Hot Issues in Fire Engineering

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Gas Explosion in Residential Buildings to Watch

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1. Introduction

Many gas explosions were reported in residential buildings in big cities in the Asian-Oceania areas including Hong Kong [1,2]. A very big gas explosion occurred recently which killed several firemen [3], raising the concern of the general public again on the hazards due to gas explosions. Gas explosions in buildings would not only damage the structures, but also hurt or even kill the occupants [4] staying inside. The explosion pressure can cause death to the neighbor as reported before in Hong Kong [1,2]. The transient gas explosion pressure has to be better understood for protecting firemen during operation.

It is very complicated to define which level of explosion or how large the overpressure can cause serious injury or death. The explosion scenario must be considered by taking into account the physical characteristics of the location, human behavior prior to the explosion and the location of the person [4]. Other physical factors such as dynamic pressure impulse, impact velocity and duration of positive incident overpressure should be included. Human factors such as the weight, peak horizontal body velocity and health condition of the person are also important.

2. Explosion Pressure

The explosion pressure should not exceed 21 kPa or about 0.21 bar for avoiding serious damages to the building as suggested [5]. Brick walls of thickness 114 mm are able to stand 23 kPa or 0.23 bar, but be destroyed at 35 kPa or 0.35 bar [4]. The consequences of overpressure had been reported [6] and for example, glass breakage typically occurs at 1.03 kPa with 10% window glass broken at 2.07 kPa; and total destruction of buildings might result at 68.9 kPa.

Damages to building structures were classified [4] into four zones: from zone A for total destruction with peak pressure over 83 kPa or 0.83 bar to zone D for light damage with pressure over 3.5 kPa or 0.35 bar. Explosion damage to houses can be expressed by distance-charge or pressure-impulse relations. There are some housing damage categories established [7] based on the damages.

3. Liquefied Petroleum Gas (LPG) as the Fuel Gas

As reviewed before [1,2], liquefied petroleum gas (LPG) is composed of 70% propane (C_3H_8), 10% propene (C_3H_6), and about 15% mixture of butane (C_4H_{10}) and butene (C_4H_8), usually stored in bottles at a pressure of 800 to 1,500 kPa, and a density about 520 kgm^{-3}. Upon releasing from the storage bottle, liquid petroleum changes to gas phase with its volume expanded by 250 times [8-10]. Complete reaction with oxygen requires 5.5 times volume of oxygen or 25 times volume of air to release 560 kcal/mol:

$$C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O \quad (1)$$

The explosion limit for the mixture of LPG and air is about 2.3 to 64%. When the mixing ratio of LPG to oxygen is within the range 1:45 to 1:6.5, the combustion temperature can go up to 2600^oC. The rate of flame spread under a pressure of 1 atm can reach 0.85 ms^{-1}, and its explosion pressure can be as high as 800 kPa. Under normal conditions, the shock wave peak pressure that a person can stand is lower than 20 kPa. The pressure that two layers of brick wall can stand is about 45 kPa, and that for a 0.25 m thick reinforced concrete wall is about 300 kPa.

4. Earlier Explosion Suppressing Tests

Explosion due to propane and air mixtures under two geometric configurations had been studied thoroughly by Gmurczyk and Grosshandler [11]. Shock wave generated by an accelerating flame was detected at equivalence ratios between 0.65 and 1.45 with shock velocities up to 1300 ms^{-1} recorded. Suppressing explosion by using three possible chemical agents C_3F_8, CF_3I and C_2HF_5 were then studied. CF_3I gave the lowest shock pressure ratio on the passage of the shock through the stoichiometric propane/air mixture. The pressure ratio dropped to 5 when the suppressing agent is close to the extinguishing concentration. The other two agents did not cause such drops in pressure ratio, C_3F_8 even increased the pressure ratio slightly at low concentrations. For the flame velocities in the rich propane/air mixture, CF_3I gave the highest extinguishing value of 8% by volume. The most suitable suppressant among the three might be C_3F_8, with extinguishing value of 4%. Following what is concluded

in the testing reports [11], gases can be used to suppress possible LPG explosions in a residential flat.

5. The Way Forward

With so many explosions [1-3] due to fuel gas leakages reported in residential buildings in this part of the world, there is a strong need to control the possible explosion for protecting firemen while entering the spaces suspected to have gas leakage. Explosions [1,2] due to gas leakage in semi-enclosed small compartments should be controlled carefully. An explosion control scheme was proposed earlier [1] to protect the firemen. Appropriate agents will be injected into the room suspected to have fuel gas leakage. The relative oxygen content of the flammable gases is then reduced to below lower explosive limit in the space to prevent explosion. Further, chemicals with inhibition effects would suppress the combustion reactions as well. This will prevent or delay ignition caused by small sparks produced by opening the door as experienced [3] and other unknown reasons.

Before putting the scheme into practice, a long-term study on this method for explosion control of LPG and town gas commonly used as domestic fuels in Hong Kong [1-3] should be carried out. The first stage is to review the effects of explosion to the buildings, effects of suppressing agents and the possible resultant pressure. The explosion pressure under different concentrations of the flammable gases was studied by a simple model. Feasibility tests on injecting chemical agents into the site should be carried out in a small-scale deflagration experimental rig first. Based on the preliminary results, larger-scale experiments on different explosion suppressants can then be carried out. A detonation experimental rig will be developed to measure useful data for designing feasible explosion control methods for real-scale scenarios. Verification tests will then be conducted in a full-scale space. All these had been reported years ago [2].

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