DOI: 10.36137/2015E

Materials and Products that do not Meet Fire Protection Requirements but Are Permitted for Use in Rolling Stock Due to Functional Necessity

Izabela TARKA[1], Danuta MILCZAREK[2], Aneta ŚWIETLIK[3]

Summary
Ensuring fire safety in rolling stock is related to the use of materials and products that meet the required fire properties presented in particular in the EN 45545-2 standard. However, there are situations in which the fire protection guidelines cannot always be met due to other requirements, e.g. those related to the safe use of the material or component or its functionality in the vehicle. This paper outlines the principles enabling materials/products to be approved for use in rolling stock in such cases, based on the functional necessity of their application according to clause 4.7 of EN 45545-2. The possibilities of approving components under this clause should be subject to thorough analysis to ultimately determine the risk of their use, in accordance with the principles of the Common Safety Method relating to risk evaluation and assessment.

Keywords: fire safety, specified materials, risk evaluation and assessment

1. General Fire Safety Requirements for Materials/Products

The dynamic development of rail transport forces rolling stock manufacturers to use increasingly new technical and material solutions. This is closely tied to the need to ensure safety, including fire safety. Fire protection is therefore a broad concept related to the prevention and suppression of fires. The primary concern is the protection of life, health, property, and the environment from fire. The great emphasis on safety in means of rail transport has resulted in an intensive development of requirements and methods in this area, which in turn has spurred the advancement of materials and products. These requirements are intended to specify measures for, among other things: the prevention, formation and spread of fire, the provision of forces and means to fight fire [1–5].

The key documents detailing the specific requirements for fire protection in rolling stock are:

- Commission Regulation (EU) 1302/2014 of 18 November 2014 [6], and
- Commission Regulation (EU) No 1303/2014 of 18 November 2014 [7].

Fire protection measures and the relevant requirements are specified in the EN 45545 series of standards (seven parts), which are designed to protect passengers and staff in rolling stock in the event of an on-board fire. These measures are intended to reduce the likelihood of fire, reduce the speed and extent of flame spread, and consequently minimise the impact of fire products on passengers and staff. As stated in the first part of the EN 45545 standard [8], the protection of passengers and staff is primarily achieved through actions that:

- prevent fires caused by technical failures and design errors in vehicle equipment,
- minimise the likelihood of ignition of materials used in railway vehicles due to defects, accidents or vandalism,
- detect the occurrence of fire,
- limit the spread of fire by using materials according to their operational categories and providing means for limiting the spread of fire,
- minimise the effects of fire, taking into account the effects of heat, smoke and toxic gases on passengers and staff, by specifying requirements for different groups of materials installed in rolling stock,

[1] M.Sc. Eng.; Railway Research Institute, Materials and Structure Laboratory; e-mail: itarka@ikolej.pl.
[2] M.Sc.; Railway Research Institute, Materials and Structure Laboratory; e-mail: dmilczarek@ikolej.pl.
[3] M.Sc. Eng.; Railway Research Institute, Materials and Structure Laboratory; e-mail: aswietlik@ikolej.pl.

- control and contain the fire through early detection, suppression, or emergency power cut-off.

The primary objective of effective fire protection in the event of a fire on a railway vehicle is to enable passengers and staff to evacuate and reach a safe location (this does not necessarily mean that the non-metallic materials used must be non-combustible).

Materials used for the construction and equipment of railway vehicles according to the specifications listed must meet the requirements of EN 45545-2 [9, 10] in terms of the "operation category":

- operation category 2 – for category A passenger rolling stock (including passenger locomotives),
- operation category 3 – for category B passenger rolling stock (including passenger locomotives),
- operation category 3 – for freight locomotives and self-propelled railway vehicles designed to carry other payloads (mail, freight, etc.),
- operation category 1 – for track machines, whereby the requirements are limited to the areas accessible to staff when the unit is in transport configuration.

Depending on the operational and design category of the vehicles, the materials used in their construction and equipment are assigned an appropriate HL (*hazard level*) according to EN 45545 clause 4.1 [9, 10]. The required levels are shown in Table 1.

The data presented in Table 1 shows the relationship between the fire hazard level (HL) and both the operation and design categories of the rolling stock.

For a given HL level, Table 5 in the EN 45545-2 standard [9, 10] lists the required values for various fire and smoke parameters, specified in sets of requirements labelled with symbols R. According to these requirements, non-metallic materials intended for installation in railway vehicles are classified into:

a) Listed products, for which sets of requirements from R1 to R28 are defined, in accordance with Table 2 of the aforementioned standard. This table outlines the sets of requirements assigned to spe-

Table 1

Required fire hazard levels for individual rolling stock types [9, 10]

Operation category	Design category			
	N: Standard vehicles	**A: Vehicles forming part of an automatic train having no emergency trained staff on board**	**D: Double deckeed vehicles**	**S: Sleeping and couchette vehicles**
1	HL1	HL1	HL1	HL2
2	HL2	HL2	HL2	HL2
3	HL2	HL2	HL2	HL3
4	HL3	HL3	HL3	HL3

Table 2

Selected extracts from Table 2 of the standard [9, 10]

Product no.	Name	Detailed information	Requirement
IN	**Interiors**	–	–
IN1A	Interior vertical surfaces	Interior components (structure and covering) such as side walls, front/end walls, partitions, room dividers, flaps, boxes, hoods, louvres. Interior doors, interior lining of the front/end wall doors and external doors. Windows (including plastics and glazing). Insulation material and interior surface of body shell. Kitchen interior surfaces (except those of kitchen equipment).	R1
IN3B	Light diffusers	For example, polycarbonate diffusers, light coverings for lamps. Light units themselves and indicators are not within the scope of INBB.	R4
IN15	Floor composites	The floor composites include the floor substrate (together with any thermal insulation) and floor covering (together with any fixings or adhesives applied in end use conditions).	R10 or R28 according to 5.3.1.2
IN16	Interior seals	Longitudinal seals such as window seals, door joints and panel connections.	R22

Table 2

Product no.	Name	Detailed information	Requirement
F	**Furniture**	–	–
F1	Complete upholstered seats in passenger areas	Complete passenger seat including seat shell, upholstery, arm and head rests. Tip-up seats and staff seats (if accessible to passengers) are also included. Details of seat tests (including the conditions for vandalism testing) are given in EN 16989.	R18
E	**Electrotechnical equipment**	–	–
EL1A	Cables for interior	Cables not compliant with one of the standards referenced in 4.2c.	R15
EL6A	Supply line system and high power devices – used Interior	Isolators, current and voltage transformers, main circuit breakers; contactors.	R22
EL9	Printed circuit boards	Printed circuit boards with all varnishes applied but without any attached technical equipment.	R24 or R25 or R26
EL10	Low power electrotechnical and electronic products	Examples include low power circuit breakers, overload relays, contactors, contactor relays, switches, control or signalling switches, terminals, fuses.	R26
M	**Mechanical equipment**	–	–
M1	Flexible metal/rubber units	Flexible metal/rubber units including elements in bogies.	R9

cific, detailed products, considering their location and function within the vehicle.

b) Non-listed products for which specific sets of requirements depend on the exposed area of such a product and its location (Table 3).

Table 3

Requirements for non-listed products [9, 10]

Exposed area	Location	Requirement set
> 0.20 m²	interior	R1
> 0.20 m²	exterior	R7
≤ 0.20 m²	interior	R22
≤ 0.20 m²	exterior	R23

Materials not listed in EN 45545-2 [9, 10] can also be assessed according to the grouping rules described in clause 4.3 of the standard.

The sets of requirements R1 to R28 are closely linked to the test methods according to which tests must be carried out for the specific application of the material or product. Table 4 presents an example set related to R1 requirements from standards [9, 10] with the specified limit values of fire parameters.

The example (Table 4) relates to a set of requirements assigned to materials that are very commonly used in the construction and furnishing of rolling stock: elements of internal surfaces, enclosures, panels, gangways, displays, roller shutters, etc.

Table 4

Example set of R1 requirements according to Table 5 of the [9, 10] standards

Requirement set (listed product)	Test method reference	Parameter Unit	Maximum or minimum	HL1	HL2	HL3
R1 (IN1A; IN1B, IN1D; IN1E; IN4; IN5; IN6A; IN7; IN8; IN9B; IN11; IN12A; IN12B; IN14; EX4A, F5)	T02 ISO 5658-2	*CFE* [kW·m^{-2}]	Minimum	20a	20a	20a
	T0·3.01 ISO 5660-1: 50 kW·m^{-2}	*MARHE* [kW·m^{-2}]	Maximum	–	90	60
	T10.01 EN ISO 5659-2: 50 kW·m^{-2}	$D_s(4)$ no unit	Maximum	600	300	150
	T10.02 EN ISO 5659-2: 50 kW·m^{-2}	*VOF4* min	Maximum	1200	600	300
	T11.01 EN 17084 Metoda 1: 50 kW·m^{-2}	CIT_G no unit	Maximum	1.2	0.9	0.75

2. Possibility of Approving the Use of Materials/Products in Railway Vehicles That Do Not Meet the Required Fire Properties Due to the Functional Necessity of Their Application

Materials and products intended for rolling stock must meet various operational requirements. As a result, the fire protection guidelines contained in the EN 45545-2 standards [9, 10] cannot always be met if other requirements (e.g., related to the safe use of the material or component) prevent their fulfilment. In such a case, clause 4.7 of the EN 45545-2 standard [9, 10] provides the possibility of approving those components that do not meet the requirements specified in clauses 4.2 to 4.5 of the EN 45545-2 standards [9, 10] due to their superior functional properties. However, for the sake of maintaining the fire safety of rolling stock, the ill-considered and hasty use of accepted products should be avoided. To prevent this, it has become necessary to define detailed guidelines for analysing these materials and methods for their verification. This is intended to enable the legal use of such components and to limit the misinterpretation of this clause.

The exact definition and resulting requirements for the applicability under clause 4.7 of EN 45545-2 [9, 10] are stated as follows:

"If it can be shown that any of the requirements specified above are not technically achievable with functionally suitable products, then existing commercially available products can be used until and unless a suitable product is developed. There shall be no requirement to consider products made available after the date of the contract. The use of this paragraph has the following conditions:

- essential requirements in 4.1 shall not be compromised;
- this shall be verified by assessment; taking the proposed design into consideration; including the functional reason and limitation for using the material in question (e.g. climate and/or infrastructure)".

The cited provision is quite general, therefore, to facilitate the correct interpretation of clause 4.7 [9, 10] and avoid the unjustified use of certain materials in rail vehicles that do not meet the requirements of the EN 45545-2 standard [9, 10], the body representing notified bodies for the Railway Interoperability Directive has prepared a document entitled "NB-RAIL (*Notified Bodies* – RAIL) Recommendations, so-called Recommendations for Use (RFU) RFU RST-313 « Use of EN 45545-2 § 4.7 for products that do not require to be compliant»" [11]. This document details the proper procedure for applying clause 4.7 of the EN 45545-2 standard [9, 10] in order to accept the fire performance of materials and components to be used in the construction of rail vehicles due to their functional necessity. When accepting products (which do not meet the required fire parameters) for use, it is essential to consciously assess the risk associated with their implementation. Therefore, the RFU RST-313 document [11] adopts the risk management approach specified in the CSM-RA Regulation (*Common Safety Method for risk evaluation and assessment* – a colloquial term for Regulation No 402/2013 [12]). This regulation emphasises the need to assess the potential impact of changes on the safety of the railway system (the change is related to the introduction of products that meet the functional parameters but do not meet the required fire properties of the EN 45545-2 standards) [9, 10]. The RFU provides a step-by-step analysis scheme for the applicability of clause 4.7 of the standards [9, 10], which is shown in Figure 1.

In the first step of the analysis, the component that is to be used due to functional necessity must be thoroughly characterised. For this purpose, it is essential to provide the following information:

- a description of the functions performed by the component,
- a description of the area where the component will be installed,
- a description of the intended accessibility of the component's application area for personnel, passengers, and third parties.

The frequency of maintenance or replacement of the component during the vehicle's operation should also be considered.

In the second step, the appropriate sets of requirements (from R1 to R28) applicable to the specific use case of the component must be determined, as specified in clauses 4.2 and 4.3 of the EN 45545-2 standard [9, 10]. According to these requirements, fire property test results obtained for these components must be presented. Positive results are the basis for approving the product for use. If the required fire properties are not met, the component supplier shall conduct a market analysis to search for alternative components that meet all the necessary requirements. Therefore, conducting a market analysis regarding the possibility of using an alternative product is a crucial step in considering the application of clause 4.7. The alternative component should meet the requirements identified as functionally essential. The selection of alternative components available on the market requires the presentation of documented proof of their suitability. It is necessary to verify the properties of components and the quality control system with the suppliers.

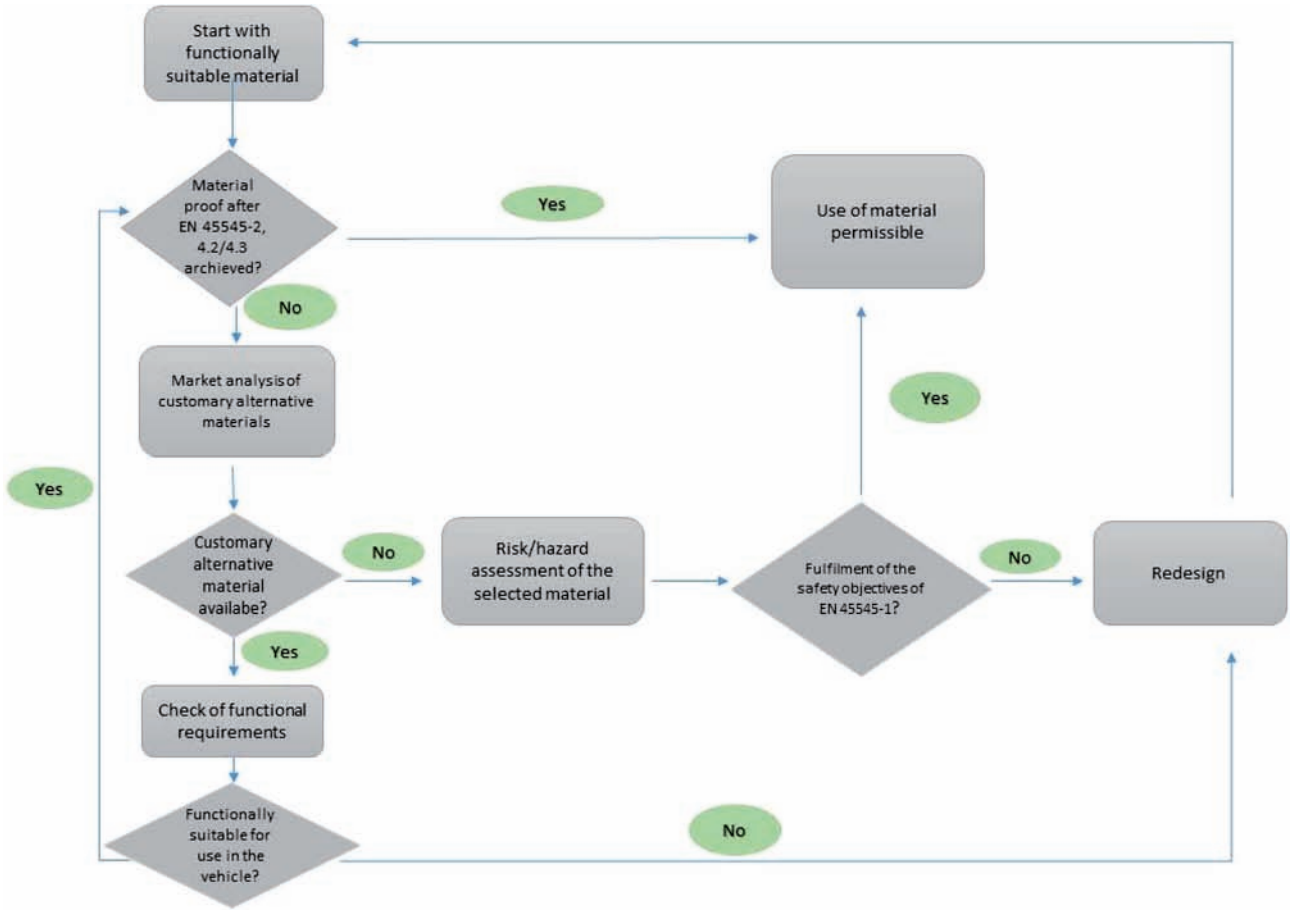

Fig. 1. Scheme for analysing the applicability of clause. 4.7 of the standards [9, 10]

After confirming the required functional parameters of the component, the components in question should be checked for compliance with the EN 45545-2 standard [9, 10]. The manufacturer should query suppliers with representations or distributors or distribution possibilities in the European Economic Area, from which the fulfilment or partial fulfilment of the component specification can be assumed. When analysing the suitability of alternative materials, the following proofs for the functional requirements have to be requested:

- test results of fire protection tests of the material,
- results of the tests of the defined functional requirements.

If the manufacturer/distributor of a component that meets the functional requirements but does not meet the required fire properties demonstrates that, after market analysis, it has not been possible to find an alternative component for which compliance with the requirements for each of these areas can be confirmed, a risk analysis for approving the use of the component in question must be conducted. The evaluation method used to assess the risk of using the component must comply with the guidelines of CSM-RA (EU) 402/2013 [12] and standards such as EN IEC 60812 [13] or EN 50126-1 [14]. To confirm the possibility of using a functionally necessary component in the construction of rolling stock, the assessment must include, among other things, the following data and information:

1. Definition of safety objectives according to EN 45545-1 [8]. Clause 4.1 of this standard states that the objectives of fire protection are to minimise the likelihood of fire, to control the rate and extent of fire spread and, as a result, to minimise the impact of fire products on passengers and staff. These objectives are considered in the context of the operation and design categories of the rolling stock. If the objectives set out in clause 4 of the EN 45545-1 standard [8] are met, there should be a high probability that, in the event of fire, passengers and staff will be able to independently evacuate and reach a safe location. The scope of the EN 45545 series of standards does not include measures which ensure the preservation of vehicles in case of fire and which go beyond what is necessary for the protection of passengers and staff.

2. Operation and Design categories of the vehicle and the derived hazard level.
3. Set of requirements and, if possible, deviations of the obtained fire test results from the limit values.
4. Component description including: functions performed by the component, description of the area of installation of the component and accessibility of the area of use to staff, passengers and third parties.
5. Demonstration of the fire behaviour of the components in the form of an analysis of the results of already performed fire tests (national or European fire safety standards).
6. Description of a potential ignition source (pursuant to EN 45545-1 [8]) located in the installation area of the functionally necessary component.

With regard to the performance of the risk and hazard analysis for the component under consideration, the relevant fire risk with the associated following ignition models should be taken into account:

- Accidental ignition or arson – this type of fire typically includes ignition of the component by newspapers, cigarettes and gas lighters. Normally, these areas are freely accessible to passengers, staff and third parties. For this case, ignition models 1 and 2 should be considered in accordance with Annex A of EN 45545-1 [8].
- Technical defect – this type of fire typically involves the ignition of a component by an electrical defect and thus an overheating of the component. In this case, ignition models 3 and 4 should be considered in accordance with Annex A of EN45545-1 [8].
- Major fire events – this type of fire event is larger than those described in clause 3.4.1 and 3.4.2 incipient fires of the EN45545-1 standard [8]. In this case, the ignition model 5 should be considered in accordance with Annex A of the above-mentioned standard.
- Identification of risk minimisation measures – for example, using a non-combustible enclosure and a fire detection or extinguishing system in the component's installation area.

The fire risk analysis for a component should be carried out based on the provisions of EN 50126-1 [14] and EN IEC 60812 [13]. In doing so, the following parameters are determined and quantified:

- the event's severity/meaning (*Severity, S*) (similar to the degree of the hazard or its consequences);
- the event's occurrence/probability of occurrence (*Occurrence, O*) (similar to frequency);
- error detection/probability of detection (*Detectability, D*).

The fire risk analysis is based on qualitative risk analysis, as described in EN 50126-1 [14]. However, to simplify the method, the three mentioned parameters are presented by numbers, which are multiplied to calculate the risk priority number RPN:

$$\mathrm{RPN} = S \times O \times D \qquad (1)$$

Tables 5–7 show the values proposed by RFU RST-313 [11] for the individual degrees assigned to the above-mentioned parameters.

Each of these three parameters is assigned a specific value (grade) according to technical data, failure statistics or analysis by an expert. If the risk priority number RPN determined according to the given formula (1) is greater than the established limit value shown in Table 8 (risk matrix), measures must be taken to minimise the risk.

The presented procedure for analysing the applicability of a component according to clause 4.7 of EN 45545-2 [9, 10] requires a great deal of preparatory work at each stage of the assessment leading to the collection of a significant volume of information on the component's operating principle, area of installation, possible ignition sources and potential failure leading to a fire hazard. As a general rule, the Applicant is responsible for the completeness and consistency of the documents concerning the product. When carrying out the fire risk analysis for a product, the chosen values in the different catego-

Table 5

Classification of the values assigned to the significance indicator S [11]

	Criteria	Grade
Meaning / S	Insignificant; possible minor injury minor damage to the system.	1
	Marginal; minor injury and/or notable environmental threat serious damage to the system(s).	3
	Critical; few fatal accidents and/or seriously injured and/or significant environmental damage, loss of a major system.	5
	Catastrophic; fatal accidents and/or numerous seriously injured and/or serious environmental damage.	10

Table 6

Example reference for the probability of occurrence O [11]

	Criteria	Grade
Probability of occurrence / O	Unlikely; the occurrence is unlikely, but possible. It may be assumed that this danger only occurs in exceptional cases.	1
	Rare; may sometimes occur during life cycle. It is advisable to be aware of occurring danger.	3
	Occasional; may occur more than once. It is expected that danger occurs more than once.	5
	Frequent; will occur frequently. The danger is always present.	10

Table 7

Example reference for the probability of detection D [11]

	Criteria	Grade
Probability of detection / D	High; the incident is identified during formation in time by technology (BMA) or people.	1
	Little; the incident is detected delayed or detected by secondary incidents (e.g. smoke, smell).	3
	Unlikely; the incident is hard to detect.	5

Table 8

Example of value ranges for individual risk categories [11]

	Value range	Category	Consequence
Risk priority number $S \times O \times D$	> 60	Intolerable	Shall be excluded
	60÷31	N60 undesirable	May only be accepted if a risk reduction is practically not feasible and an agreement of both, the railway company and the responsible supervisory authority for safety and security, is available. Note: The IOD 2016/797 includes that the authorisation of a vehicle type/ vehicle can be granted without a railway company (=RU) participating. Therefore, the risk assessment of the RU shall be optional during TSI conformity assessment.
	30÷16	Tolerable	Acceptable with suitable monitoring and with the consent of the railway company.
	5÷1	Negligible	Acceptable without further approval of the railway company.

ries must be justified, the RPN must be determined and it must be verified that this value is within the established limits.

3. Description of material groups accepted out of functional necessity; example of a component accepted out of functional necessity according to clause 4.7 [9, 10] using a risk assessment of their implementation

The note in clause 4.7 [9, 10] lists many products that are likely to have to be approved out of functional necessity due to an inability to meet both functional and fire requirements. These include such products such as "rubber tyres; rubber suspension components; intercommunication gangways, electronics devices on printed board, flexible metal/rubber units; window seals; seals for doors; brake hoses; pneumatic hoses; flexible fuel hoses; high voltage cables; data bus cables, the anti-spall layer for windscreens on the driver's cab, windscreen washer water containers."

Some of these products, including seals, brake and fuel hoses and electrical cables (high voltage and data bus cables), have been refined through technology development and meet the full range of required parameters. What remains problematic is products containing rubber, like metal/rubber components, rubber suspension components and rubber intercommunication gangways. Before the issue of RFU RST-313 [11],

such products were assessed using most of the guidelines contained therein. For example, despite many attempts to adjust the rubber and carbon black mixes intended for the intercommunication gangway rollers, it has not been possible to simultaneously achieve positive results for these products in terms of physical, mechanical and fire performance. According to the test results reported in [15], while the selected mixture labelled CX7 met the required physical and mechanical parameters (e.g. tensile strength, abrasion resistance, ageing resistance, hardness), it did not reach the required hazard level HL2 for the assigned set of requirements R1 and R7 in terms of smoke properties and toxicity. After analysing products of this type commonly available on the market, no product was found to meet the full range of requirements. Analysing the fire hazard for possible ignition sources, these products can be assigned ignition models 1 and 2 per Annex A of EN 45545-1 [8], corresponding to accidental ignition or arson. In this case, the ignition of an element due to its technical defect is impossible (it is not an electrical device) and the location of the products at the ends of the carriages places them away from devices that could be a source of ignition. The required safety objectives outlined in EN 45545-2 clause 4.1 [9, 10] for limiting the spread of fire in the event of ignition and ensuring effective rescue and evacuation measures (visible elements, easily accessible to passengers and staff to extinguish the fire, quick detection of potential fire or smoke) are also met. Based on the analysis, the CX7 compound for intercommunication gangways was approved for use in rolling stock out of functional necessity per clause 4.7 [9, 10].

Currently, a risk analysis must be carried out to implement in rolling stock any products approved by functional necessity under clause 4.7 of the standards [9, 10], as set out in RFU RST-313 [11].

An example of how this procedure can be carried out is presented using an E-Ink matrix employed in displays intended for use inside rail vehicles. The main components of the matrix, made using e-paper technology (specifically E-Ink), are millions of microcapsules about the diameter of a human hair. Each microcapsule is filled with a transparent liquid polymer and dye particles with a diameter of 1 micrometre. The microparticles have a small negative or positive electrical charge. The capsules themselves are also suspended in the liquid, forming a kind of ink. This "ink" coats the electronic circuitry comprising the electrodes that control the display. E-Ink technology is commonly referred to as bistable. This means that the image on an E-Ink screen will be retained even when all power sources are removed. Therefore, such displays have very low energy consumption, only consuming energy during the image change.

The assessment of the fire properties of the E-Ink matrix display was carried out according to the grouping rules provided in clause 4.3 [9, 10] used for non-listed components. According to the principles stated there, the matrix was assigned the R24 set of requirements since the total combustible mass of materials in this device did not exceed 500 g. The results of the oxygen index test (the only test included in the R24 set) showed that this material does not meet the established requirements (an OI value of < 28% was obtained, with the required value being > 28%). This is due to the fact that the materials used in e-paper matrices are mainly various types of polymers characterised by increased flammability. However, the matrix itself is housed in a non-flammable metal casing, and the exposed side is covered with glass, and the mass of the matrix on its own represents only a small proportion of the total display mass. The occurrence of a fire in displays where this matrix is installed is essentially only possible as a result of the action of external ignition sources, and therefore ignition models 1 and 2 can be assigned in this case in accordance with Annex A of EN 45545-1 [8], corresponding to accidental ignition or arson.

The other non-metallic components used meet the requirements of EN 45545-2 [9, 10] and are characterised by limited flammability, smoke generation and low smoke emissions. The possibility of a fire due to a technical failure of the display cannot be excluded, but this is very unlikely due to the low power consumption of this device – 3 W (maximum power consumption of 40 W during image change), with a nominal voltage of 24 VDC. Due to the closed design of the display, the possibility of ignition is very low due to the limited access of fire to the casing.

A detailed analysis of the application, the operating parameters and the location of the components in question makes it possible to conclude that their use in displays does not violate the main requirements of clause 4.1 of EN 45545-2 [9, 10], i.e. limiting the spread of fire in the event of ignition to achieve an acceptable level of safety. In the event of fire, due to the location of the equipment in a visible, easily accessible area, the staff will be able to extinguish the fire or evacuate themselves and reach a safe place.

The company responsible for the distribution of the displays also conducted a market analysis to check whether e-paper matrices meeting the requirements of the standards [9, 10] are available. Currently, at this stage of the development of this technology, e-paper matrices that maintain the required functional properties and simultaneously meet the fire protection requirements in rolling stock are not available on the market.

Based on the above data, the values of the individual parameters necessary to determine the risk priority number (RPN) were assigned according to the guide-

lines of the discussed RFU [9, 10]. For the parameter (S) defining the severity/meaning of a failure of the E-Ink matrix display leading to ignition, a grade of 1 was assigned (Table 5 – insignificant; possible minor injury or minor damage to the system) This is due to the very low mass of the combustible materials of the E-Ink matrix relative to the other fire protection-compliant non-metallic materials found in the analysed displays. Additionally, the sealed metal-glass casing makes it difficult for fire to escape to the outside, and the good visibility of the device facilitates its quick extinguishing, preventing the fire from spreading.

The probability of occurrence (O) of ignition from this component was determined to be 1 (according to Table 6 – the occurrence is unlikely, but possible. It may be assumed that this danger only occurs in exceptional cases). This is due to the very low power consumption of the matrix, and its electronic circuits do not heat up during operation.

The value of the parameter corresponding to the probability of detection (D) was set as 1 (high) according to Table 7, due to the fact that the area of installation of E-Ink matrix displays is accessible to both rolling stock staff and passengers, and due to the nature of the device (display), it is frequently observed, which facilitates the quick detection of the first signs of fire (e.g., smoke emission). Based on these parameter values, the risk priority number (RPN) was calculated as follows:

$$\mathrm{RPN} = S \times O \times D = 1 \times 1 \times 1 = 1$$

Given the obtained result, the risk of introducing this component is fully acceptable as it falls within the range of values assigned to the category: negligible, according to Table 8.

As a result of the analysis based on clause 4.7 of EN 45545-2 [9, 10], the discussed E-Ink matrices are considered approved out of functional necessity at hazard levels HL1, HL2, and HL3 until matrices based on E-paper technology that meet both flammability and functional requirements are developed.

4. Conclusions

There are few materials approved for use due to functional necessity according to the guidelines of clause 4.7 of the standard [9, 10] that do not meet the fire safety requirements specified in the standards [9, 10], relative to all the non-metallic materials and components used in devices. However, they pose a significant problem for their manufacturers and distributors due to the need to ensure the fire safety of rolling stock [16]. To maintain safety standards, all components considered for approval under this clause should undergo a thorough analysis to ultimately determine the risk of their use, in accordance with the guidelines of the discussed RFU RST-313 [11], based on the principles of the Common Safety Method relating to risk evaluation and assessment. If the approval of a component or material is conducted according to the presented procedure, it can then be considered compliant with the overarching material requirements specified in TSI Loc & Pas (1302/2014 (EU)), clause 4.2.10.2.1 (2) [6].

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