Flame Exhaust from Compartment with Burner or Pool Fire

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1 Introduction

Flame emergence from a compartment with a fire source can be sudden and intense, it can cause rapid fire spread to other compartments. Flame exhaust through a ventilation opening takes place when the conditions in the compartment are ventilation-controlled; this phenomemon often accompanies flashover [1, 2]. This mechanism of fire spread is a major hazard for offshore platforms and onshore hydrocarbon facilities [3, 4]. The time delay between the ignition and flame exhaust, called the induction period, is one of the main fire characteristics which is important both for theory and practice. This parameter can be very useful and practical, for example, in fire investigation.

Understanding the fire behaviour in enclosures is important for the prediction of fire growth and impact on the building structures. By now, the general features of fires and the influence of such conditions as fuel properties, geometric configuration, and ventilation conditions have been investigated and correlated quite extensively. Nevertheless, there are some compartment fire phenomena that still need to be studied [5, 6].

The main aim of the presented research is to investigate the critical conditions for flame exhaust, to obtain the induction time in different conditions, and compare the results with those obtained previously in the burner fire tests [7], where pool fires were modelled by a gas fuel burner in different geometrical configurations.

2 Experimental facility

The general view of the research facility is shown in figure 2.1. The main element of the facility is the fire box with 25 mm-thick walls made from Monolux®, a lightweight, non-combustible material which is widely used in fire resistant constructions and linings, providing up to 240 minutes fire resistance. The internal dimensions of the box are 0.72×0.48×0.48 m, which is exactly 1/5 of the standard ISO room. Four rectangular openings were tested in the presented research, the opening geometries are listed in table 2.1.

Two fuel source configurations were used in the experiments: a burner fire, and a pool fire. In the former case, the scheme of the experimental facility is presented in figure 2.2. A specially designed burner of the diameter of 60 mm providing uniform and constant fuel supply rate was placed on the floor level at the centre of the box to serve as a source of fuel and fire. The fuel supply rate was measured (with the accuracy ±3%) and maintained at a constant level during the experiment. In these tests, propane was used as a fuel.

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Fig.2.1 Picture of the experimental facility. Pool fire configuration.

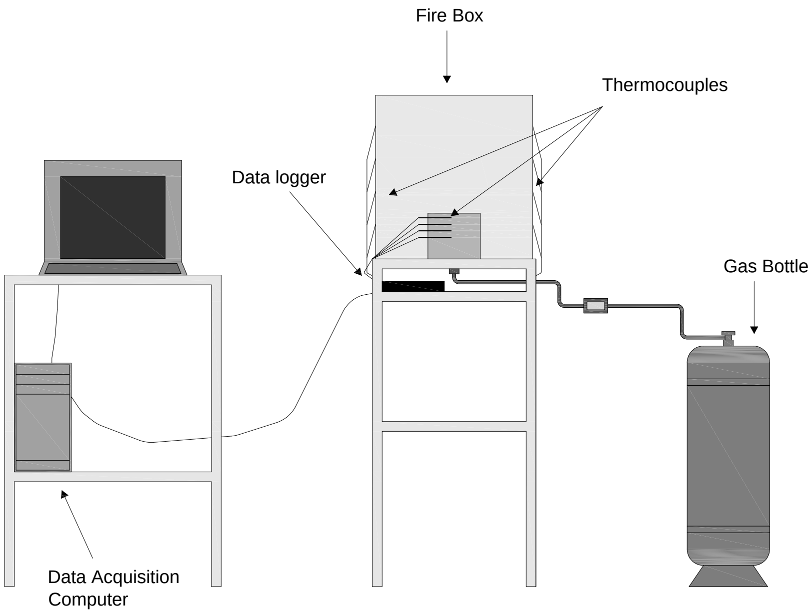

Fig.2.2. Scheme of the experimental facility. Burner fire configuration.

Opening number	Height	Width	Area of opening	Ventilation factor
	[m]	[m]	[m^2]	[$m^{5/2}$]
1	0.150	0.125	0.01875	0.007262
2	0.140	0.160	0.0224	0.008381
3	0.180	0.080	0.0144	0.006109
4	0.190	0.160	0.0304	0.013251

Table 2.1 List of opening geometries.

In the pool fire experiments, a square metal container with liquid fuel was filled with a liquid fuel to serve as a source of and fire. Five different sizes of the container were used in the tests, with the side length equal to 60, 100, 120, 150, and 200 mm, and the height of the container walls equal to 25 and 50 mm. In these experiments, the influence of the fuel source position on the flame behaviour and flame exhaust out of the opening was studied. In the pool fire experiments, the average mass loss rate was estimated by subtracting the mass of the unburned fuel from the initial fuel mass. Different kinds of fuel were tested and, finally, petroleum ether was chosen for further research on the flame exhaust.

3 Results of experiments

The normalized experimental results obtained for the burner and pool fires are plotted in figure 3.1.

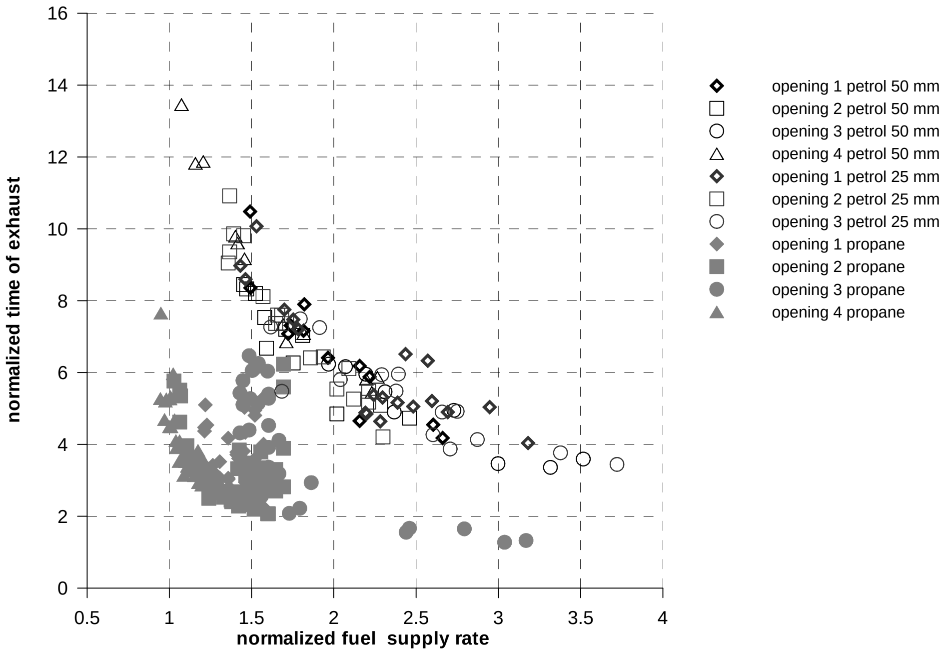

Fig.3.1. Normalized results of experiments with burner and pool fire.

The normalized time to flame exhaust and normalized fuel supply rate are calculated using the following correlations [7] :

- Normalized fuel supply rate :

$$\tilde{\dot{m}} = \frac{\dot{m}_{fuel} / \dot{m}_{air}}{r}$$

$\tilde{\dot{m}}$ - normalized fuel supply rate,

$\dot{m}_{fuel}$ - fuel supply rate,

$\dot{m}_{air}$ - air supply rate through the opening,

r - stoichiometric fuel - to - air ratio.

- Normalized time to flame exhaust :

$$\tau = \frac{t_{\exp}}{t^*}; t^* = \frac{(\rho_0 \cdot V^*)}{\dot{m}_{air}}; V^* = 0.5 \cdot V$$

t_{exp} - time to flame exhaust measured in the experiment,

ρ_0 - density of cold air,

V - volume of the enclosure.

In the pool fire experiments, flame exhaust occured later than in the burner fire tests with the same normalized fuel supply rate which determines the equivalence ratio. This can be explained by the presence of the initial stage during which the fuel in the pool heats up to the boiling point by the radiation feed back. In these tests, fuel must be vaporised to react with oxygen, and the combustion reactions for larger molecules in liquid fuel are more complex than those for a gas fuel. The fact that the petroleum vapour is denser than that of propane, and can be mixed easier with the air in the lower layer can also have influence on the results. The combustion efficiency for a pool fire is probably lower than for a burner fire, and this can also affect the flame exhaust process.

4 Conclusions

The main conclusion drawn from the research is that not all phenomena and features of pool fires can be modelled by the burner fires. Flame emergence from an opening is one of the processes where only general properties can be reproduced by a burner fire. In the pool fires, the process is affected by the radiation feedback to a pool, the process controlling the fuel supply rate. The molecular weight of the vaporised fuel is different from that of the gas fuel, and this also influences the flame behaviour in the compartment and the flame exhaust.

5 Acknowledgement

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