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Effect of ventilation procedures on the behaviour of a fire compartment scenario

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Abstract

This contribution presents a study on the consequences of applying ventilation procedures during a fire scenario involving a TPH/TBP pool fire in a ventilated enclosure. This research is addressed to fire safety in the nuclear industry in which ventilated enclosures remain a configuration frequently encountered. This work presents experiments comprising a 300 kW liquid pool fire in a 400 m^3 vessel connected to an industrial ventilation system featuring one inlet and one exhaust branch. The investigated ventilation procedures consist in closing the inlet branch only or closing both inlet and exhaust branches. The analysis compares fire behaviour with and without the implementation of a ventilation procedure and points out the effects of said procedures on the combustion rate, fire duration and gas temperature within the vessel. It highlights pressure variations within the vessel when both the inlet and exhaust ventilation branches are closed. Conclusions provide practical answers that would be useful when designing appropriate ventilation strategies limiting fire hazards.

1. Introduction

The scenario comprising a fire within a ventilated enclosure remains one of the key issues for fire safety assessment in the nuclear industry. Indeed, partitioning is frequently encountered irrespective of the building's designated use, building reactor, fuel processing or reprocessing plants. Moreover, to ensure confinement, these enclosures are equipped with a ventilation air cleaning system that allows negative pressure to be created in the compartments and thus prevent radioactive materials or harmful products from escaping out of the compartment (Jiang et al., 2002; Nuclear Air Cleaning Handbook, 2003). It is for this reason that configurations involving a fire in a mechanically ventilated enclosure are extensively studied in the framework of nuclear fire safety research (Audouin and Tourniaire, 1999; Prétrel et al., 2001).

In such fire scenarios, the oxygen feeding into the compartment is mainly controlled by the ventilation system; consequently, one procedure that could limit the fire hazards would be to switch the ventilation

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Nomenclature

c_v	heat capacity at constant volume
C_p	heat capacity at constant pressure
C	coefficient
m	mass
$\dot{m}$	rate of mass flow
n	exponent
P	pressure
$\dot{Q}$	rate of heat release
r	oxygen to fuel stoichiometric ratio
t	time
T	temperature
V	volume
$\dot{v}$	rate of volumetric flow
X	molar fraction
Y	mass fraction

Indices

c	combustion
ex	exhaust
ext	extinction
f	fuel
g	gas
in	inlet
leak	leakages
o	reference
O_2	oxygen
th	theoretical
v	ventilation
w	losses

Greek symbols

γ	isentropic coefficient
ρ	density

system to a special control mode. There are many possible approaches; these depend on the particularities of the enclosure and the expected efficiency (Klote, 1993; Vaari and Hietaniemi, 2000). A typical example is the rapid extraction of smoke (using positive pressure ventilation (PPV) concept) by mechanical fans. This approach limits the increase in gas toxicity and gas temperature (Svensson, 2002). In the case of one ventilated compartment equipped with inlet and exhaust branches, a possible ventilation procedure would be to close the valves situated either upstream or downstream of the fire compartment. In the nuclear industry, this procedure is of particular interest because it allows the compartment to be isolated and thus protects the rest of the installation against the consequences of fire, such as the plugging of filters with smoke or the release of radioactive dust. In order to determine the efficiency of such procedures and to identify the most appropriate one, the behaviour of the compartment and of the pool fire has to be investigated. To address this issue, an experimental study was undertaken within the framework of the FLIP research programme developed by IRSN in collaboration with COGEMA.

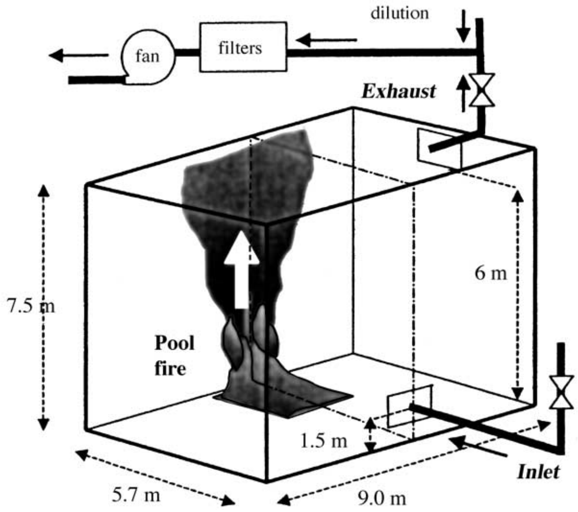

Fig. 1. Schematic representation of the investigated fire scenario and the PLUTON facility.

Fig. 1 illustrates a fire scenario representing actual situations in reprocessing plants where some enclosures are dedicated to chemical processes using flammable liquids. The fire scenario is a pool fire located against one side of a rectangular enclosure. The ventilation network comprises an inlet branch and an exhaust branch each equipped with a closing valve. A fan located on the exhaust branch is used to create negative pressure in the compartment thus ensuring confinement. The location of the pool fire next to the wall, its shape and the ventilation characteristics, are selected in order to be representative of a typical scenario found in the nuclear industry. The research programme, performed at IRSN's fire test laboratory at Cadarache (France), involved large-scale experiments designed to mimic the real situation as closely as