Smoke contribution of some partition components during a fire test

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TECHNICAL NOTE

PREPARED BY T. T. Lie CHECKED BY APPROVED BY NBH

DATE July 1968

PREPARED FOR Inquiry and Record Purposes

SUBJECT SMOKE CONTRIBUTION OF SOME PARTITION COMPONENTS DURING A FIRE TEST

Smoke is considered to consist of particles suspended in a gaseous medium. The concentration of the particles depends on the conditions under which they are produced, particularly the energy and oxygen supply to the material.

At present, knowledge of the factors which affect smoke generation and accumulation in enclosures is not adequate for making quantitative predictions of smoke obscuration under real fire situations from smoke measurements taken under laboratory conditions.

To estimate the potential hazard of a material in practice, however, it may be sufficient to compare, under standard burning conditions, the smoke generation of the considered material with that of an acceptable reference material such as wood.

Such comparative tests have been carried out on a number of partition components used in Canada. The influence of a cover of incombustible material on smoke production has been examined in particular. White or red pine, which produce the same amount of smoke, were chosen as reference materials.

DESCRIPTION OF SPECIMENS

The following specimens have been tested:

1. White pine (Pinus strobus), thickness 1.9 cm, moisture content 11% by weight, density 0.4 g/cm^3.

2. Red pine (Pinus resinosa), thickness 5 cm, moisture content 8% by weight, density 0.5 g/cm^3.

3. Particleboard, untreated, thickness 1.9 cm, density 0.75 g/cm^3.

4. Particleboard, with 5% boric acid, thickness 1.1 cm, density 0.7 g/cm^3.

5. Particleboard, spacewood (with holes inside), untreated, thickness 5 cm. Covered with metal, thickness 0.06 cm. In the middle of the specimen there is a vertical gap of 0.6 cm width.

6. Woodwool cement, thickness 2.5 cm, density 0.4 g/cm^3.

7. Cork, thickness 5 cm, density 0.13 g/cm^3.

8. Cork, thickness 5 cm, density 0.13 g/cm^3, covered with 1.25 cm gypsum board type X.

9. Polyurethane cellular insulation, thickness 2.5 cm, density 0.055 g/cm^3.

10. Polyurethane cellular insulation, thickness 2.5 cm, density 0.055 g/cm^3, covered with 1.25 cm gypsum board type X.

11. Polystyrene cellular insulation, thickness 5 cm, density 0.03 g/cm^3.

12. Polystyrene cellular insulation, thickness 5 cm, density 0.03 g/cm^3, protected with 1.25 cm gypsum board type X.

13. Compressed straw, thickness 5 cm, density 0.28 g/cm^3.

TEST METHOD

The smoke generation of the materials was determined by measuring the optical density of the smoke which flowed out an opening at the top of a furnace containing the samples (Figure 1). The specimens, having dimensions of 61 x 61 cm, were placed in a steel frame and sealed at the edges to prevent smoke contribution from these parts. During the tests, the specimens were exposed on one side to the heat of an electrically powered furnace. A description of this furnace is given elsewhere (1). The temperature of the furnace was controlled to follow the standard temperature curve described in ASTM E119. Smoke generated inside flowed out of the furnace through an opening at the top. Air was supplied through an opening in the bottom of the furnace.

The optical density of the smoke was determined with the aid of a light source and photocell, by measuring the intensity of a light beam before and after it passed the smoke column between light source and cell. The meaning of the measured optical density and further details are given in Appendix A.

TEST RESULTS AND CONCLUSIONS

The measured optical densities for the various tested partition components are given in Table I.

As shown in Appendix A, D_{rel} can be interpreted as a factor which expresses how many times quicker the visibility in an enclosure will be reduced to a certain level, if, under testing conditions, smoke is produced by the test specimen instead of by the reference wood. The relative time required to reach a certain visibility level is given in the second column. The figures in this column can also be considered as a relative visual range.

It follows from the values in Table I that treatment of particleboard with boric acid gives a significant reduction in the smoke production. This agrees with test results found from tests carried out according to ASTM E84 (3).

The smoke contribution from gaps (length 1.6 m per m^2 partition surface area) of particleboard partitions covered with metal is less than the production of the reference wood.

A substantial reduction in the smoke production is obtained when the material is covered by type X gypsum board. The smoke production of cork and polystyrene cellular insulation protected with type X gypsum board reduces to below the smoke production of the reference wood; however, that of polyurethane cellular insulation remains above the reference smoke production.

Specimen	Relative Optical Density D_{rel}	Relative Time to Reach a Certain Visibility Level in an Enclosure or Relative Visual Range
1. White pine	1	1
2. Red pine	1	1
3. Particleboard, untreated	1	1
4. Particleboard, with 5% boric acid	0.3	3.3
5. Particleboard, covered with metal except a vertical gap of 0.6 cm width, length 1.6 m per m^2 surface area	0.6	1.7
6. Woodwool cement	0.03	33
7. Cork	3.2	0.3
8. Cork protected with gypsum board type X	0.06	18
9. Polyurethane cellular insulation	16	0.06
10. Polyurethane cellular insulation protected with gypsum board type X	4.5	0.22
11. Polystyrene cellular insulation	5.3	0.19
12. Polystyrene cellular insulation protected with gypsum board type X	0.8	1.3
13. Compressed straw	0.7	1.4

REFERENCES

(1) Blanchard, J.A.C. and T.Z. Harmathy. Small-scale fire test facilities of the National Research Council. Fire Study No. 14, Division of Building Research, National Research Council, Ottawa, November 1964.

(2) Thomas, P.H., P.L. Hinkley, C.R. Theobald and D.L. Simms. Investigations into the flow of hot gases in roof venting. Fire Research Technical Paper No. 7, Dept. of Sci. and Ind. Res. and Fire Offices Committee Joint Fire Research Organization, London, 1963. p. 14.

(3) Rose, A. Private communication.

APPENDIX A

SMOKE BALANCE IN FURNACE AND INTERPRETATION MEASUREMENTS

When there are no losses of smoke from the furnace other than by outflow from the chimney, the smoke balance for the furnace can be given as

Smoke produced by material = increase of smoke in the furnace + smoke loss from the chimney, or by assuming that the concentration of the smoke at the height of the light beam is proportional to the concentration of the smoke in the furnace,

$$Sq\,dt = V\,dC + KCvA\,dt \tag{1}$$

where

S = exposed surface area of the specimen

q = volume of smoke particles produced per unit surface area of the specimen per unit time

V = volume of the furnace

K = a constant

C = concentration of the smoke in the furnace

v = velocity of the outflowing smoke

A = area of the chimney opening

t = time.

The concentration C can be related to the intensities of a light beam before and after it passes the outflowing smoke column, by assuming that the law of Beer - Bouguer is valid. According to this law:

$$\frac{T}{To} = \ell^{-FC'\ell}$$

or

$$D = \log \frac{To}{T} = \frac{FC'\ell}{2.3} \tag{2}$$

where

D = optical density

F = a constant

C' = concentration of the smoke at the height of the light beam

ℓ = width of the smoke column at the height of the light beam

To = intensity of the light before passing the smoke column

T = intensity of the light after passing the smoke column.

Because the concentration of the smoke at the height of the light beam can be written as

$$C' = BC$$

where B is a constant, Eq. (2) becomes

$$D = \frac{FBC\ell}{2.3} \qquad (3)$$

From Eqs. (1) and (3) it follows that

$$q = \frac{2.3}{FBS\ell} \left(V \frac{dD}{dt} + KvAD \right) . \qquad (4)$$

For the wood, which has been chosen as reference material, relation (4) can be written as

$$F_w \, q_w = \frac{2.3}{BS\ell} \left(V \frac{d\,D_w}{dt} + K\, v_w \, A\, D_w \right) \qquad (5)$$

where the subscript w refers to wood. And for an arbitrary specimen as

$$F_s \, q_s = \frac{2.3}{BS\ell} \left(V \frac{d\,D_s}{dt} + K\, v_s \, A\, D_s \right) \qquad (6)$$

where the subscript s refers to an arbitrary specimen. With the aid of Eqs. (5) and (6) it is possible to compare the smoke generation of an arbitrary partition component with that of the wood.

Because the smoke generation during a test is not constant and the period over which it is generated depends on the amount of smoke-producing material it is necessary to choose a certain period for comparing the smoke productions. A suitable period is the period near the maximum smoke density in the furnace. In this region the smoke production in the furnace is approximately equal to the smoke outflow from the furnace. Because near the maximum, D_w and D_s are nearly constant, $\frac{d\,D_w}{dt}$ $\frac{d\,D_s}{dt}$ in Eqs. (5) and (6) are approximately zero. Then the ratio (6) and (5) can be written as:

$$D_{rel} = \frac{F_s q_s}{F_w q_w} \sim \frac{v_s D_s}{v_w D_w} \qquad (7)$$

The velocities v_s and v_w of the outflowing gases are determined by buoyancy forces, which are mainly a function of the temperature of the gases and the ambient temperature. During the measurement the gas temperatures are 600 - 800°C and the ambient temperature about 20°C. It can be shown that at these temperatures the velocities of the outflowing gases are only a weak function of the temperature and nearly the same (2). Thus v_s and v_w are approximately equal and Eq. (7) becomes:

$$D_{rel} = \frac{F_s q_s}{F_w q_w} \sim \frac{D_s}{D_w} \qquad (8)$$

It follows from Eq. (8) that D_{rel} can be interpreted as a factor which expresses how many times quicker the visibility in a certain enclosure will be reduced to a certain level, if under the testing conditions smoke is produced by the test specimen instead of by the reference wood.

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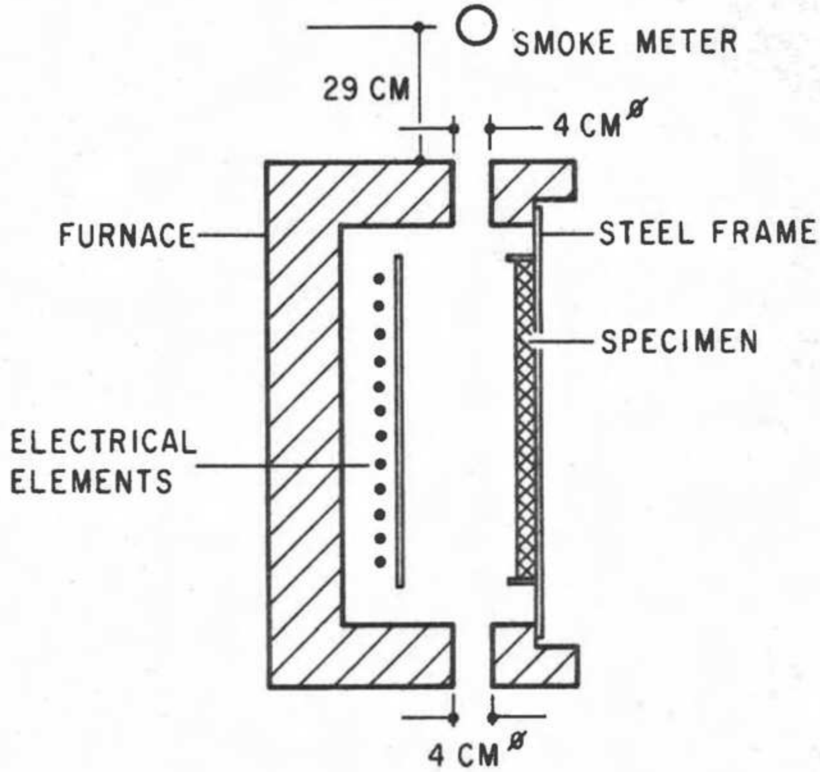

FIGURE I
DEVICE FOR SMOKE MEASUREMENT

BR 4188

TITLE TECH NOTE - DR. LIE SMOKE CONTRIBUTION of PARTITION COMPONENTS DURING A STANDARD FIRE					DRAWING No. BR 4188
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