European Train the Trainer Programme for Responders

Lecture 10

Dealing with hydrogen explosions

LEVEL I

Firefighter

The information contained in this lecture is targeted at the level of Firefighter and above.

This topic is also available at level III and IV

This lecture is part of a training material package with materials at levels I – IV : Firefighter, crew commander, incident commander and specialist officer. Please see the lecture introduction regarding competence and learning expectations

FUEL CELLS AND HYDROGEN
JOINT UNDERTAKING

Disclaimer

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Summary

This lecture considers the main features of 'chemical' explosions, i.e. deflagrations and detonations, and 'physical explosions', i.e. tank ruptures.

Keywords

Deflagrations, detonation

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1. Target audience

The information contained in this lecture is targeted at LEVEL 1: Firefighter. Lectures are also available at levels III and IV: crew commander, incident commander and specialist officer.

The role description, competence level and learning expectations assumed at crew commander level are described below.

1.1 Roll description: Firefighter

A firefighter is responsible and expected to be capable of carrying out operations safely in personnel protective equipment including breathing apparatus using equipment provided, like vehicles, ladders, hose, extinguishers, communication and rescue tools, under any climatic conditions in areas and to emergency situations which can be reasonably anticipated as requiring a response.

1.2 Competence level: Firefighter

Trained in the safe and correct use of PPE, BA and other equipment which it is expected they will operate first responders must be supported by appropriate knowledge and practice. Behaviours that will keep them and other colleagues safe should be described by Standard Operating Procedures (SOP). Practiced ability to dynamically assess risk to self and others safety is required.

1.3 Prior learning: Firefighter

EQF 2 Basic factual knowledge of a field of work or study. Basic cognitive and practical skills required to use relevant information in order to carry out tasks and to solve routine problems using simple rules and tools. Work or study under supervision with some autonomy.

2. Introduction and objectives

The hydrogen economy has become a part of our everyday life. Hydrogen fuelled vehicles are already on our roads. Possible hydrogen explosions can generate high levels of overpressure and thus present threat to life and property. The safety of hydrogen automotive applications and the related infrastructure, including garages, maintenance workshops, parking, and tunnels is one area of concern.

We have already discussed the specific properties and hazards associated with different types of FCH application in previous lectures. This lecture will deal with explosions driven by chemical reaction (i.e. by combustion) and "physical explosions" (i.e. not involving combustion). There are two types of "combustion explosions", i.e. deflagrations and detonations. There are other types of "explosions", e.g. "physical explosions" of vessels by overpressure above the established limit due to overfill (vessel rapture), as a result of runaway reaction, etc. The word "explosion" is rather a jargon one and we will avoid applying it in this lecture where/when possible. Sometimes the use of the term "explosion" could lead to misunderstanding. For example, some standards incorrectly introduce a so-called “explosion limit” [1]. This is done in spite of the fact that there can be a significant difference between the “flammability limit”, which is relevant for deflagrations, and “detonability limit” [1]. This lecture will introduce responders to the phenomena associated with deflagrations and detonations, with their main features and consequences as well as possible means of prevention and mitigation [1]. The most cost-effective and widely used mitigation technique such as vented deflagration will be discussed in detail.

3. Useful terminology

Cell size is the parameter that characterises the detonation sensitivity of a hydrogen-air mixture [2].

Deflagration is the phenomenon of combustion zone propagation at the velocity lower than the speed of sound (sub-sonic) into a fresh, unburned mixture [1].

Detonation is the phenomenon of combustion zone propagating at the velocity higher than the speed of sound (supersonic) in the unreacted mixture [1].

Flame speed is the velocity of the flame with respect to a fixed observer [2].

Overpressure is the pressure in the blast wave above the atmospheric pressure, or the pressure within a containment structure, that is above atmospheric [3].

4. The effects of blast waves on people and buildings

The blast waves are harmful in a number of ways. These can be classified as primary, secondary and tertiary effects [4].

- Primary effects:
  - Damage to hearing
  - Damage to lungs and other internal organs
- Secondary effects:
  - Injuries due to flying debris (e.g. glass shards)
  - Collapse of structures on to people resulting in severe injuries or death
- Tertiary effects:
  - A whole-body displacement of an individual

It is not only overpressure that causes harm but also impulse imparted on a person or object, where person is located and what personal equipment he/she wears.

Table 1. The thresholds of overpressures for harm to humans (outdoors).

Effect	Overpressure, kPa
Temporary threshold shift [5]: "no harm" threshold for hazard distance (evacuation perimeter)	1.35
1% probability of eardrum rupture (chosen as "injury" threshold) [6]	16.5
1% probability of fatality-lung haemorrhage (chosen as "fatality" threshold) [6]	100

Table 2. The thresholds of overpressure for buildings damage [6].

Damage	Overpressure, kPa
Minor damage of the house	4.8
Partial demolition of the house-remains inhabitable	6.9
Almost total destruction of the house	34.5-48.3

Acknowledgement

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