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VENTILATION REQUIREMENTS FOR FIRES IN BULTI-STOREY PLATS

PART I - SMOKE AND GAS CONCENTRATIONS LIKELY TO OCCUR

by

P. H. Thomas

# Summary

This is a paper prepared for the Means of Mscale Working Party of the Department of Health for Scotland which is considering allowing one instead of two staircases for the means of escape from high flats. From the data available on smoke and gas concentrations in a burning building some estimate is made of the air dilution which must be achieved in the common hallway and staircase.

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Fire Research Station, Boreliam Wood, Herts. PART I - SMOKE AND GAS CONCENTRATIONS LIKEL. TO OCCUR

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# Introduction

Three aspects of escape from multi-storey flats must be considered: escape from the rooms in the flat (A), escape along the common hall from the entrance to a flat to the stairway (B), and escape down the stairway itself to outside the building (C). This paper is primarily concerned with the latter two escape routes; the first of these (B) affects all occupants of the storey involved in fire, and the second (C) the occupants of the whole building, whereas escape from the rooms of the flat involved (A) affects only the occupants of the flat in which the fire starts. The provision of one or more means of escape for the occupants of the flat (A) is dependent on such circumstances as whether or not an exit can be made from any one room without passing through another room, and on the height of the flat above ground level. This problem will be discussed elsewhere.

In order to estimate the amount of diluting air required to bring the concentration of noxious gases and smoke in the common hall to tolerable amounts some estimate must be made of the amounts likely to be present inside the flat near the doorway between the fl.t and the common hall.

### Discussion of test data

The amounts of toxic gases and smoke will differ according to the location of the burning room with respect to the doorway. If the burning room is not adjacent to the door the atmospheric conditions other than temperature are possibly worse since the noxious gases and smoke will tend to accumulate there.

The principal data available (1), (2) on the concentration of gases in a building on fire are obtained from two series of tests (1 and 2). They refer to bedrooms above a burning living room; there being no data for the burning room itself. In the second set of tests (2) the house was of three storeys, the visibility measurements being made on the stairway at eye level in the first floor. The atmospheric conditions were slightly worse in the second floor bedroom than the 'first floor, and it is to this upper bedroom that the results refer.

In both sets of tests the internal doors were open. The windows in the living room in which the fire was started were closed in the first tests (1) and partly open in the second tests (2). The upstairs windows were shut except for the ventilators in the first tests, and a 6 in. gap in the second floor bedroom in the second. In both tests the living room windows broke during the build-up of the fire.

In Fig. (1) and (2) referring respectively to tests 1 and 2, gas concentrations are given for a bedroom above a burning room. The tests were made for rooms with noncombustible linings and ceilings, a wooden floor and furniture having a total fire load of about 5 lb/sq.ft. In the first test (1) (Fig. (1)) a bitumen felt representing linoleum covered the floor. These arrangements are in general comparable with that proposed for the flats. Fig. 3 shows the variation in visibility during the growth of the fire.

For the purpose of this paper it is assumed that the conditions in the bedroom in the tests to which the above data refer are comparable with the conditions near the flat doorway if a fire developed in the flat in a room other than that nearest to the doorway. There is some support for the view expressed above that conditions other than temperature are worse than in the burning room itself for in Fig. 1 the oxygen concentration is seen to fall to zero whereas in the burning room a local concentration of about 14 per cent is necessary to sustain flaming. The data in Fig. 1 show the atmosphere in the bedroom to become more toxic in the 5 minute period after flashover than in the living room.

The worst conditions recorded in the above tests are summarized in Table 1. Whilst they may last for a short time if only one room is burning, they will tend to be repeated as fire spreads from room to room. The concentration of carbon monoxide in Fig. 1 is greater than that recorded in Fig. 2. Five minutes after flashover i.e. 30 minutes after the start of the fire it is 4 per cent. Even if this figure is exceeded, it may be assumed that it is only exceeded after this time; up to flashover the concentration is not more than 2 per cent and the mean value up to flashover is about 1 per cent. After flashover in one room there may be a decrease in carbon monoxide concentration at some stage. This would happen if the aeration of the fire were improved sufficiently. However in the absence of data on this point it is especially necessary to emphasise the importance of any early alarm and a rapid evacuation of the building. It is assumed in what follows that the building can be evacuated within 5 minutes after the time of flashover, or 30 minutes from the ignition of a piece of furniture such as an upholstered chair.

There is evidence (1) that with a more flammable lining the concentrations of carbon monoxide may be considerably greater but 4 per cent is the highest available figure for incombustible or plastered linings.

TABLE I
Approximate worst conditions in first 30 minutes

Oxygen		nil
Carbon dioxide		20%
Carbon monoxide		4;%
Reduction in visibility	:	1/10,000

# Temperature

The temperature about 6 in. from the ceiling of the burning room may vary from under 200°C to over 400°C in the period 10 minutes prior to flashover (2). During this period flames may well impinge and spread on the ceiling. This is probably the reason for the high temperature at about 18 minutes. Other data (1), (2) suggests air temperatures in the bedrooms above the fire of about 200°C at flashover.

### The hazard from the toxic atmosphere

### Smoke

In F.C. Note 27/1950 (3) it is estimated that the reduction in visibility to 1/10,000 is equivalent to a concentration of approximately 64 mgm/cub.ft. and in F.C. Note 25/1950 (4) data are given showing that the concentration for a visibility of 20 ft. with a hand lamp of about 1 watt and a directed beam is 2 mgm/cub.ft. This means that a similar lamp would be visible at a distance of greater than 20 ft. In addition visibility would be increased in the presence of natural illumination from open windows. Thus on the basis of visibility a dilution of about 30 would be necessary, i.e. one cubic foot of hot gas requires 30 cubic feet of cold air to reduce the concentration to about 2mgm/cubic feet.

# Concentration of gases

Henderson & Haggard (5) state that rapid loss of function occurs at oxygen concentrations less than 10 per cent and less than 6 per cent is dangerous to life. Jacobs (6) states that 12-15 per cent of carbon dioxide rapidly produces unconsciousness. The dilution of 30 times necessary on account of smoke would therefore produce oxygen and carbon dioxide concentrations which could be considered safe.

Herderson & Haggard <sup>(5)</sup> assessed the hazard from carbon monoxide in air in terms of the product of exposure time and concentration. For time in hours and concentration in parts per million by volume they regard values of this product less than 300 as safe and over 1,500 dangerous to life. If other toxic gases, including carbon dioxide, are present or the oxygen concentration is reduced these limits are reduced.

If evacuation is completed within 5 minutes after flashover the mean concentration of carbon monoxide would be about 1 per cent, giving a concentration-time product of  $\frac{300}{473} \times \frac{1}{2} \times \frac{10^4}{30} = 110$  assuming the gases are initially at 200°C and are diluted 30 times with cold air. Although the carbon dioxide concentration would have risen to  $\frac{20}{473} \times \frac{300}{30}$  i.e. 0.42 per cent (14 times that for normal air) in this time, these conditions may be considered safe. If, however, escape is delayed so that it is not completed until more than 5 minutes after flashover, a higher level of dilution is necessary.

If, for example, the dilution were 100 the concentration-time product up to 5 minutes after flashover is 30 units, the safe limit being 300. A conservative estimate of the most severe exposure condition could be made on the assumption that all the atmospheric oxygen becomes carbon monoxide (1 volume of oxygen becoming 2 volumes of carbon monoxide). The concentration of carbon monoxide would then be  $\frac{(21 \times 2) \times 100}{(21 \times 2) + 79} = 35$  per cent. The time for which exposure to this concentration diluted by 100 is safe (i.e. the total concentration time product is less than 300) is T,

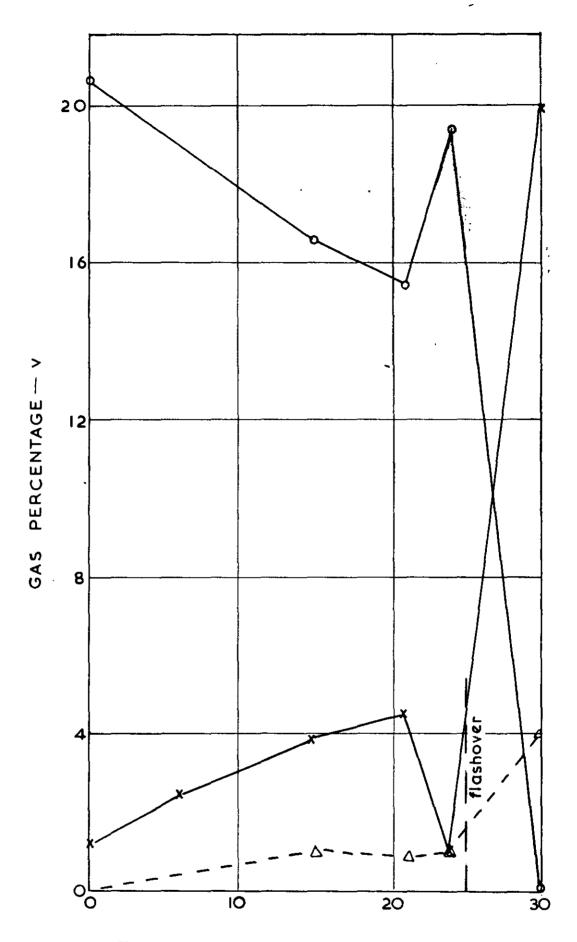
where 
$$\frac{35}{100} \times \frac{40^6 \times 300}{473 \times 100} = 270$$

i.e. T = 0.12 hours (or about 7 minutes).

Thus a dilution of 100 should enable escape to be made up to a theoretical minimum of 12 minutes after the flashover.

## References

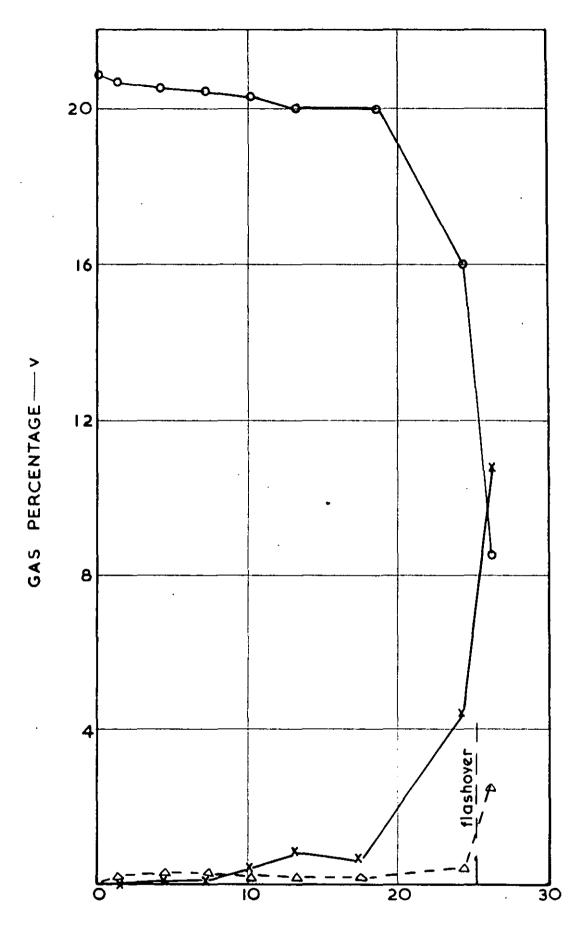
- (1) "Report of Special Investigation on the Spread of Fire in Cruden
  Houses for the Department of Health for Scotland". Department of
  Scientific and Industrial Research and Fire Offices' Committee
  Joint Fire Research Organization. F.R.O.S.I. No. 129
- (2) Hird, D. and Perry, M. D. and Nash, P. Experimental Fires in "Back to Back" Houses in Birmingham. Ibid. P.R. Note 150/1955.
- (3) Rasbash, D. J., Palmer, K. N. and Skeet, G. "Measurement of Smoke in Burning Buildings". <u>Ibid.</u> F.C. Note 27/1950.
- (4) Rasbash, D. J. "The Use of Smoke Extractors in Basement Fires". Ibid. F.C. Note 25/1950.
- (5) Henderson, Y. and Haggard, H. W. Noxious gases and the principles of respiration affecting their action. New York (1943) 2nd Edition Rheinold Publishing Corporation.
- (6) Jacobs, M. B. The analytical chemistry of industrial poisons, hazards and solvents. New York (1949) 2nd Edition. Interscience Publishers Inc.



TIME FROM START OF FIRE - min

FIG.I. VARIATION OF ATMOSPHERE WITH TIME (TEST !)

MELLIA 1/2327



TIME FROM START OF FIRE - min

FIG. 2. VARIATION OF ATMOSPHERE WITH TIME (TEST 2)

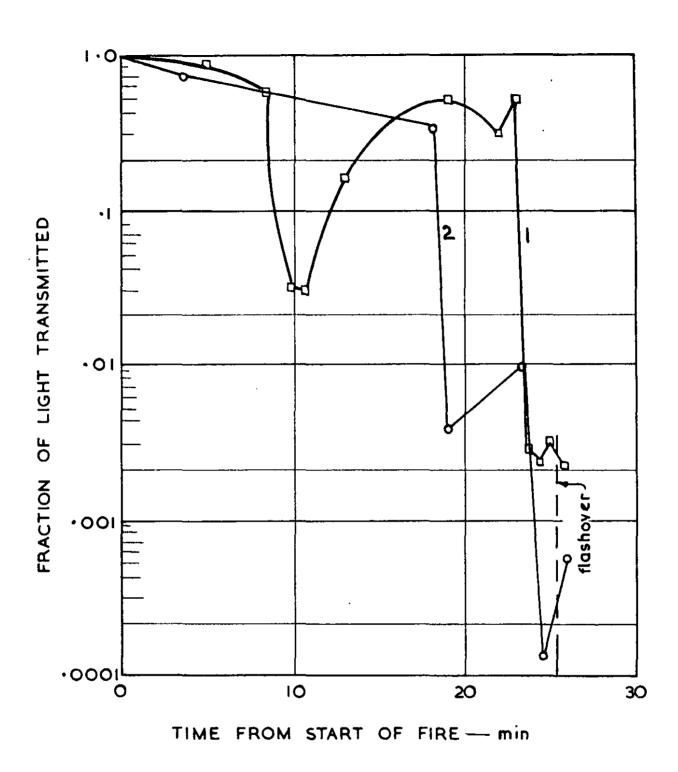


FIG.3. FRACTION OF LIGHT TRANSMITTED (OVER 2ft PATH)
DURING GROWTH OF FIRE (TESTS 1 & 2)