Fire Detection and Fire Fighting Testing on Railway Vehicles – New Developments

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Abstract

Fire detection system and firefighting solutions are getting a common safety measure on newly designed and built trains in Europe and other parts of the world. While international and national regulations as laws or the European TSI often prescribe the minimum requirements on vehicle safety, these regulations do not give guideline to evaluate and verify the performance of such systems.

To compensate for this lack of guidelines and standards the European manufacturers of fire safety system for rolling stock together with the attestation and certification bodies have developed a series of guidelines (so-called ARGE guidelines) to determine the system performance and give success criteria for fire detection, aerosol and gas fire extinguishing and water mist firefighting on railway vehicles. The paper will present the shortly the three ARGE Guidelines [2-4] which were developed since 2009 and elaborate the changes introduced with the 2018 edition.

It will further outline the research work currently conducted and planned during the next working period of the ARGE group. This includes the design of potential new test fires and the measurement of smoke release rates. The motivation for the work is coming from EN standardization. Currently CEN/TC 256 is working on a European standard for the assessment of “Fire Containment and Control Systems” (FCCS) on railway vehicles. Key focus here is the potential replacement of fire doors between railway cars by an FCCS which may be consisting of fire detection and fire-fighting systems. Target is to achieve the same performance as a fire door would give.

Keywords: Fire detection, fire suppression, railway vehicles, ARGE guidelines
Introduction

The European Technical Specifications for Interoperability for Railway Traffic (TSI) [1], and the European standard EN 45545-6: 2015 include requirements for the installation of fire detection and firefighting systems. These requirements are depending on the type of vehicle and its class of operation.

However, an assessment of these fire safety systems is not defined in these standards. The ARGE Guidelines Parts 1 to 3 [2, 3, 4] define a practical assessment method based on the objective of personal safety. The same targets have the Italian standard UNI 11565 and the planned future European standard on “Fire Containment and Control Systems” for railway vehicles within CEN/TC 256.

ARGE Requirements on fire detection

The ARGE document Part 1 “Fire Detection in Rolling Stock” [2] gives guideline to the choice of detector type and defines functional testing of installed fire detection systems on railway vehicles with the target to measure detection response on optimize the detector positioning in the vehicle. It addresses both occupied areas as well as technical areas. Testing (here type testing) shall always be done on a real vehicle. ARGE Part 1 was thoroughly presented in [5], this article will focus on the changes made in the 2018 edition [2].

Detection principle

The detection principles of the ARGE guideline remain unchanged, it still considers smoke and heat detection only with the following choice:

- Occupied (passenger) areas smoke detection
- Technical areas smoke or heat detection

Thresholds

A change occurred to the maximum detection time allowed. The 2012 edition defined the following strict limits:

<table>
<thead>
<tr>
<th>Area</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passenger and staff areas</td>
<td>1 minute</td>
</tr>
<tr>
<td>Technical areas (not combustion engines)</td>
<td>2 minutes</td>
</tr>
<tr>
<td>Combustion engines</td>
<td>1 minute</td>
</tr>
</tbody>
</table>

This table is still valid for the 2018 edition. The response time of 1 minute in passenger and staff areas can however be extended under the following conditions.
“The response time of 60 seconds may be exceeded by 100% at maximum if the following two conditions are fulfilled:

- The operating company accepts this variation in connection with the notified operational concept. In addition, there is a confirmed evacuation concept for the scope of application which takes into account escape and evacuation situations in the infrastructure.

- The fire detection system is not being used for initiating a self-rescue from the train, for activating the closing mechanism or for deactivating hold-open devices for fire barrier doors, or for activating a fire suppression system.”

Testing equipment and assessment
Testing of smoke detectors is done using a smoke generator with thermal lift. Figure 1 shows the potential test set-up.

![Test set-up with methanol pan or gas burner](image)

Fig. 1. Test set-up with methanol pan or gas burner [1].

The thermal lift is generated using chimney of 50 cm height and

- Either a methanol pan with 22 cm x 22 cm surface max.
- Or a gas burner with 2.9 W power max.

The gas burner method was added in the 2018 edition to the guideline as the methanol creates a risk especially in case of moving vehicles. The smoke generator must be calibrated before the test and only one smoke fluid is allowed since 2018:

- Regular Fog (Look Solutions)

For a 60 seconds test 10 ml of fluids shall be used, for a 120 seconds test 15 ml.
ARGE Requirements on fire fighting

The ARGE Guideline - Part 2 "Fire-fighting in Rolling Stock" [3] focuses on the assessment of fire-fighting and fire extinguishing systems on railway vehicles by setting minimum requirements. It supports the selection of the extinguishing agent. It was described in [5]. This article focused on the changes made in the 2018 edition.

For the requirement of the vehicle's continued ability to run in case of fire, the assessment must achieve:

- "Areas of relative safety" for affected persons in the passenger areas, at least by a fire-fighting system which controls a fire, or
- "Areas of absolute safety" in equipment areas, by a fire extinguishing system.

The following table summarizes this definition and defines the possible extinguishing media:

<table>
<thead>
<tr>
<th>Area</th>
<th>Safety</th>
<th>Requirement</th>
<th>Extinguishing media</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passenger and staff</td>
<td>Relative safety</td>
<td>Fire containment</td>
<td>Water mist</td>
</tr>
<tr>
<td>Technical area</td>
<td>Absolute safety</td>
<td>Fire extinguishing</td>
<td>Gas, Aerosol, Water</td>
</tr>
</tbody>
</table>

Fig. 2 defines the requirements for an area of relative safety [6]:

![Fig. 2. Requirements for a safe area [6].](image)

Extinguishing agent and equipment

Assessment and thresholds for occupied areas

The assessment of water mist fire-fighting systems shall be done in a mock-up conservatively representing passenger areas. Tests done in a real first series vehicle will be only valid for this vehicle class. Figure 3 shows the mock-up. It is conservative as the materials for seats and walls are formed of PUR foam blocks (400 mm x 400 mm x 100 mm) and wood, which form a higher fire source compared to real materials on rail vehicles, which are barely ignitable following current regulations and standards as EN 45545-2:2020.
Fig. 3. Test mock-up and test position as well as fire sources acc. to [3].
The following four tests have to be performed at each testing position:

- Travel bag test (see [3]) two times (on seat and below seat)
- Test with two PUR foam blocks (see [3]) two times (on seat and below seat)

The fire is always ignited using a paper cushion according to UIC 564-2 [7]. Edition 2018 did modify the pre-burning time of the tests. Figure 4 shows the new times. The pre-burning times where extended by 15 seconds in order to include time for the typical system reactions observed (system, reaction = time between alarm at the detector and release of extinguishing medium).

<table>
<thead>
<tr>
<th>Pre-Burning Time</th>
<th>Edition 2012</th>
<th>Edition 2018</th>
</tr>
</thead>
<tbody>
<tr>
<td>PUR-foam block fire test</td>
<td>60 seconds</td>
<td>75 seconds</td>
</tr>
<tr>
<td>Travel bag fire test</td>
<td>120 seconds</td>
<td>135 seconds</td>
</tr>
</tbody>
</table>

Fig. 4. New pre-burning times for water mist mock-up tests acc. to [3].

Assessment and thresholds for technical areas
In technical areas - differently form the passenger and staff areas - a full extinguishing of a fire is required. Possible extinguishing agents are gas, aerosol or water mist. No change was made in the 2018 edition of ARGE Part 2. For gas extinguishing agents those agents are allowed listed in EN 15004. The design concentration of this standard has to be proven by a concentration measurement. For water mist or aerosol extinguishing system a 1:1 extinguishing test is needed.

European Standard on “Fire Containment and Control Systems” (FCCS)

Until 2019 CEN/TC 256 was working on a European standard for the assessment of “Fire Containment and Control Systems” (FCCS) on railway vehicles. Key focus here is the potential replacement of fire doors between railway cars by an FCCS which may be consisting of fire detection and fire-fighting systems. Target is to achieve the same performance as a fire door would give. This may lead to new concepts like fire-fighting not over a whole car, but only at the connection between two cars.

As CEN/TC 256 could not agree on a draft for a standard, work was stopped in 2019 and the current state of work was published as a technical report in 2020 [8]. This technical report contains in most cases references to the ARGE guidelines Part 1 to 3 [2 – 4] and the Italian standard UNI 11565. For testing fire detection systems, the paper will propose a new test in addition to the smoke generators used both in ARGE and UNI and described above. As an alternative a toluene tray fire source according to figure 5 may be used.
Fig. 5. Toluene Tray for test fire according to planned technical report by CEN/TC 256.

The tray shall be filled by 70 ml of water, 80 ml of toluene and 20 ml of methanol. That will lead to the following fire dimensions:

- 3 minutes test duration
- Power output: 7 kW
- Heat flux generation 25 kW/m\(^2\) to 30 kW/m\(^2\)

It was developed with the target to be more reproducible than the smoke generator tests and in line with EN 45545-1 Ignition model 1. However, several test houses and train manufacturers have signalled concern about using toluene on a finished and potentially moving train during acceptance testing. CEN/TC 256 plans to develop the document in a full standard at a later stage but sees the requirement of experiments and testing to define new acceptable procedures for acceptance testing of both fire detection and fire-fighting.
Current Experiments by ARGE Group

The ARGE guidelines and fire models used are based on the travel bag scenario. The travel bag as fire source is in alignment with the "ignition model No. 5" of Appendix 1 of EN 45545-1. Its size is in line with the Swedish study "Carried Fire Load in Mass Transport Systems" – see Figure 6 [9].

Fig. 6  Heat release rates of travel bag fire source [3].
The smoke release rates of the smoke generator used in ARGE Part 1 were experimentally determined based on this test fires of a burning travel bag ignited by an UIC paper cushion.

In order to open the ARGE Part 1 to other possible detection testing methods on real vehicles than just the smoke generator, a series of comparison experiments was initiated by the ARGE group and carried out at DMT in Dortmund. The target of the work is to compare different potential smoke sources to the smoke generator and the travel bag.

The work shall also help to get knowledge for the future further development in European standardization (FCCS).

The following new smoke sources are evaluated:

- UIC paper cushions
- PUR foam blocks
- smoke powders and pallets
- EN 54-7 cotton test fire
- Toluene tray as per CEN/TC 256

For the experiments are carried out in a test room, which is equipped with a smoke exhaust hood according to ISO 9705. The measures are at the lower side 3000 x 3000 mm. The lower edge of the exhaust hood is 2300 mm above ground as in Figure 7.

The following data is recorded:

- Environmental conditions at start (temperature, pressure, humidity)
- Transmission at 2100 mm height
- Temperatures during experiment at different positions
- Gas concentrations (O2, CO, CO2)
- Resulting loss of mass of smoke source

Figure 8 shows examples of transmission results for different smoke sources.
The results are still preliminary but show that certain smoke pellets, but also PUR blocks according to UNI 11565 or the toluene tests of CEN/TC 256 may be promising.

The required detection time has to be normalized - as it was done with the smoke generators as well - based on the smoke release rate of the source. As a next step the reaction of real smoke detectors in a real vehicle shall be compared for the different sources. These experiments were conducted in 2020, but the evaluation had to be delayed due to the Corona-Virus situation.

Another motivation of the testing described is the evolvement of new technologies which are considered for use in railway vehicles. Examples for detection methods under evaluation for passenger areas are

- Multi-criteria (smoke & Heat) detectors for smaller compartments
- CO detectors
- Video fire detection (based on smoke and flame)
Fig. 8  Transmission results for different smoke sources.
New Technologies - Outlook

The first two technologies are already established in building technologies, but less on the rail market. One reason is that the current testing equipment according to ARGE is based on smoke alone and does not allow for heat detection or CO detection in passenger areas. This may be overcome with new smoke or fire sources.

While multi-criteria detectors that include smoke, heat and possibly CO are mainly used to reduce nuisance alarms in railway vehicles, the use of video may combine the currently separated fields of security and fire in railways. The latter is a topic for future research and activities.

The reduction of unwanted alarms on the other side is an essential problem, as nuisance smoke alarms lead to delays in rail travel and in the worst case (e.g. release of an extinguishing system) to an evacuation and cancellation of the journey.

References


