

# **Test methods for sealed glazing units**

**Norwegian experience with accelerated tests and their  
correlation with field experience**

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# How the Norwegians test insulating glass units

*Their experience, independent of similar work in other countries, was begun in 1958; refined since that time, accelerated aging methods have been correlated with field experience*

by Tore Gjelsvik

**W**ORK ON sealed glazing units at the Norwegian Building Research Institute started in 1958, independent of similar work in other countries. The first part of the project was sponsored by a Norwegian company, and led to the construction of an apparatus for accelerated aging. At that time, the accelerated aging tests constituted the whole test program.

Systematic field studies were introduced in 1959, to check the results of the accelerated tests and to gain more general experience. The results of the field studies and the information available from other sources have resulted in successive modifications of the accelerated aging tests. The test program has been changed, and the apparatus itself improved several times. The basic apparatus, however, has been the same all the time.

## Arbitrary

The actual strains on the edge seal of sealed glazing units were thoroughly examined before the apparatus for accelerated aging was designed. The following types of strains were considered as actual (details not included; see references <sup>1</sup> and <sup>2</sup> at conclusion):

- Transportation stresses.
- Assembling stresses.
- Variations in atmospheric pressure.
- Temperature changes.
- Wind stresses.
- Sunlight.
- Water.
- Mechanical stresses caused by vibrations.

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TABLE I

Period of strain	I	II	III	IV	V
Day cycle number	1-10	11-30	31-34	35-44	45
Maximum pressure during windgusts, mm water column	40	25	70	15	100
Corresponding to wind force Beaufort No.	8	7	10	5	11
Air temperature °C.	25	35	15	50	15
°F.	77	95	59	122	60

Of the types of stresses mentioned above, transportation and installation strains must be considered as more or less arbitrary. Transportation strains can easily be reduced by suitable measures, and with the present installation recommendations,<sup>3</sup> the assemblage strains can be virtually eliminated. The real climatic strains must be said to be variations in the atmospheric pressure, changing temperatures, wind, and sunlight. Water and vibrations can certainly be of importance in special cases, but whether they shall be included in normal test methods is an open question.

In general, there seems to be agreement between scientists in the different parts of the world about the types of strains acting on sealed glazing units. The importance of the different types of strains is, however, judged somewhat differently. This is perhaps unpleasant, but not really surprising. Some of the strains on sealed glazing units are fairly well known, while, for others, the available information is rather limited. The different judgment is only a natural result of the differences in the basic material. The situation is now considerably better than in 1958, but an accelerated test program still has, to a high degree, to be based on common sense.

On the basis of earlier considerations, the Norwegian Building Research Institute decided, in 1958, to build an apparatus where installed units could be subjected to temperature changes and pulsating wind pressure. It was found that variations in the atmospheric pressure could be omitted, as the stresses derived from the two other factors would be considerably stronger. On the other hand, it was thought desirable to include sunlight. This factor, for practical reasons, had to be dropped, however. Water was also left out, as at that time it was considered possible to avoid the entry of water into the rebate with perfect installation. The last factor, vibrations, was more or less unknown at that time.

A unit size of 120 x 170 centimeters (47 x 67 inches), with about 12 millimeters (1/2-inch) air space and a glass thickness of about 4 mm, was estimated to

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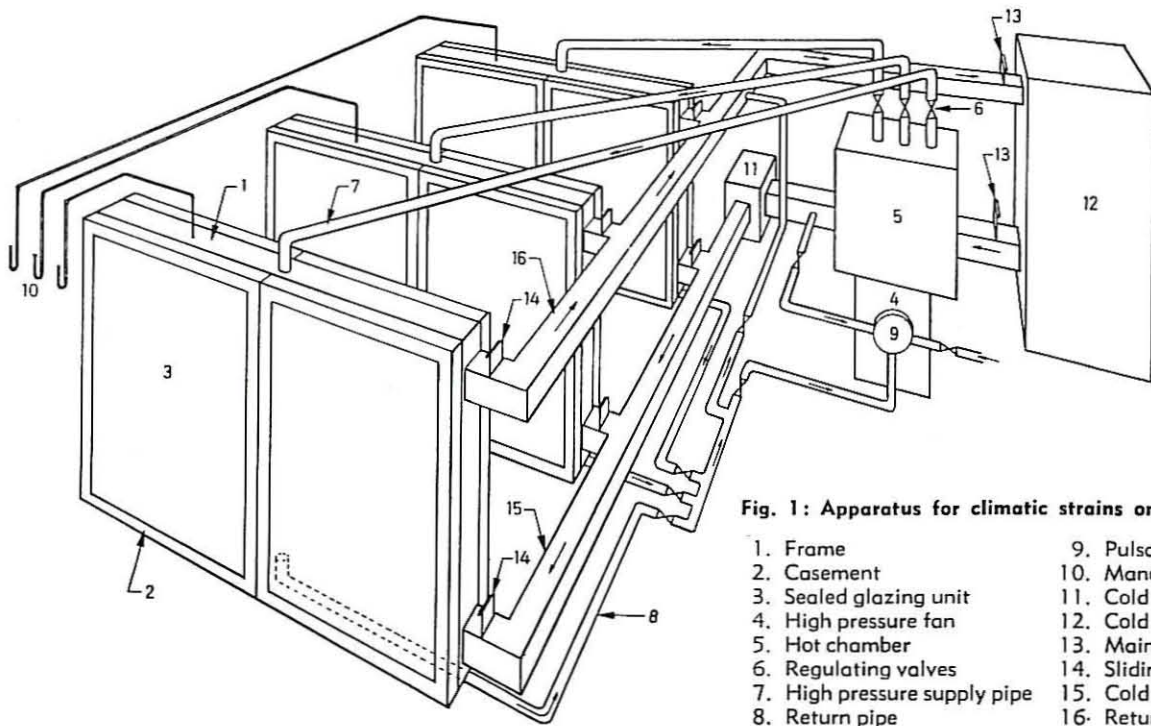


Fig. 1: Apparatus for climatic strains on sealed glazing units.

- |                              |                          |
|------------------------------|--------------------------|
| 1. Frame                     | 9. Pulsating damper      |
| 2. Casement                  | 10. Manometer            |
| 3. Sealed glazing unit       | 11. Cold air fan         |
| 4. High pressure fan         | 12. Cold chamber         |
| 5. Hot chamber               | 13. Main sliding damper  |
| 6. Regulating valves         | 14. Sliding damper       |
| 7. High pressure supply pipe | 15. Cold air supply pipe |
| 8. Return pipe               | 16. Return pipe          |

correspond most correctly to actual conditions. Fig. 1 shows the NBRI apparatus for climatic strains on sealed glazing units. Actually, the apparatus in the figure is the second main version from the period 1963-66, with several improvements compared with the original version of 1959. The principle, however, is the same for both.

### Three frames

The system consists of three frames made of teak wood. In each frame, four casements can be attached, each bearing one sealed glazing unit 120 x 170 centimeters or a higher number of smaller units. When the installation is completed, closed chambers are formed, in which air, with adjustable pressure and temperature, can be circulated. In other words, the air in the closed chambers represents the outdoor climate. The complete apparatus is located in the laboratory, which represents the indoor climate with a temperature of about +20°C. (+68°F.).

The apparatus can be adjusted in two ways. One method is to let a high pressure fan supply the air to the chambers. A pulsating damper regulates the air supply, so that the pressure within the chambers pulsates, like wind gusts. The pulsating damper, in the beginning, had a frequency of six periods per minute, but this was changed to five periods per minute after the first series of tests, in 1960. The maximum superpressure within the chambers during the wind gusts can be varied between 10 and 100 millimeters water column, corresponding to wind force Beaufort No. 5 to 11. The temperature inside the chambers, measured centrally in front of the units, can be varied between +10°C. (+50°F.) and +55°C. (+131°F.). The low-

est temperatures are reached by adding cold air from the cold chamber.

The second method is to let a low pressure fan blow cold air directly from the cold chamber through a larger set of pipes. In this way, the temperature inside the chambers can be lowered to about -10°C. (+14°F.). The superpressure, however, is significant, and pulsation is not possible. By changing from a hot to a cold period, and vice versa, the units can be subjected to temperature changes.

### Moderate level

The installation of the units in the apparatus from 1959 to 1966 was done with plastic glazing compounds—in the first series of tests without spacers, later with spacers to avoid extrusion.

In the first series of tests, the wind stresses were started at a moderate level, and gradually increased

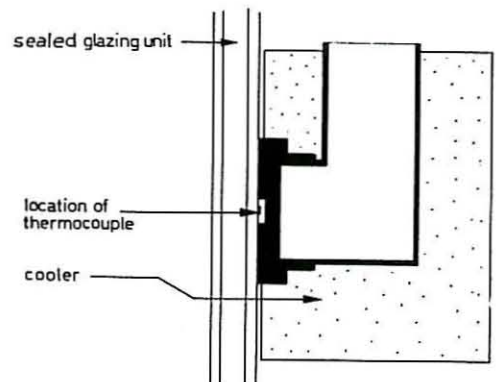


Fig. 2: Dew point measurement on sealed glazing unit.

step by step. In the later tests, from 1961 to 1966, the stresses were in accordance with a somewhat revised test program. In carrying out this program, an attempt was made to include 20-year wind stresses in comparatively exposed places. The wind pressure and air temperature were fixed to follow a day cycle consisting of four hours cooling at a low and constant air pressure to an outside air temperature of about  $-10^{\circ}\text{C}$ . ( $+14^{\circ}\text{F}$ .), followed by a 20-hour period with five wind gusts per minute under simultaneous heating to a prescribed temperature level. The actual tempera-

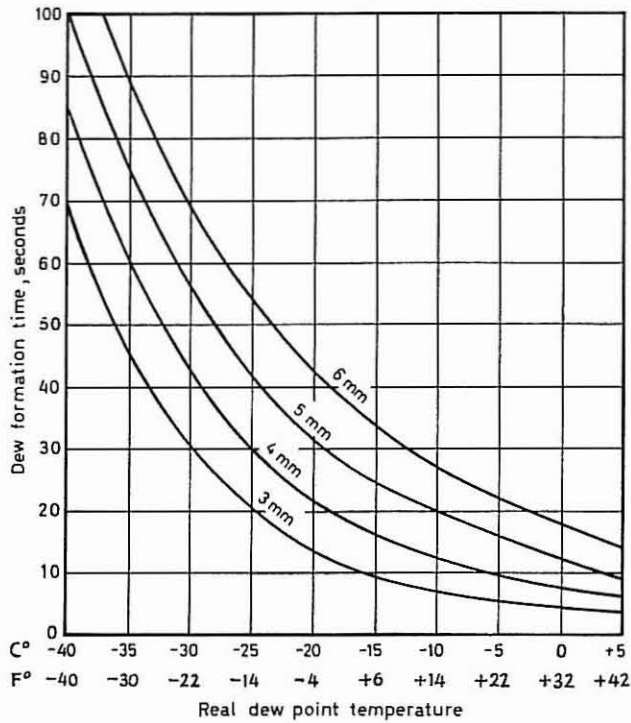


Fig. 3: Dew formation time vs. real dew point temperature, BRNI measuring method. Unit temperature,  $+20^{\circ}\text{C}$ . ( $68^{\circ}\text{F}$ .); glass thickness, 3-6 mm.

tures, the maximum wind pressures during the wind gusts, and the number of day cycles at each period of strain are indicated in Table I. This 45-day program was repeated once, making a total effective operation time of 90 day cycles.

The units were inspected regularly for visible damage during the operation of the tests. Dew point measurements were taken at regular intervals. Finally, the units were taken out for inspection. They were usually taken apart and the edge seal examined in detail, too.

All dew point measurements were carried out with the apparatus developed at the NBRI laboratory in Trondheim. Fig. 2 shows a cross section of the cooler. This is made of brass, and the cooling surface is polished and nickel- and chromeplated. When dew point measurements were taken, the cooler was filled with a mixture of dry ice and alcohol, having a temperature of  $-75^{\circ}\text{C}$ . ( $-103^{\circ}\text{F}$ .). Originally, the method was based on thermocouples glued to the outside glass surfaces. Later on, the method was further developed<sup>4</sup> and investigated.

The thermocouples are now left out, and the measurements are taken simply by placing the cooler against the glass with good thermal contact, and measuring the time from when the contact is obtained till visible condensation can be detected by an experienced observer. This dew formation time is then converted to real dew point temperature with the help of the curves in Fig. 3.

### Typical method

The NBRI dew point method is a typical dynamic method, suitable for very fast readings with acceptable accuracy. In practice, readings are usually taken in less than one minute, while dew formation times above two minutes occur very rarely. The measurements are also carried out with the units in a vertical position, and this makes the method specially suitable for measurements in the field. The only drawback is that the method is dependent on a well-trained observer. Inexperienced persons will usually see the condensation too late, and this will result in dew point readings which are too low and too good.

Systematic field studies were organized by NBRI in 1959, 1960, and 1963. The most important was the west coast field study of 1963. In this study, an attempt was made to cover all types of units which had been on the Norwegian market, and units of different age, as long back as possible. The final result was 2,040 units, divided among 10 different brands and installation years from 1951 to 1963. The investigations covered inspection for visible damage as well as dew point measurements, and the results have been treated statistically.<sup>5</sup> It is not possible to give all details here, but the main conclusions of the report are the following:

- The study clearly shows that it is not an easy job to manufacture durable sealed glazing units. Even large, reputable companies have failed to do so, and obviously put their units on the market before they were sufficiently developed and tested.

- For all types of units, there has been a wide variation so far in the dew point temperature of new units. Although the manufacturing of sealed glazing units is an industrialized process, it has still maintained its character of manual work. Extreme care in the dehydrating of the units, as well as all other steps in production, seem to be necessary to obtain units of uniform quality with low dew points.

- The average damage frequency for the units covered by the study is rather high. The old production of certain types of units is responsible for this high figure. For the rest of the units, the number of damaged units is comparatively low, and this was found to be either a result of special strains or quite simply failures in production.

- Even the intact units of the improved types are not absolutely tight, at least not those with a direct-glass-to-metal seal or a glued seal. For these types, there is an increase in dew point with age of unit, indicating certain leakage rates. The units must be considered to have a finite span of life. The rate of increase in dew point temperature, however, is so low that the expected span of life is fully acceptable.

- Very small units, as well as oblong units with one really short side, are weakened more rapidly than the normal and larger sizes.

- The special strains mentioned above include vibrations and other types of rapid pulsating mechanical stresses.

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Units installed in doors with heavy traffic frequency may be weakened rapidly or even have the edge seal broken. Units installed adjacent to such doors may also be weakened or broken down if the frames are not sufficiently rigid to reduce the transmission of vibrations from the doors. When properly installed, units in doors with moderate traffic seem to serve satisfactorily.

- Strong and gusty winds have a weakening influence similar to vibrations from doors. Units broken down by wind stresses, however, have not been found in practice so far.

- Prolonged contact with water was the reason for early seal failure of several units, particularly those with a glued seal. This was especially the case with units installed in top and bottom hung windows, and to a certain point in horizontally pivoted windows. The improved types of units seem to be less sensible to prolonged contact with liquid water. There is, however, every reason to take appropriate precautions. Rebates and beads must be properly dimensioned to give the necessary clearances and edge coverage. Bottom bead and sash or frame, as well as the glazing compound, must be sufficiently sloped to shed water, even when the windows are put in a ventilating position. Glazing must be as perfect as possible, preferably incorporating a two-stage sealing system with ventilated and drained rebates. It is probable that the results of the field study might have been better if better installation methods had been used.

### Correlation

Field studies were also carried out in the years since 1963, but none has been of the same order as that on the west coast. The experience gained in the later studies fully supports the conclusions drawn on the material from 1963. It was planned to go to the west coast again and check the same units, but so far it has not been possible to get support from the manufacturers involved.

The major part of the accelerated aging tests in the period 1959-1966 were carried out with units measuring 120 x 179 cm. The first series, in 1959, were run on a tentative basis while the later tests followed a

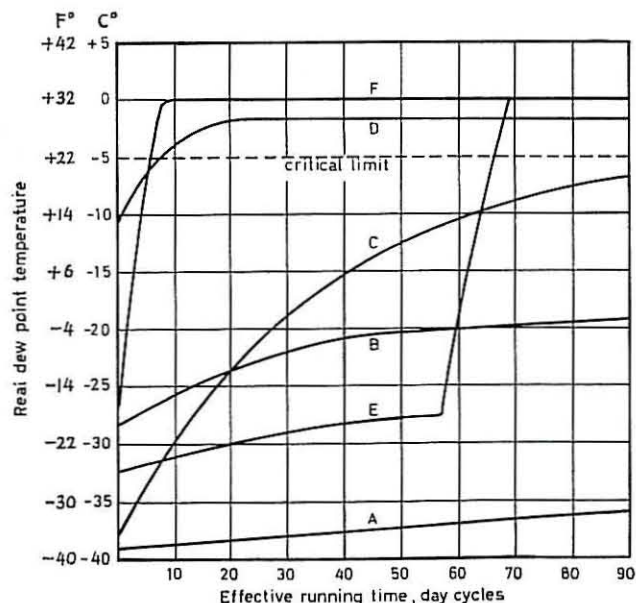


Fig. 4: Typical examples to measured dew point temperatures.

TABLE II

Period of strain	I	II	III	IV	V
Day cycle number	1-8	9-27	28-29	30-49	50
Temperature changes per day cycle	2	2	1	1	1
Maximum pressure during wind gusts, mm water column	40	25	70	15	100
Corresponding to wind force					
Beaufort No.	8	7	10	5	11
Air temperature °C	25	35	15	55	15
°F	77	95	59	131	60

fixed program. These tests covered a total of 26 sets of units from 18 different sources. The results can be divided into visible damage in the units and changes in the dew point. The visible damage comprises cracks in the glass, cracks in the metal seal, and displacement of the metal seal.

Cracks in the glass occurred in different types of units. It appears, however, that the cracks always started at the edge of a spaced block. The reason is that the bead was forced back so hard that the unit and spacer were jammed. Similar cracks also occurred in practice. Mounting with spacers must always be carried out with some care. Some types of all-glass units must either be installed with special types of spacers or entirely without them.

Cracks in the metal seal occurred only in units with a direct glass-to-metal seal. The cracks were localized on the central part of the long sides of the units, in some cases also on the short sides. In the laboratory tests, the cracks occurred at a comparatively late stage, after the units were subjected to prolonged strains. In practice, however, they have so far occurred only in units installed in doors with heavy traffic frequency or close to such doors. The cracks always had the appearance of typical fatigue breaks at the weakest and most heavily strained part of the edge seal, and are undoubtedly due to pulsation stresses.

### Rapid rise

Displacement of the metal seal is characteristic of certain periods of production in some types of units with a glued seal. Deflections up to 2 centimeters (3/4-inch) have been measured in practice; in the laboratory, up to as much as 7 centimeters (2 3/4-inch).

Changes in dew point during the laboratory tests differed greatly for different types of units. Some typical cases are shown in Fig. 4.

Curve A is typical of a good unit, where the dew point is not influenced significantly by the stresses. In curve B, there is first a certain increase, which may be due to changes in temperature, separation of water from the adhesives during curing, etc. Units with this type of dew point curve, however, have to be considered as good. In curve C, the situation is quite different. Here, the dew point rises so rapidly toward the critical limit that the units have undoubtedly had considerable leaks. Curve D must be considered as showing a real production failure, as the dew point from the outset has been much too high. Something between curves B and

D can be judged somewhat different, according to where the curves start and end.

Curves A-D represent units without visible damage. In the case of units with visible cracks in the metal seal, the dew point will follow curve E and suddenly rise above the critical limit when the cracks occur. For units with displacement of the metal seal, there will be a corresponding rapid increase (curve F).

Field experience has confirmed that the dew point of good units will rise slowly in course of time (curves A and B). For bad units, the dew point can easily rise above the critical limit (curves C, D, and E), and result in condensation. Units with a much too high incipient dew point (curve F) also occurred.

Correlation between the results of the laboratory tests from 1959 to 1966 and the field experience in many ways has been surprisingly good. The types of damage that occurred were exactly the same, and the dew points developed in a completely parallel way. Some factors, however, indicate that the strains were not on just the right level. In the units with a direct glass-to-metal seal, cracks in the metal spacer, as mentioned above, developed in the latter part of the laboratory tests. In practice, such cracks were found only in units installed in doors or adjacent to doors, while the great mass of units showed good performance. A more detailed analysis showed that the windloads used in the period 1959-1966 had been too high. The test program, therefore, was taken up for revision. This was coordinated with the development of a draft Scandinavian spec.

This specification was worked out by the four leading manufacturers in Scandinavia in joint cooperation with NBRI. The specification is much influenced by the American SIGMA specification, but is otherwise completely redrawn to take into account Scandinavian experience. One point worth noting is the inclusion of initial tests, which cover visual inspection, measurement of initial dew point, and control of initial seal. The purpose is to avoid expensive and time consuming aging tests with units which are not of a reasonably high quality.

### Aging tests

The accelerated aging tests are based on the NBRI method, but with several modifications. The size of unit has been reduced to 82 x 120 centimeters (32 x 47 inches), about half the original size, by mounting a crossbar in the sashes. On the other hand, ultraviolet radiation has been included. The actual UV lamps are fluorescent black light tubes with radiation mainly between 3,000 and 4,000 amp. The units are mounted with the bottom edge in a metal tray, filled with water

once a day so that the bottom edge is subjected to wetting and drying cycles. The number of temperature changes has been maintained and the temperature strains even slightly increased, while the number of wind gusts has been reduced to about half. The present accelerated aging test program amounts to 50 day cycles. Details are given in *Table II*.

The most important novelty in the revised program is perhaps the wetting and drying cycle. The reason for this is that the field studies showed clearly that water will sooner or later reach the edge seal. Then the combination of humidity and ultraviolet radiation becomes of importance.

Testing in accordance with the draft Scandinavian specification has now been going on for two years. Thirty-one sets from 23 different sources have been tested in Trondheim. Experiences gained in these comprehensive tests show that some improvements in the aging tests are desirable. First of all, the black light tubes should be replaced with the American type of sunlight tubes specified by the SIGMA organization. Further, the wetting and drying cycle should be made a little more effective. Finally, the size of unit should be increased, at least a bit toward the original NBRI size of 120 x 170 centimeters (47 x 67 inches). Available material shows that 121.4 x 142 centimeters (48 x 60 inches) will probably be a future common Norwegian and Swedish standard size. This size is recommended as the basis for type testing.

For control testing, it is also desirable to test units of different sizes, at least sizes deviating a little from the base size. A completely new apparatus for accelerated aging tests has been outlined at the NBRI laboratory. The new apparatus will be completely different from the old, but will perform the same basic functions. The apparatus is expected to be far more effective, and all the desired improvements can be realized. There also seems to be a real chance to obtain a temperature of about +70°C. (+158°F.) in period IV, as originally sought by the Scandinavian manufacturers.

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