SECUREMETRO

Inherently Secure Blast Resistant and Fire Safe
Metro Vehicles

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WP 3
– Design Solutions for Fire and Firebombs–

DELIVERABLE: D3.02
Practical and Operational Implementation of Firebomb Mitigation Technologies

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1. INTRODUCTION

The objective of this deliverable (D3.02) is to design and evaluate vehicle systems and materials to suppress and prevent spread of fire, smoke and toxic products in the event of a firebomb or fire-setting attack. Such systems and materials should meet the requirements of railway vehicle standard CEN 45545 (EC, 2009). CEN/TS 45545 specifies fire prevention measures and requirements intended to protect passengers and staff in railway vehicles in the event of a fire on board.

The work presented in this document also considers the fire suppression and mitigation technologies discussed in Deliverable D3.01 which discusses three national standards, the British BS 6853, French NFF 16-101 and Germany DIN 5510. More importantly, it discusses the EC CEN TS 45545.

Deliverable D3.01 presents fire suppression technologies namely water mist, gas systems and aerosol systems. It ends by discussing fire and smoke detection technologies. Six technologies were considered namely ionisation smoke detectors, scattered – light optical smoke detectors, projected light (beam) smoke detectors, aspiration smoke detectors (ASDs), heat detectors and flame detectors.

This report evaluates the fire suppression technologies and detectors mentioned above to assess the practical and operational implementation of firebomb mitigation technologies. Further it discusses and recommends fire barrier or isolation measures aimed at presenting fire from spreading. This will contribute to the overall aim of enhancing fire resilience.

Where conflict occurs with any of the content of EN45545, then the EN standard takes precedence over the content of this deliverable.

1.1. Goals for Fire Protection

Fires in passenger trains are generally rare, but can lead to serious disasters (Peacock et al, 1995). However, in the last decade potential for fires has increased due to terrorist attacks.

The goals for fire protection are universal: only the means chosen to achieve them vary. These goals can be simply stated in the following list:

(1) Prevent the fire or retard its growth and spread

- Control fire properties of combustible items.
- Provide adequate compartmentalisation.
- Provide for suppression of the fire.

(2) ***Protect occupant; from the fire effects***

- Provide timely notification of the emergency.
- Protect escape routes.
- Provide areas of refuge where necessary and possible.

(3) ***Minimise the impact of fire***

- Provide separation by tenant occupancy, ***or*** maximum area.
- Maintain the structural integrity of property.
- Provide for continued operation of shared properties.

(4) ***Support fire service operations***

- Provide for identification of fire location.
- Provide reliable communication with areas of refuge.
- Provide for fire department access, control, communication, and water supply.

The first part of the goal 'prevent the fire' may not apply to firebombs, but only the second part 'retard its growth and spread'. Therefore, the aim of this document is to recommend improvement of fire resilience through retardation of fire growth and spread. The two proposed technologies are,

- Fire suppression (extinguish if possible)
- Fire barriers (use of materials that do not promote fire reaction but improve fire resistance). (e.g. hip high barriers instead of open the typically 14m to 16m metro interiors)

The design of rolling stock and the products used are aimed at limiting fire development should an ignition event occur in order that a sufficient level of safety is achieved (EC, 2009b, EC, 2009c). Fire safety requires a multi-level approach in which all of the components of system safety are treated in a systematic manner, such that a potential failure is countered by a safety feature. Therefore, fire resilience would require suppression systems, and fire barriers (such as fire retardant materials) which reduce the development of fire.

An example of fire started intentionally is shown in Figure 1.

Figure 1: An example of arson on a metro (Impact Lab, 2008)

International Union of Railways Code UIC Code 564-2 includes as a general guideline for vehicle design 'The coach design and interior fittings must above all prevent the spread of fire'. To meet this goal a set of material test methods is included covering vehicle design (to reduce potential ignition), compartmentalisation (to prevent spread of fire from one vehicle to another), electrical systems, fire detection in engine compartments, fire extinguishers, fire alarms, and emergency egress (via door and window design).

1.2. Some Lessons Learned from Past Metro Fires

The Regie Autonome des Transports Parisiens (RATP) of France has documented fires which have occurred since 1903 (Marchais, 2010). It shows that fire can spread along the train set (such as the Paris 1975 Vincennes station metro line 1 fire) or fire and/or smoke can spread to other metro lines (such as the Paris 2001 Gare de Lyon station RER line A fire).

One of the mitigation measures for the Vancennes station incident was upgrading of rail rolling stock by replacing the existing materials in passenger spaces, inclusive of walls, partitions, ceiling, floor and seats by new materials which have better fire retardant characteristics. In the Gare deLyon station fire, a review and modification of operational protocols was made to mitigate spreading of smoke from one line to another. Noting that other projects such as the EU Project RailProtect (EC, 2012) are studying the infrastructural aspects of fire prevention and mitigation, this Deliverable D3.02 deals only with mitigation measures that relate to the rolling stock itself.

Like many other fire protection programmes, emphasis of the fire mitigation measures documented by the RAPT considered a progressively developing fire rather than firebombs.

1.3. Characteristics of a Firebomb

A firebomb is a thin-skinned container of fuel gel designed for use against dug-in troops, supply installations, wooden structures, and land convoys. Firebombs combine high explosive and incendiary effects. High explosives release a great deal of energy over a broad area, in firebombs they also release a large quantity of extremely flammable material (gelled-fuel mixtures, magnesium, white phosphorus, etc.) which immediately bursts into flame. The aim of a firebomb is to start a fire in an explosive manner. Firebombs can also have further destructive effects:

- In underground installations, the fire rapidly consumes all available oxygen—suffocating any potential survivors.
- During large-scale firebomb attacks, a massive conflagration creates an upward air current (convective) which causes air to rush in towards the fire from all sides; this rapidly circulating air provides the fire with quantities of fresh oxygen, increasing the size of the fire and, in turn, the speed of the air current. This positive feedback loop creates extremely large and intense fires.

Firebombs rupture upon impact and spread burning fuel gel on surrounding objects. One or more igniters and fuzes are used to ignite the fuel gel mixture upon impact. Firebombs are used primarily for low level attacks (Ordnance, 2012). The following are the key fire characteristics of a firebomb.

- Instant flames
- Instant heat release
- Instant smoke release

In the recent past, however, use of firebombs by terrorists has threatened the security of transportation systems. By implication, in a metro the surrounding furniture and people would catch fire directly and immediately. Although not directly related to metros, Figure 2 and Figure 3 illustrate the effects of a firebomb. Compared to other passenger rail vehicles, metros have open interiors (with minimal furniture). The openness would aid air flow towards the fire, thus rapidly reducing oxygen for passengers.

Therefore, the instantaneous characteristics of a fire bomb, it is recommended to apply the following fire detection technologies:

- Heat detection (D3.01 page 25)
- Flame detection (D3.01 page 26)

This is in addition to the usual smoke detectors fitted for smouldering fires.

Tests have found that a typical arson firebomb (consisting of 3.8 litre plastic container filled with unleaded gasoline) has a heat release rate of about 258kW, burning for 300s (Icove and DeHaam, 2006). The temperature rises to a maximum of between 500^{o}C to 600^{o}C. It should be noted, however, that a rail vehicle with combustible furniture with an incipient fire could result in peak HRR of about 5MW (Chow et al, 2011) and up to 30MW (Liu et al, 2007).

Figure 2: Fire Bomb – Instant flame, smoke and heat (ThirdAge.com, 2011)

Figure 3: Fire Bomb – sets the target in fire instantly (NDJ World, 2011)

1.4. Characteristics of Metro Design

A metro is an electric railway operating below the surface of the ground (usually in a city); In some cases, it is referred to as the subway system and in others (e.g. London) it is called the `tube' or the `underground'". Typical characteristics of the metro include:

- Stops within 1 – 10 minutes (with most falling around 2 – 4minutes)
- Operates largely underground
- Seating Configurations include inline (transverse) (Figure 4), Bay (Figure 4) and longitudinal (which is the most common) (Figure 5 and Figure 6).
- Many more grab handles and poles per coach/car compared to heavy rail
- Long open spaces (14m to 18m long with less furniture compared to heavy rail)

Presented in Figure 4, Figure 5 and Figure 6 are typical examples of metro interiors. The major combustible components absent in a metro compared to heavy passenger rail include Key components absent include:

- Mattresses (sleepers)
- Tables
- Toilets
- Curtains
- Absence of hydrocarbon (diesel) fuel tanks
- Carpets
- Luggage shelves

Figure 4: Swedish Subway System – Stockholm Metro The Fun Learning (2012)

Figure 5: Inside a C69 Stock train Kings Cross 2010 (London UG) (Wikipedia, 2010)

Figure 6: Metro in Korea (Railway-technology.com, 2012)

When addressing fire resilience, metros have much fewer combustible components than heavy passenger rail. From a general list of combustible components that apply to passenger rail (Peacock, 1995), shows the list of components that would be applicable to metros.

Table 1: Potentially Combustible Materials to consider for Metros

Category	**Function of Material**	**Comments**
Passenger area	• Cushions • Seat frames • Seat upholstery • Ticking and covers	
Panels	• Wall, ceiling, partition, windscreen • HVAC ducting • Window	
Flooring	• Structural • Covering	
Insulation	• Thermal, acoustic	
Elastomers	• Window gaskets, door nosing, diaphragms, roof mat	
Exterior plastic components	Interior, Exterior boxes	

2. DECISION SUPPORT FOR IMPLEMENTING THE SUPPRESSION AND MITIGATION TECHNOLOGY

This section defines fire suppression systems. For each case, the vehicle types for which they are suitable is evaluated along with design compromises implied by this use. Both ‘new build’ and ‘retrofit/refurbishment’ vehicles are considered.

The railway vehicles to be considered are classified using the EC categories and by interior design under the following operation categories (EC, 2009):

Operation Category 1
Vehicles that are not designed or equipped to run on underground sections, tunnels and/or elevated structures and which may be stopped with minimum delay, after which immediate side evacuation to a place of ultimate safety is possible.

Operation Category 2
Vehicles that are designed or equipped to run on underground sections, tunnels and/or elevated structures, with side evacuation available and where there are stations or emergency stations that offer a place of ultimate safety to passengers, reachable within a short running time.

Operation Category 3
Vehicles that are designed or equipped to run on underground sections, tunnels and/or elevated structures, with side evacuation available and where there are stations or emergency stations that offer a place of ultimate safety to passengers, reachable within a long running time.

Operation Category 4
Vehicles that are designed or equipped to run on underground sections, tunnels and/or elevated structures, without side evacuation available and where there are stations or emergency stations that offer a place of ultimate safety to passengers, reachable within a short running time.

Design categories
Railway vehicles are additionally classified under the following design categories:

A: vehicles forming part of an automatic train having no emergency trained staff on board;
D: double decked vehicles;
S: sleeping and couchette vehicles;
N: all other vehicles (standard vehicles).

Vehicle classification
The classification of the railway vehicle into the relevant categories contains the operation and design categories. It is also specified in the procurement documents.

Metros fall under Category 2. Figure 7 shows a typical underground metro system.

Figure 7: London Underground (Britannica.com , 2012)

2.1. Design Specifications for Firebomb Resilience

Generally, the term resilience is the ability to manage disruptive challenges, such as terrorist attacks, major flooding or accidents that can lead to, or result in, crisis. For a firebomb attack, resilience would entail minimising spread of fire in the metro, damage to the vehicle structure and its operating systems, thereby improving occupant safety and evacuation.

Based on the fire hazard levels are defined as shown in Table 2, a metro falls under HL2:

Table 2: Hazard Levels Classification

	Design Category			
Operation Category	N: Standard Vehicles	A: Automatic vehicles having no emergency trained staff on board	D: Double decked vehicle	S: Sleeping and couchette cars, double decked or single deck
1	HL1	HL1	HL1	HL2
2	HL2	HL2	HL2	HL2
3	HL2	HL2	HL2	HL3
4	HL3	HL3	HL3	HL3

CEN/TS 45545 specifies prevention measures. The measures and requirements specified in CEN/TS 45545 are intended to protect passengers and staff in railway vehicles in the event of a fire on board. This protection is essentially based on the ability of the rolling stock to allow for safe evacuation.

Firebomb resilience is mainly concerned with delaying development (or spread) of fire. The requirements for fire protection are mainly covered in CEN 45545 Part 2, Part 3 and

Part 4. Part 2 specifies requirements for fire behaviour of materials and components, while Part 3 specifies the fire resistance requirements for fire barriers. CEN 45545 Part 3 specifies the fire resistance requirements and testing methods for fire barriers for railway vehicles.

Finally, CEN 45545 Part 4 aims to protect passengers and staff in railway vehicles in the event of a fire on board by minimizing the risk of a fire starting, delaying the fire development and controlling the spread of fire products through the vehicle, thus aiding evacuation. Therefore, the specified materials should exhibit low fire reaction and high fire resistance properties. Ultimately, this should aid safe passenger evacuation.

2.2. Current Fire Mitigation Technologies

A typical fire evolves through four stages:

Stage 1: Incipient stage. In conspicuous (invisible) smoke release.
Stage 2: Visible smoke.
Stage 3: Flaming fire.
Stage 4: Intense heat.

Once deployed, the inception of fire for a firebomb cannot be prevented. The first two stages may not occur for a firebomb. Therefore, the main concern is stages 3 and 4. There is a sudden increase in flame, temperature and smoke; subsequently, it is being recommended that fire bomb resilience will incorporate fire suppression technology in addition to fire barriers (surrounding materials being of low fire reaction and high fire resistance).

2.2.1. Systems Approach to Fire Prevention

The trend toward a systems approach to fire safety is evident in nearly every country. This is driven largely by the realisation that the interactions among various system components can create mitigating or extenuating conditions not evident when examining the performance of an individual component.

2.2.2. Fire Suppression

From the fire suppression systems presented in Deliverable D3.01, it this Deliverable D3.02 has recommended deployment in railway vehicles is a water mist technology.

2.2.3. Fire barriers

A fire barrier is an element that is intended for use in 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. The design of rolling stock and products used is aimed at limiting fire development should an ignition event occur in order that a sufficient level of safety is achieved (CEN 45455-Part3).

Explosion/fire protection technology include: explosion prevention and suppression systems using reticulated foam inserts, fine water mist, on-board oxygen concentration reduction; explosion isolation systems and flameless deflagration venting devices (Zalosh, 2005). These are further detailed below as follows:

1. **Inerting Technology**
   Inerting requires that the oxygen concentration be reduced below the Limiting Oxygen Concentration for a particular fuel at a specified temperature and pressure. The LOC is the smallest concentration of oxygen that can support flame propagation at the stated temperature and pressure.

   The cost of commercially purchased compressed nitrogen and the need for high pressurize gas piping have been deterrents for widespread use of nitrogen inerting until recently. One new development that may eliminate these deterrents for some applications is the availability of new air separation technology to produce oxygen-vitiated air on site.

   The "safety kit" shown in Figure 8 is composed of air separation. The arrows show the direction of air flow through the ASM. Nitrogen-enriched air flows out the other end while the oxygen-enriched waste air stream comes out the side.

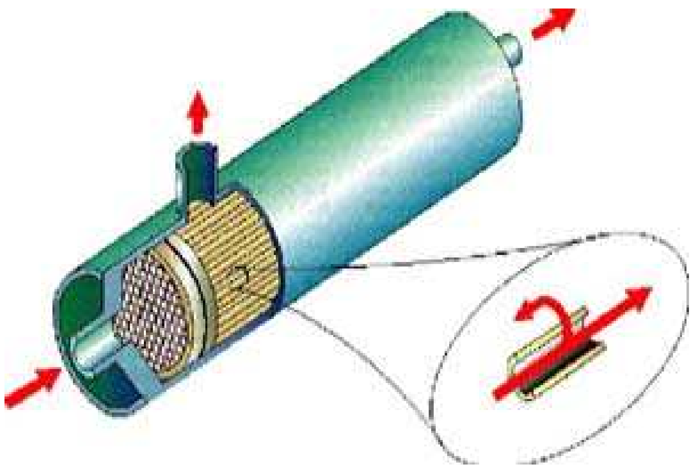

Figure 8: The Air Separation Module (ASM) NASA (2004).

2. **Deflagration Venting Technology**
   The most widely used deflagration protection technology is deflagration venting. In order for deflagration venting to be effective, the vent area must be sufficiently large to accommodate the rate of pressure increase due to combustion. Guidelines for deflagration vent design are provided in 4NFPA 68 (NFPA, 2002), other national and regional standards such as the CEN/TC 305 draft standard for dust explosion venting (EC, 2002).

3. **Explosion Suppression Technology**
   Explosion/fire suppression is the interruption of an incipient deflagration by quenching the propagating flame before destructive pressures have developed.

Most explosion suppression systems are active in the sense that they respond actively to the developing deflagration, and then inject the suppression agent into the enclosure. Other types of suppression systems are passive in that they are pre-installed throughout the enclosure.

Commercially available active explosion suppression systems are provided with explosion detectors (either flame sensors or pressure transducers), a suppression agent stored under high pressure in one or more agent containers, a rapid activation device to trigger the discharge of agent upon explosion detection, and a control unit to monitor the system during standby and send the trigger signal upon detection.

A possible alternative for expensive suppression agents is the use of water spray surge systems with a supply of water and spray nozzles distributed throughout the enclosure. In many cases, the water spray significantly mitigates the explosion but may not completely suppress it. Passive explosion suppression systems use reticulated metal or polymer foams preinstalled in the enclosure for portable flammable liquid containers. The large specific surface area due to the reticulated foam configuration can provide ample surface area for flame quenching during an incipient gas explosion.

4. Explosion/Fire Isolation Systems

Although explosion venting and explosion suppression can be very effective for protecting a single enclosure, both methods can be defeated when there is explosion propagation between enclosures. The two most common active types of explosion isolation devices are fast-acting mechanical barriers and chemical isolation systems.

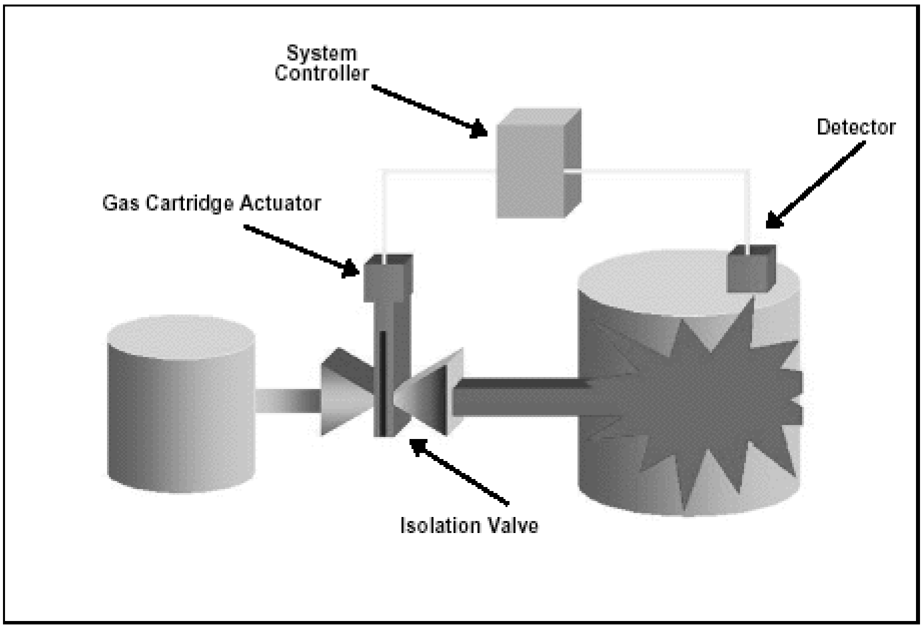

Figure 9: The Components of Explosion Isolation Systems (Reliable Fire, 2012)

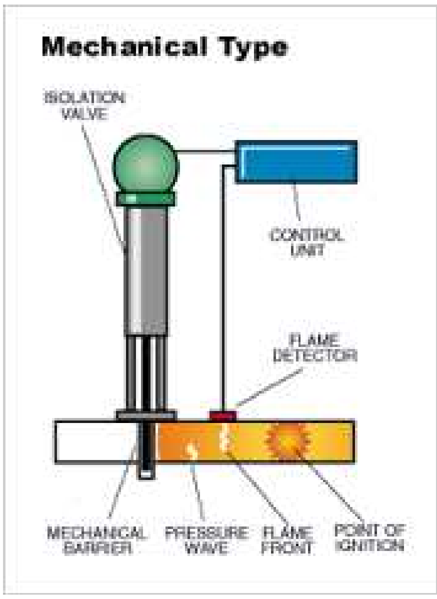

Figure 10: Explosion Mechanical Isolation Systems (Fenwal Protection Systems, 2012)

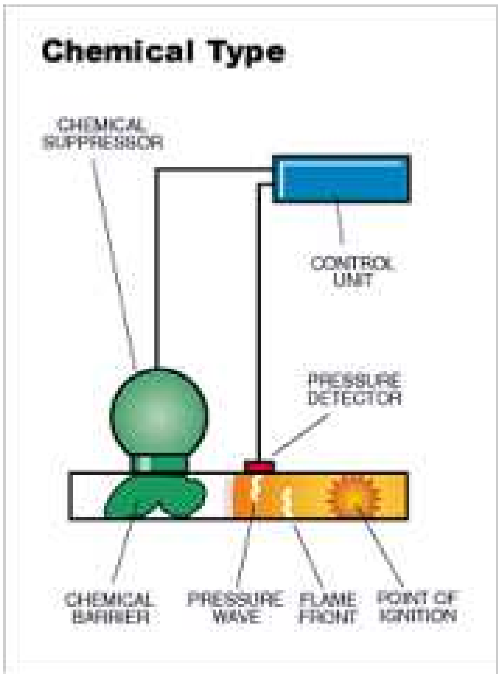

Figure 11: Explosion Mechanical Isolation Systems (Fenwal Protection Systems, 2012)

The first option is not suitable for rail vehicles because the passengers need oxygen to survive. Similarly, the second option is not practical to implement because the exterior doors would need to be opened to allow for evacuation of the passengers, thereby making optimisation of the venting area complex.

The third option involves fire suppression. In this deliverable, the use of water mist system has been recommended. To this effect, it is the only system that has been elaborated further because it is better suited for environments where there are people. The high specific heat capacity of water maximises temperature reduction thereby reducing passenger injuries resulting from burns. Water mist system has been applied for the metro train for Copenhagen (Vibæk, 2010) where the sprinklers are setup as follows:

- Response Time Index (RTI): 100 (starting point)
- Activation temperature: 74^{o}C
- Water: 30 l/min per sprinkler
- Spray angle: 45 degree (should be evaluated close to design specification)
- Spray velocity: 5 m/s (should be evaluated close to design specification)
- Sprinkler distance in model: 2 metres. However can be increased up to 3 metres, if the sprinkler coverage area is better (spray angle and velocity should be different)

A parametric study by Liu et al (2007) on water mist system fire suppression showed that fire suppression capability increases with proximity of nozzles to the fire source. The capability also increases with increasing number of nozzles.

For fire barriers, due to the presence of people, the chemical technology would not be promoted. Instead, automatic closing doors between coaches are applicable. While rail vehicles mainly apply active fire suppression systems, they rely on passive fire isolation systems. These are barriers in form of automatic closing doors (between coaches), ceiling, side walls and floor panels. All these can be classified as passive mechanical barriers. For these barriers to be effective, they must have low fire reaction and high fire resistance properties, which are dependent on the material properties. It is for this reason that material selection for the following rail vehicle components is critical – side walls, partitions, ceiling, floor and the automatic closing doors between coaches.

2.3. Barrier Technologies

2.3.1. Explosion or Fire Isolation Systems

Origin of fire in a metro could be outside/exterior, inside/interior (passenger area), driver cab and under carriage not accessible. Each of these areas can be isolated to prevent fire spreading to the other areas. Isolation is best achieved by introducing fire barriers between them.

Fire barrier design characteristics should conform to CEN 45545 Part 3, depending on the origin of the fire. For firebombs, the likelihood is that the fire is coming from the passenger area. The fire resistance performance of fire barriers are determined using standard fire test procedures in accordance with the general requirements specified in EN 1363-1.

Fire resistance requirements for fire barriers

The objective of barriers is to protect passengers and staff in railway vehicles in the event of a fire on board by containing fire. In reducing the risk of fire development,

1. Fire and smoke barriers shall be installed in vehicles to delay the spread of fire and its combustion products. These barriers shall be sited in a vehicle such that they:

a. Delay the spread of fire and combustion products between vehicles with a vehicle / vehicle performance according to the category of the vehicles. (side walls, ceiling, floor)
b. Delay the penetration of fire from underneath the floor of a vehicle into the vehicle interior. Floor fire barriers shall achieve a 20 minute integrity and insulation in accordance with BS 476 Part 20 and Part 22 or BS EN 1363-1:1999 partition test. (floor)
c. Delay the spread of fire and combustion products into areas where the driver and traincrew carry out their operational duties under emergency conditions (such as driving the train to a safe place for evacuation and initiating an evacuation), and to safeguard their escape routes from those areas on completion of those duties. The fire barrier performance shall be in accordance with the category of the vehicles (doors, partitions).

2. Doors in fire barriers shall be self-closing. However, the passage of people through such doors shall not be impeded by that feature.

Classification of fire barriers
Fire barriers may have performance in one of the three parameters:

1. The lowest performing barrier is E = Integrity
2. The next level of performance would be requested EW = Integrity and Radiation Transfer.
3. The top level is E I = Integration and insulation requirement

In the event of a fire developing, the vehicle design configuration and the materials used in its construction shall ensure, as far as reasonably practicable, that:

a) The required mechanical strength of the vehicle main structure is retained.
b) The rates of fire propagation, of flame spread, heat release and of smoke and toxic gas emissions are sufficiently low as to:

i. Enable people not to be unduly hindered in their escape and evacuation to a position of ultimate safety, taking account of the specific operational characteristics of the category of vehicles.
ii. Reduce as far as is reasonably practicable the effects on the railway infrastructure and on railway operations.

Currently, fire barriers applied in passenger areas include roofing, side walls, partitions, floor and doors. The materials used to make these components should have inherent fire resistance properties. Materials applied as fire barriers include:

- Sandwiches / Cavity barriers
- Laminates
- Composites (e.g. phenolic composites)
- Foam

2.3.2. Materials Selection

In a rail vehicle a fire, smoke spread is more life threatening than flame spread (Chow et al, 2011). The fire standards EN 45455 (and the most stringent BS 6853) favours highly fire retardant composites that burn with low levels of toxic gas emission.

The reaction to fire performance requirements of materials and components depend on their intrinsic nature but also on the,

- Location of materials or components within the design;
- Shape and the layout of the materials; and
- Direction surface exposed and relative mass and thickness of the materials

Fire resistance is the ability of an item to fulfil for a stated period of time the required stability and/or integrity and/or thermal insulation, and/or other expected duty specified in a standard fire-resistance test. For metros barriers should achieve 20 minute integrity. On the recent past, Fibre Reinforced Polymer (FRP) composites have been applied in rail vehicle construction to achieve this requirement. They not only offer light weight/high strength solutions, but also reduce maintenance costs. The following sections present examples of current composite solutions for rail vehicle con

2.3.2.1. Sandwich Composite Solutions

A sandwich-structured composite is fabricated by attaching two thin but stiff skins to a lightweight but thick core. The core material is normally low strength material, but its higher thickness provides the sandwich composite with high bending stiffness with overall low density.

As an example, DIAB's transport cores are used in rail vehicle construction (Figure 12 and Figure 13). They are thermoplastic, recyclable, compatible with polyester, vinyl ester, epoxy and phenolic resins, and have been designed for FST performance at elevated temperature. Divinycell F shows excellent heat aging at 180° C (356° F) and is compatible with most common composite manufacturing processes up to 220° C (428° F) cure cycles, including prepregs and infusion. (McConnell, 2008). Examples are shown in Figure 12 and Figure 13. Rail vehicles capitalising on the benefits of DIAB's core materials in composite rail components are the Austrian Bayerische Oberlandbahn (flooring), Siemens Combino tram (front panel incorporating bumper), Bombardier's Talent and Regina trains (front, sides and roof) and the Adtranz Regio Shuttle (front panel).

Figure 12: Divinycell Cores (DIAB, 2012)

Figure 13: Laying up a composite train with Divinycell Cores (Railway Technology, 2012)

Figure 14 and Figure 15 give examples of components that could be manufactured using sandwich components.

Figure 14: Core supplier DIAB identifies the multiple interior and exterior applications for its Divinycell core products in sandwich constructed composites for rail carriages. (McConnell, 2008)

Figure 15: KTK Group interior components utilise DIAB core materials on the new Shanghai metro (McConnell, 2008).

2.3.2.2. Sheet Moulding Compound

Sheet moulding compound (SMC) or sheet moulding composite is a ready to mould fibre-reinforced polyester material primarily used in compression moulding. The compound is increasingly being used in rail vehicles to meet FST requirements. Siemens uses glass reinforced sheet moulding compound (SMC) in its Desiro trains running in Europe, specifically SMC 2400 from Menzolit-Fibron GmbH. Introduced in 2005, this polyester-based compound meets the strongest fire safety standard in Europe – British standard BS 6853 for railways – and is also used in interior components on the Tucheng rail line in China and street cars in Berlin (McConnell, 2008).

In wall claddings, window frames, door and seat structures, SMC 2400 (based on unsaturated polyester resin) is easily moulded in large panels. A key FST ingredient is aluminium-trihydrate (ATH), a mineral filler that acts as a quenching element in the SMC by releasing water at elevated temperature up to 200° C like a built in fire extinguisher. Under fire conditions, SMC components do not generate poisonous gases, collapse, or spread molten material or droplets keeping escape ways open for passengers to get out. In case of fire smoke is released to a small extent. Smoke is, except for carbon monoxyde non-toxic. This makes SMC 2400 suitable for railway interior or exterior applications, like wall panels, window frames, luggage bins, seat shells and structures or similar rail way components. Fire safe furniture or sanitary furniture on ships, trains or prison cells are another typical use.

Shown in Figure 16 and Figure 17 are some application of SMC rail vehicle

Figure 16: Interior SMC components for rail carriages in China may provide a new growth segment in this market (McConnell, 2008).

Figure 17: On the Siemens Desiro train, FRP interior components using Menzolit's SMC 2400 meet high FST standards through the addition of aluminium trihydrate.

An example of a material with particularly low toxicity levels is Synolite 5001-T-1 ATH, a filled polyester system has a very low R value. Synolite 5001-T-1 is a DCPD based, thixotropic, non-halogenated, non-pre-accelerated unsaturated polyester resin.

SMC technology also enables application for the structural laminate and the cosmetic pigmented surface, therefore eliminating the need for painting the components and providing a through colour. This offers technical advantages over painted systems, firstly any minor damage due to graffiti or scratches can be polished out to produce a refurbished component and secondly, there is no negative effect on the fire performance properties of the composite which is the case with painted systems.

2.3.2.3. Phenolic Prepregs

A large range of interior rail components can be made from phenolic prepregs including seating, ceilings, floorings, bulkheads, vestibules, fire barriers, wall panels, window surrounds, doors, corridor adapter frames, staircases, luggage bins/racks, fairings, and toilet modules. E-glass reinforced phenolic prepregs from Gurit’s Aerospace and Rail divisions in Switzerland and Germany, feature good surface finish achieved in short cure cycles (10 minutes at 160° C) with 63–68% glass loading.

The prepregs have been used in interior components aboard the Siemens high speed AVE S103 in Spain and in the exterior front end for the Combino Plus in Portugal. Gurit’s PH840-300-42 prepreg is available in 8H satin woven fabric with 42% phenolic resin, whereas PH840-600-40 comes in satin HD special with 40% phenolic resin.

2.4. Cost – Benefit Analysis of Applicable Fire Suppression Technology

Some designs have shown that that up to 80% of a (metro) vehicle’s tare mass could potentially be amenable to composites with good FST properties, which would result in mass reductions through material substitutions.

3. CONCLUSION

This deliverable recommends the application of water mist as the fire suppression system because it is amenable to environments where there is mass movement of people such as metros. The high specific heat capacity of water renders it a good option to quick absorption of the rapid heat released by a firebomb. In view of the fact that a firebomb releases heat, smoke and flame almost instantaneously, it is recommended that a heat detector and/or flame detector is fitted.

Under the EC, CEN 45545 Part 3 specifies fire barrier design for rail vehicle applications. Since stops for metros are typically 1 to 10 minutes (with 2 to 4 minutes being the mode), it is being recommended that a 15m minutes fire barrier could be fitted, although a 20 minutes one would be preferable. The fire barrier system recommended would be passive in form of fire retardant floors, side walls, windows and ceiling. Automated closing doors would ensure that flame does not progress to other coaches and transfer of fresh air into the combusting coach from other coaches in minimised. These metro body parts would exhibit good FST properties. Such materials are now readily available on the market in form of sandwich composites, Sheet Moulding Compounds (SMC) and phenolic prepregs. The materials can be used to make both interior and exterior metro components. The low fire reaction and high fire resistance properties exhibited by these materials also makes then suitable because unlike the typical smouldering-starting fire, firebombing results in immediate heat release. Laminated glass and toughened glass is recommended for window and, where applicable, partitions and automated doors.

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