FIRE PROTECTION MEASURES IN RAILWAY VEHICLES AS A ‘COMPENSATION’ TO FIRE PROTECTION REQUIREMENTS

Michael Klinger
Project Manager
FOGTEC Fire Protection

SUMMARY

High-pressure water mist technology systems with discharge rates significantly lower than traditional fire fighting systems are finding greater application in railway vehicles where traditional systems may not offer an optimum solution. This paper examines the use of high-pressure water mist technology as a cost effective method of compensation compared to traditional fire protection systems as used on rail vehicles and offers an alternative method of enhancing the safety of passengers who use rail transit systems.

INTRODUCTION

The basis of fire detection systems is to detect the combustion process early during the formation phase and then implement effective fire suppression techniques to control the fire. One of the most important aspects of any fire protection system is to maintain the survivability of people. The achievement of this can be costly using traditional approaches but evolving technologies are now available that are considered cost effective (by compensating other elements) while maintaining very high levels of people survivability.

The effective control of fires requires three main defences comprising constructional (i.e. the design of vehicles, the use of fire resistant doors, fire resistant products, etc), plant-specific (i.e. the systems used to detect and suppress the fire) and operational procedures.

Adequate fire protection is usually achieved by the effective combination of several of these measures.

CASE STUDY

Hundreds of passengers’ frequent stations throughout the Essen area every day and therefore the importance of protecting them against the risk of fire are clearly evident. Fire protection requirements with respect to train stations, particularly underground stations, are exceptionally demanding and the cost of implementing traditional solutions is costly.

The following case study examines the use of high-pressure water mist technology for the refurbishment of railway vehicles on the Essener Verkehrs AG (EVAG), Germany as an overall strategy for lowering fire risk and examines a cost effective solution in protecting passengers.

Essen is a city in the central part of the Ruhr area in North Rhine-Westphalia, Germany. It is located on the River Ruhr and has a population of over ½ million people. Essen is linked to the surrounding towns and cities by a comprehensive railway network. Essen and these surrounding cities are served by a large number of railway stations many of which are very old (Figure 1) and do not comply with current safety requirements mandated by the latest fire protection standards.

Refurbishment of these stations to meet modern fire protection standards would therefore be very costly and in some cases almost impossible to achieve.

Figure 1: Main Station in Essen (opened 1862)

Current thinking in Essen has therefore been to find an economic solution which can be used as an alternative to traditional fire protection solutions and was expanded to embrace the protection of the trains themselves as they actually pose a considerable fire risk at stations.
A basic requirement of any fire detection and fire suppression system is effective fire control, by limiting the spread of combustion, in the shortest possible timeframe during the fire formation phase. One primary objective is to control the fire in the shortest possible timeframe so that passengers can be evacuated.

A positive outcome in using the high-pressure water mist technology system on board rail vehicles was recognition of a ‘compensation arrangement’ which realised the benefit of protecting the vehicles as part of an overall fire protection strategy. The ‘compensation arrangement’ not only recognised the additional protection afforded to rail vehicles it importantly recognised associated benefits in relation to the reconstruction works associated with underground stations such as those in Essen.

This meant that the assessment of fire risk for trains and underground stations was considered lower. This influenced the fire protection measures applied for the underground station areas and recognised the enhanced protection given to passengers.

For the work done in the field of high-pressure water mist technology for rail vehicles, our company, FOGTEC, was recognised (Figure 2) for its work by the UITP (International Association of Public Transport) in 2009.

**HIGH-PRESSURE WATER MIST TECHNOLOGY**

Combustion is an exothermic process between a fuel source and oxygen that produces heat and light. The requirements for a fire comprise four parameters: combustibles, an oxidation medium that results in energy, and the correct ratio between the combustible and oxidation medium. This is typically illustrated in what is called the ‘Fire Triangle’ (Figure 3).

![Figure 3: Fire Triangle](image)

If any one of these parts is taken away a fire cannot exist. Water mist systems have the positive effect of taking away two parts, the oxidation medium (inertisation effect) and the energy (by using cooling effect of water).

The Essen solution uses high-pressure water mist technology for fire protection in rail vehicles. This technology uses nebulisation by high-pressure and special nozzles of the reaction surface of water substantially enlarging its surface area compared to conventional systems. The distinctive cooling effect of water not only suppresses the fire but also protects people and goods from any negative influence of heat. The so called housing-in effect (filling the room with water mist and housing-in the fire) is very positive in this area. The small water droplets evaporate very fast so that energy and oxygen is abstracted out from the fire, called the ‘inertisation’ effect. Inertisation only takes place where a high level of temperature exists. Hence the combustion process is effectively fought at the surface of the fire and fire spread is detained.

Nozzles (Figure 4) specifically developed for their application divide the water into very fine droplets to create the largest possible reaction surface. The fast transfer of energy from the fire to the small droplets facilitates an effective and immediate enclosing of the fire event while temperatures and concentrations of toxic gases are reduced to a level tolerable for people. The vaporised very small and fine water mist droplets give a large reaction surface at the fire surface which takes the energy out of the fire. A very small amount of water is used for this process, so there is no or minimal water damage.
The water mist also has an enormous cooling effect, so that the complete area is cooled down. The water mist droplets are accelerated to reach the fire surface. The fire surface can also be reached behind obstacles. Water mist can also be used to fight liquid fires. The fine water mist droplets do not reach any burning liquid; they merely react with the heat of the fire at its surface and turn into steam. The steam has more volume than the original water mist droplets and expands rapidly which displaces oxygen (which is one requirement for a fire) at its surface.

This is one major advantage in suppressing the fire with high-pressure water mist technology systems. Oxygen is displaced, but only in the area of the flames, not throughout the surrounding areas. The fire is ‘inertisated’, a flash over to the surroundings is stopped and still there is always enough oxygen for people to breathe.

Class 1 water mist comes in droplet sizes of 10 to 50 μm. Only this droplet size has the efficiency to absorb the heat and take the energy out of the fire in a proper way. Larger droplets have a different effect, much more water is used which will go through to the fire and damage the underlying vehicles. Water mist does not need closed areas as is required for gas suppression systems. Gas suppression systems cannot be used in passenger areas due to human safety aspects and do not reduce the fire temperature. Water mist has also a wash-out effect on smoke, dust and gases. The smoke and dirt particles are trapped by the fine droplets and fall to the ground. Toxic gases are washed out and this results in a survivable atmosphere for the passengers. Tests were conducted on a range of passenger rail vehicles, the results here-under at Figure 5 and Figure 6. These tests clearly show the reduction in toxic gas concentration achieved in using high-pressure water mist technology.

![Figure 4: Class 1 Water Mist in accordance to NFPA 750: 1996](image)

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![Figure 5: Toxic gas concentrations in case of fire within passenger areas](image)

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The design of the system in Essen is such that when a fire is detected a (24V) signal is sent to the valve of a nitrogen cylinder, which is part of the high-pressure water mist system. The activation signal opens the electromagnetic valve of the nitrogen cylinder. The valve is the only moving part of the cylinder system. Nitrogen flows through the hoses to the water cylinders and pressurizes the water. Water is pressed out of the water cylinders into the pipe work and into the nozzles. High-pressure is only used to accelerate the droplets and reach the required range. Due to the use of special nozzles and the high pressure, the water is vaporised.

Figure 6: Toxic gas concentrations in case of fire within passenger areas, with activation of a high-pressure water mist system.

Figure 7: Release of the water mist system inside an EVAG vehicle.
Passengers and staff can stay directly in front of the activated nozzles without incurring injury, because the pressure is reduced due to the use of special nozzles. These nozzles are designed to reduce the pressure but also to guarantee the required range of the droplets by using the high pressure energy.

Valves can be used to divide the protected area into sections. Water mist is therefore only sprayed in areas where a fire is detected. Section valves are located within the pipe work.

The modular design (Figure 8) and easy combination of different components enabled the integration of the fire protection systems as part of a refurbishment program for different types of rail vehicles. For the EVAG project the module box, consisting of high-pressure components as well as valves etc., for on-the-roof installation, was designed to be adaptable on different cars and at different locations to minimize the effort of any refurbishment works. This allowed a fast and efficient refurbishment of the active fire protection systems into existing railway vehicles.

The final solution was a cost effective outcome for the protection of trains and underground stations in the greater Essen area.

Automatic fire protection systems have historically been based on prescriptive technical specifications and directives mandated by public authorities. However, the work done at Essen illustrates that up-to-date technologies are available as a cost effective alternative solution to traditional fire protection systems for enhancing the safety of passengers using rail public transport systems.

**FUTURE OPPORTUNITIES**

A positive outcome in using the high-pressure water mist technology on board rail vehicles was the affirmation of a ‘compensation arrangement’ which recognised the benefit of protecting rail vehicles as part of an overall fire protection strategy. The ‘compensation arrangement’ not only recognised the additional protection afforded on rail vehicles, it importantly recognised that enhanced levels of fire protection could be achieved for reconstruction works associated with the underground stations, such as those in Essen.

The ‘compensation arrangement’ became an effective tool to reduce the fire protection requirements at stations and buildings.

In recent times, public expectation with respect to safety has risen significantly; this is reflected in many areas of law, including OHS and rail safety.

*Figure 8: Modular Cylinder System Box, on the roof, ‘plug & play’*
In addition, crumbling prices occurring during negotiations for the building of new rail vehicles is often an issue pushing the development of new vehicle concepts to the verge of failure. The demand for new onboard technically heavy weight solutions can also lead to axle load problems for regional train sets.

Specifications requiring the integration of heavy-weight fire-protection doors, will confront engineers with nearly insoluble problems. For this reason, vehicle manufacturers are moving away from mandating 'word for word' compliance and increasingly looking for alternative technical solutions while demonstrating the underlying requirement of 'proof of equal safety'. The use of active fire protection systems using high-pressure water mist technology offers an alternative approach in protecting passengers. High-pressure water mist technology systems have been effectively used by FOGTEC in protecting a large number of vehicles as compensation against the requirement of using fire protection doors and high level fire protection material specifications.

Rail vehicles fitted with the high-pressure water mist technology system have now been admitted into traffic throughout Germany, Austria, Switzerland, France and Italy. The high-pressure water mist technology system makes use of the physical properties of water as an extinguishing medium with a maximum degree of efficiency.

Fire tests on 1:1 scale vehicles have demonstrated equal levels of safety can be realised compared to traditional systems of fire protection and have now been accepted by public authorities and experts involved in the area of fire protection. An analysis of test data confirms that the system not only rendered proof of equal safety, but also shows that a substantially higher level of safety is achieved by comparison to traditional systems, such as the use of fire protection doors. The benefit of high-pressure water mist technology is that it directly impacts on the burning process, i.e. on the initial fire and creates a safe low-temperature environment around the fire source. The benefit associated with a reduction in the thermal effects of the fire on the vehicle body structure is also significant.

The use of the high-pressure water mist technology system has also shown positive outcomes on aspects such as the operability of rolling stock. Based on these types of benefit, manufacturers such as ThyssenKrupp Transrapid embraced the use of high-pressure water mist technology for their project in Munich.

In official correspondence, experts have presented vehicle manufacturers several options for mitigating the risk of fire risk by compensation using alternative fire protection technologies. When incorporating high-pressure water mist technology for fire protection, several advantages have been realised, such as the omitting of fire protection doors, using lower standards of material for the ceiling area, using materials with lower requirements in the sitting area, omitting the arithmetical proof of operability during the critical fire phase, the simplification of evacuation concepts, as well as smaller dimensioning of smoke exhaust systems at railway stations.

The benefits of high-pressure water mist technology is broader than just realisation of compensation. Another wide field of application is the operating of vehicles for cross-border traffic. In most cases, country-specific requirements exist with respect to the use of extinguishing media, which make it very difficult to use the same extinguishing medium in different countries. However, by using the high-pressure water mist technology system it has been possible to solve this problem for different projects without further requirements.

As a consequence, the TRAXX locomotives of Bombardier have been the first to go from Scandinavia to Italy without change of locomotives. High-pressure water mist technology can be applied for both electric and diesel-electric locomotives.

CONCLUSION

In conclusion, it needs to be stated that up-to-date fire protection system solutions should no longer be considered a necessary evil, but as a vital feature playing an important role in the process of development and construction of modern rail vehicles.

What is important in developing a safety case is to demonstrate 'proof of equal safety' and substantiation with evidence both in function and applicability.

Work done in Essen using high-pressure water mist technology has been a cost effective method of fire protection in public transport regarding rail (also in underground stations), further enhancing the safety of passengers.

High-pressure water mist technology clearly has wide application for the rail industry particularly where there is a requirement for meeting current high standards of fire protection on rail vehicles.