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EVALUATION OF
FACTORY - SEALED DOUBLE - GLAZED WINDOW UNITS

BY

A. G. WILSON, K. R. SOLVASON AND E. S. NOWAK

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EVALUATION OF FACTORY-SEALED DOUBLE-GLAZED WINDOW UNITS

BY A. G. WILSON, K. R. SOLVASON, AND E. S. NOWAK¹

SYNOPSIS

General performance requirements for sealed double-glazed windows and the need for performance tests are discussed. The possibility of condensation of moisture and clouding or scumming on the inside glass surfaces is emphasized. The results of some exploratory studies on the degree of sealing achieved in a number of units and on condensation on the interior surface are given. These results are based on measurements of the dew point of the air between the panes and on surface temperature measurements taken with various temperature differences across the windows. Factors involved in determining the adequacy of the sealing of the space between the panes are considered and lines of study suggested. General requirements of a test procedure for determining the degree of sealing achieved and the relative life of seals are discussed and accelerated aging apparatus proposed for this purpose is described.

The number of manufacturers in Canada of factory-sealed double-glazed units intended for use in buildings was very limited until quite recently. Units being marketed had been developed over the years from a background of field and laboratory experience. In the past year or two, however, several new manufacturers of sealed windows have entered the Canadian market, due in part to the availability of new compounds for sealing purposes. There has apparently been a ready market for these sealed units in housing construction, largely created by the advertising of established firms.

No performance standards or test pro-

cedures directly applicable to evaluating these units have been published. The Division of Building Research of the National Research Council of Canada was therefore asked by Central Mortgage and Housing Corp. (CMHC) to assist in developing a basis for determining the acceptability of various factory-sealed units for use in houses built under the terms of the National Housing Act of Canada. Submissions to CMHC by manufacturers for acceptance were often accompanied with the results of *ad hoc* tests designed to show that the units could withstand extremes in exposure without failing. There was no basis, however, on which to determine the significance of the tests or results.

As a beginning, the Division obtained

¹ Building Services Section, Division of Building Research, National Research Council of Canada, Ottawa, Ont.

specimens of a number of types of sealed windows and carried out some simple exploratory tests. The second step was to arrange for discussions with technical representatives of two of the major producers in the United States who have much technical experience in this field. This was done through affiliated Canadian companies and the fullest cooperation was received from all concerned.

With this background, a tentative basis of evaluation has been arrived at and apparatus has been designed to provide the necessary conditions of exposure. It is hoped that this work will contribute to the ultimate preparation of a product specification.

GENERAL REQUIREMENTS FOR SEALED DOUBLE-GLAZED UNITS

The sealing of the space between the panes of double windows is sometimes incorrectly assumed by the layman to be associated with some advantage in reducing heat transmission. In actual fact, the sealing of the space against the entry of air, water vapor, and dust is necessary because the space between the panes is inaccessible for cleaning. Indeed, the need to clean only two surfaces is one of the major advantages claimed for such windows. Another advantage claimed for sealed windows is that there is no condensation between the panes to obscure vision. The space between the panes is usually stated to be dry.

This implies that the dew point within the space is low and that the units are sufficiently well sealed so that the dew point does not rise during service to the point where significant condensation between the panes can occur.

There is another, perhaps more important, reason for the maintenance of a low dew point condition between the panes. According to technical representatives of glass producers, alkalies are present in most common glasses. When the

surface of glass is wetted and dried, this alkali, principally sodium salt, is brought slowly to the surface, forming a cloudy film. This is sometimes referred to as scumming and is a common form of glass soiling. When glass is accessible for cleaning, this film is readily washed away. Such soiling of the inaccessible glass surfaces of sealed units may, however, be regarded as highly undesirable, if not as an indication of failure of the units.

It would appear, then, that the dew point condition of the space between the panes and the degree to which a seal is obtained and maintained, are important aspects of the performance of factory-sealed window units. The degree of sealing necessary will depend on the seriousness of condensation and soiling. This is related to the basis on which the units are sold or purchased. Objections to the appearance of condensation between the panes may be partly psychological, because purchasers normally assume that it will not occur. Small patches of condensation that occur only during the coldest weather might otherwise not be regarded as serious. Substantial condensation that occurs even in relatively mild weather, however, not only obscures vision through the window but is an indication of potential soiling of the glass through leaching of the alkalies. This may have the effect of lowering the value of the building in which this occurs and is therefore the concern of any lending institution involved as well as the owner.

Breakage of sealed double-glazed windows is of special importance because of the relatively high replacement cost. Failures induced by stresses resulting from temperature differences are therefore of particular concern in cold climates. Such failures when due to improper installation are outside the scope of a product specification. Weaknesses in the design of the units that may lead to

glass breakage should, however, be exposed by test methods.

Another factor in connection with any window arrangement is condensation on inside surfaces. Double windows are used almost universally in Canadian houses, and increasingly in commercial buildings, in order to reduce winter heat losses and inside surface condensation as well as summer heat gains. Even double windows have a higher heat loss factor than other elements of buildings in most instances, and the relative humidity that can be carried is, therefore, limited by window surface condensation. The advantage of double windows over single windows in permitting higher inside relative humidities without excessive condensation is partly lost if a high conductivity sash or frame is used. Ideally, the construction around the periphery of the window should not result in inside surface temperatures lower than those that would otherwise occur on the glass surface.

EXPLORATORY TESTS

Exploratory tests were carried out on seven different types of factory-sealed double-glazed units to obtain information on the dew points of the space between the panes, the adequacy of the seals, and the inside surface temperatures as related to the edge construction. Three specimens of each type were installed in panels between a warm and a cold room. All units were approximately 20 by 40 in.

Inside surface temperatures were measured with the cold room held successively at temperatures of 38, 20, 0, -20 and -40 F, with the warm room at 72 F, the relative humidity in the latter being lowered to avoid surface condensation. In the test with the cold room at -40 F, an air stream heated to 170 F was directed over the inner panes in an attempt to simulate the thermal

shock that might occur in windows installed over radiators or warm air outlets. The cold room was next cycled daily between 20 F and -20 F for two weeks, with the warm room at 70 F and 30 per cent relative humidity. Observations of inside surface condensation were made over a two-week period with the cold room held successively at temperatures from 20 F to -40 F and with different levels of relative humidity in the warm room. Finally, the cold room was maintained for one week at 20 F with the warm room at 70 F and 40 per cent relative humidity. Units were examined periodically for condensation between the panes throughout the tests. Before and after installation between warm and cold rooms, the units were stored in the cold room at -40 F and examined for condensation between the panes. Measurements of the over-all thickness at the center of the units were made in the cold room for comparison with thickness measurements at room temperature.

SURFACE TEMPERATURE MEASUREMENTS

The results of inside surface temperature measurements on one specimen of each of four different units are shown in Fig. 1 together with the method of mounting and details of each of the units. The surface temperatures were taken along the vertical center line of the specimens with copper-constantan thermocouples (Brown & Sharpe gage 30) in conjunction with an electronic indicating potentiometer. During the measurements, the temperature of the cold room was controlled within ± 0.25 F with an air temperature gradient over the height of the glazing units not greater than 0.25 F. Air movement over the outer pane was downwards at about 7 mph. Heating of the warm room was by an electric baseboard convector on the wall opposite and approximately 7 ft from that con-

taining the glazing units. The air temperature variation at any point in the warm room did not exceed ± 1 F and the air temperature gradient over the height of the units did not exceed 0.5 F. Shown at the top of Fig. 1 for comparison purposes are surface temperature gradients obtained for a simple wood-sash window having dimensions similar to those of the factory-sealed units.

For the measurements of inside surface temperature, each thermocouple junction and approximately 1 in. of bared wire were fastened to the window in a horizontal position with black plastic tape extending about $\frac{1}{4}$ in. beyond the thermocouple tip. More extensive measurements on the wood window obtained subsequently indicated that the temperatures so measured might be higher than the actual surface temperatures by as much as 1 F at a cold room temperature of 38 F and 3.5 F at a cold room temperature of -40 F.

Surface temperatures along the vertical center line of the factory-sealed units were also obtained from observations of the extent of surface condensation and the known room dew point temperatures during the cold room tests. These values, also shown in Fig. 1, are in fair agreement with the vertical temperature gradient curves. The observations of condensation were, however, somewhat crude for purposes of establishing surface temperatures.

Inside surface condensation always formed initially as a band of constant height across the bottom of the unit. As the dew point temperature was increased, the condensation would next occur along the two vertical edges and then across the top edge, framing the unit. The extent of condensation in this pattern would increase with increasing dew point until the entire unit was covered. These observations are in agreement with the vertical temperature patterns shown in

Fig. 1. It will be noted that there are large surface temperature gradients near the top and bottom of the factory-sealed units with smaller gradients in the central region. The wood window has similar temperature gradients in the central region, but the gradients in the vicinity of the top and bottom edges are not so pronounced.

The increase in surface temperatures with height that occurs in the central region with all units can be attributed mainly to vertical temperature gradients in the air spaces resulting from convection. These were measured in the wood window and found to be substantial. For example, at a cold room temperature of 0 F, the difference in temperature between the top and bottom of the air space was 28 F. A decrease in this air space temperature gradient with decreasing air space thickness would be expected. There are, however, definite inside surface temperature gradients in the central region, even with an air space width of $\frac{3}{16}$ in., suggesting significant vertical air temperature gradients. Surface temperatures at the center of the windows are consistent in general with the thickness of the air spaces and in reasonable agreement with calculated values. The small difference in center surface temperatures at the higher cold room temperatures between units having $\frac{3}{16}$ -in. and $\frac{3}{4}$ -in. air spaces is noteworthy.

The sharp temperature gradients at the edges of the factory-sealed units result in condensation near the edges at much lower relative humidities than will produce condensation in the central region of the units. These gradients can be attributed mainly to edge heat loss effects, although the degree to which the units are recessed in the wall construction may also be a factor. The degree of recessing was comparable in all the units shown in Fig. 1. The extent to which the edges of the factory-sealed units are

buried in glazing compound will also affect the edge surface temperatures. The installation of the units tested was in this respect in accordance with the distributors' instructions. The edge surface temperatures are generally lowest with the units having edges of highest conductance. However, the difference between the factory-sealed units in this respect is again small, particularly at the higher cold room temperatures. Edge surface temperatures with the wooden unit are substantially higher at all cold room temperatures.

FIG. 2.—Apparatus for Window Dew-Point Measurement.

No frost was observed between the panes of four of the units at any stage in the cold room tests, although small patches of frost were observed in the other three units at all cold room temperatures. During the cycling test, a considerable amount of ice formed on the inside surface of the outer pane of one specimen, but this was the only case in which any accumulation of water between the panes was observed.

The several units showed different amounts of deflection at the center during storage in the cold room. Generally the amount of deflection increased with increasing air space thickness. A few of the specimens among those units exhib-

iting condensation between the panes showed very little deflection, indicating equalization of the air space pressures with outside as a result of leaks.

In considering the results of the cold room tests in relation to evaluating the adequacy of the seals, it was concluded that the laboratory conditions were not sufficiently severe or prolonged to represent the degree of aging that would be provided by actual conditions during the required service life. It was clear that

the degree of accelerated aging that could be provided by the cold room apparatus was limited, since it was not possible to produce rapid cycling of temperatures. It was also concluded that the observations of frost or water accumulation between the panes did not provide a sufficient basis for determining the adequacy of the units and that some refinement in the method of determining the moisture condition within the space was necessary. It was suspected that moisture accumulation between the panes of some of the specimens might have occurred but for the protection afforded by the glazing compound used for installation.

DEW POINT MEASUREMENTS

The specimens used in the cold room tests were stored at room temperature for approximately two years. The dew points in the air spaces were then measured with the apparatus shown in Fig. 2. This apparatus and the technique used for measuring the dew point of the space between the panes was patterned after methods used by the two glass laboratories visited by the authors in the United States. The flat exposed metal face is held firmly against one face of a double-glazed unit while dry ice is dropped into acetone contained in the reservoir to provide the desired temperature as measured with a thermometer. The temperature of the acetone and dry ice is lowered in steps until condensation in the form of liquid water or frost appears as a small circular patch on the air space side of the glass in contact with the metal face. Observations for condensation are made by removing the apparatus following each change in temperature and quickly wiping the glass surface with acetone. Once condensation is observed, the dew point can be re-established more precisely by using smaller steps in temperature. It was possible to reproduce dew point measurements within about 5 F, the major limitation being the control of the acetone dry ice temperature.

The temperature of the glass surface on which condensation forms is somewhat higher than the temperature of the acetone as a result of the lateral heat flow along the glass and the temperature gradient through glass and metal. Thus the actual dew point of the space will be higher than that measured. The difference between actual and measured values will increase with decreasing dew point temperatures. Where the method is being used for comparative purposes, for product control or development in a given

laboratory, reproducibility and not accuracy is important. If, however, the method is to be used in specifications, it must be standardized and some further investigation of it would be warranted.

Results of the dew point measurements are given in Table I. Specimens A to G were those used in the cold room studies; B₁ to N were new units obtained shortly before the dew point measurements were made. The dew points for units A to C are approximately equal to that of the storage room. It would appear that the leaks in the seals are such that the spaces

TABLE I.—RESULTS OF DEW POINT MEASUREMENTS.

Unit	Number of Specimens	Dew Point, deg Fahr
A.....	3	+42
B.....	2	+42
C.....	2	+41
D.....	3	-100
E.....	3	-90
F.....	3	-23
G.....	3	+16
B ₁	4	+49
H.....	3	+7
I.....	2	+1
J.....	1	-100
K.....	3	-39
L.....	3	+43
M.....	3	-42
N.....	3	+22

assume the same average vapor pressure as that of the surrounding atmosphere.

CONSIDERATIONS IN DETERMINING DEGREE OF SEALING REQUIRED

It is clear that the degree to which a seal is obtained and maintained in sealed double-glazed units is a major consideration in their evaluation. The degree of sealing required is associated in the first instance with the desirability of maintaining a low dew point condition, or at least avoiding objectionable condensation, between the panes.

Moisture can be transferred through

small cracks and openings in the seal by diffusion as a result of vapor pressure differences, or as a component of air that moves under total pressure differences caused by temperature changes or barometric pressure changes. As long as the vapor pressure or dew point inside the space is below the ambient value, there will be a net gain in water vapor to the space due to these flow mechanisms if there are any openings.

Different degrees of sealing of double windows can be envisaged in terms of the dew point temperatures maintained in the space between panes. Several ex-

definitely established by technologists in the glass industry. Presumably, water in the liquid phase is required and, therefore, dew points above 32 F are to be avoided if scumming is regarded as a problem. It was suggested by one source that dew points above 50 F led to serious scumming. With sealing as in (2) above, there should be no problem so long as the maximum permissible dew point is properly established.

If there are openings in the seal, or if these develop, it can be envisaged that ultimately the space between the panes will come into equilibrium with the en-

TABLE II.—AVERAGE DEW POINT TEMPERATURE, DEG FAHR.

City	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Vancouver, B.C.....	36	37	39	43	48	52	56	56	53	48	40	37	45
Edmonton, Alta.....	7	10	18	28	37	46	53	50	41	32	20	11	29
Saskatoon, Sask.....	3	5	5	30	37	46	53	51	41	33	15	4	28
Winnipeg, Man.....	2	1	15	29	40	51	57	54	46	37	20	9	30
Windsor, Ont.....	20	21	28	37	49	61	62	61	55	44	34	24	41
Toronto (Malton), Ont.....	16	17	23	33	46	56	60	58	52	41	33	21	38
Montreal (Dorval), P.Q.....	8	9	23	31	45	55	59	58	51	38	29	12	35
Moncton, N.B.....	12	15	21	30	42	51	57	56	51	41	31	17	35
Halifax, N.S.....	18	18	24	31	40	48	57	57	53	44	35	22	37

amples are listed below:

1. During required service life, the dew point within the space does not change significantly from the original value,

2. During required service life, the dew point within the space does not rise above some established maximum value, or

3. During required service life the dew point within the space comes into equilibrium with the environment.

With sealing as in (1) above, there should be no problem with either scumming or condensation between the panes if the initial dew point is low enough. It is not known by the authors if the conditions leading to, or the time required for, appreciable scumming have been

environment. If the openings are extremely small, this might not occur within the required life of the unit. With somewhat greater leakage, the dew point in the space might come into long-term equilibrium with the environment during this period, equivalent to the mean of average annual ambient conditions.

In such a case, if the cracks or openings connect the space to the outside, the dew point in the space will level out at the mean annual outside dew point. The monthly and yearly average outside dew point temperatures for some Canadian cities are given in Table II.²

It can be seen that in no instance does

² Based on data contained in "Climatic Summaries of Selected Meteorological Stations in the Dominion of Canada," Vol. 1, Meteorological Division of the Canadian Department of Transport, Ottawa, Ont.

the annual average dew point exceed 50 F. On this basis, units in long-term equilibrium with the outside environment should not exhibit objectionable scumming. However, if the cracks or openings were such that the air space followed monthly fluctuations in outside dew point, the dew point of the space could exceed 50 F during two to four months of the year. Regardless of the degree of sealing provided, there would appear to be no problem with condensation between panes seriously obscuring vision when leaks in the seal are to the outside, since there is no accumulation of water, unless rain can enter.

The dew point inside many nonair-conditioned buildings in the summer can be assumed approximately equal to the outside dew point. During the winter the dew point in occupied buildings is higher than outside, being limited in general by the inside surface temperatures of the windows. On the other hand, the dew point inside the air space of a double window can be no higher than the temperature of the outside pane regardless of the amount of moisture present. Thus, if the leaks in the seal connect the air space to the inside there will be an accumulation of water as liquid or solid in the space between the panes during the winter.

The amount of water that can accumulate under given environmental conditions will depend on the degree of seal leakage. It might amount to little more than small patches of water or frost or it might be sufficient to obscure vision through a substantial part of the window under some weather conditions.

If moisture accumulates between the panes during the winter, the relative humidity in the space will be essentially 100 per cent during the summer until this moisture is released. During this period the dew point in the space will correspond to the air space temperature

and the time during which the dew point can exceed 50 F will be extended in proportion to the time required to release the wintertime moisture accumulation.

The question arises as to whether moisture that accumulates between the panes during the winter is entirely released during more favorable conditions or is partly carried over from year to year with a gradual annual accumulation. A simple calculation for the Ottawa-Montreal region indicates that accumulation from year to year in this or milder climates is improbable, even under conditions of high wintertime inside relative humidity. In more severe climates, the results of the calculation depend on the choice of wintertime inside relative humidities.

In the calculation, based on monthly time increments, it was assumed that the number of cycles of pressure difference between the air space and room air are equally distributed throughout the year and that the inflow or outflow of vapor from the space between the panes can be taken as proportional to the difference in humidity ratio or vapor pressure between the space and inside the building. Inside vapor pressure was taken as that corresponding to saturation at the temperature of the inner pane during the winter and equal to outside vapor pressure during the summer, while the air space vapor pressure was taken as that corresponding to saturation at the temperature of the outer pane during the winter and corresponding to saturation at outside air temperature during the summer.

On the basis of the foregoing, it appears that, if the dew point of the space between the panes of sealed units follows short-term fluctuations in ambient dew point, objectionable condensation between the panes is likely to occur. Some direct observations of the degree of condensation that occurs under service conditions with specimens providing differ-

ent degrees of sealing would be useful. If the space comes into long-term equilibrium, equivalent to the annual average of ambient conditions, the units are suspect from the point of view of eventual scumming. It is important to establish what psychrometric conditions between the panes of sealed units can be tolerated without soiling of the glass by leaching of alkalis. Presumably this will depend on the amount of alkali present in the glass. Advice from the glass industry on this point is required. Finally, test methods are required to determine what degree of sealing is provided by specimens of factory-sealed units and the degree to which specimens will maintain a seal during service life.

REQUIREMENTS OF TEST PROCEDURE FOR EVALUATING ADEQUACY OF SEALS

The foregoing considerations, together with discussions with experts involved in the development of factory-sealed units, have led to a number of general conclusions regarding physical tests for determining the adequacy of the seals of factory-sealed units.

For purposes of determining the acceptability of the psychrometric conditions between the panes at any time and as an index of the ability of a unit to maintain its seal under simulated service conditions, direct dew point measurements are essential. These can be made with apparatus similar to that shown in Fig. 2.

The time required for pressure between panes to equalize with ambient pressure can be an extremely useful index in quickly identifying those units that have very poor seals. To determine these times, the units are exposed to lowered temperatures or pressures and the deflection at the center measured. The use of a vacuum chamber would be advanta-

geous since a wider range of pressure differences can be provided and effects of barometric pressure changes during a test can be avoided.

In determining the durability of the seals, the conditions of exposure must accelerate failure of specimens to simulate service over several years. The test should be capable of causing the eventual failure of any practical unit. The conditions should create the type of stress on the seal that will occur in service. For units used in building construction, these stresses are principally the result of temperature cycles. Therefore, cycling temperature conditions are necessary to create realistic stresses and, at the same time, to induce water vapor transfer by creating total pressure differences between the space and outside. Average ambient vapor pressures during testing should be sufficiently high so that leaks in the seals can be detected by a rise in dew point of the air space. Provision of temperature gradients across the units during artificial weathering is desirable since this may cause stresses not otherwise provided and is conducive to moisture accumulation between the panes.

Since there will be differences in performance between specimens of a given unit and since some failures in all practical units can be expected, testing of a large number of specimens is desirable. The specimen size should be as small as practical so as to minimize specimen costs and the size of the apparatus required. Since specimen size may be a factor in the durability of the seals, sizes should be similar for comparative testing of different units. The effect of specimen size on the durability of the seals in a given unit should perhaps be investigated. Since air space thickness may have an effect on the rate of dew point rise, testing of each thickness of a given seal design would seem necessary.

FIG. 3.—Weather Simulating Device for Window Tests.

APPARATUS AND PROCEDURES FOR EVALUATING FACTORY-SEALED UNITS

With this background, procedures and test apparatus are being developed along the following lines for evaluation of factory-sealed units marketed in Canada:

1. Determination of the relative tightness of the seals and the relative moisture content of the space between panes as received,
2. Determination of the durability of the seals as indicated by the ability of specimens to withstand accelerated weathering without excessive rise in dew point of the space between panes, and
3. Correlation of laboratory test results with observations under actual weather conditions.

As an index of initial seal tightness, specimens as received will be placed in a vacuum test chamber with dial gages to measure glass deflection with vacuums up to 5 in. of mercury. The absence of initial glass deflection will indicate a large leak in the seal; an initial deflection that subsides slowly, a smaller leak; and a sustained deflection a substantial degree of tightness.

The dew point apparatus already described, although not indicating the exact dew point, will be used to determine the relative moisture content of the air between panes as received and during exposure to accelerated weathering.

For accelerated seal durability tests, a weather simulating device for windows is being developed. The apparatus, shown in Fig. 3, was designed to expose one side of the factory-sealed units to cycling temperatures and a water spray, with the other side exposed to controlled room conditions. The test specimens are to be mounted on either side of the heating coils, cooling coils, and sprays to form a $1\frac{3}{4}$ -in. air space. It is anticipated that test specimens will generally be 14 by

20 in. This size was chosen as a minimum based on advice received from experts in the industry. The testing apparatus was designed to accommodate 24 units of this size. It can, however, be used for any size of unit up to 5 ft 6 in. square.

Four heating coils have been provided. These consist of electric tubular heaters placed inside finned tubing to increase the heater surface area. Cooling is achieved by a direct expansion Freon 12 system, consisting of a 12-row finned tube evaporator and a water-cooled condensing unit. The heating and cooling coils are spaced uniformly between the test windows to provide a uniform exposure for all specimens. To aid further in uniformity of exposure and also to increase air film conductances, two fans are used to provide air circulation. The fans draw air from the lower duct, discharging it into the top duct *via* the two side ducts and down the space between the test windows. The lower duct also serves to drain the spray water back to its tank situated on the floor. The space between frames was kept to a minimum to reduce the volume flow rate required to provide a given air velocity.

The test samples will be mounted in a simple frame of $\frac{3}{4}$ -in. plywood as shown in Fig. 3. This type of mounting was selected rather than that used in the field in order to expose all of the sample edges. It is believed that glazing compound may in some cases mask defective seals. It is anticipated that only units that have shown no leakage in the vacuum test need be subjected to the weathering test. The weathering cycle can be varied but the one proposed is as follows:

1. Cooling until the inside glass surface temperature reaches -20 to -30 F,
2. Heating until the inside glass surface temperature reaches 120 to 130 F,
3. Cooling until the inside glass surface temperature drops to about 110 F,
4. Spray inside surface with water at 70 to 75 F, and

5. A short rest period to allow water to drain, then repeat (1) to (4).

The whole cycle is expected to take 3 to 4 hr permitting some 6 to 8 cycles per day. Longer cycles are, of course, possible. Dew point temperatures of the space between the panes will be measured regularly during exposure, and the rise in dew point during a given number of cycles will be the criterion of performance of the glazing units. The number of cycles that a unit should withstand without excessive rise in dew point will require investigation. It has been suggested that, as a minimum, units should withstand 300 cycles of a somewhat similar exposure without the dew point exceeding 30 F. For some purposes, classification of units based on the number of cycles that can be withstood without excessive dew point rise might be considered.

Consideration is being given to long-term exposure of units with both sides exposed to the weather with periodic measurements of the dew point in the space. Records of dew point rise might provide a useful comparison with the results of measurements with the weather simulating apparatus. The degree to which the dew points are sensitive to outside dew point conditions would provide an index of tightness that could be compared with laboratory results. Finally, observations of the degree of leaching of alkalis on the unexposed faces as related to measured dew point conditions would provide some information on maximum permissible dew points.

Consideration is also being given to installation of units with defective seals, either as received or as a result of the weather simulating treatment, in outdoor test huts with controlled interior conditions. Observations of such units would indicate the degree to which condensation formed between the panes and the

extent of scumming at known dew points of the space between panes.

CONCLUSION

There is an increasing need for standard test procedures and specifications for factory-sealed double-glazed units because of their increasing use in buildings and the increasing number of manufacturers. Apart from thermal performance, the provision and maintenance of a low dew point between the panes appears to be the major requirement. Low dew points are desirable in order to prevent condensation between the panes and soiling of the glass by leaching of alkalis. Standard test procedures are required to measure the dew point conditions in the space of factory-sealed units, to measure the relative degree of sealing provided, and to determine the extent to which a unit can maintain a tight seal under service conditions. Test apparatus and methods being developed for this purpose, based largely on procedures now in use by the industry, have been described. Information is required on the relative degree of sealing required to avoid objectionable condensation between the panes and on the psychrometric conditions that lead to soiling of glass by leaching of alkalis. Some information on the relationship between the effect of artificial weathering and actual weathering on dew point rise in factory-sealed double units is also needed.

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