RESULTS OF AN INTERLABORATORY TEST PROGRAM ON A NEW FIRE RESISTANCE TEST FOR FLEXIBLE ROOFING SHEETS

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The setup and background of a new fire reaction test for flexible roofing sheets was given in a paper presented in 1995 at the IX International Waterproofing Association (IWA) Congress in Amsterdam.[1] The IWA Fire Reaction Test is a so-called one-part method, which means that all combinations of brand, wind, and radiation are possible with one apparatus. There are several advantages to this test as compared with other one-part methods.

An extensive interlaboratory test program was executed according to ISO 4259: 1992 with the cooperation of eight European laboratories under the supervision of the IWA Technical Committee.

This program resulted in further fine-tuning of the IWA Fire Reaction Test, including the change of "reaction" into "resistance." The final version of this test includes combinations of wind and/or radiation with a "flying" brand. The paper gives the results of the different test rounds, a proposal for a classification under different conditions of testing, and a comparison with other fire tests.

The new fire resistance test and classification system have been adopted by both the IWA and the CEN Technical Committee 254 Flexible Sheets for Waterproofing. It also has been presented to the Fire Regulators Committee of the European Commission.

KEYWORDS

Fire test, flexible roofing sheets, interlaboratory test program.

INTRODUCTION TO THE IWA FIRE TEST

The IWA Fire Test is based on the Scandinavian Nordtest[2] with the inclusion of a source of radiant heat to comply fully with the relevant Interpretative Document[3] of the Construction Product Directive of the European Communities.[4] The IWA Fire Test includes a possible combination of wind and/or radiation with a brand. The main test conditions of the IWA Fire Resistance Test[5] are summarized in Table 1, and the IWA Fire Resistance Tester is shown in Appendix A, Figures 2 and 3.

Subject	IWA Fire Test method
dimensions test specimen	0.40 m by 1.60 m (15.7 inches by 5.2 feet)
ignition material	brand of expanded perlite, forming a grid 50 mm (2 inches) square and 23 mm (0.9 inches) deep; before use the brands are soaked with n-heptane
air velocity above test specimen	(3.0 ± 0.2) m/s ([9.8 ± 0.7] feet/second)
total heat flux	(8.0 ± 0.2) kW/m²; pre-heating time of 3 minutes

Table 1. Main test conditions the IWA Fire Test.

TEST ROUNDS

After the first interlaboratory program,[1] the participants of the fire test project met to discuss the results and to exchange experiences on this round robin test. The participants proposed the following two main modifications of the IWA Fire Test—Sixth Draft:[6]

- Calibration of the radiant panel should take place with closed lid and wind, measuring the total heat flux inside the test specimen box.
- A more reproducible ignition source compared to the wooden brands of the Sixth Draft should be used because of the difficulty of obtaining consistent wood samples. A brand made of expanded perlite should be used; before use, the samples should be soaked with a certain quantity of n-heptane.

The IWA Technical Committee adopted the above and other (smaller) revisions, which resulted in the IWA Fire Resistance Test—Seventh Draft.[5] To determine the repeatability of this test method, IWA commissioned the Fire Research Station (FRS) of the Building Research Establishment (UK) to perform tests in accordance with the revised test method. FRS performed the fire tests on test specimens that were prepared for the interlaboratory program of the IWA Fire Test—Sixth Draft. Staff of BDA attended the first 20 of 81 fire tests performed by FRS and ascertained that the fire tests were performed in accordance with the test method and witnessed that the method showed good repeatability. Thereafter, BDA analyzed the test results in order to assess the repeatability of the test method.[7]

The statistical models described in ISO 4259[8] and ISO 5725[9] for determining the repeatability of the test method could not be applied, because only one laboratory was involved. It was decided that to give a well-founded opinion upon the repeatability, the analysis of the data should involve the following stages:

- critical examination of the data in order to identify and treat outliers or other irregularities
- computation of the mean (m) and the estimate (s) of the standard deviation ($\sigma_{(n-1)}$) of the flame spread and the damaged area

The data have been critically examined by determining a two-sided tolerance interval with a confidence level of 95 percent. Fractiles of Student's distribution[10] have been applied. Production of flaming droplets or debris falling from the underside or from the exposed surface of the test specimens was not observed. Only one outlier had to be rejected. The results are given in Appendix B, Tables 4 through 6. General statistical computation and rounding-off procedures have been applied.[11] It was concluded that the test results and the analysis of the data prove a good repeatability of the IWA Fire Test—Seventh Draft.

Based on this result, IWA commissioned BDA to coordinate an interlaboratory program of the IWA Fire Test-Seventh Draft in order to prove the good precision (repeatability and reproducibility) of the test method. Five laboratories of different European countries participated in the test program: Belgium, Germany, the Netherlands, Sweden, and the United Kingdom.

The IWA Technical Committee decided to prove the precision of the test method with reproducible test results of the test condition with the most variables. In the case of the IWA Fire Test, this is the test condition with wind and radiance with the test variables test specimen, ignition source, wind, and radiance.

As decided by the IWA Technical Committee, two systems have been tested:

- The first system consisted of:
  - top layer (cap sheet) SBS bituminous waterproofing with polyester reinforcement;
  - underlayment of oxidized bitumen with glassfleece reinforcement;
  - 50 mm (2.0 inches) of mineral wool insulation;
  - 18-mm (0.7-inch) deck of particle board.
- The second system consisted of:
  - PVC single layer waterproofing 1.2 mm (45 mils) with polyester reinforcement, mechanically fixed;
  - 50 mm (2 inches) of mineral wool insulation;
  - 18-mm (0.7-inch) deck of particle board.

The five participants prepared a total of 90 test specimens. BDA bought the roofing sheets at random on the Dutch market from three different manufacturers (SBS, oxidized bitumen, and PVC). The participants were instructed by BDA on the test program. The construction build-up of the test specimens is given in Figure 1.

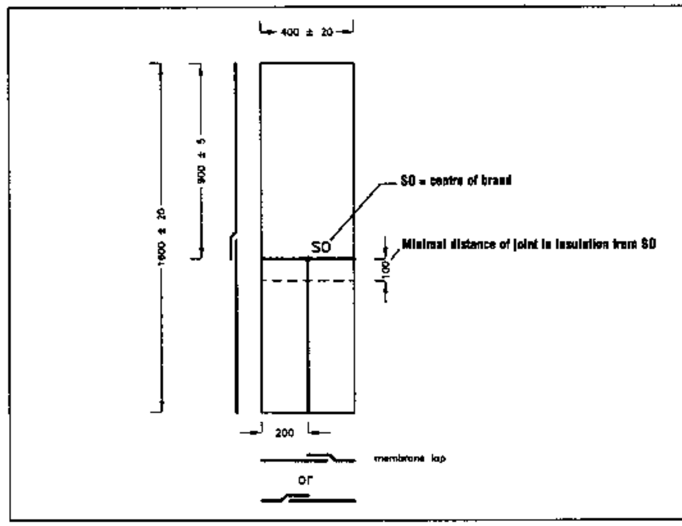

Figure 1. Construction build-up of the test specimen (plan view, not to scale, dimensions in millimeters)

The results of the following two measurements were analyzed:

- fire spread
- damaged area of top layer

Previous research proved these two measurements to be the most reproducible.

The analysis of the data was done in accordance with statistical models described in ISO 5725. The examination of the data to identify and treat outliers was done as described in BDA's report[7] on the repeatability of the IWA Fire Test—Seventh Draft. Hawkins' 1 percent outlier test[8] was applied to the laboratory averages over all tests to determine whether it was necessary to reject the complete set of any particular laboratory.

Production of flaming droplets or debris falling from the underside or from the exposed surface of the test specimens was not observed. Only one outlier was rejected, and Hawkins' test showed that no complete laboratory rejections were necessary. The outlier (SBS system, damaged area) was rejected because it fell outside a two-sided tolerance interval (confidence level 95 percent; fractiles of Student's distribution[10] were applied). In Table 5, m, s, r (repeatability), R (reproducibility), n (number of replicate tests) and p (number of participating laboratories) of the two measurements are given. General statistical computation and rounding-off procedures were applied.[11]

It was concluded that the test results prove a good precision of the IWA Fire Test—Seventh Draft at the test condition with wind and supplementary radiant heat. Based on this conclusion, it may be assumed that test results at the other two test conditions (wind and brand, brand only) will prove the same or even better precision of the test method, because the test condition with wind and radiant heat has the most variables (i.e., brand, wind, and radiant heat) of the three different test conditions.

In the report,[12] it was stated that the IWA Fire Test is not yet

Aspect	m	s	r	R	n	p
SBS system; damaged area [m² (ft²)]	0.221 (2.38)	0.105 (1.13)	0.121 (1.30)	0.344 (3.70)	35	4
PVC system;* damaged area [m² (ft²)]	0.132 (1.42)	0.053 (0.57)	0.069 (0.74)	0.172 (1.85)	27	3
PVC system;† damaged area [m² (ft²)]	0.278 (2.99)	0.042 (0.45)	0.121 (1.30)	0.112 (1.21)	15	2
SBS system; flame spread [mm (inches)]	867 (34.1)	113 (4.45)	283 (11.1)	322 (12.7)	44	5
PVC system; flame spread [mm (inches)]	776 (30.1)	61 (2.4)	140 (5.51)	176 (6.93)	41	5

*Standard measurement procedure
† Alternative measurement by applying a transparent siliconized foil with a known mass/m² (mass/ft²)

Table 2. Test results (m, s, r, R, n *and* p)

standardized and in daily use in the participating laboratories and that many different factors (apart from variations between supposedly identical test specimens) may have contributed to the variability of the test results.

The test results also show that the "flame spread" is more reproducible than the "damaged area." Therefore, it is recommended to relate a pass-or-fail system of roofing sheets to the aspect of flame spread.

PROPOSAL FOR CLASSIFICATION OF ROOF SYSTEMS

A possible classification of roof systems (insulation with roof waterproofing) based on consideration of flame spread is given in Table 3. As stated before, the measurement of flame spread appeared to be the most reproducible aspect of the IWA Fire Test.

The pass-or-fail criteria and the levels of radiation should be established by performing comparative testing at the four test conditions on commonly used roof constructions. A possible pass-or-fail criterion regarding the flame spread could be that two out of three test specimens should have a flame spread of no more than 800 mm (31.5 inches). The roof system could be classified depending on the conditions at which this criterion is met.

Class	Test conditions		
	brand	wind	radiation
1	yes	no	no
2	yes	yes	no
3	yes	yes	yes*
4	yes	yes	yes†

*Lower radiation level (e.g., a total heat flux of 5 kW/m²)
†Higher radiation level (e.g., a total heat flux of 8 kW/m²)

Table 3. Classification of roof systems

IWA FIRE TEST COMPARED TO OTHER FIRE TESTS

There are not yet comparative data available about the IWA Fire Test and other fire tests for roof systems. However, based on experience, the following comparison may be assumed (the tests are ranked from 1 [least severe] to 5 [most severe]):

1. IWA Class 1[5] (see Table 3)
2. Scandinavian Nordtest[2]
3. American ASTM E108[13] Class B; German DIN 4102 Teil 7,[14] Dutch NEN 6063;[15] IWA Class 2; prEN 1187-1[16]
4. IWA Class 3
5. American ASTM E108 Class A; IWA Class 4; prEN 1187-2[17]

As stated before, this comparison is based on experience and not on real, comparative data.

CONCLUSIONS

- The results of the interlaboratory test program show a good precision of the IWA Fire Resistance Test—Seventh Draft.
- The IWA Fire Resistance Test—Seventh Draft is a simple, inexpensive, relatively environmentally friendly, and precise one-part fire test.
- Roof systems (insulation with roof waterproofing) may be classified by varying the test conditions and using the flame spread criterion.

ACKNOWLEDGMENTS

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ENDNOTES

1. Hendriks, N.A. "Evaluation of fire reaction tests on waterproofing systems with respect to the Construction Products Directive," *Proceedings from the IX International Congress of the International Waterproofing Association*, Amsterdam, 1995, 90-105.
2. *Nordtest method NT fire 006: Roofings: Fire Spread-Approved*, 1985-11, Edition 2, Nord Test, Helsingfors, Finland.
3. "Communication of the Commission with regard to the Interpretative Documents of Council Directive 89/106/EEC," *Official Journal of the European Communities*, 94/C62/01, February 1994.
4. "Construction Products Directive," Council Directive 89/106/EEC, *Official Journal of the European Communities*, February 1989.
5. *IWA Fire Resistance Test: External fire exposure to roofs—Method of test representing different combinations of exposure to burning brands, wind and supplementary radiant heat*, IWA, Nottingham, UK, Seventh Draft, 1996.
6. *IWA Fire Reaction Test: External fire exposure to roofs—Method of test simulating exposure to burning brands, with wind and supplementary radiant heat*, IWA, Nottingham, UK, Sixth Draft, 1995.
7. *IWA Fire Resistance Test—Report on the repeatability of the IWA Fire Resistance Test method-7th draft*, BDA report 0148-L-

93/2, Gorinchem, The Netherlands, 1996.
8. *ISO 4259: 1992: Petroleum products—Determination and application of precision data to methods of test*, ISO, Switzerland.
9. *ISO 5725: 1986: Precision of test methods—Determination of repeatability and reproducibility for a standard test method by inter-laboratory tests*, ISO, Switzerland.
10. *ISO 2854: 1976: Statistical interpretation of data—Techniques of estimation and tests relating to means and variances*, ISO, Switzerland.
11. *NEN 1047: 1967: Instructions for statistical treatment of series of observations*, NNi (Dutch Normalisation-institute), the Netherlands, 1991.
12. *IWA Fire Resistance Test—Inter-laboratory programme of the IWA Fire Resistance Test method-7th draft*, BDA report 0148-L-93/3, Gorinchem, the Netherlands, 1996.
13. *ASTM 108-93: Standard Test Methods for Fire Tests of Roof Coverings*, ASTM, Philadelphia, USA, 1993.
14. *DIN 4102, Teil 7: Brandverhalten von Baustoffen: Bedachungen, Begriffe, Anforderungen und Prüfungen*, DIN, Berlin, Germany, 1977.
15. *NEN 6063: Determination of the fire exposure of roofs on external exposure to flying brands*, NNi, Delft, the Netherlands, 1991.
16. *prEN 1187-2: External fire exposure to roofs—Part 2: Method of test simulating exposure to burning brands, with wind and supplementary radiant heat*, CEN, Brussels, Belgium, 1994.
17. *prEN 1187-2: External fire exposure to roofs—Part 1: Method of test simulating exposure to burning brands, without wind or supplementary radiant heat*, CEN, Brussels, Belgium, 1993.

APPENDIX A

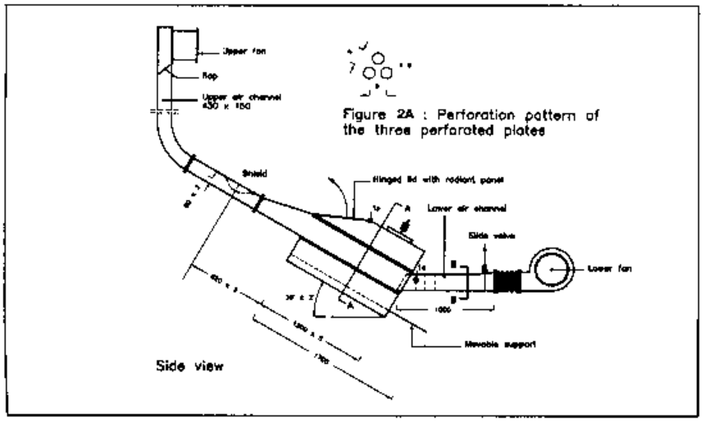

Figure 2A. *Test disposition (side view, not to scale, dimensions in millimeters).*

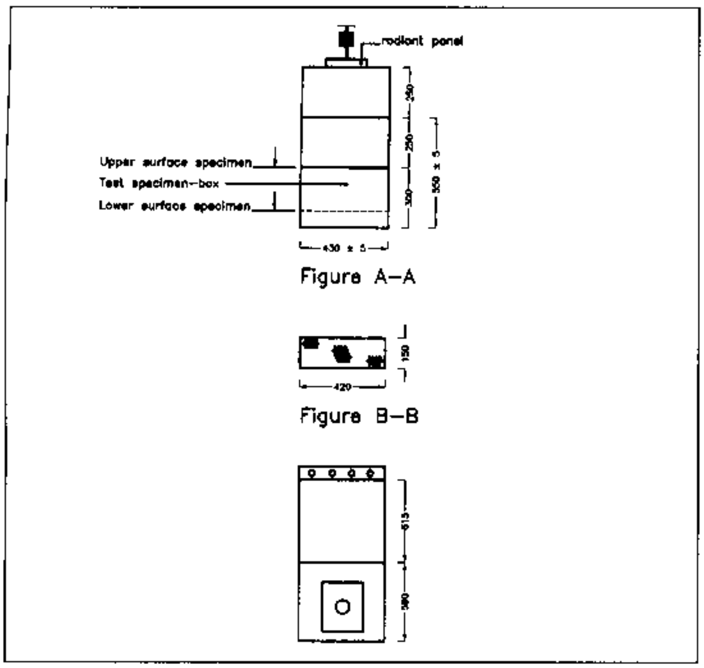

Figure 2B. *IWA Fire Resistance Tester.*

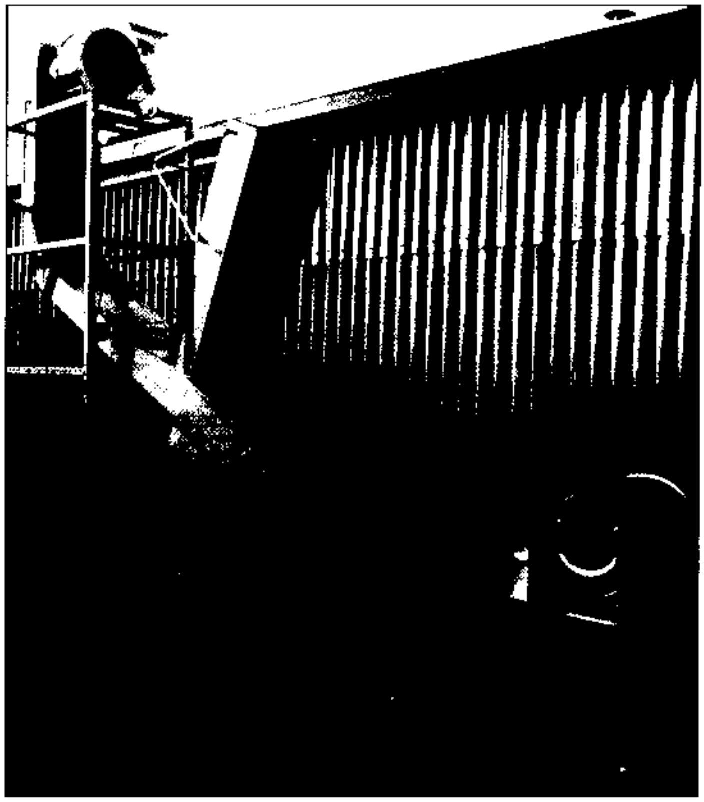

Figure 3. *The IWA Fire Resistance Tester.*

APPENDIX B

Measurement	Test condition					
	wind		wind and radiation		burning brand only	
	m	*s*	*m*	*s*	*m*	*s*
damaged area of top layer (m^2 [ft^2])	0.0121 (0.1302)	0.0010 (0.0108)	0.0208 (0.2239)	0.0027 (0.0291)	0.0037 (0.0398)	0.00071 (0.00764)
length of damaged area top layer (mm [inches])	166 (6.54)	19 (0.75)	216 (8.50)	12 (0.47)	36 (1.4)	7.4 (0.29)
time to reach top (min:sec)	-*	-	-	-	-	-
Number of replicate tests (*n*)	9	9	9	9	9	9
*Flames did not reach the top of the test specimen.						

Table 4. Test results (m and s), test specimen type: double layer SBS on EPS

Measurement	Test condition					
	wind		wind and radiation		burning brand only	
	m	*s*	*m*	*s*	*m*	*s*
damaged area of top layer (m^2 [ft^2])	0.036 (0.388)	0.0117 (0.1259)	0.24 (2.58)	0.09 (0.97)	0.0034 (0.366)‡	0.0005 (0.0054)
length of damaged area top layer (mm [inches])	347 (13.6)	42 (1.7)	-†	-	49 (1.9)	12 (0.47)
time to reach top (min:sec)	-*	-	4:04	0:40	-*	-
Number of replicate tests (*n*)	9	9	9	9	9	9
*Flames did not reach the top of the test specimen. † flames reached top of all test specimens within 15 minutes; fire extinguished. ‡ n = 8, one outlier rejected.						

Table 5. Test results (m and s), test specimen type: single layer SBS on mineral wool

Measurement	Test condition					
	wind		wind and radiation		burning brand only	
	m	*s*	*m*	*s*	*m*	*s*
damaged area of top layer (m^2 [ft^2])	0.0290 (0.312)	0.0040 (0.043)	0.099 (1.07)	0.038 (0.409)	0.00467 (0.0503)	0.00050 (0.0054)
length of damaged area top layer (mm [inches])	328 (12.9)	26 (1.0)	6.6 x 10z (26)	75 (3.0)	53 (2.1)	7.6 (0.30)
time to reach top (min:sec)	-*	-	-	-	-	-
Number of replicate tests (*n*)	9	9	9	9	9	9
*Flames did not reach the top of the test specimen.						

Table 6. Test results (m and s), test specimen type: single layer PVC on mineral wool