Theoretical and Practical Perspectives of Application of High Pressure Water Mist Systems for Railway Vehicles

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Summary

The paper presents the technology of the high pressure water mist in the field of the applications for railway vehicles. The paper gives design basics and performance indicators for such systems, as well as application examples in passenger areas, diesel engines for locomotives and power-packs, and analyses the advantages of using such solution for the fire safety of the railway vehicles.

Key words: fire protection; fire fighting; water mist; high pressure; rolling stock; passenger areas; compensation; fire safety

1. Introduction

In the last two decades fire protection of rolling stock have become more and more popular, especially in regards to active fire detection, extinguishing and suppression systems. As key-factors of such increasing interest, the following reasons can be pointed out: a more sensitive and pragmatic approach to fire safety, new market possibilities, specific regulatory frameworks and the new chances given by compensation measures. Water mist have been one of the primary protagonists of such development: due to its extremely effective fire fighting and cooling effect, and very low amount of water which requires, this technology happened to be wide the most popular solution for fire fighting in railway vehicles, especially in passenger areas and combustion engines.

This article will present the basics of this technology, analyse the practical applications, and explore the possibilities given by using such technology as compensation in regards of traditional fire safety measures.

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2. Water mist as extinguishing agent

The fire extinguishing features of the water, together with its obvious and fully environmentally friendly characteristics, make water the most common used and diffused fire extinguishing agent in all application where, for several reasons, other agents are not usable. Water's enthalpy of vaporization reaches the highest value known in nature for non-flammable materials, and this is the base of its effectiveness as fire extinguishing agent (Table 1).

Table 1

Water fire fighting features

	Specific heat capacity [J/kg*K], liquid, at 298°K C_p	Specific heat capacity [J/kg*K], steam, at 373°K C_p	Enthalpy of vaporization [J/kg] ΔH_{vap}
Water	**4181.3**	**2080**	**2257**

Water mist is a very fine water fog made by special nozzles, where pressurized water passes through. The combination of pressure and small orifices of nozzles creates a water mist.

The high effectiveness of water mist as extinguishing agent is based on its ability to fight all hazardous elements in a fire scenario (Fig. 1). In detail, water mist gives great contribution in:

- Heat absorption: main feature of water is its heat absorption and therefore cooling ability. Water' enthalpy of vaporization is more than 2 MJ/kg, higher then all substances known. For having such higher cooling ability, water mist based fire extinction systems need much less water of traditional sprinklers systems.
- Oxygen displacement: caused by the reason that at environmental pressure water increases its volume up to 1670 times from liquid to gas state, water vaporization makes locally the atmosphere inert by subtraction of oxidizers.

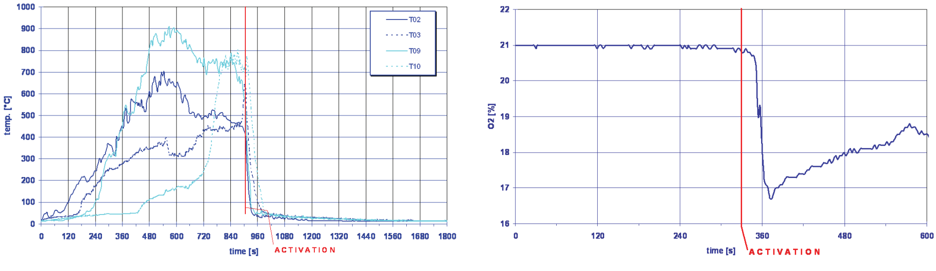

Fig. 1. Heat absorption (cooling) and oxygen displacement effects of a high pressure water mist in a full scale fire test

Such effect is localized where the heat is bigger, means in the core of the flame and its front's direct surroundings.

- Radiation heat stop: water mist play an important role as a heat barrier between the heat source (combustion and flame) and the surrounding atmosphere. Atmosphere is cooled by water mist avoiding the heat and flame diffusion: such effect is moreover extremely helpful for the safety of the persons in a passenger area. People can therefore evacuate in safety the vehicle; rescue personnel and fire fighters can get closer to the fire to aid eventual incapable people and extinct the flames.

Basic feature of water mist in the „quality" of the „fog" created. It is defined as water mist a water fog characterized by at least a 99% of droplet with a diameter smaller than 1000 µm[2]. Such definition comprises different qualities of water mist, and most of the commercial high pressure water mist systems already foresee realization and use of mist made by even smaller droplets. Depending on technology used and related patents, nowadays the droplet size in high pressure water mist systems ranges indicatively between 50–250 µm (Table 2). Droplet size is a fundamental indicator as different qualities belong to it:

- volume / surface ratio: it represents the thermal exchange surface of the droplets, and so the ability to absorb heat and vaporize,
- temporal life of the mist (*stability*), and its turbulence, and so its ability to infiltrate in the most hidden spaces, before falling to the ground and ceasing its beneficial action against the fire.

Table 2

Droplets size is a fundamental parameter of a water-based fire suppression system, affecting heat absorption (cooling effect) and vaporization abilities of water.

Extinguishing system	Droplet size, average [mm]	Water heat exchange reaction surface [m^2/l]
Sprinkler systems (water)	1	2
Water spray systems (low pressure water mist)	0,1	20
High Pressure Water Mist systems	0,01	200

Important to understand while approaching to water mist fire fighting systems is the concept of fire *suppression* or fire *control*.

[2] According to: NFPA750, *Standard on Water Mist Fire Protection*, US National Fire Protection Agency 2000.

A lot of fire fighting systems and technologies are based on fire *extinguishment* as design goal: means that the design goal of the system is to stop and quickly completely extinguish the fire, avoiding its reigniting as well.

Water mist systems are often used with fire *suppression* or *control* as design goal: means, to create boundaries conditions that avoid fire spread, also in regarding smoke release, and that keep the fire small and inoffensive to the surroundings, can be persons or goods, limiting major damages and allow an easy direct extinction by staff or fire brigades. Such safety conditions needs to be realized, as told in before, for several different fire scenarios and maintained for a specific time, which allows a prompt evacuation and / or intervention by rescue staff. This is the approach used by design of water-mist based fire fighting systems in passenger areas of railway vehicles.

The philosophy of fire *extinguishment* is indeed used in technical areas, because it is important to preserve material's integrity, in terms of economic value and operability of the vehicle. Moreover, unlike in passenger areas, in technical areas fire hazards can defined in detail, by type of fire, type of burning material, potential size of the fire and potential location, therefore the fire fighting system can be tailored on the specific layout. This is clearly not possible in a passenger area scenario: too many factors are out of the range of foreseeable fire source.

2.1. Water mist based fire fighting systems

The main families water mist systems can be grouped in are, based on the pressure, the followings:

- *high pressure water mist* systems (normal operating pressure 100–200 bar),
- *water spray systems* or so-called *low pressure* water mist (operating pressure 10–40 bar).

The features of water mist systems had been shortly introduced in before: in table 2 is shown how, by decreasing the size of the droplets, the reactive surface increases, being the water mist more effective in heat absorption and oxygen displacement by vaporization. Pressure is fundamental for defining water mist features: the water atomization is in fact done at nozzle level, and upstream pressure and flow rate are the only source of energy available for fracturing water droplets to create a real fine mist. In general, we could assert a good quality water mist system must give such performances:

- finest droplet size possible, typically sub-millimetre sizes ranging around 0,01 mm: this, is necessary for having a wide reaction surface, a high inertization effect by vaporization, high stability of the fine fog in the way to saturate the ambient,

- enough kinetic energy of the droplets: water particles must be able to flow all over the area to protect, to reach the fire, the reach the most far and hidden spaces,
- water particles flow must be adequate in quantity in rapport to the time and area to protect, to ensure fire control and suppression, and toxic smoke drag.

3. High Pressure Water Mist systems for rolling stock application

Main features which made water mist (Fig. 2) the most diffused and appreciated solution for on board fire fighting systems 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 any restriction in use and transport, differently from e.g. chemical gases banned or subjected to gradual banning in a lot of countries.

Fig. 2. High pressure water mist fire fighting systems are far the most effective and diffused technology for protection of passenger areas. Here a Fogtec application in a metro train

Its effectiveness, its absolute environmental friendly features, its low invasiveness made water mist solutions the most used technologies for fire fighting in rolling stock, especially (but not limited to) in passenger areas. In general, a high pressure water mist system consists in (Fig. 3):

- a tank, for storing the water and the propellant fluid (nitrogen) necessary for pressurizing the water and create the water mist. The tank must include as well a devoted activation system,
- the water mist distribution system, consisting in piping, section valves, flexible hoses, connection etc.,
- the nozzles to create the water mist.

By a basic functional point of view, when the fire is detected by the fire detection subsystem, the fire suppression subsystem 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.

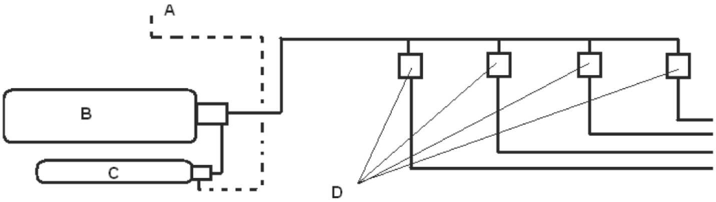

Fig. 3. Basic high pressure system functional schematics:
A) input from detection system; B) water cylinder, C) nitrogen cylinder;
D) electrical driven section valves; E) release lin**es**

3.1. Nozzles

Nozzles are a fundamental player in high pressure water mist technology. High pressure water mist nozzles' technology dates back to the early 30s of 20th century, and nowadays nozzles are a real example of fine tooling of sub-millimetre precision (Fig. 4). By an accurate nozzle's design different types of mist can be created, achieving different performances.

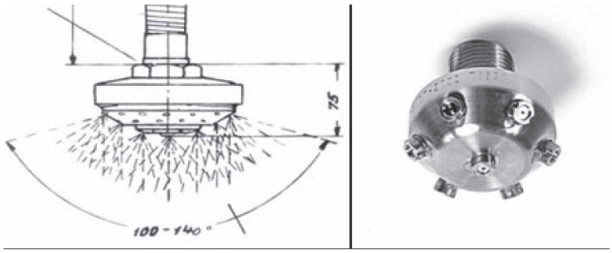

Fig. 4. Early 1930es water mist nozzles, and a last generation stainless steel nozzle of FOGTEC's range

The main features depicting the qualities of a nozzle, and therefore the quality of the water mist produced, are: *flow rate*, *average size* of the droplets created and the droplet's *momentum*, axial and rotational. *Flow rate* identifies the quantity of water the nozzles is able to let flow through and release in the area involved by the fire. It is the fundamental and most important parameter in the characterization of a nozzle. For its definition, a calculation parameter named *K-factor* is commonly used.

Such parameter allows an easy identification of the nozzle's flow rate, and manufacturers are asked to define and calculate it for all nozzle type used in their applications.

Flow rate can be calculated through the K-factor, by using the following formula:

$$Q = K \cdot \sqrt{p}.$$

Where:

K is the K-factor, expressed in l/(min $\cdot \sqrt{\text{bar}}$),
Q is the flow rate, expressed in l/min,
p is the upstream pressure, at nozzle level, in bar.

The *average size* of the created droplets is the fundamental parameter which identifies the water mist effectiveness in face of the flames. As told in before, smaller droplets can more easily fill the complete volume to protect, and have a wider heat exchange surface giving better performances in cooling and inertization effect by vaporization. The energy necessary for atomization comes from the pressure acting against the nozzle's small orifices. Since the size of the droplets is not fixed and unique in the same nozzles, but contrarily a nozzle produces a mist made by droplets of several sizes, often a Gauss distribution is used to depict the quality of the realized atomization and therefore the medium size is the feature to be considered (Fig. 5).

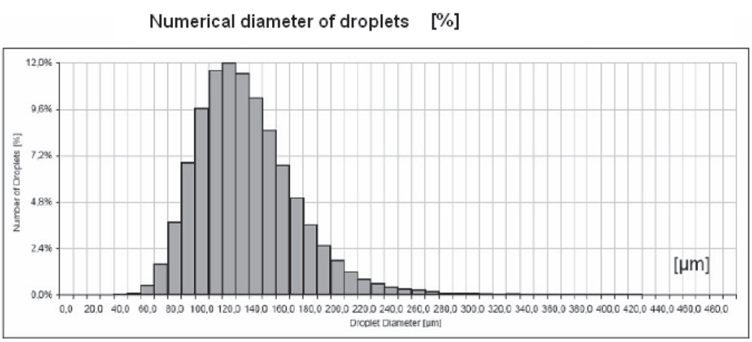

Fig. 5. example of distribution of water mist droplets size, created by a nozzle

The Gauss distribution is centred in the desired size of the droplets realized, its extension indicates the deviation from the design size. In general, smaller is the deviation; higher is the effectiveness of the nozzles to realize the design features. Depending on the nozzle quality and on the technological detail solutions adopted, the Gauss distribution can be then centred in corresponding of smaller of higher droplet diameters. Approximately, we could say that more is effective the atomization process, smaller will be the diameter of the droplets, and therefore higher will be their effectiveness in heat absorption; therefore an atomization made by using high pressure should bring better results.

Momentum is the quantity used as indicator while referring to the kinetic energy owned by the droplets just after the nozzle where the mist is created. The quantity momentum figures the ability of the water particle (and, therefore, of the water mist flow) to penetrate the flames and diffuse in the area to protect, and can be subdivided in its main components: axial and rotational.

A high value of axial momentum will give high linear speed to droplets, allowing them to cover longer distances from the nozzles. On the other hand, a higher rotational momentum will advantage the diffusion of the mist in the surroundings environment. The fundamental feature necessary for calculating the momentum is the speed of the water particle just after having crossed the nozzle, in a specific reference section named *vena contracta* (Fig. 6), placed in the most strict point of the water flow, generally just downstream (some millimetres) from the nozzle orifice.

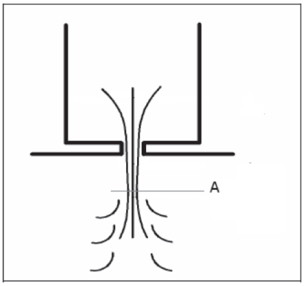

Fig. 6. Position (A) of the *vena contracta* section in the water mist flow sprayed by a nozzle

We can say that approximately the energy available to give to the momentum a big value at nozzle level is proportional to the pressure available at nozzle level. As soon as part of such energy is necessary to atomize the water, we can in principle say that, at same pressure, the two features (momentum and droplet size) are inversely proportional: means, while a higher momentum is requested, we will have as result an increasing of droplet size and vice versa.

As another example, varying the pressure available, to keep the same quantity of one of such features, will be necessary to adapt the other accordingly to the new lower or higher value of the pressure.

3.2. Water mist piping system

To bring the pressurized water to the area of the vehicle where the agent has to be released, a devoted piping has to run from the tank to the nozzles. The piping has to run long the areas to protect, and according to the design of the system must foresee a certain number of branches, protected e.g. by section valves, to release the extinguishing agent in the devoted area. The piping basically consists in:

- a first connection with the tank, which often is made by using flexible hoses due to the necessity disconnect for maintenance or crossing walls (e.g. the tank can be placed in the roof);
- a main piping, running all long the train or, more in detail, all long the different areas to protect. The used material is stainless steel;
- connected to the main piping by using section valves, the branches which cover directly the different release areas: can be a section of the saloon area in a passenger vehicle, or the power pack of a DMU;
- section valves and non-return valves, to create the correct path for the water mist to the release area;
- finally, along the piping, a number of nozzles to ensure the release of the water and its proper atomization.

The size of the piping is depending mainly in the pressure adopted, and it ranges between 16 and 12 mm of outer diameter.

The basic features to be considered in the design of the piping are:

- calculation of the *friction losses*,
- engineering of the integration in the carbody.

The calculation of the friction losses is fundamental to ensure that, starting at tank level with a certain pressure, the pressure at the last nozzles will be not minor than the design pressure, necessary to create the right quality of water mist. The design pressure at nozzle level ranges, in high pressure applications, between 70 and 120 bar.

The friction losses in a piping are the energy dissipated by the flow per time and flow rate, and is defined as the difference between the pressures at two extreme points of a piping, divided the density of the fluid:

$$R = \frac{p_1 - p_2}{\rho}.$$

Where R are the friction losses, p_1 and p_2 the pressures at the extreme points of the piping, is the density of the fluid running through.

Such friction losses are then calculated, according to the traditional theories of fluid mechanics, by considering length and diameter of the piping, the kinetic energy of the fluid, and specific *friction coefficient*.

The friction coefficient, conventionally indicated with λ, is determined by considering the roughness of the internal surface of the piping and the characteristics of the fluid flow (laminar or turbulent). Laminar or turbulent flow features can be defined by the *Reynolds number*, *Re*, which is calculated considering the mechanical features of the fluid (viscosity and density), its speed and the diameter of the pipe.

The coefficient λ is then normally estimated by using the *Moody chart* (Fig. 7) in which Reynolds number and friction factor are correlated by the roughness of the piping, both for laminar and turbulent flows.

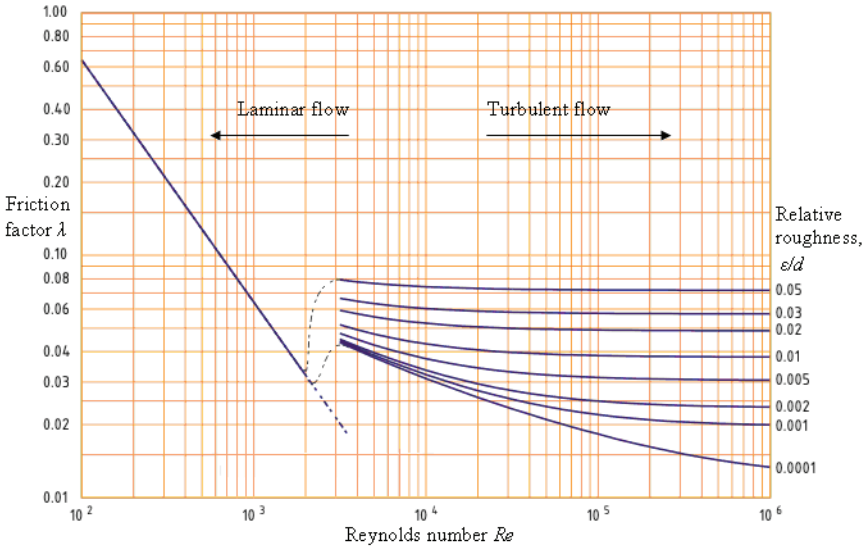

Fig. 7. Moody chart for the estimation for the friction loss coefficient

The roughness of the piping is defined by the relative roughness, means the ratio between a specific roughness factor ε, known for the common materials, and the diameter of the piping. Defined λ, the linear friction losses R_l can be calculated by using the formula:

$$R_l = \lambda \frac{L}{D}\frac{w^2}{2}\,.$$

Where L and D are linear length and inner diameter of the piping and w is the speed of the flow (expressed as kinetic energy).

The concentrate losses are to be added to the calculation, too. Concentrated losses are the pressure drops created by specific critical points of the piping (angles, valves, connections, diameter variations) which cause a localized obstruction of the flow. For this, for all specific points which can create a concentrate pressure drop an equivalent length in meters is introduced. The values of such equivalent lengths are tabled in all fluid mechanics manuals, depending on the size of the piping, and are added to the linear friction losses by using a similar formula:

$$R_c = \frac{w^2}{2}\left(\beta_n\right).$$

Where R_c are the concentrated losses, w is the speed as before and β_n are the equivalent lengths of the n critical points. The complete friction losses are therefore:

$$R = R_l + R_c.$$

The second aspect introduced, the integration in the car body, is actually the most specific of the rolling stock application, as it has to take into account specific factors that are not normally present in traditional fire fighting applications like e.g. building technology. Important aspects to be considered are:

- Spaces available: the piping has to run all train long, normally between the ceiling structure and the ceiling panels. In several scenarios, like double deck trains, the space available in height can be very limited.
- Weight: the piping has an important role in the weight of the system. For this reason, high pressure solutions are much more effective as the piping has a reduced size the in low pressure systems.
- Inter-car and cross wall and roof connections: depending on the design of the system could be necessary to run the piping between one coach and the next one. In such situation, devoted cross wall fittings and flexible hoses are necessary. Likely, the piping could run through walls or on roof: proper cross wall connections has to be integrated in the way to be pressure tight, detachable and, especially for cross roof piping, water proof.

Section valves (Figure 8) are another fundamental component of the piping. Their role is to open a specific branch of the main piping in the way to release the water mist only in a limited area. As their crucial role, section valve must be reliable and monitored in position. Lighter weight is always preferable, and the integration with the pipework has to be subjected to detail engineering, too. Section valves can find place in a devoted area, installed in battery, or localized in the specific points of the main piping, where the branch starts. Depending on the project, section valves with two or three positions can be adopted, covering therefore up to two areas together.

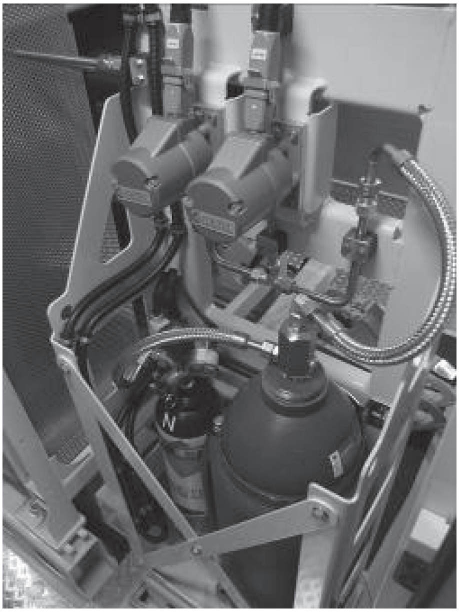

Fig. 8. Fogtec 2-way section valve, example of installation in an electric dual-voltage locomotive

3.3. Tank design

As a continuous access to a water source is clearly not possible in a rolling stock, the fire fighting system must have its own tank where store the water necessary to create the water mist. The role of the tanks is:

- storing the necessary water for ensure a proper fire fighting,
- storing the nitrogen, used as propellant for the water,
- with the devoted equipment, activate the release of the water.

A typical tank for a high pressure water mist system consists in a number of high pressure cylinders, connected by high pressure flexible hoses, and a frame to keep them together, allow its handling and transport and fix it to the train structure. The cylinders are common industrial high pressure cylinders, and are used to store the water and the nitrogen used as propellant.

Tanks are connected to the main piping of the fire suppression system and, due to their weight, need to be placed where is possible to connect them to structural elements of the car body. As done by Fogtec, tanks can be realized as plug and play modules, including cylinders, connection flexible hoses, all the equipment necessary for its activation; such modules can then find application as roof mounting, underfloor or in devoted spaces inside the car body.

The water tank capacity is determined by the water flow rate and the activation time of the water mist suppression system. The activation time is normally an input coming from the standard used for validation of the system, or project-defined basing on different standards or risk analysis.

The total necessary flow rate is done by the number of the nozzles that are activated together. The flow rate requested can be determined using the K-factor of the nozzle and the upstream pressure in the nozzle. The main formula for calculating the volume V of the tank can be expressed as:

$$V = Q_{tot} \cdot t \ .$$

Where Q_{tot} is the flow rate requested (by all the nozzles activated at same time) and t is the time of activation, expressed respectively in litres per minute and in minutes.

4. Examples of application

The first applications of high pressure water mist systems in rolling stock came to appear at the beginning of the 21st century. At nowadays, after almost 15 years of development, high pressure water mist systems demonstrated a high level of maturation in the design and in the overall quality. High pressure water mist systems have through the years been installed in passenger areas, diesel engines of locomotives, power packs of diesel traction units (so called *DMU*s) and are wide world well-known as standard solution for rolling stock. Fogtec has been pioneer in that field and based on this strong return of experience it will be now presented the applicative aspects of such systems in the vehicles.

4.1. Application in passenger areas

The first aspect to considered and understood while approaching water mist systems in passenger areas is their design goal: fire suppression instead of fire extinguishment. Such feature has been explained at the beginning of this paper.

The main aspect to be considered in a high pressure water mist system for passenger areas is the selectivity of the activation. In fact, passenger areas can be relatively open (standard UIC coaches up to 26 m in unique saloon), and therefore a fire suppression system without and sectorial activation („total flooding”) can result in very huge amount of water and subsequent excessive weight. For this purpose, a suitable detection system allowing discriminating the sector of the coach where the fire is detected will be very helpful in minimizing the number of nozzles to be simultaneously activated (Fig. 9).

Fig. 9. Sectional activation of a high pressure water mist system in a passenger vehicle (train type „German U-Bahn”)

On the other side, the area subjected to the release of water mist must be long enough to create a „safety zone” where people can stay during the fire event and evacuate in absolute safety.

At the actual state of technology, the right compromise for normal single deck coaches is to have the passenger saloon divided in two zones. Often an overlapping between the two zones is required[3] for safety reasons. This allows the use of up to 3–5 nozzles simultaneously activated with water quantity ranging between 70 and 100 litres based on number and type of nozzles and dimension of the area.

In shorter coaches, like typically in trainsets with Jakob or Talgo boogies, is not uncommon to have only one single detection and therefore suppression area in each coach, as in the next picture referring to a suburban electrical multiple unit with 13 m long coaches (Fig. 10). In double-deck coaches, always more and

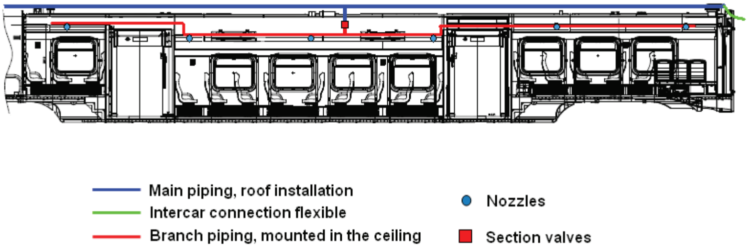

Fig. 10. General layout of a Fogtec fire suppression system for passenger areas (application: suburban electrical multiple unit coach), using high pressure water mist technology

[3] ARGE Guideline - Part 2 „Fire fighting in Rolling Stock”, Functional assessment procedure for the effectiveness of firefighting systems in rooms accessible to persons, in electric cabinets and in areas of combustion engines.

more common due to the increase of traffic in the existing lines with short platforms, the areas must be of course more: is it typical to have 3 or 4 areas of detection and subsequent suppression.

4.2. High pressure water mist system for diesel engines – power-packs and locomotives

Intensive testing activities have been carried out by FOGTEC for studying and demonstrating the effectiveness of high pressure water mist also in applications like in heated up engines and oily or pool fires, which are the typical fire risks in diesel locomotives or in diesel units powered by the so-called „power-packs" (Figure 11).

Fig. 11. Extinguishment of a fuel pool fire by high pressure water mist, during FOGTEC full scale fire tests in a mock-up of a locomotive engine room

Traditional water-based extinguishing agents (sprinkler systems, foams, water spray systems) have in fact bigger droplets size which can reach the oily surface, get inside it still at liquid form and evaporate suddenly with explosion risks. The reason why high pressure water mist can indeed be applied to heated up engines and oily or pool fires without danger can be found in the behaviour of the small water droplets. Their vaporization in the core of the flame and in its surroundings gives significant benefits in comparison with „traditional" water based systems.

The water droplets in fact do not reach the hot surfaces of the engine because they vaporize before. This is the opposite of normal water, which crosses the flames and goes up to the engine surface, potentially creating side damages even higher than the damages of the fire itself. In pool fires, the vaporization of the droplets creates a condition where the water does not reach the liquid and or heated up bottom of the pool fire, avoiding the extremely dangerous associated explosive effect.

High pressure water mist fine droplets vaporize and gradually cool down the atmosphere. The fire is extinguished step by step without environmental shocks and the water reach the heated up parts (exhaust manifolds, turbocharger, crankcase) only when they are already cooled down in a progressive and gradual way.

Also the strongly higher cooling effect of high pressure water mist systems in comparison to other water-based extinguishing systems makes the first suitable for safe and effective fire fighting in diesel areas. In fact, the thermal radiation of a fire in a diesel area can be extremely high to spread fire (*flashover* effect) to the materials and object all around the fire source being quickly no more controllable.

A fast activation of a high pressure water mist system allows therefore achieving not just a quick fire extinguishment, but also a preservation of the whole vehicle. Big engine rooms of traditional diesel locomotives are a typical application of high pressure water mist systems. For protecting such areas, usually equipped with big sized engines of original marine design, are usually necessary 20 to 50 litres of water and 7 to 20 litres of nitrogen as propellant. Depending on the layout of the engine room, it might be necessary to use 4 to 12 nozzles in the above and bottom part of the engine (Figure 12, 13).

One of the major dangers to be considered while designing a high pressure water mist system for diesel locomotives is the accumulation of fuel, oil and dirt at the bottom of the engine room. This dangerous fire source must be accordingly taken into consideration while defining the position of the nozzles. Power-packs are also a very common and suitable application for high pressure water mist (Fig. 14). In that case the engines are usually from heavy automotive industry and smaller than the one for locomotives. Also the risk of pool fires at the bottom can be reduced, as often power packs (if mounted hung underfloor) are opened on the bottom side for aeration purposes. For such application typically the water quantity is between 10 and 30 litres and a subsequent reduced quantity of nitrogen, having very compact and light tanks.

The number of the nozzles is usually from 4 to 6, depending on the size of the engine and its architecture (V or flat engine).

5. Conclusions

High pressure water mist systems are far the most diffused solution for fire protection in railway vehicles. While considering the protection of locomotives, the main goal is to preserve the operational readiness of the vehicles: each time the locomotive is out of service, money is lost.

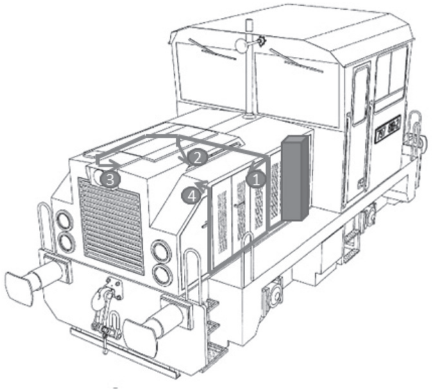

Fig. 12. Simple layout of a high pressure water mist system for a small-sized shunting locomotive, reference in Metro Warszawa

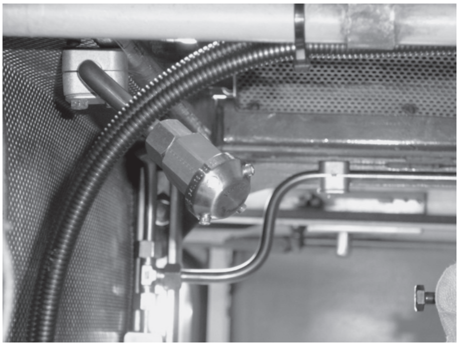

Fig. 13. High pressure water mist nozzle for application in a diesel engine room

Fig. 14. High pressure water mist release test at 120km/h in a power pack installed underfloor in DMU

Modern active fire protection systems based on high pressure water mist technology can improve the general cost balance of a fleet of locomotives while giving the chance of an up to date fire protection concept also to old vehicles. High pressure water mist systems for locomotives increase the safety level can be increased while the operational costs are decreased by minimizing breakdown times in case of incidents with fire. A modern and rail-developed active fire protection system can help to reduce direct fire damage, breakdown times and costs and will increase the availability of the vehicles at fleet level.

In passenger areas, they are used in high speed and longer distance trains to optimize the weight of the trains by using active fire protection solutions instead of e.g. fire barrier doors and to allow an open gangway philosophy like it is expected by the operators of local trains.

With the newest changes in the technical specifications for interoperability it is now also allowed from the side of law in Europe to realize this way of passenger protection in regard to incidents with fire. Additional benefits could be created by using these solutions during the specific approval processes.

Use of high pressure water mist can give good performances in terms of limiting the quantity of water stored, which means limiting the weight: such aspect is always more and more important in modern trains, which are asked to limit as much as possible the forces and the stresses between the rail and the wheel, often at higher and higher speeds.

Less quantity of water means also less space necessary for storing the water: also this aspect can be very important, especially in modern EMU/DMU passenger vehicles, where the car-body must be as much as possible reserved to the paying load and, accordingly, most of technical equipment must find installation on the roof or under the car-body (which sometimes is not available too, as in low-floor stocks).

With the goal a higher level of safety on board of the trains, high pressure water mist systems are an existing and validated solution, making also compensations measures possible (in materials, in construction, in design) and keeping, if not improving, the reliability, the weight management and the general quality level of the vehicle.

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Zastosowanie wysokociśnieniowych systemów mgły wodnej w taborze szynowym

Streszczenie

W artykule opisano zakres i wyniki badań projektu TRANSFEU (*Transport Fire Safety Engineering in the European Union*) „Inżynieria ochrony przeciwpożarowej w transporcie UE", finansowanego w ramach 7 Ramowego Programu UE (FP7-SST-2008-RTD-1 dla Transportu Powierzchniowego). Wykorzystując holistyczne podejście do bezpieczeństwa pożarowego taboru pasażerskiego, po analizie ryzyka i wytypowaniu najbardziej krytycznych scenariuszy, przeprowadzono wiele badań od skali laboratoryjnej do naturalnej. Wyniki badań walidowano symulacjami numerycznymi na każdym etapie. Uzyskano dużą przewidywalność rozwoju pożaru w skali naturalnej na podstawie symulacji FSE w zakresie szybkości wydzielania ciepła, temperatury i stężenia dwutlenku węgla. Natomiast dla emisji tlenku węgla oraz innych gazów toksycznych wystąpiły duże rozbieżności. Powyższe potwierdziło, że pożar w wagonie jest zjawiskiem bardzo skomplikowanym, na którego przebieg ma wpływ wiele czynników.

Słowa kluczowe: TRANSFEU, bezpieczeństwo pożarowe, tabor pasażerski, przewidywalność rozwoju pożaru, symulacja FSE

Применение систем тушения пожара в подвижном составе водяным туманом, распылённым под высоким давлением

Резюме

Автор представил теорию воспламенения и распространения пожара, а также технологию применений в подвижном составе водяного тумана, распыляемого под высоким давлением. В статье даны принципы проектирования и показатели эффективности для таких систем, а также приведены примеры их применений в пространстве пассажирского пользования и в отсеках дизельных двигателей локомотивов. Кроме того представлен также анализ преимуществ применения представленного решения для пожарной безопасности в подвижном составе.

Ключевые слова: противопожарная защита, подвижной состав, вода, водяной туман, система водяного тумана, распылённого под высоким давлением