Fire Resistance Testing of Railway Rolling Stock – – Initial Findings from the Implementation of a Standard EN 45545-3:2013

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Summary
This paper is intended primarily for designers and manufacturers of railway vehicles as the authors describe and explain the new requirements of fire resistance testing process relevant to the railway industry.
Before 2013, fire resistance tests of railway rolling stock have been performed according to UIC card no. 564-2 (regulations of International Union of Railways) which referred to the ISO Standard 834-1 „Fire-resistance tests – Elements of building construction – Part 1: General requirements" containing a description of the testing procedures used in the building industry. In July 2013, a new standard was published, EN 45545-3:2013, „Railway applications – Fire protection on railway vehicles. Part 3: Fire resistance requirements for fire barriers" which describes testing methods and classification rules for different railway vehicles according to the indented use and location.
This paper presents a set of requirements described in the EN 45545-3:2013 and standards cited there. The authors explain the details of the introduced, testing method together with an in-depth discussion on the classification requirements. The explanation is supported by presentation of selected results from a fire test of railway fire barrier performed according to EN 45545-3:2013 in the fire laboratory in the Ship Design and Research Centre (abbreviated CTO in Polish).
In summary, explanation of the rules governing the fire resistance testing of railway vehicles and demonstration of such a test may assist the designers and producers in the creation of new constructions which meet the requirements of this standard.
Keywords: fire protection, fire safety, rolling stock

1. Introduction

It may appear that escaping from a train in case of a fire is a trivial problem, however railway vehicles travel very often at high speeds and occasionally

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in locations such as tunnels or bridges where there is limited infrastructure for evacuation. Consequently, appropriate measures to contain fire to the place of its origin are of vital importance for passenger evacuation.

Generally, fire containment can be achieved either by passive or active fire protection or by a combination of both. In this paper the authors will present only requirements for passive fire protection, which is based on separation of adjacent locations by fire barriers. Fire barriers are elements of construction used for *maintaining separation between two adjacent areas of a railway vehicle in the event of a fire which resists the passage of flame and/or heat and/or effluents for a period of time under specified conditions* [1]. The requirements for fire barriers depend on so called „operation categories" which are determined by the service type of the train and thus infrastructure available for evacuation. In other words the requirements for fire barriers are higher for these trains which cannot stop immediately in the event of fire, for instance trains travelling at high speeds or in tunnels as the main goal of these requirements is to allow passengers and staff to evacuate safely in case of fire. It is noteworthy that these requirements are not intended to preserve the railway vehicles in the event of fire.

In the European Union fire barriers must pass prescribed regulatory tests before are allowed on the market. Before 2013, fire resistance tests of railway rolling stock have been performed according to UIC card no. 564-2 (regulations of International Union of Railways) [2] which referred to the ISO Standard 834-1 [3] containing a description of the testing procedures used in the building industry.

In 2013, after more than 20 years of development [4], a new standard was published for railway applications, EN 45545, containing seven parts, and part three describes fire resistance testing methods and classification rules for different railway vehicles according to the indented use and location [1].

Publication of this part, EN 45545-3, of the new international standard clarified the way how elements of rolling stock should be tested for fire resistance. Moreover the new standard gives detailed rules for classification and explains the requirements for different trains and various locations within the railway vehicles. Precise requirements are beneficial for all interested parties as they increase the safety level of products on the market.

2. Testing Procedure

Fire resistance for railway applications is tested in a similar way as in the case of elements of building constructions, namely the tested specimen is installed on a special furnace (Fig. 1) and then heated. Heating is performed following a well know, standard time–temperature curve, which simulates developing fire. The prescribed curve is presented in Fig. 2, however, one has to keep in mind that the sample

is not directly attacked by flames but by the incident heat flux, mainly convective and radiative. The radiative fraction of the incident heat flux is presented in the right part of Fig. 2.

Fig. 1. Furnace for fire resistance testing, this photograph was taken just after the fire test

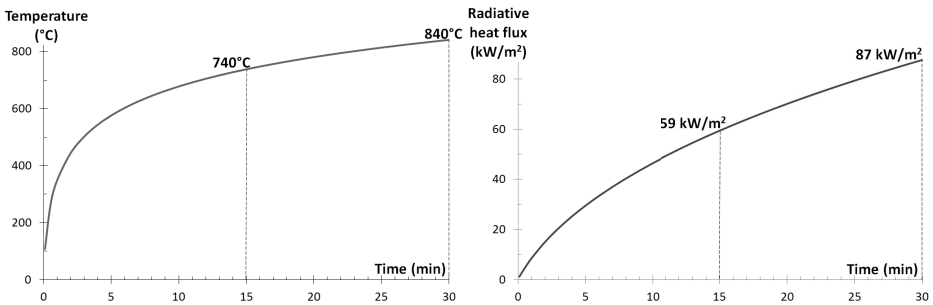

Fig. 2. Standard temperature-time curve according to EN 1363-1 [5] (left) and corresponding approximate incident radiative heat flux on the tested object (right)

The EN 45545-3 standard stipulates that the furnace construction and testing requirements shall be based on EN 1363-1 [5], which is technically relatedto ISO 834-1 [3] known in the railway industry from UIC card [2]. However the EN 45545-3 lists precise requirements for mounting and testing the specimens which were not given in the UIC card. For instance, normative Annex A of EN 45545-3 describes requirements for mounting and fixing of test specimens, including requirements for their size and number, restrain and boundary conditions, and specimen parameters which should be verified.

3. Classification of Fire Barriers

Fire barriers used in railway applications are classified according to EN 13501-2 [6], based on their performance characterised by three criteria:

1. Integrity criterion **E**;
2. Insulation criterion **I**;
3. Radiation criterion **W**.

The most common criterion for rolling stock is the requirement for integrity, which describes the time in full minutes for which the test specimen continues to maintain its separating function during the fire test. In other words, no flames should be allowed to penetrate to the unexposed side of the tested fire barrier. It is assumed that the specimen is no longer fulfilling the requirement for its fire integrity if one of the following applies:

- There is a gap detected wider than 6mm and at least 150 mm long or a gap wider than 25 mm irrespective of its length or
- Sustained flaming is visible on the unexposed side lasting longer than 10 seconds.

The second criterion, insulation, describes the time span before the temperature of the unexposed side exceed prescribed threshold. At any location the temperature rise above the ambient should not exceed 180°C and the average temperature at five prescribed locations should not exceed 140°C above the ambient temperature.

The last criterion, radiation criterion is verified in a non-direct way in most cases. The fulfilment of the insulation criterion, **I**, means that the radiation criterion, **W**, is also satisfied because radiation is a function of surface temperature (to the fourth power).

Each criterion is established either for 10, 15, 30 or 60 minutes. For instance, if a construction fails the integrity criterion after 13 minutes it can be classified only as E10. Moreover, it has to be kept in mind that integrity failure means also insulation failure, but it is possible to classify for integrity without any requirement for insulation.

The performance of a fire barrier shall be designated for example, as E30, I15, which means: integrity is maintained for 30 min and insulation is maintained for 15 min. The most common characteristic of fire barriers in railway application is E15, and other requirements depend on the operation category of train and protected locations. These issues will be explained in the section to follow.

4. Performance Requirements

The requirements for fire barriers depend upon the operation category (OC) and their location in the railway vehicle. There are four operation categories, summarised in Table 1. Please note that details provided here are relevant to vehicles operating on infrastructure subject to the Directive 2008/57/EC [7]. Detailed requirements for other cases are given in [8].

Table 1

Summary of four operation categories of railway vehicles

Operation category	Required running time (after fire detection)	Minimum average speed	Additional information
OC1	Train is allowed to stop immediately.	N/A	The available infrastructure allows side evacuation, and sections without such option are no longer than the minimum permitted train length. Tunnels or elevated sections **no longer than 1 km**.
OC2*	Train has to run 4 minutes after fire detection.	80 km/h	Trains will run underground, in tunnels and in elevated sections which are **no longer than 5 km.** Side evacuation and rescue stations available for passengers within short running time.
OC3	Train has to run 15 minutes after fire detection.	80 km/h	Trains will run underground, in tunnels and in elevated sections which **are longer than 5 km.** Side evacuation and rescue stations available for passengers within long running time.
OC4*	Train has to run 4 minutes after fire detection	No requirement	Trains will run underground, in tunnels and in elevated sections which are **no longer than 5 km.** Side evacuation is not available and only evacuation from either end or both ends of the train is feasible.

* The main difference between OC2 and OC4 lies in the available infrastructure for side evacuation.

4.1. Examples of Performance Requirements for Fire Barriers

In this subsection a few examples of classification requirements will be given. It is not the intention of the authors to present an exhaustive list all the cases described in EN 45545-3:2013 [1] and interested readers are referred to that standard. Moreover, it has to be mentioned here that the EN 45545-3 standard specifies different testing regimes for horizontal and vertical fire barriers. A detailed explanation will be presented in the following subsections.

4.1.1. Fire in One Passenger Area, Protection of Another Passenger Area

Firstly, a case with fire in a passenger area is presented. The aim of the fire barrier in that scenario is to protect the adjacent passenger area. A quite common for this application would be a fire door, however, it is important to stress here that the fire barrier is not only the door, but the whole cross-section of railway carriage (highlighted in red in Fig. 3), which means that whole section must be tested in accordance with EN 1364-1 (walls) [9]. All components of the whole cross section must be positioned as they would be in real life application. Such a barrier needs to have fire performance E15 only for trains with operation category 3, which means for trains which operate in underground tunnels longer than 5 km and these trains are required to run another 15 minutes after fire detection. Please note that for instance underground metro trains are not falling into that category as long as the distance between two adjacent underground stations (or places for side evacuation) is shorter than 5 km. There is no requirement for other operation categories (Table 2).

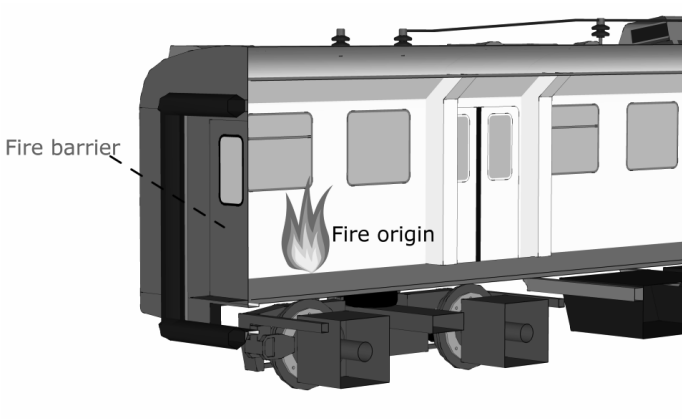

Fig. 3. Fire barrier between adjacent passenger areas

Table 2

Requirements for fire barriers between two adjacent passenger areas

Operation category	Requirement
1, 2 and 4	No requirement
3	E15

4.1.2. Fire in a Passenger Area, Protection of Driver's Cab

Secondly, a case with fire in a passenger area is presented again, but now the aim of the fire barrier would be to protect the adjacent driver's cab. Similarly, the whole cross-section of railway carriage (highlighted in red in Fig. 4), must be subjected

to fire test. Such a barrier needs to have fire performance E10 for trains with operation category 4, and E15, I15 is required for trains with operation category 3 however I15 is required only for vehicles subject to the Directive 2008/57/EC [7]. For other railway vehicles W15 is required instead of I15 (Table 3).

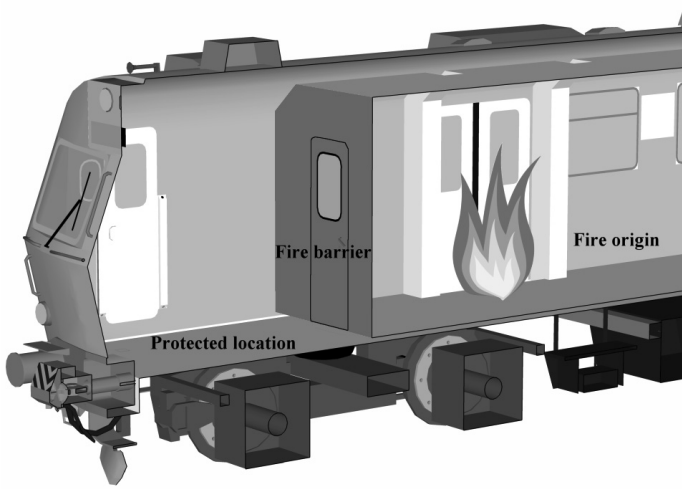

Fig. 4. Fire barrier between passenger area and driver's cab

Table 3

Requirements for fire barriers between passenger area and driver's cab

Operation category	Requirement
1 and 2	No requirement
4	E10
3	E15; I15*

*I15 is required for vehicles subject to the Directive 2008/57/EC [7].
For other railway vehicles W15 is required instead of I15.

4.1.3. Fire in an Underfloor Combustion Engine (inc. fuel tank), Protection of Passengers and Staff

This subsection contains requirements for horizontal fire barrier, in this example, separating an underfloor combustion engine and / or fuel tank with auxiliary pipes from the passenger / staff area (Fig. 5). Such a barrier must be tested in horizontal orientation and in accordance with EN 1364-2 (ceilings) [10] and whole cross section and 1 m longer than the object on each longitude direction must be tested. Such a barrier needs to have fire performance E15 for trains with operation categories 1 and 2, whereas E15, I15 is required for trains with operation categories 3 and 4 (Table 4).

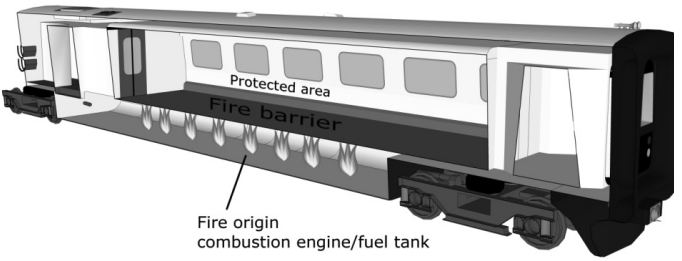

Fig. 5. Horizontal fire barrier between an underfloor combustion engine and / or fuel tank and the passenger area

Table 4

Requirements for horizontal fire barriers between an underfloor combustion engine / fuel tank and passenger / staff

Operation category	Requirement
1 and 2	E15
3 and 4	E15; I15

4.1.4. Fire Inside a Technical Cabinet Located in the Body Shell Which Contains High Power Electrical Equipment, Protection of Passengers and Staff

This subsection contains requirements for vertical fire barrier, in this example, separating a technical cabinet located in the body shell which contains high power electrical equipment from the passenger / staff area (Fig. 6). Such barrier must be tested in accordance with EN 1364-1 (walls) [9] but different testing approach is used for fire barrier containing door (for instance measurement of deflection) and different for wall without fire door. However requirements for fire performance for a given operation category will be the same. In this case E15 is required for trains with operation categories 1, 2 and 4, whereas E15, I15 is required for trains with operation category 3 (Table 5).

Table 5

Requirements for vertical fire barriers between a technical cabinet located in the body shell which contains high power electrical equipment and passenger / staff area

Operation category	Requirement
1,2 and 4	E15
3	E15; I15

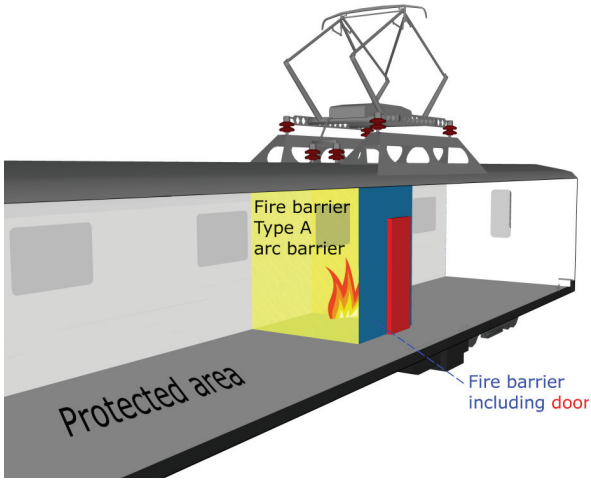

Fig. 6. Vertical fire barrier – different testing requirements for the fire barrier containing fire door and the walls being Type A arc fire barrier

5. Selected Results

In this section some selected results will be presented with the special emphasis on constructions which failed the tests.

5.1. Integrity Failures

As explained previously, integrity criterion is no longer met as soon as any gap is visible, which is wider than 6 mm and at least 150 mm long (or 25 mm wide irrespective or its length) or sustained flaming on the unexposed side are visible. An example of integrity failure is shown in Fig. 7.

Fig. 7. Example of integrity failure

5.2. Insulation Failures

Insulation criterion is assessed by the measurement of temperature of the unexposed side. The criterion is fulfilled as long as the average temperature rise above the ambient determined from the measurement at five prescribed points is not higher than 140°C. At the same time, temperature rise above ambient should not exceed 180°C at any single location. An example of an insulation failure is shown in Fig. 8. It can be seen that average temperature from measurement points 1–5 (see the small diagram on the right) exceeded the threshold just after 9 minutes (doted line in Fig. 8) so the minimum requirement of 10 minutes was not achieved.

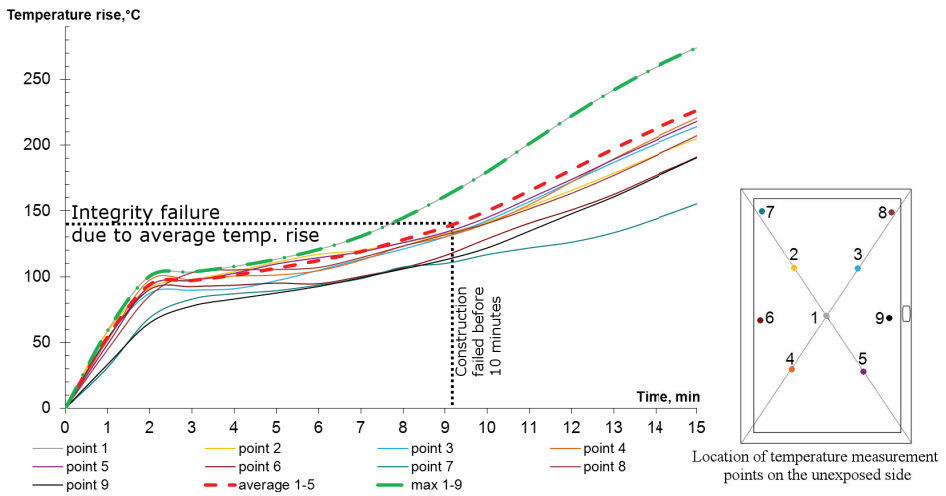

Fig. 8. Example of insulation failure

6. Conclusions

The authors described in this paper classification requirements and testing method from a recently published standard: EN 45545-3:2013 covering rules for testing of fire barriers for railway applications.

The authors have shown that publication of this new standard assisted in the testing process as some ambiguous issues present in the past have been clarified. Examples of these clarifications were discussed by the authors in section 2 called Testing procedure.

The next important problem addressed by the standard was related to detailed fire performance requirements. The guidelines presented in the standard were discussed by the authors in section 4 where numerous examples were shown

(Figs. 3–6). Additionally, some cases of test failures were presented by the authors in order to illustrate non-compliance with classification requirements.

Concluding, this standard is a great step forward however still some minor issues have to be resolved. For instance testing of floor assemblies should be performed according to EN 1364–2 which is designed for ceilings and not floors. Moreover cotton pad is excluded from EN 45545–3 and integrity failure should be assessed only by presence of sustained flaming and/or gap gauges penetration whereas EN 1364-2 specifically call for cotton pad as usage of gap gauge is prohibited due to safety concerns. Issues like this one need to be resolved in future but implementation of this standard can greatly enhance testing routines and thus safety level of end users.

7. Acknowledgements

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