

The Development of a Standard Test for Assessing the Effectiveness of Transit Vehicle Fire Extinguishing Systems

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ABSTRACT

Few standard approval tests exist for fire extinguishing systems for commercial vehicles, such as transit vehicles, coaches etc. Therefore, a representative test article has been constructed to evaluate the fire extinguishing performance of current in-house fire protection systems. This data will then be used as a benchmark against which the performance of future fire extinguishing systems can be judged.

The test article is a fire-hardened simulation of a rear-engine transit bus. Several fire locations are used, in two configurations: "small" and "large". The former encompasses diesel fuel spray fires and small, obscured diesel pool fires some containing additional wood chips; the latter represents a more developed diesel fuel spray and larger diesel pool fires. Tests have also been run simulating the ignition of a diesel fuel spray impinging on a hot turbocharger. Parameters pertaining to restrike have also been investigated.

Suppression tests have been carried out varying the type and amount of fire extinguishing agent, the location of the nozzles, and the presence or absence of airflow. In addition, the application rate was varied for dry chemical agents.

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INTRODUCTION

RATIONALE FOR THIS WORK

Whilst fires in transit vehicles are a small fraction of overall fire occurrence (car fires represent the vast majority of vehicle fires) they still occur frequently. Data from NFPA estimates the annual number of bus fires as 2,350 per year or about 6.4 fires per day [1].

In comparison with many other branches of fire protection, few standard approval tests exist for fire extinguishing systems for commercial vehicles, such as transit vehicles, coaches etc. As far as the authors are aware, the only approval test specifically for transit vehicles is SBF 128[2,3]. Currently SP Technical Research Institute of Sweden (SP) is in the process of defining a more robust approval test [4]. Despite this lack of approvals, many fire protection systems have been installed, but the precise pass/fail criterion was either not ascertained or has been lost in the mists of time. To address this issue, a test article has been constructed to evaluate the fire extinguishing performance of

current in-house fire protection systems installed on commercial vehicles. This data will then be used as a benchmark against which the performance of future fire extinguishing systems can be judged.

Previous experience has taught that testing against a representative fire threat leads to robust fire protection. It is not the aim of this work to define an approvals test; that would be the role of the various authorities, but we do aim to show that the use of such a test article and fires can help in benchmarking fire suppression systems prior to more formal (and expensive) external test programs.

Notes:

1. Several agents tested here are referred to by their trade names. This paper is not an endorsement of these products; the use of the trade name is purely for the sake of brevity in the publication, and for the readers' convenience.
2. This work was carried out by a team of research engineers and scientists, with the sole aim of completing an objective study of the in-house fire extinguishing systems in question.

No commercial considerations were allowed to influence the execution of, or the findings of, this study.

CONTENTS OF THIS PAPER

The test article and the instrumentation will be described in detail. The paper will present a comprehensive description of the fire threats and justification for selecting them. A selected summary of results from the 400 plus fire tests carried out to date will be included, to illustrate trends. The paper will conclude with the lessons learned from this testing, and provide insight into key aspects of the more important parameters for successful fire extinguishment in this demanding application.

This paper is accompanied by a “companion” paper [5] describing the issues pertaining to the detection of the different fire threats encountered in transit vehicles.

EXPERIMENTAL

THE TEST ARTICLE

The test article (see [Figure 1](#)) was based on the dimensions of a representative US transit bus engine compartment. The dimensions are as follows: 2.50 m width $\times$ 1.35 m length $\times$ 1.18 m height. The height extension, shown on the left of [Figure 1](#) is 1.22 m high $\times$ 0.41 m wide $\times$ 0.76 m long. To provide a robust and long-serving test article, the structure of the test article was fabricated using mild steel I-Beams, angle and sheet. Inspection windows were included to enable the fire tests to be captured on video. The top frame was made to be removable in order to a) enable the engine to be fitted easily and b) be replaced by a different configuration of engine compartment if and when required in the future.



Figure 1. Test Article

As tested the article has a fully open bottom. It is believed that this is typical of city transit buses. Provision was also made within the design of the test article to fit plates to the base in order to create an enclosed or partially enclosed engine bay - an arrangement typically found in passenger

coaches to reduce road noise and vibration. It was considered that the open bottom would represent worst case in terms of ease of extinguishment, as the agent would be more likely to be lost through the open floor.

In order to have a realistic amount of clutter in the engine compartment it was decided to use a real engine within the test article (see [Figure 2](#)). A search of commercial vehicle dismantlers led to the purchase of an IVECO 8060.45R six-litre diesel engine complete with its ancillaries (radiator, starter motor etc.) and transmission. Although the engine was removed from a UK truck, it is representative in size and layout to engines typically be found in passenger buses. The engine was delivered still attached to its mounting frame so it was possible to lower the assembly straight into the base of the test article. It should be noted that it was never intended that the engine should be running within the test article and therefore all oils and transmission fluids were drained from the unit prior to delivery to satisfy local EH&S requirements.



Figure 2. Engine prior to installation in the test article

VENTILATION

A key requirement for the specification of the test article and fire tests was that a simulation of the air flow be made to represent the vehicle moving and/or the engine running. This was achieved by means of an axial fan coupled to an inverter for speed control. A spring damper was also fitted to the test article in order to eliminate the possibility of damage and back pressure on the fan during the pre-burn phase of the fire tests. The fan was mounted on a portable stand and was wheeled into place and switched on during the fire test sequence. The specifications for the fan were based on air intake values suggested during research carried out by SP in their report ‘Bus Fire Safety’ which concluded that at an engine speed of 2200RPM a flow rate of 1.95 m³/s through the engine compartment was appropriate [3].

The fan used in these tests was subjected to a series of air velocity calibration tests using an anemometer which

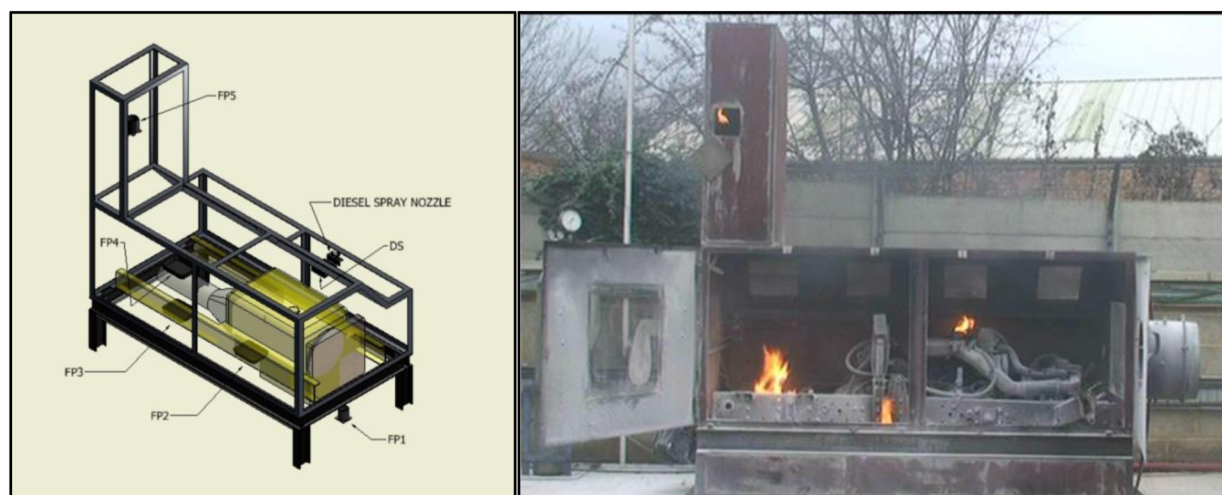


Figure 3. Layout of the Standard Fire Threat

determined that a maximum airflow of $1.95 \text{ m}^3/\text{sec}$ could be achieved within the test article with the damper open. In addition, an intermediate fan setting of $0.98 \text{ m}^3/\text{s}$ representing 1100 RPM, a reasonable tick-over speed, was used in some tests.

It should be noted that up to 80% of tests were conducted with the maximum airflow as this was considered to be the 'worst-case scenario' for the suppression system to work in. The remainder of tests were carried out using an airflow of $0.98 \text{ m}^3/\text{sec}$ or no airflow (i.e. fan switched off and damper closed) this representing the vehicle standing still with the engine switched off.

Part way through the test program, the position of the fan was moved from the "rear" of the test article to the side. This was carried out for two reasons: 1. to assess the effect of a different airflow pattern, 2. to mirror more closely the standard test currently being developed by SP.

FIRE THEATS USED

Three basic fire scenarios have been developed during the course of this work. All were based on fires involving diesel fuel, as fuel or flammable liquid fires are the most common [1]. The first scenario comprised relatively small, obscured fires in defined positions within the clutter and represented a fire in the early stages of growth. This is referred to in this report as the Small Fire Threat. The second represented a more involved fire threat and comprised larger fires, and is referred to as the Large Fire Threat. The third fire threat was a fuel spray impinging on a preheated turbocharger. Each of these is now described in more detail.

Small Fire Threat

Using the SP report [3] as the starting point, a suitable small fire threat for the test program was devised using a total of six fire pans (of three different sizes) positioned in pre-defined locations around the rig with five fires positioned amongst the engine 'clutter' and one placed in the exhaust

compartment. Three of the pans (FP2, FP3 and FP4 shown in Figure 3) were fuelled with a mixture of Diesel (100 ml) and sawdust (25 g). These quantities of fuel provided a class B / deep-seated class A fire of at least 2 minutes duration when unsuppressed. FP1 and FP5 were based on fire cans used within an industrial fire extinguishing standard ISO 14520 [6] and were half-filled with water onto which 50 ml of Diesel was added. The final fire was a sixth pan fire, "Pan DS", positioned adjacent to a diesel spray in order to light it reliably. ("Pan DS") was also fuelled by half-filling with water and adding 50 ml of Diesel. The Diesel spray fire was a derivative of one used previously for military vehicle testing. The fuel is preheated to 82°C (180°F) and sprayed through a bespoke nozzle at a pressure of 1 bar using nitrogen as the propellant. An electromechanical valve gives a spray of 30 s duration (5 s before suppressor is actuated, 25 s after). The fuel flow rate is approx. 6.7 ml/s , meaning that 0.2 L is discharged in total.

The total heat output for the standard fire threat has been calculated to be approximately 750 kW, based on the area of the pans. Note that this assumes that all the diesel sprayed into the engine compartment is involved in combustion. This calculation also neglects any contribution for the sawdust in fires FP2, FP3 & FP4. The key purpose of this fire threat was to demonstrate the ability to distribute extinguishing agent all around the engine compartment with enough concentration to extinguish fires at the earlier stages of development.

Large Fire Threat

The Large Fire Threat comprised three larger pan fires underneath the engine block, but still within the engine compartment, thus simulating a "bilge fire". The approximate locations are shown in Figure 4. The heat output of the three combined pans has been calculated to be $\sim 1.6 \text{ MW}$, based on the combined area of the three pans. This test highlights the ability of extinguishing agent to distribute around a cluttered environment and still provide enough