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### Fire testing of roofing materials

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#### **Publisher's version / Version de l'éditeur:**

<https://doi.org/10.4224/20338579>

*Technical Note (National Research Council of Canada. Division of Building Research); no. TN-471, 1966-08-01*

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**TECHNICAL NOTE**

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APPROVED BY NBH

DATE August 1966

PREPARED FOR Associate Committee on the National Building Code

SUBJECT FIRE TESTING OF ROOFING MATERIALS

Regulations have been made from time to time imposing limits on the use of certain roof-covering materials in order to reduce the probability of spread of fire from building to building. The danger that was most to be feared appeared to be that of conflagration: the situation where spreading fire involves a number of buildings and is beyond the control of the available fire fighting services.

Tests of roof-covering materials have been made in North America since about 1920. Three methods of test that are of particular significance to Canada are:

- (1) The test developed by the Committee on Combustibility of Roofing Materials of the Dominion Fire Prevention Association in Montreal, 1921 to 1927 (1).
- (2) Fire Tests of Roof Coverings, ASTM E108-58 (2) of the American Society for Testing and Materials, Philadelphia.
- (3) External Fire Exposure Roof Tests, BS 476, Part 3, 1958, of the British Standards Institution, London (3).

These tests differ in many respects but all attempt to measure one or more of the following properties:

- (1) Ease of ignition when exposed to radiant heat, flame or brands
- (2) Surface spread of flame
- (3) Resistance to penetration of fire
- (4) Production of flying brands.

for

The first three properties relate to protection of a building from fire originating outside the building. The fourth introduces the possibility that the building on fire will be a hazard to other buildings. It is recognized that flying brands in a wind can travel up to three miles from the point of origin and are capable of igniting buildings where they land.

## FIRE TESTS OF ROOFING MATERIALS

### Dominion Fire Prevention Association

In September 1921 the Dominion Fire Prevention Association adopted a resolution calling for an investigation into the qualities of various roofing materials sold and used in Canada (1). In the resolution it was stated that the danger of such conflagrations is said to be largely increased by the prevalent use of combustible roofing materials. The investigating committee was asked to deal as exhaustively as possible with the following points:

- (a) Combustibility
- (b) Liability to communicate fire to other properties
- (c) Comparative costs
- (d) Durability and cost of maintenance
- (e) Appearance on roofs
- (f) Treatment of combustible roofings to render them fire resistive
- (g) The adoption of standards for roofing materials and designation in accordance therewith of each material reported on.

The research committee developed two types of test: a flame test and a brand test. The roofing materials were laid on 3- by 3-ft decks made of 7/8-in. t & g boards, laid tight, on 2- by 3-in. battens. The face of each deck was scored with seven shallow saw cuts in each direction, and weighted cotton threads were placed in the grooves. The deck was mounted in a sloping position facing a wind tunnel that maintained a 12-mph wind during the tests. In the flame test the roof was subjected to flame from a gas burner and the 12-mph wind. Times of failure of the cotton threads and the time to appearance of flame on the underside of the deck were noted. In the brand test four sizes of brands -- 3 1/2 by 3 1/2 in., 5 5/8 by 5 5/8 in., 7 3/4 by 7 3/4 in., and 12 by 12 in. -- were placed in succession on the roof until the roofing materials ignited or until fire penetrated the deck. During both tests observations were made of the production of flaming or glowing fragments. The grouping of roofing materials in descending order of resistance to fire as a result of these tests is shown in Table I.

The description of each group in the reference paper (1) is as follows:

- "Group 1. Will give protection against severe fire exposure.
- Group 2. Will give protection against large burning brands and direct flame for limited time. Will not produce any burning brands.
- Group 3. Will give protection against large burning brands and direct flame for limited time. Will not produce dangerous burning brands.
- Group 4. Will give protection against small burning brands but not against direct flame. Will not produce dangerous burning brands.
- Group 5. Will not give protection against small burning brands or direct flame. Will not produce dangerous burning brands.
- Group 6. Will not give protection against small burning brands or direct flame. Will produce dangerous burning brands."

#### National Bureau of Standards

In 1942, the Subcommittee on Fire Resistance Classification of the Central Housing Committee on Research, Design and Construction of the National Bureau of Standards prepared a Classification of roof coverings based on tests by Underwriters' Laboratories. This was published in BMS Report 92 (4). The Subcommittee suggested five classes. Classes 1 and 2 are parallel with classes A and B subsequently established by Underwriters' Laboratories, and to be discussed later. Class 3 is similar to class C except that asphalt rag-felt roll roofing laid in single thickness is not included in the former. Class 4 covers roll roofing and some wood shingle roofing. The roofing materials fall into the classes as shown in Table II.

#### American Society for Testing and Materials

The current ASTM test for roofing materials (ASTM E108 (2)) appears to have developed from the Dominion Fire Prevention Association test and the Underwriters' Laboratories tests referred to above. It includes three parts and three degrees of severity in each part.

The test deck for method A, the intermittent flame exposure test, and method C, the brand test, is 3 ft 4 in. wide and 4 ft 4 in. long and is made of 1 in. nom. by 8 in. nom. boards laid 1/4 in. apart on 2- by 4-in. battens. The test deck for method B, the spread of flame test, is the same as that described above except that it is 3 ft 4 in. wide by 13 ft. long. The deck with the roof covering to be tested

is mounted at a specified angle and exposed to a wind of 12 mph during each test.

The intermittent flame exposure is continued for 15 cycles of 2 min flame on and 2 min flame off for Class A roofing, 8 cycles for Class B, and 3 cycles of 1 min on and 2 min off for Class C. In the spread of flame test, the flame is applied continuously for 10 min in Class A or B or until the flame has spread to the top of the deck or until the flame has begun to recede from the point of maximum spread. For Class C the gas flame is applied for only 4 min.

In the brand test three sizes of brand are specified: 12 by 12 in. for Class A, 6 by 6 in. for Class B, and 1 1/2 by 1 1/2 in. for Class C. The brands are ignited and are placed on the test deck while exposed to the 12-mph wind. The brands are tied down to the deck by soft iron wire.

#### Underwriters' Laboratories

Underwriters' Laboratories list of roof-covering materials (5) is based on the Underwriters' Laboratories test U.L. 790 which is essentially the same as the ASTM test E108.

Class A Covering. - Class A includes roof coverings that are effective against severe fire exposure. Under such exposures roof coverings of this class are not readily flammable, and do not carry or communicate fire; afford a fairly high degree of protection to the roof deck; do not slip from position; possess no flying brand hazard; and do not require frequent repairs in order to maintain their fire-resisting properties.

Class B Covering. - Class B includes roof coverings that are effective against moderate fire exposures. Under such exposure, roof coverings of this class are not readily flammable and do not readily carry or communicate fire; afford a moderate degree of fire protection to the roof deck; do not slip from position; possess no flying brand hazard; and do not require frequent repairs in order to maintain their fire-resisting properties.

Class C Covering. - Class C includes roof coverings that are effective against light fire exposure. Under such exposures roof coverings of this class are not readily flammable and do not readily carry or communicate fire; afford at least a slight degree of fire protection to the roof deck; do not slip from position; possess no flying brand hazard; and may require occasional repairs or renewal in order to maintain their fire-resisting properties.

The conditions for acceptance in Classes A, B and C, based on performance in the standard test, are set out in Table III.

#### British Standards Institution

The British test method for roof coverings, BS476 (3), is designed to give information concerning the hazard that exists of fires spreading to the roof of a building from a nearby fire outside the building and, like the ASTM test, is not concerned with the behaviour of a roof when subjected to the effects of fire on its underside. The roof is subjected to flame impingement but no brands are used. The test method is in three parts.

- (1) A preliminary test in which a section of roof is exposed to flame with no radiation.
- (2) A penetration test in which the specimen is exposed to radiation of an intensity of  $0.35 \text{ cal/cm}^2/\text{sec}$ . This is said to be equivalent to the radiation of a roof from a façade 50 by 50 ft with 50 per cent openings at a distance of 45 ft. The effect of wind is simulated by applying suction to the underside of the roof equivalent to that of a 15-mph wind.
- (3) A spread of flame test. In the spread of flame test, the intensity of radiation varies over the exposed surface of the specimen. The distance of flame travel downwards from the top of the specimen gives a measure of the minimum intensity needed to produce ignition of the surface. The specimen is 33 in. square and represents the complete roof construction, including at least one sample of any joints used in each of the materials to be tested.

The roofing material is classified AA, AC, BB, etc., the letters being explained as follows:

#### First Letter

- A Those specimens which have not been penetrated in 1 hr
- B Those specimens which have not been penetrated in  $1/2$  hr
- C Those specimens which have been penetrated in less than  $1/2$  hr
- D Those specimens which are penetrated in the preliminary flame test.

#### Second Letter

- A Those specimens on which there is no spread of flame
- B Those specimens on which there is not more than 21 in. spread of flame

- C Those specimens on which there is more than 21 in. spread of flame
- D Those specimens which continue to burn for 5 min after the withdrawal of the test flame or spread more than 15 in. across the region of burning in the preliminary test.

The results of some tests on common building materials that were conducted as part of the development of the British test method are shown in Table IV. The time intervals given are from the original report; the letter classification assigned is not part of the original report but has been assigned in accordance with the description given in BS476.

#### Comparative Features of the Test Methods

It appears that the British and North American roofing tests described above have been developed to test the type of roof formerly common in each region. The British test is appropriate for the type of slate or clay tile roof on nailing strips with many gaps through which flame might pass, because a simulated wind is induced by suction from within the roof space. The North American test is more appropriate to the asphalt shingle or roll roofing applied to a boarded wood deck. In the course of the Montreal tests it was discovered that leaving a 1/4-in. gap between the roof boards made a more severe test of the roofing though this was and is not common practice in building. This is now part of the Standard Test Method ASTM E108. The test does seem to be somewhat unrealistic today in requiring this spacing between boards of the test deck, when there are so many alternative materials available for use as decks both combustible and non-combustible that may in practice improve the performance of the whole roof assembly.

An examination of the Montreal tests show that of the asphalt shingles, the lighter produced less fire resistance than the heavier ones and that pulverized rock and slate-finished shingles were better than those finished with talc, mica or soapstone. It is believed that the latter group of materials are not in use today as surface finish for asphalt shingles, because almost all shingles now on the market have a coloured mineral surface.

#### CODE REQUIREMENTS

The National Building Code of Canada (6) imposes no fire restrictions on roofing materials except that nearly all larger buildings are required to be of non-combustible construction; this may be

interpreted to mean that the roof deck would have to be of non-combustible material.

The British "Building Regulations 1965"(7) impose a number of limitations and exceptions relating the type of roof covering to the distance from the boundary of the site as follows (see description of the classification system above).

<u>Designation</u>	<u>Distance from Boundary</u>
BA, BB, BC	20 ft
AD, BD, CA, CB, CC, CD, ] DA, DB, DC, DD }	40 ft

In addition, a building exceeding 50,000 cu ft in volume, a factory or storage building or a house in a terrace of more than two houses is not permitted to have a roof designated BD, CA, CB, CC, CD, DA, DB or DD. To generalize on the fire penetration requirements, it appears that Class A roofing (resistance to penetration for 1 hr) is permitted anywhere on a site; Class B roofing (resistance to penetration for 1/2 hr) is permitted at least 20 ft from a boundary; and Class C roofing (penetration within 1/2 hr) is permitted at least 40 ft from a boundary.

The Toronto Area Building Code has recently introduced limits on roofing based on ASTM E108. These are specified by reference to the Underwriters' Laboratories designation described above and apply to both residential and non-residential construction.

In Los Angeles, regulations recently introduced (8) have been designed to encourage the fire-retardant treatment of wood shingles. It was found, however, that fire-retardant treated wood shingles cannot meet the requirements for Class C roofing in the ASTM test. A modified form of this test was therefore adopted, involving only the smaller brand test. Wood shingles are now acceptable in some parts of Los Angeles only if they have been treated, have passed the limited brand test, and have been subjected to an accelerated weathering program to determine whether the fire-retardant material will leach out.

### TESTING

There are no facilities at present in Canada for conducting tests on roofing to either ASTM or BS476. Underwriters' Laboratories of Canada list a number of roofing materials based on tests carried out in the laboratories of Underwriters' Laboratories Inc. in Chicago.

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REFERENCES

- (1) Tests on Combustibility of Roofing Materials, Conducted by Committee of Dominion Fire Protection Association. Quarterly of the National Fire Protection Association, Vol. 20, No. 1, Boston, July 1926.
- (2) Fire Tests of Roof Coverings, ASTM E108. American Society for Testing and Materials, Philadelphia, 1958.
- (3) External Fire Exposure Roof Tests. BS476, Part 3, British Standards Institution, London, 1958.
- (4) Fire Resistance Classifications of Building Constructions. Building Materials and Structures Report BMS 92. U.S. Dept. of Commerce, National Bureau of Standards, Washington, 1942.
- (5) Building Materials List. Underwriters' Laboratories Inc., 207 East Ohio St., Chicago, Ill., January 1965.
- (6) National Building Code of Canada 1965, issued by the Associate Committee on the National Building Code, National Research Council, Ottawa. NRC 8305.
- (7) The Building Regulations, 1965. Statutory Instruments Building and Buildings, 1965, No. 1373. H.M. Stationery Office, London.
- (8) Specification for the Testing of Fire Retardant Surface Finishes and Methods of Application on Furnishings or Structures, Los Angeles Fire Dept. Standard No. 52 7-65, City of Los Angeles, California.
- (9) Note on the Test for Roofs Exposed to External Fire. Dept. of Scientific and Industrial Research and Fire Offices Committee, Joint Fire Research Organization CIB/GTF/FRWP, No. 44, U.K., May 1958. Prepared for Working Party on Fire Research. Conseil International du Bâtiment pour la Recherche, L'Etude et la Documentation.

TABLE I

Classification of Roof Coverings by Dominion Fire Protection Association, 1926 (1)

Group 1	Group 2	Group 3	Group 4	Group 5	Group 6
Slate	Galvanized iron sheet	Asphalt asbestos felt roll roofing and shingles	Asphalt asbestos felt roll roofing	Asphalt rag felt roll roofing	Red and white cedar shingles
Asbestos cement shingles	Sheet copper	Asphalt rag felt shingles	Asphalt rag felt roll roofing and shingles		
Pitch built-up roof gravel finish					
Asphalt asbestos built-up roofing					
Asphalt asbestos roll roofing					

TABLE II

Classification of Roof Coverings in BMS 92, 1942 (4)

Class 1	Class 2	Class 3	Class 4	Class 5
Built-up roofing	Built-up roofing	Copper	Asphalt rag felt roll roofing	--
Brick	Asbestos cement shingles	Galvanized iron	Wood shingles chemically treated	
1-in. concrete	Asphalt asbestos sheet roofing	Asphalt rag felt shingles	Wood shingles edge grain	
Clay or concrete tile				
Slate	Asphalt asbestos felt shingles	Asphalt asbestos felt roll roofing		
Asbestos cement shingles	Asphalt felt shingles containing 45% non-combustible materials	Zinc sheet on shingle		
Corrugated sheet steel	Copper	Wood shingles with granules of crushed slate embedded in surface		
Asphalt-asbestos sheet roofing	Galvanized iron			

TABLE III

Conditions for Acceptance for Classes A, B, and C Roofing Materials  
by U.L. 790 Test Methods for Fire Resistance of Roof-Covering Materials

	Flame Exposure Test	Spread of Flame Test	Burning Brand Test
Class A	No flaming brands No exposure of roof deck No portions of roof deck fall away No sustained ignition of underside of deck	No flaming brands No exposure of roof deck No portions of roof deck fall away No significant lateral spread of flame Not more than 6 ft flame spread upwards	No flaming brands No exposure of roof deck No portions of roof deck fall away No sustained ignition of underside of deck
Class B	No flaming brands No exposure of roof deck No portions of roof deck fall away No sustained ignition of underside of deck	No flaming brands No exposure of roof deck No portions of roof deck fall away No significant lateral spread of flame Not more than 8 ft flame spread upwards	No flaming brands No exposure of roof deck No portions of roof deck fall away No sustained ignition of underside of deck
Class C	No flaming brands No exposure of roof deck No portions of roof deck fall away No sustained ignition of underside of deck	No flaming brands No exposure of roof deck No portions of roof deck fall away No significant lateral spread of flame 13 ft flame spread (top of deck)	No flaming brands No exposure of roof deck No portions of roof deck fall away Ignition of deck below 5 of 25 Burning brands permitted

TABLE IV

SUMMARIZED RESULTS OF FIRE TESTS ON ROOFS  
 from CIB/GTF/FRWP No. 44, U. K. May 1958 (9)

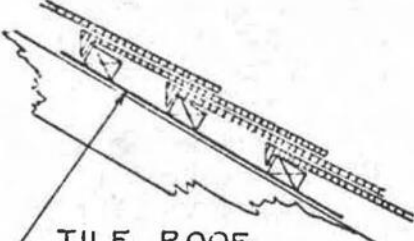
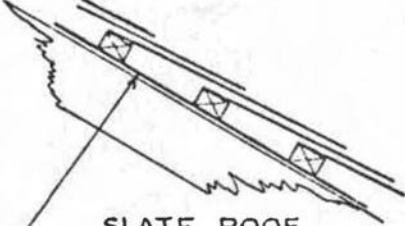
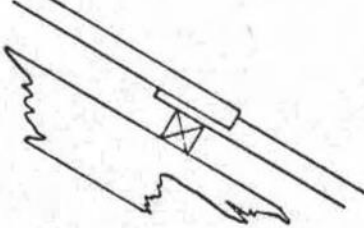
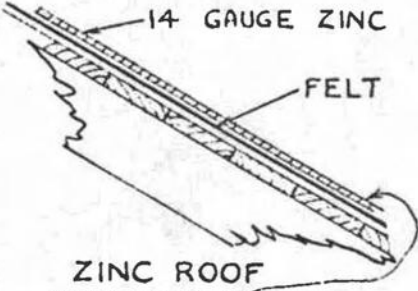
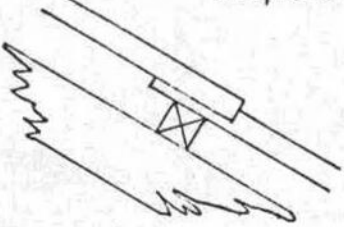
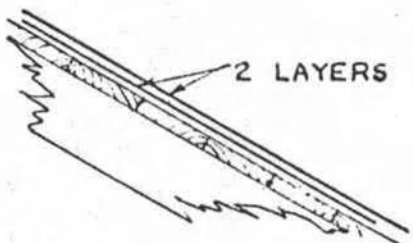
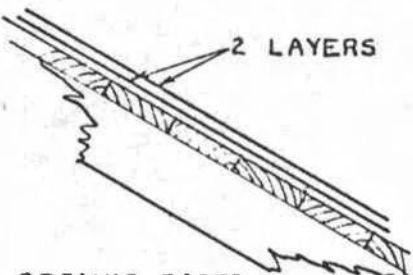
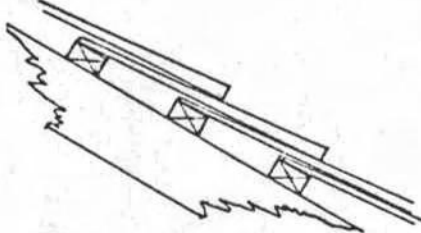
Section of roof	Average time for penetration	Distance of spread of flame, in.	Classification by BS476, Part 3
 <p>TILE ROOF                      REINFORCED BITUMEN                      FELT.</p>	over 3½ hr	no spread	A.A.
 <p>SLATE ROOF                      REINFORCED BITUMEN                      FELT.</p>	3 hr 5 min	no spread	A.A.
 <p>CORRUGATED                      ASBESTOS CEMENT</p>	over 3½ hr	no spread	A.A.
 <p>14 GAUGE ZINC                      FELT</p> <p>ZINC ROOF                      LEAD ROOF AS 4 BUT WITH                      6 LB/SQ.FT. LEAD</p>	(bright surface) over 3½ hr (black painted surface) 2 hr 23 min	no spread	A.A.
 <p>BITUMEN COATED                      CORRUGATED IRON</p>	52 min	9	B.A.

TABLE IV (Continued)

Section of roof	Average time for penetration	Distance of spread of flame, in.	Classification by BS 476, Part 3
 <p>2 LAYERS</p> <p>ASBESTOS BASED BITUMEN FELT. ON TIMBER DECK.</p>	<p>1 hr 22 min</p>	<p>20</p>	<p>A.B.</p>
 <p>2 LAYERS</p> <p>ORGANIC BASED BITUMEN FELT. ON TIMBER DECK</p>	<p>11 min</p>	<p>33</p>	<p>C.C.</p>
 <p>WOOD SHINGLES</p>	<p>6 min</p>	<p>not measured</p>	