The Protection of Machinery Spaces by means of the Local Application of Water Mist

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Contents

Introduction

Water mist fire suppression systems—originally designed for ships--have long been identified as a safe and reliable form of extinguishing fires on machinery. Yet, no matter how well designed, engineered and manufactured these systems may be, their safety and reliability depend on the utilization of fire test protocols to determine if they are suitable and approved for specific applications. Water mist fire suppression systems are not a one-size-fits-all solution. Despite this, designers-suppliers often mistakenly interpret an approval as applicable to all risks. The design of water mist systems is both technology and manufacturer dependent; therefore, verification can only be achieved if independent fire testing has been carried out by a published third party protocol. In addition, each protocol has limitations that need to be considered. There are two general categories of water mist test protocols: one in accordance to marine standards and the other in accordance to land standards. These requirements differ substantially. If a marine solution is applied to a land-based application, for example, this could result in inadequate protection. This paper will review the current protection options available for local applications and the correct solutions that should be adopted.

Local Application

In a local application system, a fixed supply of extinguishing media is discharged into a defined area that has no enclosure or is only partially enclosed. The fire risk is normally of Class B or Class K (See Table 1 below for examples).

Application	Fuel Type	Fire Class
Printing Presses	Toluene	B
Industrial Fryers	Canola Oil	F (K outside of Europe)
Generators	Diesel	B
Transformers	Oil	B
Engines	Diesel	B

Table 1 – Examples of local applications

When protecting the total volume of an area, the effect on openings such as doors and windows needs to be considered; this is not the case in a local application design. Protection by a local application system is often preferred since, in many cases, the hazard is small in relation to the room in which it is contained. To provide a solution that totally floods the volume with extinguishing medium would not be economical.

For the purposes of this paper, we consider only local application risks of Fire Class B, such as generators, transformers and industrial machinery. The protection of Class F (K) hazards differs greatly due to the high ignition temperatures of the oils. The latter is restricted to the protection of industrial deep fryers, a separate solution that Johnson Controls Fire Suppression provides.

Extinguishing Options

Historically, the two choices of extinguishing media for local application protection have been gas solution, i.e. carbon dioxide (CO_2) or water solution, i.e. water spray. Carbon dioxide is designed according to the standards NFPA 12, BS5306 Part 4, ISO 6183 or CEA 4007. Water spray is designed according to the standards NFPA15 and FM 4-1N. Water mist was introduced in the marine industry as a safer alternative to CO_2, which still today is utilized on marine vessels and can be harmful to people.

Carbon Dioxide

Carbon dioxide extinguishes the fire through the dilution of oxygen. It offers minimum cooling effect, and nozzles need to be directed appropriately for the gas to exclude all oxygen around the combustible surfaces. Since extinguishment is only achieved through reduction in oxygen, the duration of the discharge must be long enough to allow the combustibles to cool below their ignition temperature. Deep-seated fires (those that contain a large amount of residual heat beneath the surface) are normally outside of the practical use of carbon dioxide. The gas is also subject to air movements and therefore cannot be used in ventilated environments.

Water Spray

Water spray (deluge) systems extinguish the fire by physically separating the combustible with the water so that no contiguous combustion path can form. Water discharges in large quantities providing substantial cooling. Sufficient allowance for “bunding” to contain the discharged water/combustible and suitable drainage need to be provided for. Since the application is at medium or high velocity the system can function in high airflows, and is therefore suitable for outdoor use.

Water Mist

Water mist systems extinguish the fire through a combination of dilution of oxygen at the flame front and direct cooling. Their performance is dependent on the layout of nozzles and configuration of the risk. There are no design standards detailing how a water mist system must be designed. Performance criteria and limitations are detailed in third party fire test protocols. Because water mist is affected by ventilation, which must be shut down prior to activation, this system is not suitable for outdoor applications.

Fire Test Protocols

Fire test protocols are methods used to determine the suitability and approval of water mist for a given application. The first fire test protocol for water mist protection of local applications was published by the International Maritime Organisation (IMO) - IMO MSC/Circ 913 and was later updated and re-designated IMO MSC/Circ 1387. For land-based applications, there are three published fire test protocols: FM 5560 Appendix I; BS 8489 Part 4 (based on the FM protocol); and the French approvals authority CNPP “TD2”.

Each fire test protocol has limitations, and it is important that these limitations are taken into account. As mentioned previously, often, designer-suppliers mistakenly interpret the approval as suitable for all application risks. The limitations of these fire test protocols are as follows:

IMO 1387 fire test protocol

IMO 1387 was introduced as a first stage intervention to extinguish a fire on board a ship. The goal of designing the protocol around the extinguishment of spray fires from an engine casing was for the local application to be initiated without shutting down the entire engine room. Fire tests are undertaken in an enclosure 100m^2 with a ceiling height of at least 5m. There are 10 test configurations (five undertaken at maximum height, and five undertaken at a 1m height). The approval is for extinguishment to occur within five minutes with no re-ignition. The test protocol is limited to exposed spray fires only. There are no tests on pool fires or concealed fires.

As per concept, the design protocol provides primary protection only and requires that a secondary (flooding) protection system be used. This requirement is necessitated by the fact that many water mist applications on land have been installed without a secondary protection system, which seriously compromises the security of the system. A mandated requirement is a minimum 20-minute discharge: many systems are designed with a discharge of a few minutes with no safety factor. Additional requirements include mandatory interlocks for electrical, fuel, lubrication and ventilation shutdown; and suitable containment of the release of flammable liquids.

FM5560 fire test protocol

The FM5560 fire test protocol (Appendix I) is a land application test. The enclosure has to be a minimum of 500m^3 volume and at least 5m high. There are 23 tests that include:

- square pool fires
  (four tests including minimum and maximum nozzle height)
- channel pool fires
  (four tests including minimum and maximum nozzle height)
- spray fires
  (four tests including minimum and maximum nozzle height)
- combined pool and spray fires
  (five arrangements at maximum nozzle height)
- obstructed pool fire
  (two tests including minimum and maximum nozzle height)
- combined pool and spray fires with an external ignition source
  (two tests including minimum and maximum nozzle height)

The pass approval is to extinguish the fire in all tests. The minimum discharge time is 10 minutes or double the worst case extinguishing time. Similar to IMO 1387, other requirements include mandatory interlocks for electrical, fuel, lubrication and ventilation shutdown; and suitable containment of the release of flammable liquids.

The BS8489 Part 4 test protocol has been developed from FM5560 and is essentially the same fire test.

CNPP TD2 fire test protocol

The CNPP TD2 fire test protocol was established by the French approval body, is a land application test and is based around an actual mock-up.

Figure 1 – Photo of the Mock-Up of the CNPP TD2 Fire Test

The protocol's seven test configurations include: pool fires (two off); large burning spray fire; small burning spray fire; small burning fuel leak fire; large burning fuel leak that could turn into a pool fire; and a cable tray fire. The pass approval is to extinguish the fire in all tests. The minimum discharge time is 10 minutes or double the worst case extinguishing time. Other requirements include mandatory interlocks for electrical, fuel, lubrication and ventilation shutdown; and suitable containment of the release of flammable liquids.

In summary, the marine IMO 1387 only permits protection of exposed spray fires, where as FM5560 and CNPP TD2 allow the protection of risks with the potential occurrence of spray fires (exposed or obstructed) and pool fires (exposed or obstructed), as well as electrical fires – essentially all potential fire events on land. Since the latter approvals cover all eventualities, a secondary fire protection system is not mandated.

Development Programme at CNPP

Many years ago, JCI obtained marine approvals in accordance with IMO 1387 for both its low pressure AquaMist ULF and high pressure AquaMist FOG water mist systems. As part of JCI's on-going product development and to prove the differences between IMO 1387 approved systems and land application protocols, JCI undertook the CNPP TD2 tests in 2015.

A total of 58 tests were completed, including testing the nozzles approved to IMO 1387. The generator mock-up has a dimension of 5m(length) x 2m(width) x 2m(height). Installed instrumentation included thermocouples, heat flux gauges, pressure sensors and a flow meter. Cameras were used for recording.

The fuel package was diesel and fire scenarios varied in fire power: 3MW for the pool fires, 3MW for the spray fires and 2.4MW for the burning leakage fires.

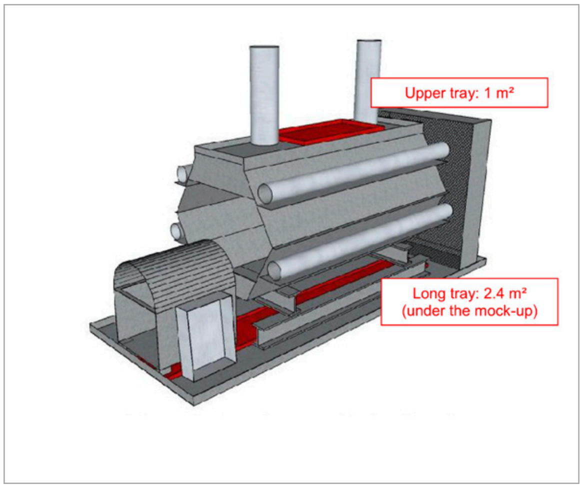

Figure 2 – Pool Fire Tests (the tray positions are in red)

For the pool fire tests, the pool fire on the upper tray ($1m^2$) above the mock-up was 1.1MW, and the pool fire on the lower tray ($2.4m^2$) under the mock-up was 3MW.

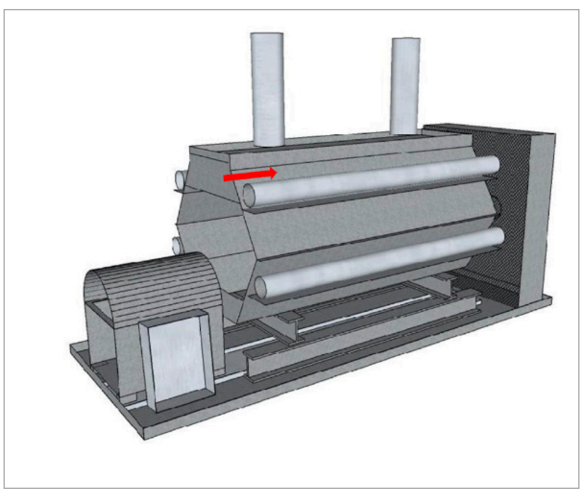

Figure 3 – Spray Fire Tests (spray location is indicated by the red arrow)

For the spray fire tests, the small spray was 480kW – 590kW, and the large spray was 2.3MW – 3MW.

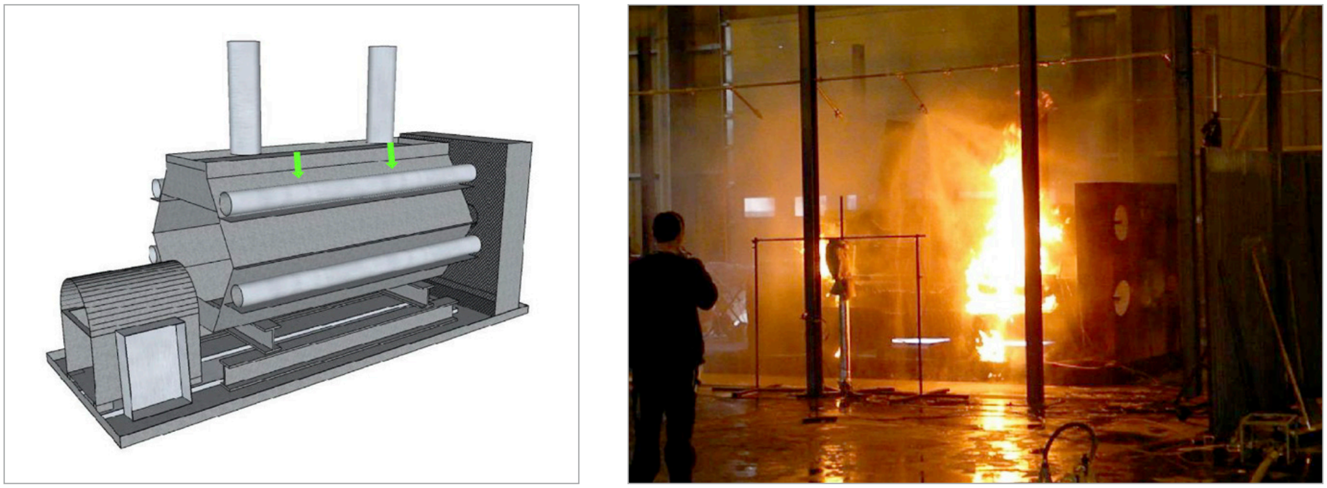

Figure 4 – Burning Leak Tests
(the green arrows indicate the two diesel injection points)

For the burning leak fire tests, the small leak was 410kW, and the large leak was 1.9 – 2.4MW.

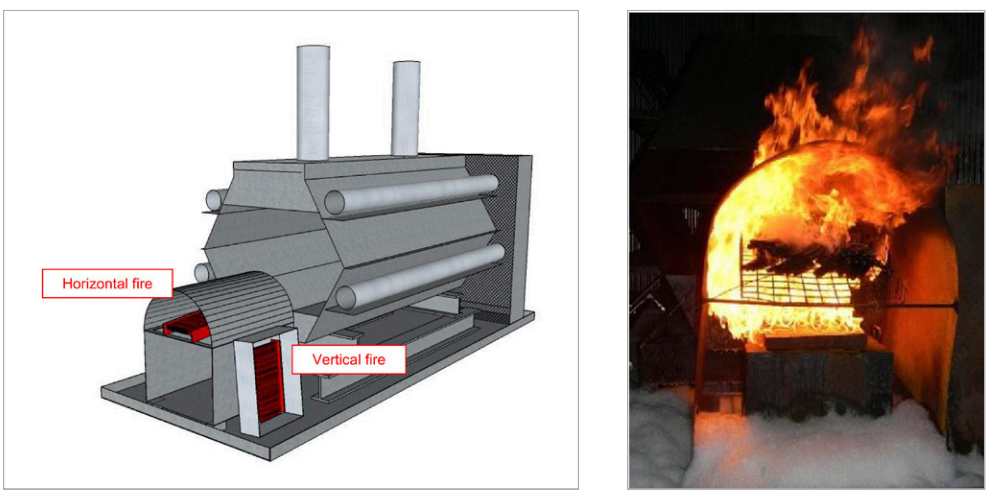

Figure 5 – Cable Fire Tests
(cable trays are in red)

For the cable fire tests, the set-up partially obstructed the cable trays.

The large (horizontal tray) had a fire load consisting of heptane (59MJ) and cables (23 quantity of 80cm length weighing 9kg, equivalent to 378MJ). The small (vertical tray) had a fire load consisting of heptane (29MJ) and cables (23 quantity of 60cm length weighing 7kg, equivalent to 294MJ).

The tests were repeated with different nozzle types. Additionally, changes were made to angles, distance, height, k-factor and discharge pressure.

The first test results on IMO 1387 nozzles showed that the design could not extinguish the concealed pool fires. In fact, the tests could only be successfully passed through the addition of a foam concentrate in the water mist supply.

The k-factor and, hence, flow were higher than that required for the IMO 1387 tests, so more water is required, and nozzle spacing is less. A combination of droplet sizes is necessary to cool the surroundings and displace the oxygen. Larger droplets penetrate the fire plume due to the increased momentum.

In reviewing the solutions from competing products approved to CNPP TD2, we identified that every solution has required the use of foam and that no "pure" water mist system is currently available.

Conclusions

In order to pass the local application fire tests for a combination of fire scenarios, additional nozzles, increased flow and the addition of foam additive are required. This increases the cost of the system above the commonly used IMO 1387 solution. However, these tests confirm that the IMO 1387 solution should not be used for land-based applications unless the limitations and restrictions of the type of fire that can be extinguished are clearly documented and accepted by the user. In this case, a secondary protection system would also be required, mitigating any possible (misguided) cost savings and complicating system management.

In summary, in accordance with the approval requirements, all systems must be supplied with approved components as tested in the fire protocols.

References:

FM5560 (2016) Approval Standard for Water Mist Systems Appendix I fire Tests for Water Mist Systems for the protection of Local Application Systems.

BS8489 Part 4 (2016) Fixed fire protection systems – Industrial and commercial Watermist Systems BS 8489-4:2016 Part 4: Fire performance tests and requirements for water mist systems for local applications involving flammable liquid fires.

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Dr. Tim R. Nichols holds a Ph.D. in Physics. He undertook postdoctoral work in Japan before returning to the UK to join the fire industry in January 1991. He has held posts in research, product development, sales and international management, and now serves as Sales Director, Special Hazards, Engineered Systems & Water Mist for Europe & Africa at Johnson Controls. He is a member of British and CEN standard committees for water mist systems. Nichols has written several papers and a book on fire extinguishing systems, is an expert witness, and has been involved in the design and supply of several prestigious and large engineering projects protected by water mist systems. He is a Fellow of the Institution of Fire Engineers and a Chartered Physicist.

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