

Detection of Fires in Heavy Duty (HD) Vehicles

Abstract

Detection of fires in the engine compartments, toilet compartments, baggage bays and sleeping cabins of Heavy Duty (HD) vehicles is arduous. The elevated air flows, concentration of pollutants and wide range of surface temperatures in the engine compartment together with the complicated geometries of the latter spaces complicate the operation of all types of detectors. These lead to difficulties defining the optimal type of detection technologies to be used as well as the adequate location of each detector.

This paper presents research for understanding the challenges and necessary characteristics of detection systems in compartments with high air flows, large temperature variations and complicated geometries. In particular, this work reports about literature surveys of existing standards, legislations and research in the field as well as experimental findings.

Keywords: fire detection, vehicles, standards, fire tests

Introduction

Fires in the engine compartments of surface and underground non-rail heavy duty (HD) vehicles are unfortunately still common around the world [1]. For instance, fires in the media drift and distribution level sections of Swedish non-coal mines and German potash and rock salt mining are predominantly caused by service vehicles, drilling rigs and loaders [2–4]. Furthermore, statistical data indicates that nearly one percent of the buses registered in northern Europe will suffer an incident related to fire during a one year period [5]. Although this quantity is alarmingly high, it does not necessarily denote that all these fires lead to fatalities or total property loss. However, statistical data do indicate that almost two thirds of the reported fires commenced in the engine compartment and that these fires were, in most cases, not promptly detected by the drivers. Late detection causes that nearly one in five of the aforementioned fires spread outside the firewall of the engine compartment putting in risk the security of its occupants [6, 7].

Engine compartments of heavy duty vehicles are, in general, spaces where detecting fires with inexpensive and simple detection systems is arduous. High air flows and large amounts of suspended pollutants in the compartment, together with the complicated geometry and the wide range of surface temperatures typically occurring during the normal operation of the vehicle, complicate the operation of all types of detectors. The deposition of pollutants on the components of optical detectors can impair their operation as well as obstruct the channels of aspirating systems, thus hindering their operation or shortening their service interval. In addition, thermal point detectors can have an extremely limited effectiveness under high air flow conditions unless these are located in the vicinity of an eventual fire where these can be effectively heated by the ensuing smoke and fire plumes [8].

UNECE Regulation No. 107 regulation stipulates that engine compartments of buses and coaches with rear mounted engines must be equipped with a fire detection system and that coaches should have fire detectors in the toilet compartments and sleeping cabins, but the regulation is unfortunately not specific about the performance and effectiveness of the employed detection system. This inaccuracy allows the employment of detection systems which would be incapable of detecting fires under high air flow conditions, providing a vague improvement regarding fire protection [9].

Although the engine compartment is the most common place of origin of fires in these types of vehicles, toilet compartments, baggage bays and sleeping cabins are not excepted of this problem. Although detecting fires in these compartments is not as difficult as detecting fires in engine

compartments, the differences in geometries among vehicle fleets may lead to difficulties defining an optimal detection technology and location of a detector to be installed in these compartments. Even though the mandatory implementation of detection systems is a fact, the effectiveness of the detectors will be highly suspected to their correct selection and placement.

Research for understanding the challenges and necessary characteristics of detection systems in compartments with high air flows, large temperature variations and complicated geometries is necessary. SP Fire Research conducts active research in the field of detection of fires in HD vehicles where different detection technologies and strategies are evaluated and compared. This paper reports experimental findings, a literature study about the existing standards and legislations in the field, and a study of bus fires in Sweden.

Bus fire statistics in Sweden

Data was collected from the Swedish Civil Contingencies Agency’s (MSB) database on fires occurring in Sweden, which is based on incident reports from the emergency services. The study was confined to reports from 2005-2013, due to that before 2005 bus fires had no separate category in the incident reports. The study includes a total of 1255 records spread over this nine-year period. The data material was processed in a repetitive process in order to obtain relevant information. Loss of the records was 26 %, partly due to the study’s limitation to commercial traffic as well as number of incidents being registered incorrectly in the bus category.

The average number of incidents per year related to fire between 2005 and 2013 was 104, which corresponds to 0.73 % of the buses in the commercial traffic. The highest number of incidents was recorded in 2006 with 130 cases; and fewest in 2012 with 88 cases and in 2013 with 81 cases. However, studying the whole period it is difficult to make a definitive conclusion on a decreasing trend regarding fire-related bus incidents.

In 61 % of the cases the incident originated in the engine compartment and in 20 % of the cases the incident originated in the wheel well. In 14 % of the cases the data was too flawed to obtain the information regarding origin area; in the remaining 5 % the incident originated inside the bus or in other area, see Fig. 1.

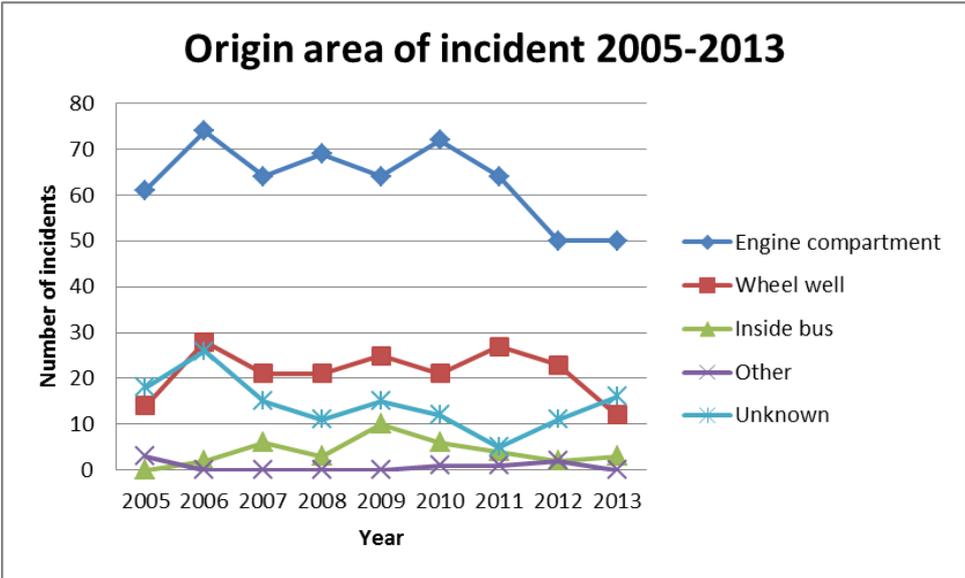


Fig. 1. Origin area of incident 2005-2013.

Flashover occurred in 7 % of all the registered incidents. The highest number of cases was registered in 2009 with 13 cases and in 2012 with 10 cases. There is no indication that the number of flashover fires is decreasing.

Fire and Rescue Service (FRS) carried out fire-fighting action in 55 % of the call outs between 2005 and 2013. In 73 % of these cases the FRS had to perform extinguishing action and in 27 % of the cases FRS conducted only cooling of the affected area.

The study shows that the bus drivers and staff have a very significant role in the initial stage of the fire-related incidents. Bus drivers extinguished the fire in 26 % of the cases prior to FRS arrival to the accident site.

Standards and legislations

To our knowledge, there are no approval standards or test methods in use for fire detection in HD vehicles. There are some standards that point out minor requirements or risk assessment methods, but no approval test methods. E.g. the Australian Standard AS 5062 is a comprehensive standard regarding fire protection in vehicles, focused on risk analysis, and the Swedish Fire Protection Association publishes two guidelines, SBF 127 and SBF 128, which include minor requirements on fire detection in HD vehicles. Also a new standard from Israel for fire suppression systems in buses, I.S. 6278, includes a few tests for detection systems. Regarding environmental tests requirements, such as resistance to vibration, ambient temperature variations, and corrosion, EN 14604 and UL 217 set out requirements for recreational vehicles. Also the NATO standard STANAG 4317 have some relevant environmental requirements for main battle tanks.

For general use, the main standards for fire alarm systems in Europe and in the US are EN 54, ISO 7240, NFPA 72, FM (3210, 3230, 3232, 3260), and UL (268, 521). All of these, except NFPA 72, include approval test programs for different types of detectors. However, these should not be used for approval of detectors for use in e.g. the engine compartment of vehicles. There are several important parameters that are not adapted for vehicle application in these standards, such as ambient temperature, vibrations, high airflow, fire sources, and false stimuli/background level.

The European automotive legislation has very vague requirements on fire detection. For buses and coaches, UNECE Regulation No. 107 sets out some minor requirements, but the regulation is not specific of the performance or installation of the system.

The following two chapters present fire detection tests conducted in the toilet compartment and in the engine compartment of buses. This and future work will be the basis for new improved standards of fire detection in HD vehicles.

Fire detection in bus toilet compartments

For the toilet compartment tests [10] a mockup was built, see Fig. 2, based on input from 26 different buses from a variety of suppliers. The most important influencing parameter was the ventilation condition, which may differ between buses. However, most buses have a fan positioned in a concealed space under the sink that extracts air from the compartment. The air enters the concealed space via air vents and in some cases also via the trash can opening (the largest hole to the left in Fig. 2). Gaps around the toilet door works as air inlet to the compartment and in the mockup these gaps are summed up in a larger gap at the upper right corner of the toilet door. Some real toilet compartments also have a feed from the air conditioning system.

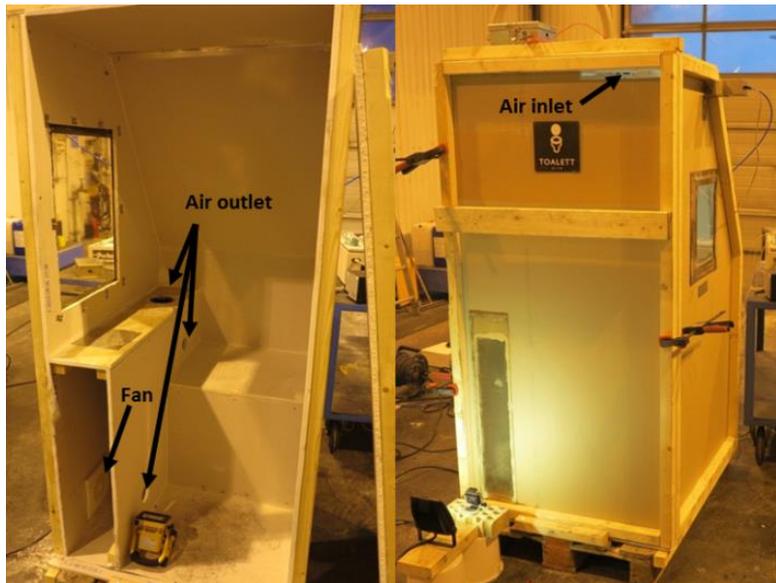


Fig. 2. Mockup of bus toilet compartment.

Five different fire detection systems were tested in different positions. The detectors included linear heat detection, point heat detection, point smoke detection, and aspirating smoke detection. Seven fire tests were conducted in accordance with Table 1. The heptane pool is not a realistic fire source in the toilet compartment, but was used because of good repeatability compared to the other fire sources. The rubber and plastics were placed in the concealed space of the fan representing a pump, cables and other electronics normally contained there.

Table 1. Test scenarios.

Test	Fire source	Fire position	Ventilation condition
1	Cigarette	Seat level	Low fan speed
2	Paper	Trash can	Low fan speed
3	Paper	Trash can	High fan speed
4	Heptane pool	Floor level	Low fan speed
5	Heptane pool	Floor level	High fan speed
6	Plastics/rubber	Above fan	Low fan speed
7	Plastics/rubber	Above fan	High fan speed

The main conclusions from the tests were:

- Smoke detectors are generally much faster than heat detectors. Heat detectors should only be used in narrow spaces where the detector is close to a potential fire source, e.g. above the trash can.
- The impact of the ventilation fan was very large. In several fire scenarios a detector in the ceiling of the toilet compartment would not give a fire alarm in the early stage of a fire. Fig. 3 shows the trash can paper fire, and no smoke entered the toilet compartment in this test.
- Because of the impact of the fan, it is recommended to have fire detectors also in the concealed space of the fan, why aspirating systems may be considered due to their capability to sample air from several spaces. Another advantage of aspirating systems is that the detector is hidden and protected.
- Aspirating smoke detectors were not affected as much as point smoke detectors by high air flows.
- It was only the most sensitive aspirating smoke detector that was activated by cigarette smoke.



Fig. 3. Trash can paper fire.

Fire detection in engine compartments

As part of an evaluation of fire detection systems for HD vehicles testing has been performed in the engine compartment of a city bus (See Fig. 4). Several systems were tested and compared regarding detection time, including heat, smoke and flame detectors.

Heat detection is the most used fire detection method in engine compartments of HD vehicles today. Flame detection is used to some extent, while smoke detection has until now not been much used in engine compartments of HD vehicles. Three widely used linear heat detectors were tested, two with fixed activation temperature of 170°C and 180°C respectively and one responding on the average temperature of the detector, with 139°C as activation temperature if the full length of the detector is heated. Also one IR/IR flame detection system and one aspirating optical smoke detection system were tested. The detection systems were installed in the engine compartment of the bus as it could have been installed in a real case with the aim of covering the entire engine compartment. Three fire scenarios were designed to simulate realistic fires and consisted of both slow developing electrically generated fires as well as a fast developing fuel leakage fire. Fig. 5 shows a fast propagating fuel spray fire. In all cases the air flow through the engine compartment was representing a stationary bus on idle speed. The rear hatch of the engine compartment was replaced with a glass window for increased visibility into the engine compartment as seen in the figures.



Fig. 4 City bus prepared for performing fire detection tests



Fig. 5 Fast developing fuel spray fire

The detection ability varied between the systems and between the fire scenarios. While the flame detector gave extremely fast response on the quickly developing fuel spray fire, it did not respond at all to the small and slow propagating electrically generated fires. The flame detector used in the test was designed to automatically adjust its detection alarm level to avoid false alarms, i.e. the detector does not respond if the radiation level increases too slowly. The results from the linear heat detectors shows that the tested systems has to be close to an open flame in order to activate, which may considerably delay the alarm time for small fires far away from the detection system. Moreover, the air flow from the engine compartment fan had a great impact on the heat transport by removing the heat from the fire area. It underlines the importance of covering the entire fire hazard area with the detectors and taking into account the heat transport direction. The tests did not show any significant differences in detection times between the different fixed temperature heat detectors. The results from the aspirating smoke detection system showed that the tested system was able to detect the fire at an early stage, i.e. already at small amounts of smoke. The test results show the importance of appropriate fire detection system design in order to avoid unwanted consequences in case of engine compartment fires.

Background noise

In the evaluation of fire detection systems it is important to study the environment in which the systems are installed into. The surrounding environment affects the durability and survivability of the systems as well as the sensitivity and risk of false alarms. Information has been collected from literature, surveys, and visual inspections. Measurements in a real bus engine compartment have also been performed. Temperature, particle size distribution and concentration, and vibrations were measured for different situations. Smoke and gas detection systems were installed parallel with the measurement systems for further analyses.

The systems were exposed to different driving conditions as well as different sources of potential false alarms, such as water mist, diesel vapor, and exhaust from other vehicles. Fig. 6, Fig. 7, and Fig. 8 show some of the results from approximately one hour drive in urban areas, on highway, and in gravel pit. The bus was driving on the highway for two minutes after about 25 minutes and in the gravel pit for 5 minutes after about 34 minutes (referring to the graphs). There is an increase of vibration amplitudes when driving in the gravel pit, which is expected, but the particle concentration is not affected that much by the dust from the gravel pit. It should be noted that the high levels of particles in the first part of the drive are primarily very small particles. Larger particles do not vary significantly for the different driving conditions.

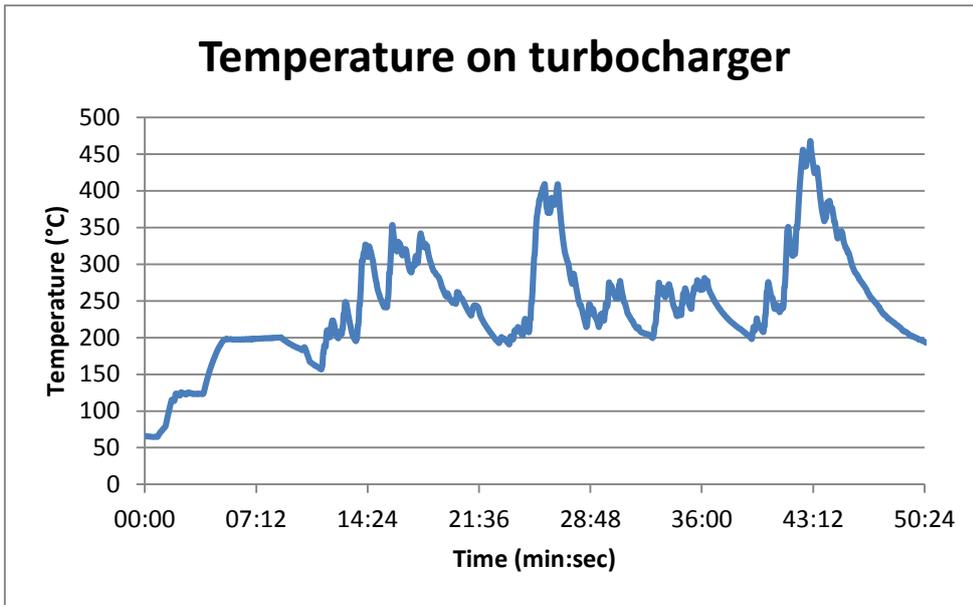


Fig. 6. Temperature on turbocharger for varying driving conditions.

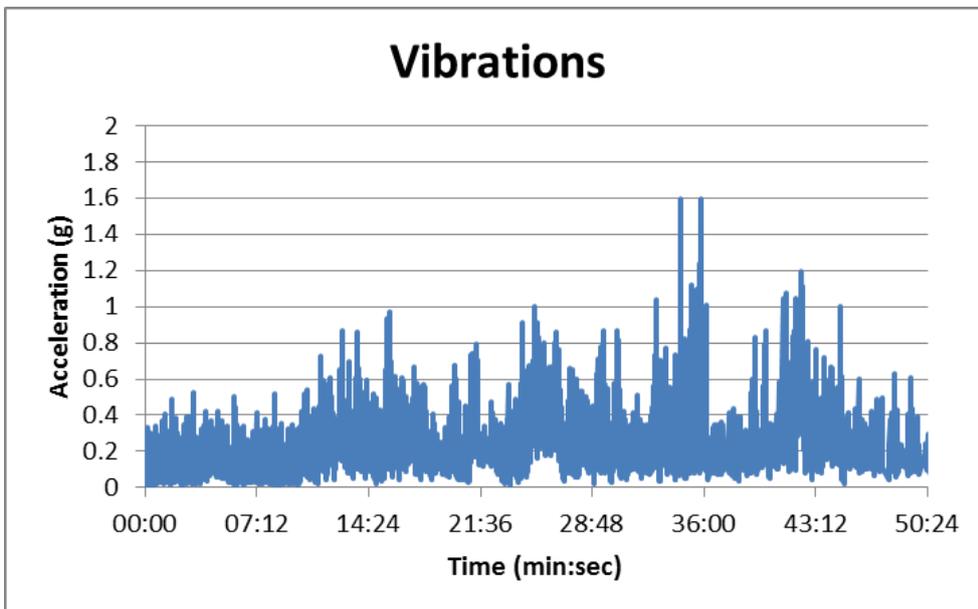


Fig. 7. Vibrations for framework of engine compartment.

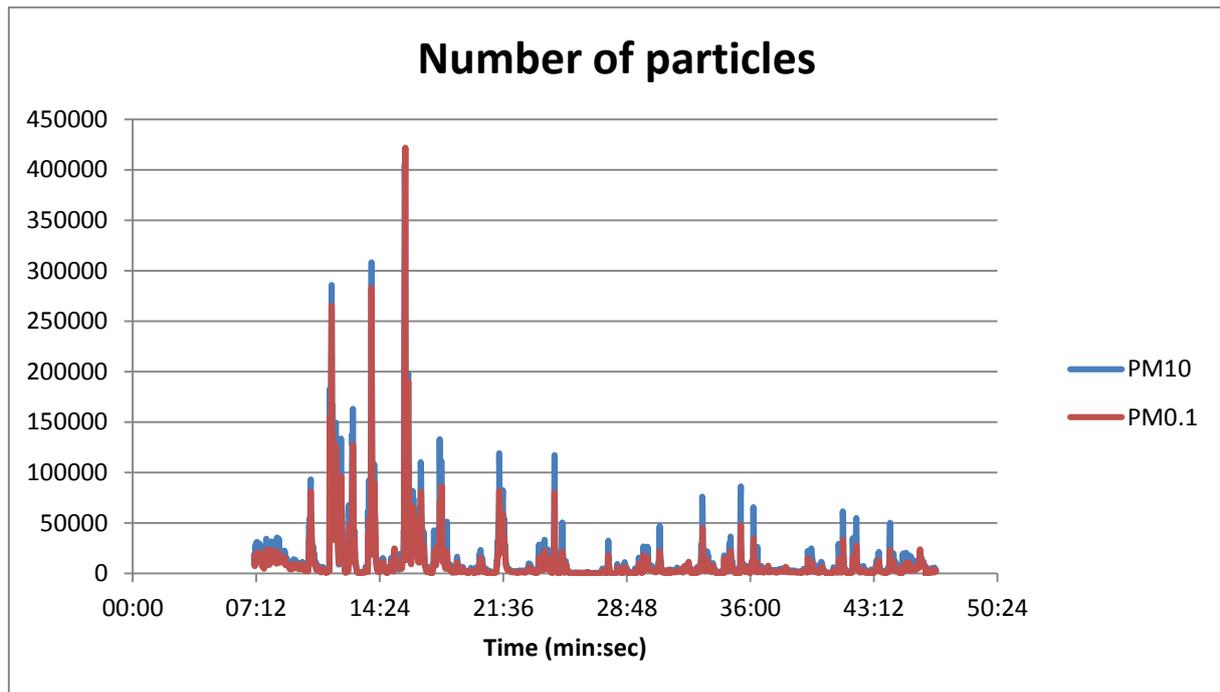


Fig. 8. Particles in the upper part of engine compartment. PM10 is particulate matter with diameter less than 10 micrometers and PM0.1 is particulate matter with diameter less than 100 nanometers.

Outlook

The work presented in this paper is part of the project “Fire detection & fire alarm systems in heavy duty vehicles – research and development of international standard and guidelines”. The aim of the project is to develop an international test method for fire detection systems in the engine compartment of buses and other heavy duty vehicles. Most work packages in the project are mainly focused on producing background material for the overall goal of defining an international test standard for engine compartments, but the project also includes work leading to recommendations on what type of fire detection system that is most suited in e.g. toilet compartments on buses and how the systems should be installed.

The remaining work consists of more testing, both full scale and small scale testing, more studies of background noise and fire causes in vehicles operating in different environments, e.g. in urban, in mines, or at construction sites, and in the end the development of an international test method.

Acknowledgements

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References

- [1] Meltzer N. R., Ayres G. and Truong M., Motorcoach Fire Safety Analysis: The Causes, Frequency, and Severity of Motorcoach Fires in the United States, FIVE - Fires in Vehicles 2012.
- [2] Hansen R., Design fires in underground hard rock mines, Licentiate Thesis 127, School of Sustainable Development of Society and Technology, Mälardalen University, Sweden, 2011.
- [3] Hansen, Site inventory of operational mines-fire and smoke spread in underground mines, Mälardalens Högskola, Västerås, 2009.
- [4] Sønksen H., Oral presentation at the Symposium on Fire Protection for Vehicles and Work Equipment Underground, Freiberg, Germany, 2009.
- [5] Hammarström R., Axelsson J. and Reinicke B., Fire Safety in Buses, WP1 report: Bus and coach fires in Sweden and Norway. SP Fire Technology, SP Report 2006:26, 2006.
- [6] Brandt J. and Försth M., Testing active fire protection systems for engine compartments in buses and coaches - a pilot study, SP Report 2011:22, 2011.
- [7] Kokki E., Bus Fires in 2010-2011 in Finland, FIVE - Fires in Vehicles 2012.
- [8] Brandt J., Modin H., Rosen F., Försth M., and Ochoterena R., Test method for fire suppression systems in bus and coach engine compartments, SAE 2013-01-0208, 2013.
- [9] J. Eriksson and M. Mansoori, Branddetektion i motorrum (Fire detection in engine compartments), MSc. Thesis, Report 5206, Lund University of Technology, 2009.
- [10] Willstrand O., Brandt J. and Svensson R., Fire detection & fire alarm systems in heavy duty vehicles, WP5 – Fire detection in bus and coach toilet compartments and driver sleeping compartments, SP Report 2014:28, 2014.