‘The Smarter Way of Using Fire Protection in Rolling Stock Applications – how innovative and active solutions could help to increase safety’

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1. Introduction

Active fire protection systems have become increasingly important in rolling stock applications during the last few decades. If requirements for such systems were still rare at the beginning of the 2000s, today they are standard in a large part of all vehicle projects. The design of them is highly diverse. Depending on the risk classification, route profile and country of deployment, the use of simple fire detectors up to complex overall systems to protect technical areas and passenger compartments is possible.

Unfortunately, the movements on standards in this area are still rather tenuous to describe. After the well-known and much-discussed EN45545 finally came into use after decades of development, further standards and regulations have been added or are being drafted, which does the business not easier. Additionally, the partly very different country-specific requirements are more blocking than solution-oriented. A united Europe is unfortunately still a long way off in this field. A united base in Europe would be even more important for European system providers, since there are only two main standards for fire protection in railway vehicles worldwide, the requirements of NFPA 130 as well as those according to European standards. With the current revision respectively the last publication of the NFPA 130, North America has meanwhile bypassed Europe in the fields of compensation and risk-based engineering.
A fire detection and fighting system must also be suitable for the application on a train: robust to electromagnetic disturbs, shocks and vibrations, possibly not too heavy and difficult to integrate, economic in first equipment price and even more in the life cycle costs, and beside all of that, must ensure the best safety for passengers and the best protection of the vehicle.

The first fire detection and fighting systems conceived as integrated systems in the architecture of the train and developed according to railway standards date back to beginning of decade 2000s. In this market FOGTEC has been pioneer. Now, after almost 15 years of development, modern active fire detection and fire fighting systems became more reliable, technologically more advanced and more easily maintainable.

But what is the actual state of art at nowadays, which technologies are used, which kind of systems are successfully running in the trains produced in Europe?

2. Systems for passenger areas

An early detection of fire plays a key role in safety of human lives and preservation of the goods by fire hazards.

Smoke detection is the safest way for fire detection in passenger areas, because detection of smoke plays an important role in the life safety of occupants. In fact, smoke is in most of the cases the fastest product of fire which can be detected, even quicker than temperature. Smoke is also extremely dangerous as it strongly reduces the self-rescuing ability of people, by limiting their mobility via intoxication, asphyxiation and decreased visibility. Moreover, while a human can withstand a high temperature for a given time and still being able of self-rescuing, the time a human can withstand toxic gases without losing his mobility and consciousness is much shorter. Therefore quick detection based on smoke is the most suitable way to ensure passenger’s safety.
Fire detection systems play a fundamental role, as the effectiveness of the complete fire protection systems depends on their good working performances. Good working performances for fire detection systems can be depicted by the following features:

- quick detection, normally according to the regulations used for validation
- sectional detection, to identify as much possible in detail the location of the fire event
- robust design in regarding of factors that could cause a false fire alarm

- low need of maintenance and competitive RAM and LCC values in general, according to train design targets
- right and adequate interface standards with train management systems, to exchange necessary information.

Right positioning of smoke detectors or sampling points is fundamental in the design of smoke detection systems, as a suitable design strongly belongs to the effectiveness of the system detecting fires. Positioning of smoke detectors / sampling points in rolling stock applications is based regarding the following aspects:

- ambient volume to protect
- geometry of the volume to protect
- air conditioning concept
- presence of specific sources of air movement as windows that can be opened
- presence of doors (and normally open or close?) or hidden spaces where a fire can start (e. g. luggage rack with closed deck and lateral panels).

The positioning must consider as well the different operational status of the vehicle. Do are there doors, dividing e. g. staff area and passenger saloon? Are such doors normally closed of open? Recirculation and HVAC can cause situations where the smoke is dragged far from a detector or from a sampling point even if the fire is very close, or hidden spaces where smoke can accumulate. HVAC systems have also a strong impact on the temperature of the smokes and subsequently on their behaviours. The analysis of such factors can therefore give answers completely different and more reliable comparing with a rough estimation based only on the traditional approach of building industry based on the volumes.

Finally, an adequate approach to smoke detectors' and sampling points' safe positioning can't be free of a real scale, real conditions evaluation of the effectiveness. That's the approach followed by the ARGE guidelines for fire detection in rolling stock applications, where a real scale smoke test is considered necessary to certify the layout of the smoke detection system, carrying on smoke tests in different conditions, especially in the potential worst-case, e. g. with max power in HVAC or open windows with running train.

The smoke detection system is then in passenger areas combined with water mist fire fighting systems. The most common solution for water mist systems is the high pressure technology. Only water can be used: other extinguishing agents (gases or aerosols) are hazardous for people's safety.

High pressure water mist systems are systems where the working pressure at nozzle level is about 80-200bar. The reasons of the success of the solution *high pressure water mist deluge system* instead of others can be identified in:

- The use of high pressure water mist makes the complete system layout much simpler, with advantages in design, architecture and weight.
- The use of high pressure allows smaller piping for the water
- The "low pressure" water mist systems have in any case a high pressure nitrogen cylinder, so the same precaution must be taken in its integration.
- Water mist systems based on temperature detectors, typically thermo sensitive glass bulbs, expose the system to the risk of delayed activation in case of fire with low thermal emission, with clear risks for safety of passengers

How do those systems look like? In general, a high pressure water mist system consists in:

- a tank, for storing the water and the propellant fluid (typically nitrogen at 200bar) necessary for pressurizing the water and create the water mist.
- the water distribution system, consisting in piping, section valves, flexible hoses, connections etc.
- the nozzles to create the water mist: in fact, the water mist is created only at nozzle's level

By a basic functional point of view, when the fire is detected by the smoke detection system, the fire suppression system moves the section valves in the way to create the right path for the water flow, then the nitrogen cylinder is opened by a special activation valve and the gas flows inside the water cylinder, pushing out the water from inside up to nozzles. The water flow can be shunted in different lines by using section valves, often electrical driven.

Main features which made water mist the most diffused and appreciated solution for fire fighting systems for passenger areas can be resumed as:

- absolute environmentally friendly and compatible with presence of passengers
- strongly limited side effects and damages to the surrounding equipment
- highest cooling effect of any other extinguishing agent
- effectiveness in absorption and dragging down of the smoke, limiting the lack of visibility
- no restriction in use and transport, differently from e. g. chemical gases banned or subjected to gradual banning in a lot of countries

3. Systems for technical areas

In technical areas the presence of smoke is not necessarily related to presence of fire. Smoke detection could therefore be not the best-fit solution. Passengers are not attending, so smoke does not consist in an immediate danger, passengers' lives protection is not the first safety objective, therefore detection by considering temperature as criterion is the method to choose. The main technologies used for temperature detection are:

- linear heat sensitive electrical detectors
- point temperature detectors
- linear heat sensitive pneumatic pressurized detectors

The last solution was very common in the past, but showed in the last years some critical points in terms of reliability: the use of this technology is therefore less and less common and will not be described here. Linear heat sensitive electrical detectors (normally marketed as LHD, *linear heat detector*) are typically made by using a metallic cable running all long the area to protect. If a fire will affect the protected area, the heat release will cause the thermal destruction of the protective sheaths, therefore the internal wires will be melted transferring an electrical signal (short circuit or resistance disequilibrium) to the evaluation unit. In simpler systems, the temperature detection is realized by point detectors: those are typically industrial thermocouples or thermostats or resistance thermometers.

Concerning firefighting in technical areas, the most used solutions are nitrous gases and aerosols.

Firefighting with gas is a very diffused solution for enclosed technical areas like electrical cabinets. Gas systems are working on the principle of saturation of the volume: in any volume, the introduction of a certain quantity of gas will dilute the oxygen down to the minimum level necessary to allow the combustion.
The main characteristics of such systems, which gave them a so wide popularity, are:

- simple design, consisting mainly only in a tank, activation device and a simple piping
- functionality: gas fire-fighting is very effective suffocating the fire
- absence of residuals, due to their clean agents features

Gas systems are clearly ineffective in application in large or wide-open areas, or equipment subjected to very strong air movements: in that case the gas system would be ineffective as the gas would never saturate the volume.
When a gas system would be ineffective due to openings or big volumes, the most suitable solution is always the use of aerosol. Aerosols are very fine powders fighting the fire by chemical interaction with the combustion process. Aerosols are available as pressurized cylinders (similarly to gas systems) and as self-container aerosol generators. This last solution reflects the state of the art and gives strong advantages in terms of weight, size, reliability and simple integration.
The last development in the market of dry agent applications, aerosol generators give great results in comparison to pressurized cylinders solutions thanks to their extreme simplicity.
An aerosol generator consists in an atmospheric pressure container where the substances necessaries to create the aerosol are stored. When a fire is detected and the activation signal commanded by the detection system, an electrical current fire the reaction between the aerosol-forming materials contained in the generator. The fast reaction pushes out the powder and creates the aerosol solution, consisting in a combustion inhibitor material.

4. Conclusion: Active fire protection system and design of the train

Often active fire protection systems are seen as an additional problem to face during the design of the vehicle, especially if imposed by the technical requirements or by law.
But if switching the point of view from the problem to the challenge, the industrial state of the art demonstrated that reliable, safe, functional and properly integrated fire detection and suppression systems already exist and reached a level of industrial maturity.
The importance of using a fire protection system which is designed for railway applications, together with a transversal know-how from both fire protection and railway industry, are the first requirements for a proper integration of the system in the vehicle. They are also the first steps for a successful homologation and a reliable problem-free operation during the future three-decade life of the train.
While this approach ensures already the manufacturing of a train with a high quality fire protection system on board, even wider opportunities are open to the designer who wants to explore them, and the railway industry has only to win from it.
In fact, when approached in a holistic way starting from the very first design, active fire protection system can be a powerful opportunity for the designers and the developers of the vehicle.
The smart use of active fire protection in the design and general concept of the vehicles and the infrastructure is currently a topic of extreme importance and interest.