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John C. Burgess

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The history, scientific basis and application of international IGU durability tests

J. C. Burgess*

BRANZ†, Judgeford, Porirua City, New Zealand

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Abstract

This paper outlines the history, scientific basis and application of several national standard IGU durability tests, namely, the IGU durability Eurocode, the British Standard, the American Standard, and the Canadian IGU durability codes. The paper discusses and traces the development of IGU durability tests since their inception to the type of test available today.

1. Introduction

A plethora of different tests for assessing the durability and expected lifetime of double glazing units, or insulated glazing units (IGUs), in human habited spaces exist around the world. These have arisen due to the demand for durable insulated glazing units, where two panes of glass are hermetically sealed together to provide acoustic and thermal insulation, being driven by the parameters of thermal comfort, energy efficiency, visual transmission, acoustic isolation, human proximity to cold glazing surfaces, fading reduction and other factors [1]. Yet the scientific basis, appropriateness and accuracy of these tests is often unknown. Some of the tests stem from common results, testing or assumptions, and are developments or extensions of each other. Other available tests are characterised in that they address specific issues, perhaps to the detriment of maintaining a conspectus over the testing purpose.

The evolution of these test methods will be investigated by this paper, which includes discussion of the historical development of the IGU durability tests of Canada, the U.S.A., the U.K. and the European Union, their scientific basis and their application, such that informed decisions may be made as to the application of these tests.

2. IGU performance Tests

Currently, many countries have standard methods that, to some degree, assess the long-term durability of IGUs, as a form of Quality Assurance for the consumer. Some of these are national or international standards in draft or complete form, and some are self-imposed industry tests. A list of the tests and regulations that have been identified is included below.

- Canadian: Insulating Glass Units, CAN/CGSB-12.8-M90. [2]
- British: British Standard Specification for hermetically sealed flat double glazing units, BS5713:1979. [3]
- American: Standard specification for sealed insulating glass units E774–92. [4]
- German: Laminated insulating glass units: air filled, aging behaviour DIN 1286 Part I. [5]
- Italian: Flat glass. Sealed insulating glass, UNI 7171. [6]
- Danish: Insulating glass. Quality requirements, and the test methods. Purity, dew point, aging behaviour, seal efficiency and identification testing. DS 1094. [7]
- Dutch: Glass in building; insulating glass; requirements and methods of test NEN 3567. [8]
- Belgian STS 38 Unified technical specification. Glazing. [9]
- Norwegian: Sealed glazing units; resistance to accelerated climatic strains NBI-119/80E. [10]
- Swedish: Flat glass. Determination of the ability of sealed units to resist accelerated climatic strains SIS224413. [11]
- Swiss: IGU installation technique regulations, Nos 1 and 2, 1980. [12]
- ISO: International Standardisation Organisation ISO/TC 160 draft standard, 1978. [13]
- WIGMA Specification for hermetically sealed insulating glass units. [14]

* Corresponding author. Tel.: 0064 235 7600; fax: 0064 235 6070.
† BRANZ: Building Research Association of New Zealand.

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- French: AFNOR P78-451-456, Insulating glazing units. Moisture penetration resistance tests. [15]
- CEN: Draft European Standard, EN 1279. Glass in building—insulating glass units. [16]

Table 1 summarises the main features of these tests, where the 'asymmetric climate test' refers to a test where either face of a rectangular IGU is exposed to different conditions, e.g., one face to laboratory conditions, and one face to artificially induced climatic conditions.

3. The evolution of IGU test methods

All IGU durability tests involve using some method to assess the moisture content of the inter-pane space of a production sample of IGUs, subjecting certain of these samples to a range of artificially induced 'weather' conditions for a time, and then measuring the effect of those conditions against another assessment of the moisture content of the inter-pane space. While the value of accelerated aging tests such as these in the laboratory have been disputed [17], it is acknowledged that these tests normally constitute the most important basis for a rapid evaluation of new types of unit. The alternative to laboratory testing is to collect information from units on natural exposure, which is time consuming and involving considerable inherent time lag before information is forthcoming as to the quality of the units.

Consequently, a variety of testing regimes have been developed for this purpose, as discussed below.

3.1. Canadian developments

In the late 1950s, researchers of the Division of Building Research (DBR) of the National Research Council of Canada (NRCC), headed by Dick Solvason, performed verification of a proposed accelerated weathering test for IGUs when, over a five-year period, they exposed a number of IGUs provided by different manufacturers to natural weathering in an outdoor exposure rig. A second set of 'identical' IGUs was subjected to a laboratory comparative artificial weathering régime of 320 cycles of asymmetric heating, cooling and water spray. From the correlation between the increasing dewpoint following the asymmetric laboratory climate cycling tests and the natural exposure field tests, Solvason's team was able to determine that this test régime of artificial weathering (which subsequently was to form a part of the Canadian IGU standard) produced the same failure mechanism as did a five-year natural weathering time.

This work to develop a test method eventually became

Table 1
Standard test comparison

Type of test	Canadian CAN/ CGSB-12.8-M90	American ASTM 773	ISO 1978 draft ISO/TC 160	French AFNOR P78–451	British BS5713	Italian UNI7171	Netherlands NEN3567	Belgian STS38	German DIN52344	Draft CEN
1 Constant climate										
Temperature	—	60C	—	60C	—	20C	—	—	52C	58C
Humidity	—	95%	—	95%	—		—	—	95%	95%
UV radiation	—		—	40 Watts	—	40 Watts	—	—	—	—
Time	—	2/4/6 weeks	—	2 × 2 weeks	—	2 weeks	—	—	4 weeks	7 weeks
2 Symmetric climate cycling										
High temperature	55C	—	55C	50C	55C	60C	55C	55C	52C	53C
Low temperature	22C	—	20C	−15C	25C	−20C	−10C	−10C	−15C	−18C
Time	28 days	—	28 days	6 × 2 weeks	28 days	4 weeks	40 days	40 day	8 × 4 days	28 days
UV radiation									8 × 64 h	
3 Asymmetric climate cycling										
High temperature	50C	57C	52C	—	52C	—	—	—	—	—
Low temperature	−32C	−30C	−15C	—	−15C	—	—	—	—	—
Time	53 days	35/49/63 days	60 days	—	60 days	—	—	—	—	—
UV radiation		2 × 85 Watts		—	—	—	—	—	—	—
Total test time	120 days	57/85/113 days	96 days	112 days	104 days	42 days	40 days	40 days	84 days	91 days
Number of cycles	544	140/196/252	544	236	544	28	152	224	32	56
Time at high C and rh	816 h	756/1260/1800	950 h	900 h	1000 h	392 h	470 h	470 h	1216 h	1232 h

a Canadian standard published in 1975 as CGSB 12-GP-8M by the Canadian Government Specifications Board, Ottawa, Ontario, K1A OS5. It became CAN/CGSB-12.8-M90 [2] in 1990.

This standard was based on the acceleration of naturally occurring climatic conditions, and also served to identify IGUs which had manufacturing faults.

3.2. American IGU test development

The 1962 Canadian test was used by SIGMA (Sealed Insulating Glass Manufacturers Association of America) until its own 1968 Weathercycle test was established. This test stretched the Canadian four hour weather cycling test to six hours to include longer times at differential water vapour pressures, and replaced the symmetric high humidity cycling test with a symmetric high humidity static test.

This 1968 test method was modified by PPG and Combustion Engineering in the U.S.A., and was published by ASTM as E6P1 in 1976, together with E6P2, being the 1968 SIGMA method originally published as SIGMA 65-7-2, and the general specification method, E6P3.

It was shown that the E6P1 method favoured IGU edge-seal technologies employing hot-melt butyl and silicone dual seal, and did not duplicate field spacer-pumping in hot-melt butyl-sealed units, and so was dropped. The E6P2 method became the E773 [18] test published in 1981, and E6P3 became E774-92 [4].

There is considerable corroborative evidence from the lifetime of IGUs in service in the U.S.A. that suggests that product passing the 'CBA level' ASTM tests can be expected to have a lifetime exceeding 25 years in correctly installed applications. Of particular interest have been the results of a nine-year field correlation study [19] of 38,000 IGUs in 133 buildings in 14 geographical areas, performed under the auspices of SIGMA. They were published in 1989, with two conclusions:

(1) Geographical location does not influence the failure rate of IGUs installed on the southern side of buildings in the U.S.A.
(2) Units undergoing the long-duration 'Class A' durability test are performing better than the shorter cycle length Class 'C' and 'B' units.

The report also noted that the study represented the field performance of units that were over ten years old in 1989, so did not include information on new sealant systems, gas-filled units, Low-E glass, capillary tubes or other new developments in IGU.

Both the ASTM and CAN standards were developed in areas with cold climates which used IGUs for heating season comfort. Consequently, the temperature limits chosen in the artificial weathering sections of the standards reflect these outdoor temperatures as they attempted to replicate and accelerate natural exposures. However, the use of IGUs in the USA to improve plant cooling performance, is becoming as important as for their use to improve plant heating performance, yet the same temperature limits were maintained in the E773 [18] standard revision of 1995, presumably reflecting the results of the SIGMA study which indicated that climate had no noticeable effect on unit failure. Norwegian work [20] has indicated that it is the average IGU spacer-gap gas temperature that has most effect on the failure of IGUs and that, due to the variability of water sorption in the desiccant, summer weather conditions may cause the greatest stress on the edge seal of IGUs.

3.3. British test development

The British standard BS5713:1979 [3] was formed by taking the Canadian standard [2] and increasing the low temperature in the accelerated weathering procedure from −32°C to −15°C. The remainder of the standard is identical to the 1976 version of the Canadian standard [2].

Like the American standard [4], the British standard [3] is acknowledged to be without scientific verification yet the test method has some corroboration through 18 years of field experience. BS5713 tested units perform consistently better than non-tested units [30].

3.4. Other standard test developments

A variety of other countries have developed IGU tests, as identified in the list set down earlier in this article. The developments in Scandinavia represent one extreme of the use of an IGU test, so they will be discussed here.

The Scandinavian standard, and consequently the Norwegian standard, was developed in parallel with the North American standards [17], using a temperature of −75°C [21] in the dewpoint test. It converted the 'time till dew formation' into an actual dewpoint temperature using pre-determined calibration curves for dewpoint vs time, for varying thicknesses of glass panes. The Norwegians extended the accelerated aging regime to cycle between −10°C and 55°C [22] and included pulsating air pressure between 0 Pa and 1 kPa at 0.08 Hz to mimic wind loading; continuous UV exposure; the daily flooding of the rebates containing the IGU edge seals with distilled water; and a weekly IGU dew point temperature assessment [23]. Although temperatures below −30°C are regularly experienced in northern Norway, it was not deemed worthwhile to include exposure to this temperature within a cyclic test régime. This reflects the changing perceptions of IGU test needs, from accelerated natural condition simulation to specifically targeted deleterious intent.

Various European nations have developed empirical models of the failure of IGUs, although the early ones such as the Backman model (as referenced in [24]) suffer from ignoring the deleterious effect of aging on the edge seal, while later models like Von Santen (also referenced in [24]) allow in different ways for physico-chemical processes. The Dutch national standard test [8], for example, involves using the Von Santen empirical adjustment method to assess the condition of the desiccant and project a consequent IGU lifetime from material properties.

3.5. Australian developments

Factory-sealed double glazing began to be used in commercial buildings in Australia in the late 1950s, and internal moisture problems were not far behind. A test method [25] was devised in 1961 by the CSIRO, in which units were placed with their bottom edges immersed in water while the temperature of the room was cycled from 4–60°C. It was found that the manufactured quality of the seal could be determined by measuring the out-of-plane deflection of the centre of the glass with a dial gauge following the establishment of thermal equilibrium, indicating a seal leak, with the deflection shown to be proportional to the temperature change. No attempt was made at this stage to develop a test procedure beyond this point, although advances were made to the Canadian dewpoint measuring apparatus, which were later picked up by researchers in New Zealand, and further developed in 1993 [26].

3.6. ISO development

A draft version of an international standard test method (ISO) for the durability assessment of IGUs was published in 1978 [13]. This took the 1976 version of the Canadian test [2] and increased the lower temperature value in the accelerated weathering section from −32°C– −15°C, as for the British standard [3]. Development of this ISO draft document ceased for a period with the advent of the European Economic Community in the late 1980s, with CEN taking up the work that ISO had performed earlier. Now, with the CEN IGU standard [16] being finalised (1997), the re-formed ISO/TC 160 WG4 under the secretariat of BSI is again working on IGU durability testing under the terms of the Vienna Agreement—where, whenever possible, ISO adopts CEN standards unchanged.

The 1978 ISO draft standard reflected 20-year-old technology when it was produced, although the main change made in the 1978-published ISO work [13] was, as in the U.S.A., to determine a 'dewpoint' temperature, by slowly lowering the temperature of a 'cold cell' in contact with the outer pane of an IGU until condensation becomes visible, rather than a pass/fail criterion of the appearance of condensation at a certain temperature. In addition to this change, the final dewpoint measured was required to be lower than a pre-determined limit temperature, which depends on the initial dewpoint and the type of desiccant used in the insulating unit. This is based upon the consideration that, after 1000 cycles of symmetric cyclic high humidity testing, the 'dewpoint' of the IGU remains lower than −5°C, so the initial dewpoint temperature and the absorption curve of the desiccant must be known [13].

3.7. European development

Similarly to the North American work from 1960–1975, a comparative test [24] was performed by the German Institute for Window Technology (IFT) at Rosenheim between 1980 and 1984. It was based on the performance of IGUs in situ [27] and in laboratory tests [28] to the proposed German national standard test method, DIN1286 [5], before the test method was ratified as a standard. The results of the study show that the DIN1286 [5] symmetric cyclic climate test introduces the same amount of moisture into the inter-pane space as do 3–4 years of typical climatic conditions in service in Germany. Therefore, it may be concluded from extrapolation of these MVTRs that IGUs passing the DIN1286 [5] standard will have a lifetime of 25 years.

As a part of the European Economic Community standards development process, a European standard prEn1279 [16] has been created by the CEN committee CEN/TC129/WG4. The experts of various countries, including those from Germany, France, Belgium and the U.K., pooled all the information that was available about their disparate test methods [29]. All the major European glass manufacturers were also represented on the committee. It became obvious early on that, despite all the efforts world-wide, no-one actually knew what test regimes were most onerous on IGU edge seals [30]. The committee therefore went back to square one and did some testing, including the size and make-up of test units. It was immediately obvious that assessing performance of IGUs by the moisture content of the desiccant (DIN method [31]) was an important improvement over dew-point measurement, as relative performance levels can be obtained, provided the sampling method is suitably controlled to avoid the introduction of error.

The dew-point method of IGU pane-space moisture determination has become less useful than when first developed, as in modern desiccants the material has to be about 80% saturated before the dew-point will rise above −50°C, and minor changes in moisture content markedly affect the dewpoint measured with this method. In addition, the dewpoint method is unable to resolve dew formation temperatures below about −50°C, which has become a common occurrence with recent IGU manufacturing technology.

These CEN investigations showed that low temperatures did not cause seals to fail [30], but that sustained high humidity, rather than high humidity cycling was the main driver of moisture into sealed units. However, the committee felt that they could not ignore low temperatures or cycling [30], because these might affect sealants not tested by the committee. Hence the regime was split into two parts, one with high humidity temperature cycling, and one with constant high temperature and humidity, with the pass criterion set at the level of less than 20% of the desiccant's moisture absorption capacity being reached by exposure to this regime. This allows the moisture loading of the desiccant to be determined.

Consequently, the test régime pass criterion is thought to be more onerous for a sealed unit than any existing national standard around the world. It has also been stated [30] that typical single-seal units without any flaws will not pass this test, nor will inferior quality dual-seal IGUs, which implies that single-seal units constructed with typical materials and components will routinely fail at least the German, French and draft CEN standards, but can be constructed to pass at least the Canadian, British and American IGU tests.

4. Discussion

The methods devised since 1950 to test the durability of IGUs have been a mixture of tests to indicate manufacturing faults, tests which replicate known problems with certain IGU-construction processes, and tests which accelerate the IGU seal aging process. Consequently, it has not been possible to obtain international agreement or corroboration of the prime drivers of field IGU failure, or indeed the major failure modes.

As the maturity, materials, technology and requirements of the IGU industries in various countries are all different, some test régimes are inappropriate, and some advances in testing may not be relevant to all IGU test applications. In addition, there is a degree of xenophobia regarding the acceptance of testing protocols developed in another country, and a significant investment in IGU test technology and equipment, which serves as an obstruction to further IGU test development.

However, with the increasing internationalisation of domestic markets, and ubiquity of IGU construction components, it is increasingly relevant for a single test method to supplant others in the assurance of performance of IGUs. The most recently developed draft CEN IGU test proposal appears to address all the issues pertinent to IGU performance, and it can be seen to be an appropriate IGU test standard to supplant existing national IGU test standards worldwide.

5. Conclusions

A wide variety of different tests for determining the durability and expected lifetime of double glazing units, or insulated glazing units (IGUs), exist in a variety of nations around the world. These tests have been developed due to the demand for durable insulated glazing units, where two panes of glass are hermetically sealed together to provide acoustic and thermal insulation, being driven by the parameters of thermal comfort, energy efficiency, visual transmission, acoustic isolation, human proximity to cold glazing surfaces, fading reduction and other factors. The scientific basis, appropriateness and accuracy of several of these tests has been examined, with a commonality in results, testing or assumptions, shown to exist, such that it is revealed that some are developments or extensions of each other. Other available tests are characterised in that they address specific issues, to the detriment of maintaining a conspectus over the testing purpose, although one test has been shown to be a significant advance over the others.

The evolution of these test methods has been investigated in this paper, which includes discussion of the historical development of the IGU durability tests of Canada, the U.S.A., the U.K. and the European Union, their scientific basis and their application. The intention has been to allow informed decisions to be made as to the application of these tests.

The study has shown that there is no international agreement on the most appropriate IGU durability test, or even the main field failure modes. The study has shown, however, that there is significant investment in IGU test technology and equipment, but, a degree of xenophobia serves as an obstruction to further IGU test development.

- The basis of all IGU durability tests is a measurement of the quantity of moisture between the panes of the unit before and after an accelerated weathering test.
- IGU durability testing has evolved since the original research work was performed in the 1950s, into a plethora of different national IGU testing standards and methods.
- The same glass, sealants and spacer systems are available worldwide. A dual-seal IGU made with typical materials, and without any manufacturing faults, can pass all the identified existing national standard IGU durability tests in the world.
- Single-seal units constructed with typical materials and components will routinely fail the German, French and draft CEN standards, but can be constructed to pass the Canadian, British and American IGU tests.
- The replication of natural conditions in IGU durability testing is not necessarily appropriate for generating stressful conditions pertinent to the long term durability of IGUs in service.
- The draft CEN standard is a suitable IGU durability test standard and should be internationally adopted to supplant the existing national IGU test methods.

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