COMMENTARY ON PERFORMANCE CRITERIA FOR FIRE SAFETY IN ENCLOSURES

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1. INTRODUCTION

A paper by Hadjisophocleous and Bénichou in a recent issue of this journal [1] presents a table of various physical quantities that relate to room fires and assigns upper and lower limits to them. The upper and lower 'limits' are best understood as a range of values of the quantity above which their respective associated hazards are expected. The present author wishes to enlarge upon this and will do so item by item.

2. PRE-FLASHOVER FIRES

In the table, a distinction is drawn between pilot (pilot*ed*?) ignition and spontaneous ignition, and limits, in units kW m^{-2}, for radiant heat flux for ignition are given for both categories. Surface temperatures are treated similarly. No issue will be taken with the figures as they relate to piloted ignition, but the assignment of any sort of limit of the radiant flux for spontaneous ignition requires more explanation. In the sense in which the term is usually understood [2], 'spontaneous ignition' involves no externally applied heat; thermal imbalance is due solely to build-up of heat released by reaction of the fuel with oxygen. Susceptible materials are legion and include coals and cellulosic substances, though usually only in industrial quantities. Moreover, in such situations, exothermic chemical reaction begins at the centre and propagates outwards so that at least during incipient ignition, the surface temperature hardly rises at all.

3. FLASHOVER

The information given here by Hadjisophocleous and Bénichou is very difficult to understand. There is a reference to 'time to flashover' but no values for this are given, and two quantities – temperature and radiative flux – are provided, a single upper limit on each quantity. The temperature given is not unreasonable if understood as a typical value of the temperature of the post-combustion gas layer at the point where its thermal instability is manifest as flashover according to models for flashover presented by such investigators as P.H. Thomas and J.G. Quintiere [3]. But to assign a single radiative flux to flashover is difficult to justify in that the critical value for flashover must surely depend on the size of the gas layer and hence of the room.

The total rate of heat-release at flashover might well be reasonably constant at around 1 MW for enclosure fires of different sizes [4], but this does not mean that the flux is the same. In any case to talk about flux at all for gas radiation is fraught with the difficulty that, in contrast to radiation from an emissive solid which is purely from a surface, gas radiation is a volumetric phenomenon having a dependence on the dimensions and shape of the enclosed mass of gas. The fact that convection contributes significantly to heat transfer at flashover also needs to be considered, but appears not to have been in the work under discussion. Whilst a great deal more could be said, it is sufficient to conclude this section by requesting clarification from the authors.

4. CARBON MONOXIDE POISONING

The table gives a lower limit, for 'life safety' of carbon monoxide of 1400 p.p.m. and an upper limit of 1700 p.p.m. Now the probit equation for carbon monoxide poisoning is [5]:

$$Y = -37.98 + 3.7 \ln (Ct)$$

where Y is the probit value, convertible by means of tables to a percentage death rate, C is the concentration in p.p.m. and t is the exposure time in minutes. The probit value corresponding to 1% death rate is 2.67, from which the time required for 1% of the occupants of a building to fatally affected at 1400 p.p.m. is:

$$1/1400 \exp [(37.98 + 2.67)/3.7] \text{ min} = \underline{42 \text{ min}}$$

This length of time, being tens of minutes, is <u>of the order of</u> evacuation times of large buildings. In an enclosed shopping mall or an airport lounge where a thousand people were assembled, ten of them would, according to the probit equation, be fatally affected by this level of carbon monoxide in a little less than three quarters of an hour. Perhaps from the point of view of the performance criteria discussed by Hadjisophocleous and Bénichou, 1400 p.p.m. is a suitable threshold below which carbon monoxide does not threaten life, but the above calculations do at least illustrate that arbitrary threshold values ought never to be viewed too uncritically.

5. HYDROGEN CYANIDE POISONING

The limit for this which, if the author is understanding the table correctly, is the concentration below which this toxic substance does not threaten life, is given as 80 p.p.m. The probit equation for this substance is [5]:

$$Y = -29.42 + 3.008 \ln (C^{1.43}t)$$

with symbols as defined previously. Performing the calculation the same as for carbon monoxide, concentration of 80 p.p.m. would cause a 1% death rate in 82 minutes, so this does appear to contain a wider safety margin than does the carbon monoxide concentration of 1400 p.p.m.

6. FURTHER POINTS OF ENQUIRY

These are as follows:

(i) What is the significance of the 'structural steel temperature'? Is this the temperature it can withstand for a specified period without failing in its structural role?

(ii) It is unusual to see glass breakage correlated with temperature only with no reference to overpressure. Relatively very small over-pressures (0.01 bar) can damage glass.

(iii) What is meant by 'convection heat', units ^{o}C?

(iv) What is meant by 'critical time to reach untenable limits'?

7. CONCLUDING REMARKS

Whilst it is true that the Table under discussion is backed up by the authors' reference 24, a twelve-page article in a specialised monograph, it nevertheless needs clarifying for the benefit of readers. The queries on piloted and spontaneous ignition and the correlation of radiative heat transfer with flashover should be addressed particularly closely since, as they stand, they appear to be at odds with very basic principles.

REFERENCES

1. G.V. Hadjisophocleous, N. Bénichou, "Development of performance-based codes, performance criteria and safety engineering methods", International Journal on Engineering Performance-Based Fire Codes, Vol. 2, No. 4, pp. 127-142 (2000).
2. P. Beever, Self-heating and spontaneous combustion, Handbook of fire protection engineering, 2nd edition, SFPE, Boston (1995).
3. For an introductory sketch of such models see:

   J.C. Jones, Combustion science: Principles and practice, Millennium Books, Sydney (1993). More detailed accounts are in the SFPE Handbook *op. cit.*
4. W.D. Walton and P.H. Thomas, Estimating temperatures in compartment fires, SFPE Handbook *op. cit.*
5. F.P. Lees, Loss prevention in the process industries, 2nd edition, Butterworth-Heinemann, Oxford (1996).