ARGE Guideline - Part 2

“Fire fighting in railway vehicles”

Functional assessment for the efficiency of fire suppression and extinguishing systems in passenger and staff areas, electric cabinets and in areas with combustion engines

Guideline/Testing instructions

Rev. No.	Date	Responsible	Comment
1.0	12-02-2008	ARGE	Adoption
2.0	11-19-2009	ARGE	1st Update
3.0	09-17-2012	ARGE	2nd Update
4.0	09-10-2018	ARGE	3rd Update
4.1	15.11.2018	ARGE	Update

This Guideline is the result of a cooperation of the Detection Technology Consortium (ARGE)

ARGE Guideline - Part 2
“Fire fighting in railway vehicles”

List of Contents

ARGE Guideline - Part 2
“Fire fighting in railway vehicles”

1. General

The purpose of the Guideline is the specification of a fire suppression or fire extinguishing system with regard to the different vehicle types or places of installation. In addition, it specifies the functional assessment of fire suppression systems in passenger areas and fire extinguishing systems in electrical cabinets regarding possible fire incidents in railway vehicles.

The assessment focuses on the efficiency of fire suppression and fire extinguishing systems and the selection of the fire extinguishing medium.

This Guideline represents minimum requirements for fire suppression and fire extinguishing systems. The vehicle manufacturer can define advanced protective aims based on requirements of the vehicle operator.

The rules and standards in the present document are valid in their latest version.

1.1. Preface

The Technical Specifications for Interoperability (TSI), the current state of the art and the European Standard EN 45545-6 include requirements for the installation of fire suppression and fire extinguishing systems. Few requirements for the assessment procedure are included in Standard EN 50553. The purpose of Standard EN 50553 is to define requirements for railway vehicles in terms of running capability in case of fire, whereas the ARGE Guideline focuses on the aim “to protect passengers and staff“. Thus, the assessment procedures are more conservative than the requirements in Standard EN 50553.

To guarantee the design and the assessment for the installation of fire suppression and fire extinguishing systems in railway vehicles, system specific requirements for design, construction and type tests are needed.

This Guideline identifies the required criteria for the practical assessment.

1.2. Objectives

With respect to the protective aims defined in laws, regulations and state of the art a fire incident must be detected already during the formation phase (e. g. smoldering fire) or after the inflammation (e. g. liquid fire in a technical cabinet).

The requirement is to protect passengers and staff in railway vehicles. The objective is to ensure health conditions acceptable for a safe evacuation, which is also intended by TSI and the Standards EN 45545.

To provide a place of relative safety – stay in a passenger area during a defined time with no danger for health, the following values shown in the table below must be fulfilled:

Table 1: Evaluation data and reference values for quantitative protective aims

Flue gas parameters	**Critical value**	**Exposure time** approx. 15 min incl. coefficient of safety	**Exposure time** approx. 5 min incl. coefficient of safety
Carbon monoxid	**< 1,400 ppm**	200 ppm	500 ppm
Carbon dioxid	**< 6.0 Vol.-%**	2.0 Vol.-%	3.0 Vol.-%
Oxygen	**> 12.0 Vol.%**	14.0 Vol.%	12.0 Vol. %
Temperature of smoke gas	**< 65 °C**	50 °C	50 °C

The values consider the information from the engineering guide for fire prevention methods review 4 of vfdb (11-2013) and the guideline "Design fire" VdS 2827 (05-2000), VdS Schadenverhütung, Cologne.

Measurements were performed in areas affected by fire in a height of approx. 1.6 m and approx. 2.0 m away from the ignition source.

The objective is a general and acceptable definition of repeatable assessment processes, which are already taken into account for the system design.

The processes defined in the Guideline shall already be applied on prototype tests, existing vehicles or 1:1 models based on design definition. These tests are the basis for final type tests or the acceptance of the fire suppression and fire extinguishing systems.

The assessment of fire suppression and extinguishing systems focuses on the ignition scenarios/ignition models according to EN 45545-1, Appendix A. It doesn't focus on other models e. g. based on natural influences or terrorism.

1.3. Acceptance

Since its release the ARGE Guideline is accepted as state of the art regarding to accreditation of railway vehicles.

1.4. Scope

The purpose of the Guideline is to design and assess the efficiency and practical use of fire suppression and fire extinguishing systems in railway vehicles and track guided vehicles.

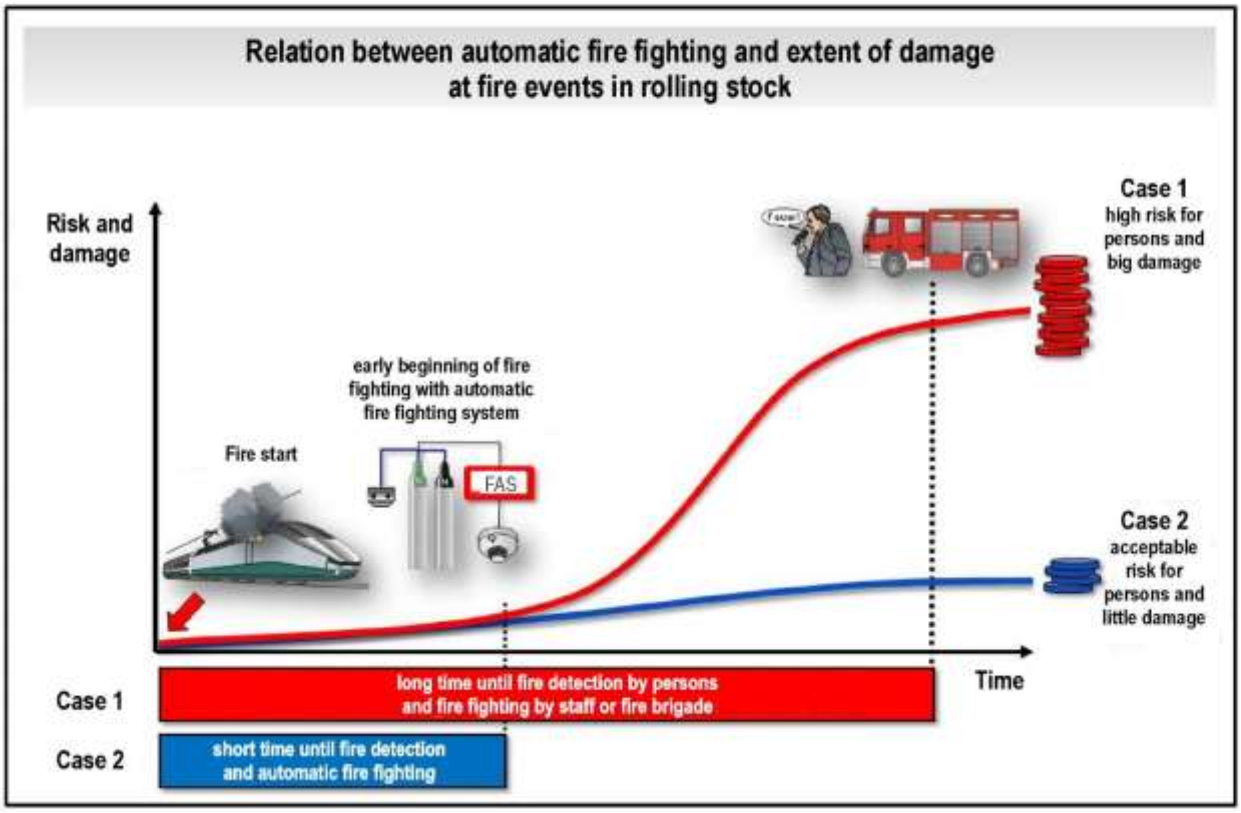


Figure 1: General fire development (fire incident without and with fire suppression /extinguishing)

The results of the assessment must ensure:

- at least a fire suppression system in “places of relative safety” for persons in passenger areas when the train keeps moving or
- a fire extinguishing system for “places of ultimate safety” in technical cabinets.

A fire risk analysis has to be the basis for the design of a fire suppression or fire extinguishing system related to the potential fire locations or fire areas.

The design fires defined in this Guideline are the basis for the assessment (for the passenger compartment see Appendix 2 and for the electrical equipment see paragraph 3.2). Note the possible fire effects, other fire effluents (e. g. smoke release) and the base conditions of operation (e. g. ventilation conditions).

The fire risk analysis is the basis for the system design and should be provided by the vehicle manufacturer. As well, the fire risk can be determined by the system manufacturer who has to take into account information of the vehicle manufacturer.

For assessing the efficiency of the system technology, this guideline has to be applied as follows:

- for gas extinguishing systems on the first production vehicle and
- for other fire extinguishing systems by using a 1:1 model, with the possibility of simplifications in case of similar location or equipment conditions via evaluation of conformity.

The assessment of efficiency and/or the evaluation of conformity must be acknowledged by officially recognized railway assessors/experts in collaboration with the manufacturer and supplier, so that an assessment is available for the approval of vehicle operation and for other certification processes (e. g. within the scope of the Technical Specifications of Interoperability – TSI).

1.5. Validity

This Guideline applies to the use in railway vehicles and other track guided systems equipped with fire suppression and fire extinguishing systems.

As necessary the Guideline can be applied to comparable technical systems (e. g. buses).

The assessment processes must be applied on the evaluation in terms of fire protection of passenger, staff and technical areas.

2. System specification and design

The system design or implementation must meet the state of the art, for example for:

- the design and installation of system equipment (according to EN 15004-1, focused on vehicles)
- the components used in the system (according to Standards EN°12094)
- the assessment of railway standards (according to EN 50155).

In case of deviations from the mentioned standards an assessment of "equal safety" is necessary, requiring the acceptance of the assessment body.

For the basic requirements of the system technology see Appendix 7. Here, the focus is on the assessment of the railway standard.

The documentation of fulfilled requirements must be comprehensively provided before the type test and for the approval of the system technology.

In addition, the maintainability and the accessibility for maintenance or visual inspections must be taken into account for the system realization.

The duration of fire suppression has to ensure acceptable stay conditions in passenger compartments with "relative safety". For reference see TSI SRT.

The duration of fire extinguishing in technical cabinets takes into account a verifiably extinguished fire. Before, the affected technical equipment has to be switched off. Otherwise, there will be the risk that the stored volume of fire extinguishing medium is exhausted before completely extinguishing the fire, which could end in other hazards.

The extinguishing process is automatically activated by fire detection and should not be interrupted or delayed. An additional manual activation is possible without any side effects on the system.

The functional requirements for the fire detection and fire suppression and extinguishing system resulting from

- fire detection system
  (reference to ARGE Guideline – Part 1) and
- system control to the point of monitoring of the required "safe" or at least of the "reliable" system functionality
  (reference to ARGE Guideline – Part 3)

3. Assessment specifications

The specifications exclusively focus on the assessment of fire suppression and fire extinguishing effects regarding the basic conditions in potential fire areas.

The areas which have to be protected are classified as:

- **Passenger and staff areas**

  The objective is to ensure a place of "relative safety", in which a person can stay without any danger, e. g. with a period of time of 4 to 15 minutes.

  The duration of fire suppression is determined according to the operational vehicle concept, essentially based on the vehicle running time (reference to standards EN 45545). After finishing fire suppression, the fire must not be increased (see Appendix 4).

- **Areas with technical equipment**

  The objective is to ensure the necessary functions for continuing vehicle operation and to limit and exclude fire effects on surrounding areas by fire extinguishing.

  The duration of the fire extinguishing is determined by the effect of the fire extinguishing medium related to the fire incident. It should be noted that both, liquid fires of Class B according to EN 2 and solid fires of Class A according to EN 2 have to be extinguished. In addition, leakages of the fire area must be considered with respect to the efficiency of fire extinguishing.

  In any case, before extinguishing the fire the technical equipment must be shutdown and technical equipment which causes fire must be prevented to restart.

  In case of continuing vehicle operation consider that the release of fire load (e. g. diesel fuel) or permanent energy input (e. g. electrical ignition power) result in more critical fire effects. The fire extinguishing system shall be capable to control and extinguish the fire, so that there is no risk of endangering passenger and staff.

In general, the focus is on the protection of passengers and staff regarding the assessment of the capability of fire suppression and fire extinguishing. This concerns the prevention of a direct danger during stay inside and outside the vehicle as well as during self-rescue from the vehicle. The object safety is also taken into account, at least as far as this is related to personal safety.

This Guideline does not focus on further requirements for object safety.

3.1. Independent evaluation

The evaluation complies with the appropriate approval process of the railway vehicle, for example:

- inspection body ISO/IEC 17020 Type A, accredited as specialist for fire safety in railway vehicles, with European evaluations of conformity according to the Technical Specifications for Interoperability (TSI),
- expert which is acknowledged by the appropriate body in the national approval process or
- other national acknowledged bodies.

This also applies to deviations from evaluation criteria mentioned in this Guideline.

Note: The test should be performed by a test center which is acknowledged according to ISO/IEC 17025, accredited according to this Guideline.

3.2. Fire suppression in passenger and staff areas

3.2.1. Principle

The used fire extinguishing medium should not include, release or develop substances during fire suppression which cause a danger to health. Fire effects must be minimized as far as possible (see Appendix 3).

EN 50553 mentions fire suppression systems in passenger and staff areas only in the informative Appendix C. EN 50553 refers to the assessment, like for electrical equipment and combustion engines in paragraph 6.5.3.2. EN 50553 does not describe special test scenarios for passenger areas.

3.2.2. Recommendation

For fire suppression in passenger and staff areas water-based fire extinguishing media are suitable. Here, irritating ingredients should not be used, as far as possible.

3.2.3. Basic test conditions

For the assessment of efficiency, related on the fire extinguishing medium water mist, a real test fire must be simulated in a 1:1 vehicle model.

In this 1:1 vehicle model, also the original materials installed in the vehicle can be used (e.g. original seats and side panels). However, it is not allowed to use other fire loads or other ignition sources, which are not described in this document.

Existent test results from projects with similar geometry and layout can be used based on an evaluation of conformity. This acknowledgement of the results ("Cross Acceptance") must be verified by an assessor/specialist for railway vehicles. An evaluation of conformity is only possible when the fire test has been performed with vehicle-neutral conservative materials (see description below). If a fire test was performed with only the original vehicle materials, the fire test is only valid for this vehicle.

The assessment of the efficiency has to be realized according to the following specification:

- As referenced fire load, two foam cushions on top of each other are used as fire object. The result is a flat burn-off of the foam cushions. Its energy release is to be assessed as conservative compared to the design fire "luggage" (see Appendix 2). The application of foam cushions is recommended particularly for setting or optimizing the system technology due to comparable test results.

Specification foam cushion:
Polyurethane foam - dimensions 0.4 m x 0.4 m x 0.1 m, density 25 kg/m³ to 35 kg/m³.

- If a verified test is required, the referenced fire load must be "luggage". Here, the requirements for characteristics of the luggage material and for the ingredients must be fulfilled according to Appendix 2.
- The fire incident must be performed in an area which is the farthest away as well as very close to the outlet nozzles.

The simulated fire incident starts by igniting a UIC paper cushion (UIC 564-2). The fire starts by igniting the four edges of the UIC paper cushion placed on the fire object.

- paper with area-related mass of approx. 50 g/m²
- mass in total 100 g (+/- 10 %)
- approx. 6-7 paper wads in the same line, in tacked sheet of paper

Figure 2: Example UIC paper cushion

From a conservative point of view, the fire model must be equipped with non-fire-resistant materials. The sidewall must be simulated with plywood and the seat cushions (seat and back) with cushion foam.

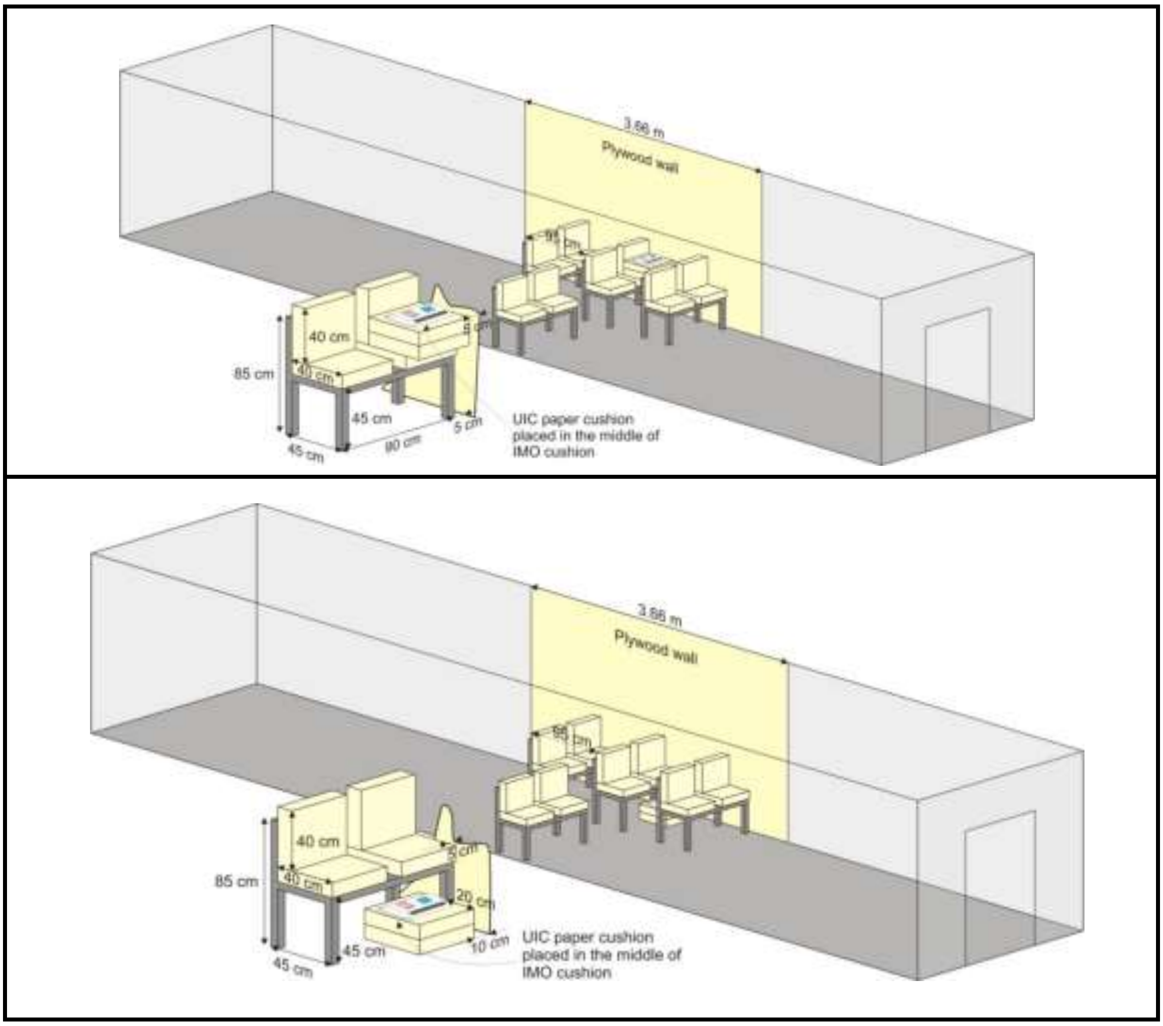
For simulating the interior wall, the following conservative material is recommended:

<u>Plywood (commercially available):</u>

- bonding resistant in areas with generally a low air humidity (e. g. IF20)
- thickness of 3 to 5mm and three-ply at maximum
- material density approx. 400 to 700 kg/m3
- without wood preservative or flame retardant
- material humidity < 20 %

The arrangement of fire loads have to be tested according to Figure 3. The focus must be on the actual dimensions of the passenger area including seat arrangement. The position of the ignition source must be chosen according to paragraph 3.1.4 (shown as example in Figure 3).

The intended tests including test preparation and selection of the fire model should be presented to an assessor before the test starts.



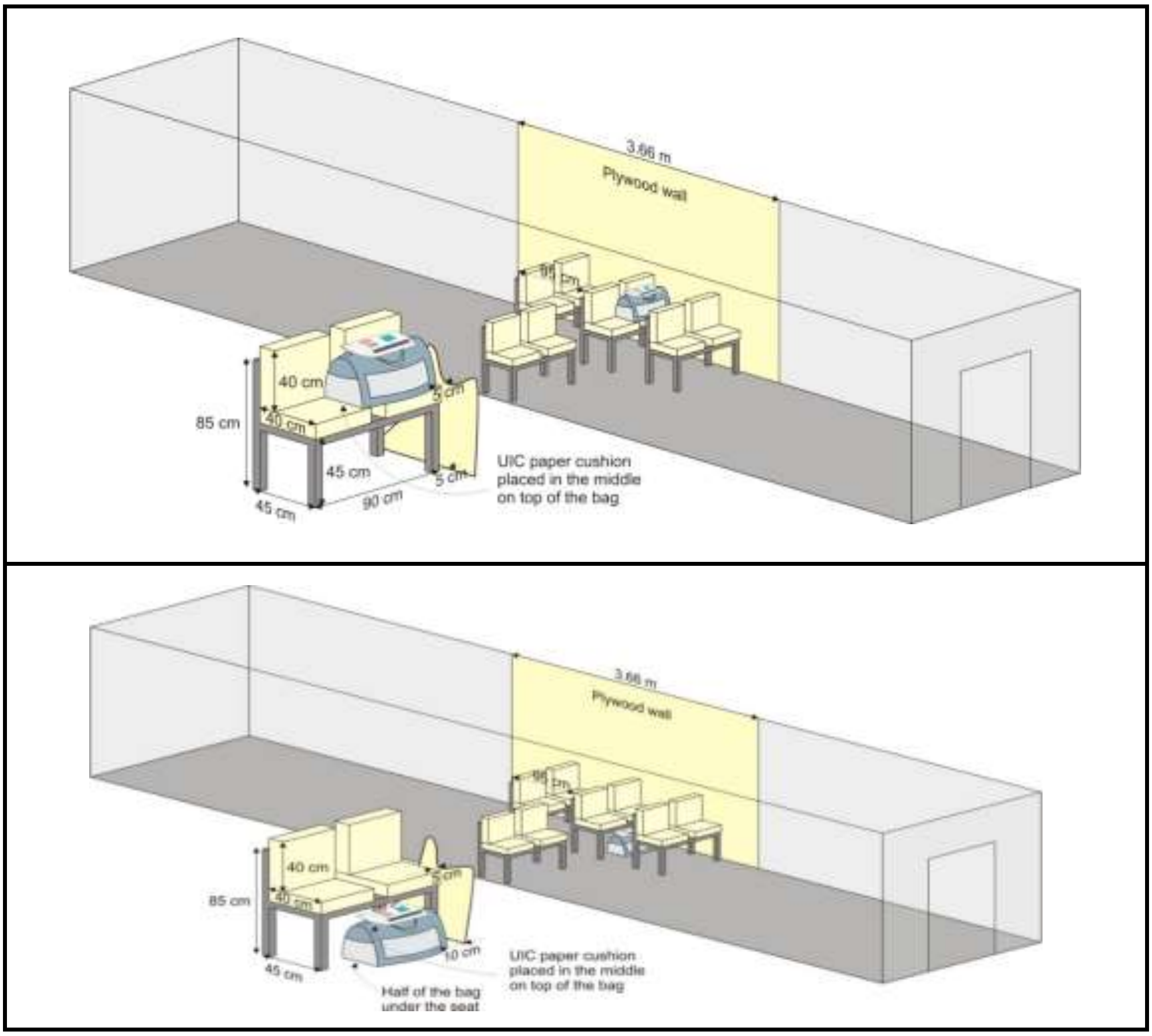


Figure 3: Example for the interior area with the position of the fire objects (approximate values)

Determining the pre-burn time (after ignition of the paper cushion until start of the fire suppression system):

By means of the pre-burn time the possible fire development until the fire detection is simulated by the fire detection system (reference to ARGE Guideline - Part 1). During this time, the construction materials in direct surrounding area of the fire object are thermally affected by the fire.

Regarding the definition of the factor of safety, the area conditions (ventilation specific for vehicles and technical cabinets), the development of fire ignited by easily inflammable materials and the technical response time of the fire detection system are taken into account. This is a common process for fire protection technology.

The **pre-burn time** is defined for the following basic conditions:

Due to the characteristics of the fire development, the use of the fire object paper cushion results in a higher energy release compared to the design fire "luggage".

- Considerating the maximum response time of the smoke detection system in the affected area the pre-burn time is **at least 75 seconds by using a paper cushion (60 seconds, plus system response time e. g. 15 seconds)**.
- The pre-burn time is **at least 135 seconds** by using **luggage** [see Appendix 2] **(120 seconds, plus system response time e. g. 15 seconds)**.

For the tests a verified system reliability and system safety is presumed, assessed by the recognized tools of RAMS-considerations (Reliability, Availability, Maintainability, Safety), (see also ARGE Guideline - Part 3).

3.2.4. Fire location

The fire load has to be positioned at a place which can be assessed as conservative regarding the outlet nozzles of the fire extinguishing media. Possible obstructions or deflection surfaces related to the discharge of the fire extinguishing medium have to be considered.

This is for example between two seats, at the side wall on the floor or on the seat or between the seat backs on the floor at a farthest point from the outlet nozzle.

3.2.5. Test criteria

The requirements which are necessary for staying in the train area must be assessed. A stay without any risk and danger must be possible **outside an area of at most 2 meters around the fire location in passenger areas**. The target values should not be exceeded, limit values must not be exceeded. Air temperature, oxygen concentration, carbon monoxide concentration and carbon dioxide concentration [see Appendix 3] must be determined during the entire test or the required period of time.

- Due to the potential quantity optimization of the fire extinguishing medium in the fire location, fire suppression areas has to overlap in case of a functional location separation.
- In the fire location, a constant distribution of fire extinguishing medium or fog concentration has to be assessed or visually inspected.
- The values shown in table 1 "Evaluation data and reference values for quantitative protective aims" must be met for at least 15 minutes after beginning fire suppression.
- After finishing spraying, flames may not increase again.

A duration of fire suppression of **at least 10 minutes** is recommended.

To fulfil the protective aims an extension of period will be required, if it is necessary due to risk analysis.

3.3. Fire extinguishing in areas with technical equipment

3.3.1. Principle

A fire in areas with technical equipment must be completely extinguished, if the vehicle cannot reach a completely safe area for the self-rescue of passengers. After fire extinguishing, a state equivalent to a technical failure without further fire impact must be reached. This has to be ensured when running through “long tunnels” in single traction or with only one drive system.

Before activating the fire extinguishing system the relevant technical equipment and engines must be shut down. Areas with technical equipment must be completely electrically shut down. In areas with combustion engines fuel supply should be cut off. Without these measures, depending on the type of fire extinguishing media, there will be the risk of further system failures. Examples for risks from the fire extinguishing medium are flash-overs caused by humidity, freezing or massive fire effects due to an increased pool fire.

For the assessment of the basic conditions the influences from the operational environment e. g. airstream transfer or effects from necessary technical equipment until vehicle stop must be taken into account.

In EN 50553 no basic conditions are defined, reference is made to EN 3-7 class B fires. There a no differences mentioned regarding the used fire extinguishing medium or the fire load in connection with the fire location.

For the assessment of the efficiency of fire extinguishing systems in areas with technical equipment (high voltage and combustion engines) a fire incident shall be simulated with 12 liters of liquid (comprising 4 litres of water on which is floated 8 litres of n-heptane). The tray should be circular with a surface area of 0.2 m² and a depth of 150 mm. It shall be made from steel of 2 mm thickness.

An assessment by CFD modelling is not accepted.

3.3.2. Recommendation

For fire extinguishing in areas with technical equipment, water-based extinguishing media (with or without additives which improve extinguishing parameters), extinguishing gases and fine grained powder or aerosols are recommended according to the present fire loads (liquids and solids).

The selection of the fire extinguishing medium requires aspects of object safety. In case of fire release, the impacts from the extinguishing medium must be limited, so that corrective maintenance can be performed with reasonable effort or that technical failures are minimized.

The protection against freezing must be taken into account to guarantee full availability.

3.3.3. Basic test conditions

Only those gas extinguishing systems are allowed which are defined in EN 15004 or which are especially authorized for application.

For **gas extinguishing systems** test flooding must verify, that the defined **extinguishing concentration-** and **minimum design concentration** related to the necessary **vehicle stop** in the complete fire risk area will be met. Regarding equipment boxes and electrical containers with automatic release by the parameter temperature an increased area temperature of at most 60°C is acceptable during test flooding.

According to table 3 of EN 15004-2:2008 the determined concentrations of the measured temperature may be converted in a temperature which is at least 20°C lower than the release temperature.

Due to a normative compliance by assessment for the used extinguishing medium – mentioned in data sheets and system specific hydraulic calculations – generally no further fire tests are required.

For **water mist extinguishing systems** and **systems with other extinguishing media** a 1:1 assessment has to be performed regarding the following conditions:

For applications with combustion engines:

1. Simulating a **spray fire** by rupture of an injection line with a heat release, which corresponds to a leaking amount of fuel of an appropriate engine pipe. Here, at least a leakage of 0.0033 l/s at an injection line must be simulated.

   A time of 15 seconds is specified as pre-burn time, to heat the area affected by spray fire. An additional direct pre-heating with manual burning will be necessary, if liquid fire loads can accumulate (e. g. depressions in pool fire). It must be assessed that, after extinguishing, a reignition by the leaking flammable fuel at overheated areas is prevented.

   If the engine has equipment to prevent leakages on injection lines (e. g. double-walled injection lines), the test will not be required.
2. Simulating a **pool fire** with a surface area of 1/3 of the fire pan, but at least 1 m² located below and centrally to the engine (Note: the heat release rate of a pool fire by diesel fuel is 1,800 kW corresponding to a surface area of 1 m²). To achieve a solid thermal lift, the fire area and the surfaces must be heated by a pre-burn time of at least 60 seconds.
3. Simulating a **pool fire** with a long surface area of at least 0.25 m² located above the engine and centrally located between the nozzles (Note: the heat release rate of a pool fire by diesel fuel is 347 kW corresponding to a surface area of 0.25 m², example for a surface area of 0.9 m x 0.3 m (0.27 m²) the heat release rate is approx. 380 kW). To achieve a solid thermal lift, the fire area and the surfaces must be heated during a pre-burn time of 30 seconds when the distance of coverage is up to 500 mm and during a period of at least 60 seconds when the distance is larger.

If there are re-ignition hazards at operationally heated surfaces, they have to be simulated.

The situation should be presented to an assessor before starting the tests.

Simulating a fire in an **electrical container/electrical cabinet**, based on a fire pan with a surface area of 15 cm x 15 cm filled with 18 ml heptane and 2 ml toluol (with reference to standards EN54).

If possible, this test has to be performed in the considered electrical container and cabinet. The test will be not required, if the area has an IP standard or the construction has only small leakages.

In an **area with electrical equipment** (in general electrical containers and electrical cabinets), a determination of the simulating fire area is not relevant. The complete filling of the area with the extinguishing medium is determined over a defined period of release. For example the thermal lift in the affected area results in "suction" of water mist by the fire. There must not be separations between the potential fire location and the nozzle installation, as shown in the fire risk analysis.

In an **area with combustion engines**, the potential development of accumulations (e. g. fuel, oil) or the leakage of coolant, considerating the possible evaporation on hot surfaces, has to be taken into account for the design and installation of extinguishing nozzles.

The assessment for fire performance or the required application time with extinguishing media **bases generally on 1:1 fire tests**. Here, the real fire situation can be simulated in a fire model with corresponding equipment (obstructions).

Test results from projects with similar geometrical and design conditions can be used based on an **evaluation of conformity**. This agreement on results ("Cross Acceptance") must be verified by officially recognized railway assessors/experts. This concerns e. g. diesel engines at locomotives from one product family as well, which have amongst others only different lengths but similar obstructions.

3.3.4. Test criteria

3.3.4.1. **Gas extinguishing systems**

Deviating from or in addition to the generally applicable standards for gas extinguishing systems, its application in railway vehicles und track-guided vehicles is defined as follows: Dynamic tests will be required, if airstream influences the air flow in the fire extinguishing area. At the activation time of the fire extinguishing system the dynamic ventilation is switched off in the fire area.

- Time until the fire extinguishing medium extinguish:

  A period of 10 seconds from activation until the outlet of the extinguishing medium from the nozzles must not be exceeded by gas extinguishing systems.

- Minimum design concentration:

  The minimum design concentration results from the extinguishing gas concentration plus a coefficient of safety, and is determined by the approval of the gas extinguishing system.

  This concentration must be achieved for

  - Non-inert gases within 20 seconds
  - Inert gases within 120 seconds

  after system activation.

  Since the concentration of the extinguishing medium will not be homogeneous at the beginning of extinguishing, the minimum design concentration has to be measured where the fire risk analysis has identified a potential fire starting point (i. e. a component of high fire risk).

- Retention time:

  - The retention time starts when achieving the minimum design concentration. The retention time for liquefied extinguishing gases is at least 30 seconds.
  - For non-liquefied extinguishing gases at least 180 seconds

  The minimum design concentration should fall short within the retention time.

3.3.4.2. **Systems with non-gaseous extinguishing media**

It must be verified that after finishing extinguishing not further burning takes place a delayed reignition is not possible.

The result must be a uniform distribution of fire extinguishing media in the whole fire area or in the area which is potentially affected by the fire.

- Time until the outlet of fire extinguishing medium:

  The period of 10 seconds must not be exceeded from the activation until the outlet of the fire extinguishing medium from the nozzles.

- Application time:

  Due to the different characteristics and effects of the agent, the effective concentration of the fire extinguishing medium in the fire risk areas cannot be determined by measurement. For this reason:

  - for water-based media, the outlet duration of the extinguishing media is at least 120 seconds according to the extinguishing time plus 50 % resulting of the fire test or
  - for solid fire extinguishing media, the amount of fire extinguishing medium must be plus 25 % to extinguish a fire in a defined area.

The simulated fire incident must be extinguished before the release of fire extinguishing media ends.

4. Revisions of the Guideline

ARGE is exclusively responsible for changes and updates of the Guideline as a result of technical discussions and exchange of experiences. Current findings in connection with the application of the Guideline are taken into account.

The leading editorial work is supervised by TÜV SÜD.

TÜV NORD ensures the 4-eyes principle.

Editorial Work:	**TÜV SÜD Rail GmbH** **Schützenstraße 15-17** **10117 Berlin** **Germany** **TÜV Rheinland AG** **Am Grauen Stein** **51105 Cologne** **Germany**	**TÜV NORD Systems GmbH & Co.KG** **Große Bahnstraße 31** **22525 Hamburg** **Germany**

List of appendixes

Appendix 1 Abbreviations, defintions and terms

A) Abkürzungen

ARGE	Arbeitsgemeinschaft-Brandbekämpfungstechnik – Consortium – Fire detection technology
BBA	Brandbekämpfungsanlage – Fire suppression system
BLA	Brandlöschanlage – Fire extinguishing system
BMA	Brandmeldeanlage – Fire detection system
BMZ	Brandmeldezentrale – Fire alarm receiving station
RILI	Richtlinie - Guideline
TSI	Technical Specification for Interoperability
UIC	UNION INTERNATIONALE DES CHEMINS DE FER - International Union of Railways

B) Definitions and terms

Refer to **EN ISO 13943** Fire safety – Vocabulary.

Areas with technical equipment	Places of installation separated from passenger and staff areas for electrical installations or machinery, which are not intended to be accessible to passengers. These areas or containers housing electrical or electronic components or equipment requiring monitoring such as batteries, fire load carrying systems or engines.
Concentration of the extinguishing medium	Actual necessary concentration of an extinguishing medium in the atmosphere of a fire area to ensure a successful extinguishing (see standards EN 15004).
Cross Acceptance	Mutual agreement of assessments or certificates with the same intention.
Fire extinguishing	Fire protection system for areas with technical equipment, combustion engines. The fire must be completely extinguished to reduce the necessary emergency scenarios to technical failures e. g. in underground transportation systems.
Fire suppression	Fire protection system for passenger and staff areas, toilets or driver cabinets. Fire incidents are reduced to their ignition source, the environmental temperature conditions are kept at an acceptable level for survival and the toxic gas concentration is minimized. The fire suppression system must ensure that passenger and staff can stay in the vehicle until a place of relative safety is reached and an evacuation is possible.

Fire object	A combustible fire load in immediate environment of an available ignition (fire starter) which can be actively included into the fire process by a temporary energy supply (highly flammable), or only by means of a permanent energy supply (flame retardant).
Fire risk analysis	By analyzing failure impacts (e. g. technical failures), the risk of a fire development and the resulting fire impacts are estimated. The evaluation is based on qualitative criteria.
Flow condition	Operation-related air flow situation in a separated area (e. g. static or dynamic ventilation), or an outside area.
Ignition load, fire load	A fire load affected by an ignition source which is required and arranged for further ignition of objects.
Ignition source	Source of energy that initiates combustion and ignitable materials.
Luggage	Fire load defined for the vehicle interior, which determines the dimensioned fire for assessing the fire protection design.
Mechanical equipment	Technical or drive system installed in, under or on railway vehicles.
Minimum design concentration	Extinguishing concentration which ensures a successful extinguishing plus safety value.
Place of installation	Room or enclosure to house technical equipment such as technical cabinets, equipment containers, roof interior.
Places of relative safety	Places, in which the residual health risk for persons is acceptable and direct danger is excluded. This is usually achieved by a fire suppression system. So, the fire incident will be suppressed and impacts will be limited. Passenger and staff still can be in the immediate environment of the area affected by the fire.
Places of ultimate safety	Places, in which impacts of fire incidents do not endanger persons health.
Railway standards	Verified characteristic of a technical system, which is applicable in railway vehicles.
Railway vehicles	These include all track-guided vehicles, such as railways, tramways, cable railways, mine railways and magnetic levitation railways.
Reference fire load	An object fire load defined in its type, mass and dimensions (in contrast to the usual, possibly variable fire loads) which allows for uniform basic conditions for analyzing purposes.
Track guided vehicles	These include railway vehicles, magnetic levitation vehicles, track guided buses and passenger transport systems.

UIC paper cushion	For railway technology, it is a common available ignition source with a burning time between 2 and 3 minutes. The mass is 100 g in the form of seven paper wads kept together by means of a paper sheet are taken. The grammage is approximately 50 g/m².

Appendix 2 Information on reference fire load "luggage"

Design fire "luggage".
Defined size of the travel bag (standard cloth bag medium size: 0.40 x 0.30 x 0.30 m³).

The travel bag has the following content:

	Composition	**$M_{travel\ bag}$ [g]**
travel bag	100 % nylon	600
sweater vest	100 % polyacrylate	300
2 sheets	100 % cotton	1,000<
toothbrush cup	100 % polyethylene	25
newspaper	100 % paper	200
rubber boot	cotton, polyvinyl chloride	900
1 standard wood		300
total mass		3,400
*alignment with R-32		

Example of a packed travel bag

Reference fire load "foam cushion":

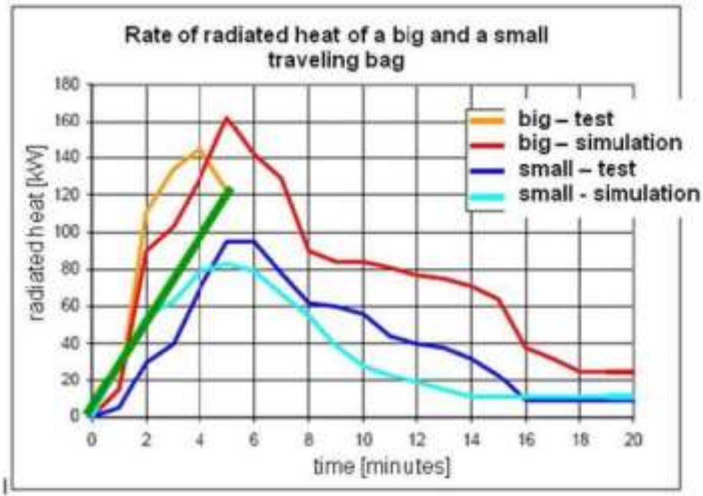
- material polyurethane foam
- densitiy 25 to 35 kg/m³
- size 40 x 40 x 10 cm.

Basic information:

In 2003, in connection with the project "passenger area fire tests", preliminary tests to determine the reference fire load were performed in the SBI (Single Burning Item) room of the fire testing institute - Material Research Centre Leipzig (MFPA). These tests were accompanied by the experts Mrs. Helbig (Expert office Katrin Helbig), Dr.-Ing. Heyn (TÜV SÜD Rail) and Mr. Wilk (Fire Protection Consult Leipzig) and documented in the "Report on the fire tests of travel bags and equivalent model arrangements", 11-24-2003.

For the fire object "luggage" the design fire is defined as follows, based on tests:

- **continuously increasing heat release rate up to at least 120 kW after 5 min**
- **minimum fire load of the bag of 136 MJ with a calorific value of at least 21 MJ/kg**
- **ignition source is 100 g of newspaper (acc. to. UIC 564-2) placed on top of the bag**



evaluation base for fire analysis - design fire "luggage"
- continuously increasing heat release rate up to at least 120 kW after 5 min
- minimal fire load of 136 MJ (calorific value approx. 21 MJ/kg)
- ignition source is a 100 g paper cushion

travel bag

$Q_{(bag\ -\ V7)}$=23 MJ

foam blocks without cotton cover

$Q_{(cushion\ without\ CC\ -\ V16)}$= 20 – 26 MJ

foam blocks with cotton cover

$Q_{(cushio\ with\ CC\ –\ V6)}$= 33 – 36 MJ

The design fire "luggage" is a realistic fire scenario in a passenger train and meets the requirements in EN 45545-1, Appendix A "Ignition models".

Typically assumed ignition models according to EN 45545-1:

Ignition model 1:

This represents a typical ignition source due to arson and vandalism, for example newspaper or rubbish.

The ignition model is a flaming source of 3 min duration and average power output of 7 kW generating a flux of 25 kWm^{-2} to 30 kWm^{-2}.

Ignition model 2:

This represents the effect of an early developing fire on surfaces near to the fire, for example horizontal surfaces of seats and floors. The ignition model is a radiant flux nominal value 25 kWm^{-2} applied to an area of 0.1 m^2.

Ignition model 3:

This represents the effect of a more developed fire than ignition model 2 or the effect of a developing fire on surfaces above or alongside the fire, for example wall and ceiling surfaces. The ignition model is a radiant flux of nominal value 50 kWm^{-2} applied to an area of 0.1 m^2.

Ignition model 4:

This represents the effects of arcing, for example resulting from the normal operation of high power electrical equipment (where Type A arc barriers would be required as set out EN 45545-5) and low power electronic equipment faults. The ignition model is a flaming source of power 1 kW and 30 s duration.

Ignition model 5:

This represents fires which are more severe than ignition models 1 to 4, for example luggage fires, and arson. For these fires the ignition model is a flaming source generating a radiant flux of nominal value in the range of 20 kWm^{-2} to 25 kWm^{-2} applied to an area of 0.7 m^2 with an average power output of 75 kW for a period of 2 min followed immediately by a flux of nominal value in the range 40 kWm^{-2} to 50 kWm^{-2} applied to the same 0.7 m^2 area with an average power output of 150 kW for a period of 8 min.

Appendix 3 Room conditions to be ensured

To ensure a place of relative safety – common area for a defined period of time meeting all requirements for health – the values shown in Table 1 "Evaluation data and reference values for quantitative protective aims" must not be exceeded.

According the values shown in Table 1, the measuring points must have a horizontal distance of 2 m to the ignition source and must be set in the middle of the escape in a height of approx. 1.6 m (position of the respiratory system in dependence on DIN EN 547 regarding the situation of the European population).

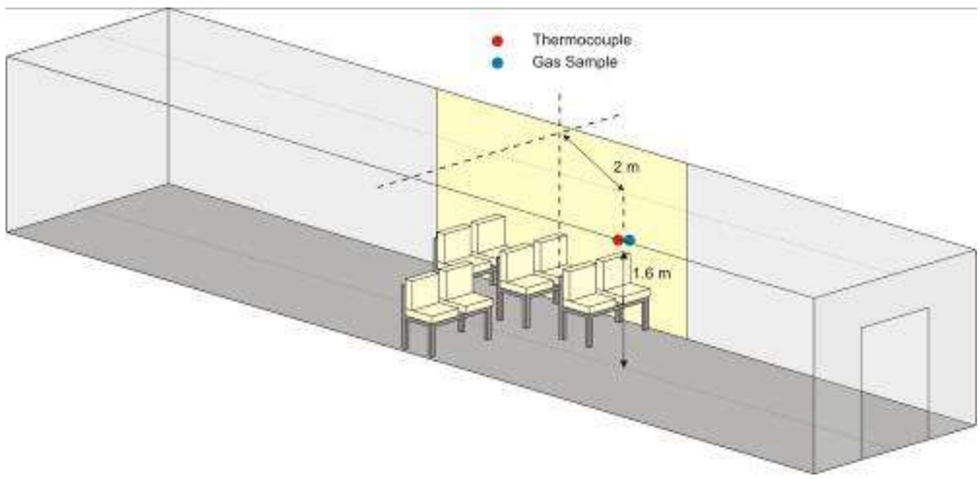


Figure 4: Drawing – Measuring points for a fire test

Appendix 4 Template F-1 “Test documentation – extinguishing technology”

Order No.:	**Document No.:**	**Number of appendixes:** (depends on number of performed tests)

<table>
<tr><th colspan="2">Parameters</th><th colspan="2">Specifications</th></tr>
<tr><td colspan="2">Vehicle type</td><td colspan="2">e. g. electric locomotive</td></tr>
<tr><td colspan="2">Vehicle design type</td><td colspan="2">e. g. RE 484</td></tr>
<tr><td colspan="2">Vehicle no.</td><td colspan="2"></td></tr>
<tr><td colspan="2">Operation category, design category</td><td colspan="2">BSS X, category</td></tr>
<tr><td colspan="2">Fire fighting system (type)</td><td colspan="2">gas extinguishing system</td></tr>
<tr><td colspan="2">Fire extinguishing medium (type)</td><td colspan="2">type x</td></tr>
<tr><td colspan="2">Manufacturer/type of system</td><td colspan="2">company x/type y</td></tr>
<tr><td>Objection</td><td>direct safety of passengers and staff
☐</td><td>indirect safety of passengers and staff
☒</td><td>object safety
☒</td></tr>
<tr><th colspan="4">Comments on the test, note, established deficits</th></tr>
<tr><td colspan="4">“punctual fluid accumulation“</td></tr>
<tr><td colspan="4">“system fault, cause is determined and corrected, include in maintenance manual”</td></tr>
</table>

	yes	in parts	no
Requirement fulfilled	☒	☐	☐
Additional tests are required	☐		☒

Tested:	**Responsibility:**	**Name:**	**Signature:**
Location: x-x-x Date: xx.yy.zzzz	expert for railway vehicle equipment:		
	responsible system engineer for fire detection technology:		
	expert/assessor for fire protection systems in railway vehicles:		

Appendix 5 Template F-2.1 "Test documentation – common area"

<table>
<tr><td colspan="3">F-2.1 Documentation – passenger and staff areas</td></tr>
<tr><td colspan="3">Principles:
• The applied extinguishing medium may not develop, contain or release substances which cause a danger to health during fire suppression.
• The fire impacts must be kept to an acceptable minimum.</td></tr>
<tr><td>Order No.:</td><td colspan="2">Document No.:</td></tr>
<tr><td>Test no.</td><td colspan="2">Xyz</td></tr>
<tr><td>Testing time</td><td colspan="2">xx:xx on yy.yy.yyyy</td></tr>
<tr><td>Test object</td><td colspan="2">passenger compartment</td></tr>
<tr><td>Basic test conditions</td><td>model ☐</td><td>vehicle/component ☒</td></tr>
<tr><td colspan="3">Description of the test</td></tr>
<tr><td>System design</td><td colspan="2">description, functional flow diagram</td></tr>
<tr><td>Test area</td><td colspan="2">drawing with geometric information, vehicle layout, 3D-figure of converter</td></tr>
<tr><td>Position of the simulated ignition source</td><td colspan="2">view of fire risk positions (possibly photos)</td></tr>
<tr><td>Arrangement of the measuring points</td><td colspan="2">identification of the measuring points for gas sampling to assess compliance with protective aims</td></tr>
<tr><td>Duration of fire suppression</td><td colspan="2">XX min
• at least 10 min, in case of deviation an assessment of compliance with protective aims is required</td></tr>
</table>

ARGE Guideline - Part 2
“Fire fighting in railway vehicles”

1. Basic test “2 foam cushions”, Ignition with UIC paper cushion, pre-burn time: 60 s		
Time of release of fire extinguishing medium	xx seconds after system activation	
Are the room conditions (Appendix 3) with a distance of 2 m not exceeded?	Yes ☐	No ☐
Is there an overlapping area of 2 m?	Yes ☐	No ☐
Uniform mist concentration or distribution of extinguishing media	Yes ☐	No ☐
2. Basic test “2 foam cushions”, Ignition with UIC paper cushion, pre-burn time: 60 s		
Time of release of fire extinguishing medium	xx seconds after system activation	
Are the room conditions (Appendix 3) with a distance of 2 m not exceeded?	Yes ☐	No ☐
Is there an overlapping area of 2 m?	Yes ☐	No ☐
Uniform mist concentration or distribution of extinguishing media	Yes ☐	No ☐
3. Confirmation test “luggage”, Ignition with UIC paper cushion, pre-burn time: 120 s		
Time of release of fire extinguishing medium	xx seconds after system activation	
Are the room conditions (Appendix 3) with a distance of 2 m not exceeded?	Yes ☐	No ☐
Is there an overlapping area of 2 m?	Yes ☐	No ☐
Uniform mist concentration or distribution of extinguishing media	Yes ☐	No ☐
4. Confirmation test “luggage”, Ignition with UIC paper cushion, pre-burn time: 120 s		
Time of release of fire extinguishing medium	xx seconds after system activation	
Are the room conditions (Appendix 3) with a distance of 2 m not exceeded?	Yes ☐	No ☐
Is there an overlapping area of 2 m?	Yes ☐	No ☐
Uniform mist concentration or distribution of extinguishing media	Yes ☐	No ☐

Comments on the test, note, established deficits
for example “very good system solidity”

	yes	in parts	no
Requirement fulfilled	☒	☐	☐
Additional tests are required	☐		☒

Tested:	Responsibility:	Name:	Signature:
Location: x-x-x Date: xx.yy.zzzz	expert for railway vehicle equipment:		
	responsible system engineer for fire detection technology:		
	expert/assessor for fire protection systems in railway vehicles:		

Appendix 6 Template F-2.2 "Test documentation – areas with technical equipment"

F-2.2 Documentation – areas with technical equipment		
Principles: • A fire in areas with technical equipment must be completely extinguished, if the vehicle cannot reach a completely safe area for the self-rescue of passengers. • Before activating the fire extinguishing system the relevant technical equipment must be shut down.		
Order No.:	**Document No.:**	
Test no.	Xyz	
Testing time	xx:xx on yy.yy.yyyy	
Test object	passenger compartment	
Basic test conditions	model ☐	vehicle/componente ☒
Description of the test		
System design	description, functional flow diagram	
Test area	drawing with geometric information, vehicle layout, 3D-figure of converter	
Position of the simulated ignition source	view of fire risk positions (possibly photos)	
Arrangement of the measuring points	identification of the measuring points for gas sampling to assess compliance with protective aims	

1. Gas extinguishing media		
Time of release of fire extinguishing medium	xx seconds after system activation • at most 10 sec nach Aktivierung des Systems	
Beginning minimum extinguishing concentration	after xx seconds • for liquefied, gaseous extinguishing media within 20 s after system activation • for non-liquefied, gaseous extinguishing media within 120 s after system activation	
Is the minimum design concentration achieved?	Yes ☐	No ☐
Beginning minimum extinguishing concentration	xx seconds after beginning minimum extinguishing concentration • for liquefied, gaseous extinguishing media at least 30 s	

	• for non-liquefied, gaseous extinguishing media at least 180 s	
Is the retention time kept?	Yes ☐	No ☐
Are further dynamic tests required?	Yes ☐	No ☐
Is a fire pan available?	Yes ☐	No ☐
2. 2. Water mist systems or **systems using other extinguishing media which are not gaseous**		
Time of release of fire extinguishing medium	xx seconds after system activation • at most 10 s after system activation	
Is the determined application time achieved?	Yes ☐	No ☐
Is there a uniform distribution of extinguishing media?	Yes ☐	No ☐
Is extinguishing successful?	Yes ☐	No ☐
Applications with combustion engines		
Spray fire (leakage 0.0033 l/s) Is simulation necessary?	Yes ☐	No ☐
Spray fire (leakage 0.0033 l/s) Is extinguishing successful?	Yes ☐	No ☐
Pool fire under the engine (surface at least 1 m^2, is extinguishing successful?	Yes ☐	No ☐
Pool fire on the engine (surface at least 0.25 m^2, heat release 347 kW, pre-burn time 30 or 60 s) is extinguishing successful?	Yes ☐	No ☐
Applications in areas with electric equipment "developing fire"		
Developing fire Is extinguishing successful?	Yes ☐	No ☐
Applications in areas with electric equipment "container fire"		
Container fire Is simulation necessary?	Yes ☐	No ☐
Container fire Is extinguishing successful?	Yes ☐	No ☐

Comments on the test, note, established deficits
for example "very good system solidity"

	yes	in parts	no
Requirement fulfilled	☒	☐	☐
Additional tests are required	☐		☒

Tested:	Responsibility:	Name:	Signature:
Location: x-x-x Date: xx.yy.zzzz	expert for railway vehicle equipment:		
	responsible system engineer for fire detection technology:		
	expert/assessor for fire protection systems in railway vehicles:		

Appendix 7 Requirements for the assessment

1. Concept description regarding safety and functional requirements (control system for fire fighting systems) which have to be fulfilled, based on purchase requisitions (e. g. specification).
2. Description of hardware, circuit diagrams, system layout and information on the used components and materials in terms of a project description.
3. Certificates by other accredited test centers and certification bodies (declaration of conformity/certificate of conformity), while for all standards mentioned a document or a statement based on test report must be available, for e. g.:
   - EN 12094 (Fixed fire fighting systems – Components for gas extinguishing systems)
   - EN 15004 (Fixed firefighting systems – Gas extinguishing systems)
   - ISO 16003, Components for fire-extinguishing systems using gas – Requirements and test methods - Container valve assemblies and their actuators; selector valves and their actuators; nozzles; flexible and rigid connectors; and check valves and non-return valves, (September 2008)
   - The stability of pressure purposes according to Directive 2010/35/EU, 2014/68/EU and Directive (EU) 2016-797.
4. Instruction manual which is relevant for safety.
5. Necessary documentation must be defined regarding
   - requirements for the professional system installation
   - instructions for approval and quality tests on production vehicle
   - deviations to EN 12094 and EN 15004 for gas extinguishing systems.

   Especially the following technical sub-systems are involved:
   - The pipe network must be made of stainless steel, but the connecting hoses (e. g. between vehicles) must meet the requirements given in EN 12094.
   - The energy for electrical systems can be supplied by the vehicle electrical system, but the electrical supply by the battery must ensure a redundancy.
   - The pneumatic activation can be supplied by the pneumatic vehicle electrical system, including a surge drum which ensures the function.
   - If a mechanic and pneumatic activation system activates fire fighting with a gas extinguishing system due to temperature influence, the activation system can be a extinguishing pipe.

Appendix 8 Specification for positioning fire extinguishing equipment in enclosed places of installation/technical cabinets

For arranging outlets of extinguishing media for example nozzles and nozzle strips note the following aspects, with regard to possible obstructions, spatial separations or leakages in the area of fire:

Recommendations:

- In the area affected by the fire, the discharge of extinguishing media should be possible without any obstructions.
- The discharge of extinguishing media should be near the potential fire risk.
- The nozzles must be fixed in a sufficient distance to mounting holes/bushings/position holes.
- The discharge of extinguishing media is pressurized and must not negatively influence the area or its content.

Gas extinguishing systems

- Gas nozzles must be adjusted downwards above the extinguishing media because the gas sinks in the fire area.
- For development or distribution of the gas, a sufficient distance of more than 15 cm between discharging beam or discharging cone and any deflecting surface is necessary.

Water mist systems

- For the development of a uniform water mist, a distance of more than 30 cm to the deflecting surfaces has to be provided.
- Water spray nozzles can be installed independently of direction, but a direct injection into the potential fire area should be achieved.

Appendix 9 Members (ARGE)

AQUASYS Technik GmbH

Diehl Aviation Gilching GmbH

Fritz Rensmann GmbH & Co. KG

FOGTEC Brandschutz GmbH & Co. KG

IFAB GmbH

IME Elektrotechnik GmbH

KIDDE-DEUGRA Brandschutzsysteme GmbH

TÜV NORD Systems GmbH & Co. KG

TÜV Rheinland AG

TÜV SÜD Rail GmbH

WAGNER Rail GmbH / Schweiz AG

Consortium meetings	Date	Location
Coordination – Kick Off (content)	06-2008	by phone
1st consulation – Technical dicussion in working groups	08-19-2008	Hamburg + Munich
2nd consulation – Discussion of technical content	09-242008	Berlin
Coordination – Conference call	11-14-2008	by phone
Final information	12-01-2008	by E-Mail
3rd consulation – Update and revision	11-19-2009	Ahrensburg
4th consulation – Update and revision	06-19-2012	Berlin
5th consulation – Update and revision	2013	Cologne
6th consulation – Revision	2018	Munich-Haar and Dortmund