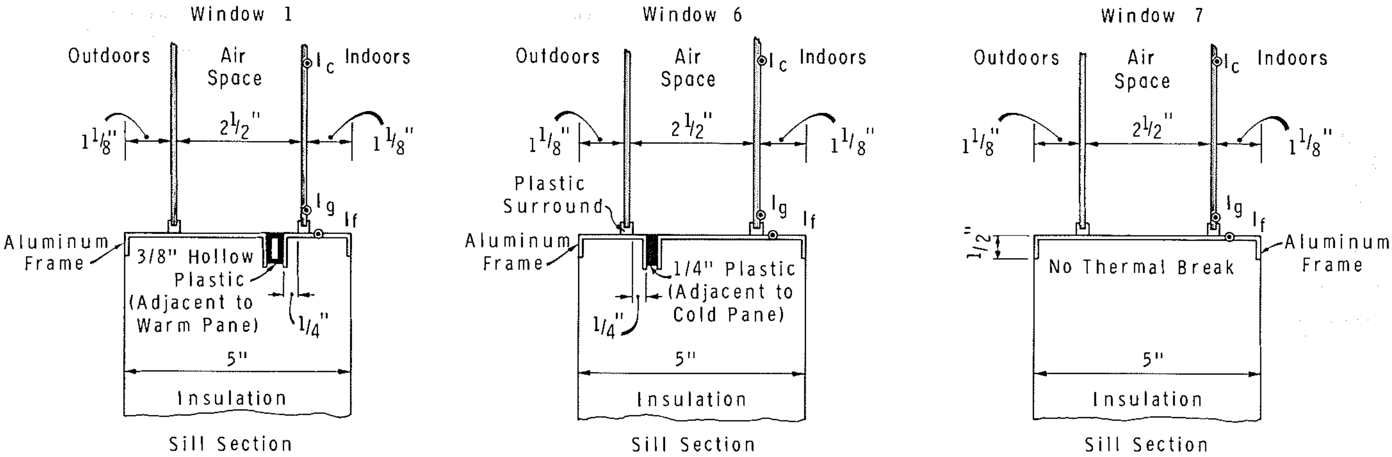

Fig. 4—*Typical idealized double windows.*

with leakage depends more on the location of large leakage sources than on the total leakage through the window. Leakage usually has a greater effect on openable windows than on fixed glazed or nonopenable windows.

Test Period/ The test period should be sufficient to ensure that surface temperatures remain constant with time.

Development of a Standard Rating Test

A standard rating test should have the following characteristics:

Ability to rank the performance of windows in the same order as they would rank in use
Good discrimination
Ease of operation
Low equipment cost

Different test procedures can be judged depending on how well they meet these four performance requirements.

The test method being considered by Subcommittee 5.1 as a possible standard has been compared with the method currently being used at the Division of Building Research (DBR) in regard to its ability to discriminate and to rank windows in the proper order. The assumption implicit in this comparison is that the DBR method ranks windows in the proper order. Although this is not absolutely true, the DBR method does simulate conditions that frequently occur in use.

The test method under consideration, designated as Method A for ease of indentification, provides the following test conditions:

Cold-side air temperature $\simeq$ 70 F
Warm-side air temperature $\simeq$ 150 F
Natural convection air flow over both warm and cold window surfaces

Figure 1 shows an apparatus incorporating the features of this method. The heat input to the warm side is adjusted manually to achieve the desired air temperature level and is maintained constant thereafter. Room air is used as the heat sink to eliminate the need for refrigeration on the cold side. Natural convection air flow is used on both sides since it is easier to standardize than uniform, forced convection.

The DBR procedure uses a small, cold room facility [*4*]. This facility, shown schematically in Fig. 2, uses the following, more realistic test conditions:

Cold-side air temperature = −20 F
Warm-side air temperature = 72 F
Forced convection air flow on cold side (film coefficient $\simeq$ 4.5 Btu/h-ft^2-deg F)
Natural convection air flow on warm side (film coefficient $\simeq$ 1.2 Btu/h-ft^2-deg F)

The ranking obtained by the DBR facility was used as the standard against which the results of Method A were compared. The thermal performance of windows, as indicated by the two methods, can be compared by plotting the minimum indexes obtained by Method A against the indexes obtained by the DBR method. If the two methods rank the performance of the windows in the same order and rate their performance in the same proportions, perfect correlation exists between the two methods. The minimum indexes should then fall on a smooth curve or a straight line as shown in Fig. 3. The correlation curve can be described theoretically by the equation given on the figure. It is a function of the surface film coefficients provided by the two methods. Figure 3 shows two examples of correlation curves for different values of film coefficients.

If the two methods yield identical results, they would all fall along line *1* in Fig. 3. In this case, performance discrimination by Method A would be equal to that by the DBR method. (Performance discrimination is directly proportional to the slope of the curve.) If the test results fall on a curve such as 2, this would indicate that Method A ranks the performance of the windows in the same order as the DBR method but provides less performance discrimination. A specified precision on the performance rating requires that surface temperatures be measured more accurately in a test providing less performance discrimination or that a greater air temperature difference be provided in the test.

Comparative Tests

Seven idealized, double window configurations and six proprietary double and double glazed windows were tested in each of the facilities. The idealized windows consisted of two panes of glass fixed in an aluminum frame with different thermal break arrangements; examples are shown in Fig. 4. The thermal performance of these windows is described by the temperature index at the center of the indoor pane (I_C) and the minimum indexes on the indoor glass (I_G) and frame (I_F) surfaces.

The proprietary windows tested are described in Table 1. All the aluminum windows incorporated a thermal break. The performances of these windows are described by the indoor glass center index (I_C) and the minimum indexes on the indoor glass (I_G), sash (I_S), and frame (I_F) surfaces.

All windows were evaluated with no leakage. In addition, the windows with an openable or removable sash were evaluated with air infiltration at a pressure difference of 1.56 psf. The results of the evaluation tests are given in Table 1; the minimum temperature indexes occurring

Table 1—Indoor Surface Temperature Performance of Idealized and Proprietary Double Windows

Window	Test Method A $t_c \simeq 70$ F, Natural Convection $t_w \simeq 150$ F, Natural Convection				DBR Test Method $t_c = -20$ F, Forced Convection $t_w = 72$ F, Natural Convection			
	I_C	I_G	I_S	I_F	I_C	I_G	I_S	I_F
Idealized Aluminum Windows								
3/8-in. hollow plastic TB, adjacent to warm pane	72.5	57.5	...	61	62.5	50.5	...	58
1/4-in. wood TB, adjacent to warm pane	71.5	57	...	57.5	62.5	49	...	51
3/8-in. hollow plastic TB, adjacent to cold pane	72	58	...	57	63	51	...	49
1/4-in. plastic TB, adjacent to warm pane	72	57	...	55.5	62.5	48.5	...	48
1/4-in. wood TB, adjacent to cold pane	71.5	57	...	52.5	62.5	49.5	...	44
1/4-in. plastic TB, adjacent to cold pane	72	57.5	...	52	62	48.5	...	40
Solid aluminum frame, no TB	71	56.5	...	46	62.5	47	...	31.5
Proprietary Windows								
Inoperable aluminum window, removable inner and outer sash								
No infiltration	69	59	61	62.5	62	53	54.5	58.5
Infiltration	68.5	52.5	52.5	48	62	49.5	45.5	49
Aluminum double horizontal slider								
No infiltration	69.5	59	59.5	63.5	62	52.5	49	58.5
Infiltration	66.5	49	50	58	60	44	39.5	53
Aluminum hopper with 1/4-in. sealed unit								
No infiltration	67	56	72.5	67.5	54	44	67	62
Infiltration	68	56	68	66	56.5	43.5	57.5	53.5
Fixed aluminum window with 1/2-in. sealed unit								
No infiltration	67.5	52.5	...	59.5	59.5	43	...	55.5
Fixed wooden window with 1/2-in. sealed unit								
No infiltration	69	51	...	...	62	38.5	...	...
Aluminum pivoting window with removable outer glazing								
No infiltration	69.5	54	51.5	51.	62	42	36.5	34
Infiltration	70	54	50.5	49.5	61.5	42	36	30

NOTE—TB = thermal break
I_C = temperature index at centre of indoor pane
I_G = minimum index on indoor pane
I_S = minimum index on indoor sash surface
I_F = minimum index on indoor frame surface
Underlined value is minimum window index.

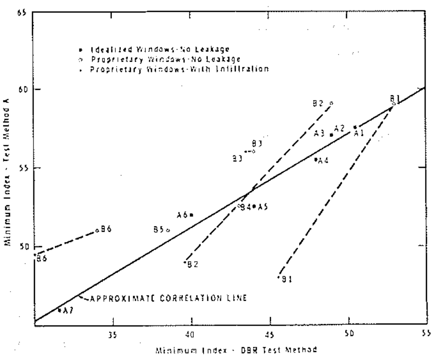

Fig. 5—*Rating of window performance as indicated by Method A and the DBR method.*

on the indoor surfaces of the windows are underlined.

The minimum indexes obtained for the 13 windows by the two test methods are compared in Fig. 5. With the exception of windows B2, B3, and B6, the minimum indexes measured by the two methods correlate well. Windows B2, B3, and B6 are ranked higher by Method A than by the DBR method.

Performance discrimination by Method A is about 60 percent of that by the DBR method; that is,

$$\Delta I_m(\mathrm{A}) = 0.6 \times \Delta I_m(\mathrm{DBR})$$

Moreover, the thermal performances indicated by the two methods with infiltration show poor correlation. Method A is capable, however, of ranking a majority of the windows tested in the same order as the DBR method. This fact, coupled with the lower cost and easier operation of Method A, indicates that Subcommittee 5.1 should give further consideration to this method as a standard rating test.

Thermal Performance Specification

Rating the condensation performance of a window requires both a standard test method to evaluate performance and a performance criterion against which it can be judged. The criterion must state the minimum inside surface temperature index that is acceptable, in either fixed or relative terms.

In fixed terms, the criterion would be a limiting value of temperature index; namely, the minimum temperature index measured on the inside surface of a window must be greater than this limit for the window to be acceptable. Such a criterion requires a highly standardized test method that will permit different testing laboratories to obtain identical values of inside surface temperature index.

In relative terms, the performance criterion would state that, for acceptable performance, the minimum temperature index measured on the indoor surface of a window must be greater than the minimum index measured on the indoor surface of a specified standard window, provided both are evaluated in the same apparatus. This approach does not require as high a degree of standardization in the test method as does the fixed criterion. Different laboratories do not have to achieve identical measurements provided the order in which they rank windows is the same. Method A appears to be adequate for assessing compliance with a relative type of performance specification.

Summary

Window thermal evaluation tests were conducted using a test method currently being considered by Subcommittee 5.1 of ASTM Committee E-6 as a standard. This study indicates that the method, although utilizing unrealistic test conditions, is able to rank windows in nearly the same order as a test method using much more realistic test conditions. The final answer regarding the suitability of the test method as a standard may be obtained when it is used to conduct comparison tests on a set of standardized windows at two or more laboratories. These comparison tests will indicate also whether performance criteria can be expressed in fixed or only in relative terms.

REFERENCES

[1] Wilson, A. G., *Canadian Building Digest*, CABDA, No. 4, Division of Building Research, National Research Council of Canada, April 1960.

[2] Wilson, A. G. and Brown, W. P., *Canadian Building Digest*, CABDA, No. 58, Division of Building Research, National Research Council of Canada, Oct. 1964.

[3] Sasaki, J. R., "Condensation Performance of Metal-Framed Double Windows with and Without Thermal Breaks," submitted to Specification Associate.

[4] Brown, W. P., Solvason, K. R., and Wilson, A. G., *Transactions*, American Society of Heating, Refrigeration, and Airconditioning Engineers, ASHTA, Vol. 67, 1961, pp. 561-577.