FIRE SUPPRESSION OPTIONS FOR MACHINERY SPACES UNDER THE NEW NATIONAL STANDARD FOR COMMERCIAL VESSELS

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Whilst the impending performance-based National Standard for Commercial Vessels is unlikely to change the requirement for fire suppression systems in machinery spaces, authorities, designers and suppliers need to ensure that the design and performance of such systems are appropriate to the hazard.

The inclusion of "marine" sections in various Australian Standards covering gaseous and water based systems now provides sound and measurable engineering standards.

After the banning of halons under Resolution A.719 (17), IMO published MSC Circulars 848 and 914 detailing real fire test regimes in which candidate gaseous and water systems are required to undergo and pass before being accepted as "alternative" agents and systems.

THE CURRENT LEGISLATION

The Australian Transport Council has adopted the Uniform Shipping Laws (USL) Code as a basis for uniform legislation within the States and Territories relating to the construction, survey, manning and operation of commercial vessels in Australia in Australian waters.

The following state and territory bodies are responsible for implementation and administration of the USL Code:

- Marine Board of Victoria
- Marine and Safety Tasmania
- NSW Waterways Authority
- Queensland Department of Transport
- Northern Territory Department of Transport and Works
- South Australia Department of Transport
- Western Australia Department of Transport

For vessels requiring USL survey, Section 11 – Part 2 – Scales of Fire Fighting Equipment – details the type and extent of such safety equipment according to Class.

Where fixed fire extinguishing systems are required in machinery spaces, these requirements are summarised below.

Appendix E

Required in:

- All Class 1A vessels with machinery spaces containing oil – boiler/settling tank/fuel unit or any internal combustion propulsion or auxiliary machinery exceeding 750kW.
- Class 1B, 1C, 1D, 1E, 2A, 2B, 2C, 2D, 3A, 3B and 3C vessels over 25 metres in length, with machinery spaces containing oil – boiler/settling tank/fuel unit or any internal combustion propulsion or auxiliary machinery exceeding 750kW.
- Class 2E vessels over 35 metres in length, with machinery spaces containing oil – boiler/settling tank/fuel unit or any internal combustion propulsion or auxiliary machinery exceeding 750kW.

Appendix E specifies a fixed, manually-operated CO_2 or halon or halon 1211 or steam or inert gas or foam or water spray system for machinery spaces, with the added requirement of an audible alarm for gaseous systems.

Appendix F

Required in:

- Class 1B, 1C, 1D, 1E, 2A, 2B, 2C, 3A, 3B and 3C vessels over 12.5 metres and under 25 metres in length with a machinery space containing oil-fired boilers or internal combustion engines.
- Class 3D vessels over 25 metres in length with a machinery space containing internal combustion engines.

Appendix F specifies a fixed, automatic (temperature) approved halon alternative system with container inside or outside the space or fixed, automatic (temperature) CO_2 or approved halon system with container outside the space or fixed, manually-operated (from outside) CO_2 or approved halon system with container inside or outside the space. Gas quantities as per Appendix F. Where the vessel is not steel or equivalent, gas quantity to be 1.5 times that specified in Appendix F.

Alternatives

Class 2A, 2B, 2C, 3A, 3B,and 3C vessels over 12.5 metres and under 25 metres in length with a machinery space containing oil-fired boilers or internal combustion engines, may substitute the Appendix F system with a manually-operated water spray system served by a hand pump outside the compartment.

The design requirements for Appendix E systems generally follow the requirements for the protection of Category "A" Machinery Spaces in vessels as are detailed within SOLAS and the AMSA Marine Orders Part 15.

The Regulations detail the methodology by which each system should be designed and theoretically any of the nominated systems can be used although the various National administrations are unlikely to accept steam, inert gas, foam and the "specified" water spray systems as meeting modern fire protection performance requirements.

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REAL FIRE TEST REGIMES

IMO Resolution A.719 (17) – Prevention of Air Pollution from Ships – adopted on November 6, 1991, prohibits the use of halons in installations of fire extinguishing systems (except those falling in the category of "essential use") on a ship the keel of which is laid on or after July 1, 1991.

With the demise of halons and the emergence of the plethora of alternative fire suppression systems and agents, IMO published MSC Circular 848 dated June 1998 and MSC Circular 914 dated June 1999 detailing real fire test regimes which candidate gaseous and water spray systems are required to undergo and pass before being accepted as "alternative" agents and systems.

In the IMO tests (Figures 1 and 2), systems, are tested in an enclosure of a minimum $100m^2$ and five metres in height. An engine mock-up of one metre by one metre by three metre on a four metre by six metre floorplate at 0.75 metres above the floor is installed within this enclosure. This test involves the use of diesel and heptane in both pool and spray configuration and a wood crib with significant pre-burn times. The candidate extinguishing agent/system is required to extinguish the fires within a specified time.

Gaseous systems, once successful at this $500m^3$ test protocol, are deemed acceptable up to any volume at their tested nozzle spacing. The gaseous agent concentrations, based on net volume, that have had to be used to successfully pass these tests have been significantly above those referenced in the land-based Codes such as NFPA.

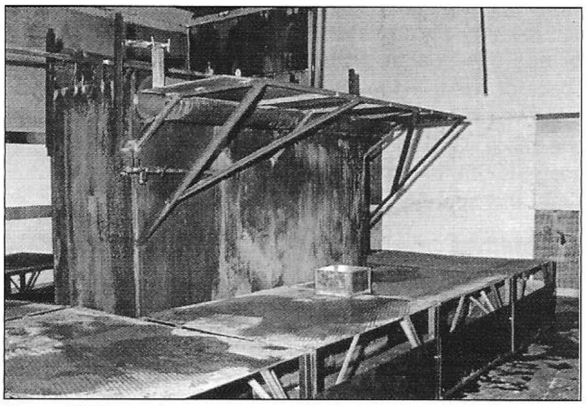

Figure 1 IMO test rig

Water mist systems however, are limited to the volume tested as it is acknowledged that water mist does not act like a gaseous agent. The concept of deckhead only nozzles and separate lower level protection however is part of the test.

It is known that IMO will soon be promulgating requirements for Local Water Mist systems to be installed on new vessels, especially VLCCs and ULCCs and quite possibly FSOs and FPSOs. Such systems are designed to

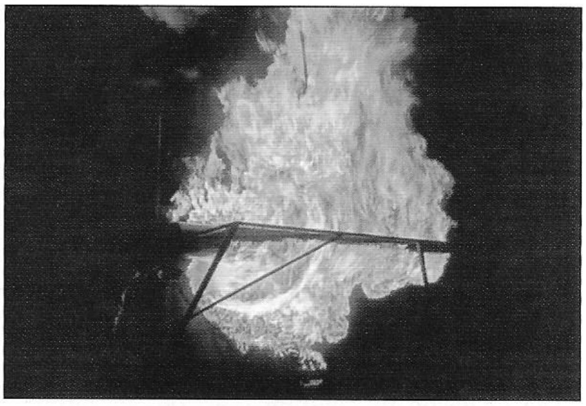

Figure 2 IMO test fire

provide automatic water mist fire suppression on and around specific high hazard areas in machinery spaces to combat fire at the earliest possible moment. The adoption of such systems is thought to be one answer to the difficulty in protecting very large spaces with a single water mist system.

EXTINGUISHING METHODOLOGY

At this point it would be useful to recap the mechanisms by which various agents extinguish fire.

- Halons and halocarbons extinguish fire by a combination of cooling and breaking the chain reaction of flame propagation and the concentrations at which they are discharged displace very little oxygen and are generally below the NOAEL (No Observed Adverse Effects Level). These gaseous agents are three dimensional in effect and can extinguish pressure, spray, running and pool fires in a very short time period.
- CO_2 and inert gases reduce the concentration of oxygen to a level below which flame can continue to propagate. These gaseous agents are three dimensional in effect and can extinguish pressure, spray, running and pool fires in a very short time period. Certain inert gases such as Inergen have precise design concentrations and a CO_2 additive, which provides respiratory stimulation enabling life to be supported.
- Water mist extinguishes fire by a combination of heat absorption and oxygen dilution due to the generation of steam. Water mist is three dimensional in effect and can extinguish pressure, spray, running and pool fires in a very short time period.
- Water spray extinguishes fire by cooling the fuel load and surrounding structure below the flash point of the fuel. Water spray is two dimensional in effect and extinguishing times are long. Shielded and pool fires are difficult to extinguish.

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- Dry powder and particulate aerosols extinguish fire by breaking the chain reaction of flame propagation. Dry powder and particulate aerosols are three dimensional in effect, no oxygen dilution is effected and extinguishment is effected in a short time period.
- High expansion foam extinguishes fire by a combination of oxygen dilution due to the generation of steam and cooling the fuel load. Oxygen dilution is minimal allowing enabling life to be supported. High expansion foam is three dimensional in effect and extinguishing times are long.
- Low expansion foam extinguishes fire by blanketing spill and pool fires thus depriving the fire of oxygen. Low expansion foam is two dimensional in effect and extinguishing times are long. Pressure, spray, running and shielded fires are difficult to extinguish.
- Steam extinguishes fire by oxygen dilution. Steam is three dimensional in effect and extinguishing times are long.

SYSTEMS SAFETY

The introduction of Halon 1301 and 1211 in the 1970s was a significant step forward in reducing system space and weight requirements and also the fact that they were "safe" agents. There is a widespread belief that occupants can survive a fire condition during agent discharge. In reality, halons and halocarbons are only safe under inadvertent discharge conditions as discussed later.

This concept of safety has been perpetuated with the replacement halocarbon, inert gas and water-based suppression agents, and to properly understand the meaning of the term "safe", one must analyse the circumstances under which an agent can be considered safe.

Unlike AMSA vessels, most USL survey vessel machinery spaces are either too small to be occupied or are unoccupied under normal circumstances. There are, however, times when the compartment may be occupied, such as during inspection, maintenance or repair.

The actuation of a fire suppression system can be considered to occur under four scenarios:

1. Under a "no fire" situation with cold machinery. Here the toxicity of the raw agent and oxygen displacement are the determining factors for safety.

   Of the available extinguishing agents, CO_2 and inert gases, with the exception of Inergen, will render the compartment untenable through oxygen dilution. High expansion foam, dry powder and aerosol particulates will severely affect visibility and steam will produce scalding effects.

   Exposure to the other agents will not affect life safety provided egress is effected promptly.

2. Under a "no fire" situation with hot machinery. Here the products of decomposition of the agent and oxygen displacement are the determining factors for safety. Halons and halocarbons will decompose on contact with hot surfaces like turbo casings producing HF, HCl and other gases that will be hazardous. Exposure risks for other agents will be as for scenario 1.
3. Under a "fire" situation. Here, regardless of the agent used, the effects of flame and combustion products present by far the greatest risk. Evacuation of the compartment is imperative before discharge of any of the agents.
4. In a "post fire" situation exposure to the compartment by re-entry must be effected with suitable breathing protection and equipment ready to combat reflash.

AUSTRALIAN STANDARDS

Various Australian published and draft Standards now exist which provide design guidelines for certain marine systems. These are:

- AS 4214 Gaseous Fire Extinguishing Systems Parts 1 to 5 inclusive covering General requirements, Inergen, CO_2, FM200 and NAF S-III. Parts 6 and 7 cover FE13 and Triodide, which have not had real marine fire test concentrations determined.
- Draft Standard DR99552 is currently out for public comment and includes specific marine requirements.
- AS 4587 Water mist fire protection systems includes specific marine requirements.

CANDIDATE AGENTS AND SYSTEMS

The agents and systems listed in Table 1 may be considered as potential candidates. The traditional prescribed systems are also analysed although none have been subjected to real fire test regimes.

Halocarbon agents - FM200 and NAF S-III	Acceptable candidates, fully tested
Inergen	Acceptable candidate, fully tested
CO_2	Acceptable candidate, approved by default
Aerosol Particulates	Acceptable candidate, subject to testing
Foam, Dry Powder, Water Spray	Unacceptable candidates, untested
Inert Gas and Steam	Unacceptable candidates, untested and unavailable

Table 1 Summary of potential machinery space fire suppression agents

Carbon dioxide

The traditional total flooding system used in marine systems. Fixed systems using carbon dioxide to protect machinery spaces were introduced in the late 1920s.

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Due to its use over many years, CO_2 has, by default, received international approval and is specifically nominated within SOLAS and other marine regulations as applicable for machinery space and cargo hold protection.

Carbon dioxide in low concentrations is not a toxic gas in the generally accepted sense of the term (ie. poisonous). However, in exposure to the high concentrations required in use of CO_2 for firefighting purposes, a person would quickly die of CO_2 acidosis and lack of severe oxygen called asphyxiation. It is most important, therefore, that those involved with the design and operation of CO_2 systems should be acquainted with all safety requirements.

The design concentration of 30 to 40 per cent is above the LOAEL and the NOAEL.

CO_2 has not been subjected to the IMO fire test regime.

NAF S-III

A mature, tested and approved gaseous agent currently in use in many commercial vessels and some Royal Australian Navy (RAN) vessels. As with all halocarbons, high levels of HF production occur on decomposition. The design concentration of 12 per cent has recently been assessed as being above the NOAEL and LOAEL of 10 per cent. Many existing small boat systems have been designed to a 10 per cent concentration based on gross volume.

NAF S-III is classified as a transient replacement agent and should only be utilised for the replacement of existing halon systems in unmanned machinery spaces.

NAF S-III has passed the IMO test regime and has USCG and MCA approvals.

FM200

A mature, tested and approved agent currently one of several favoured replacement agents for halons in the marine industry.

Figure 3 FM200 system

Under normal conditions FM200 is an odourless and colourless gas with a density of about six times greater than air. As with all halocarbons, high levels of HF production occur on decomposition.

The design concentration of 8.7 per cent is below the LOAEL of 10.5 per cent and the NOAEL of 9.0 per cent.

FM200 has passed the IMO test regime and has USCG and MCA approvals.

Inergen

An extinguishing agent composed entirely of naturally occurring gases already found in the earth's atmosphere – nitrogen, argon and carbon dioxide.

Inergen extinguishes fire by displacing a proportion of the available oxygen in the protected enclosure with an inert gas mixture so that the remaining oxygen is below the level required to maintain combustion. For the marine concentration of 37.5 per cent, the residual O_2 is 13.7 per cent and the CO_2 is 2.5 per cent.

Unlike halocarbons, no HF production occurs on decomposition. The design concentration of 37.5 per cent is below the LOAEL of 52 per cent and the NOAEL of 43 per cent.

Inergen has passed the IMO test regime and has AMSA, USCG and MCA approvals.

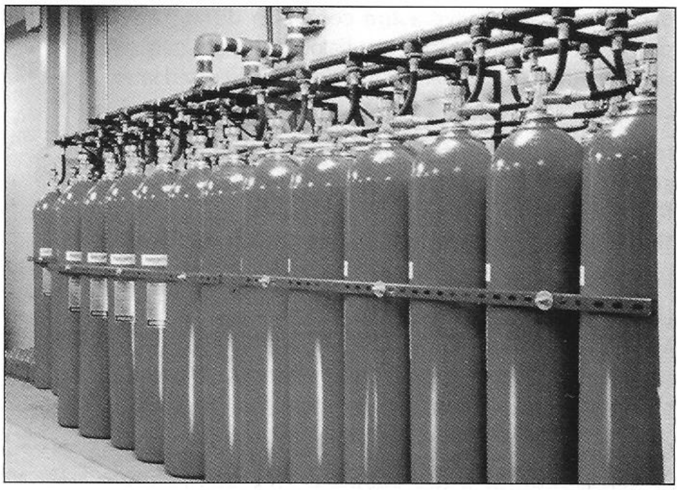

Figure 4 Inergen system

Foam

A mature extinguishing agent that can be applied in either low or high expansion forms.

Low expansion foam is applied to bilge areas and savealls in accordance with SOLAS application rates.

High expansion foam is discharged into and completely fills the compartment. Continued discharge for a specified period of time compensates for breakdown.

Foam has not been subjected to the IMO fire test regime.

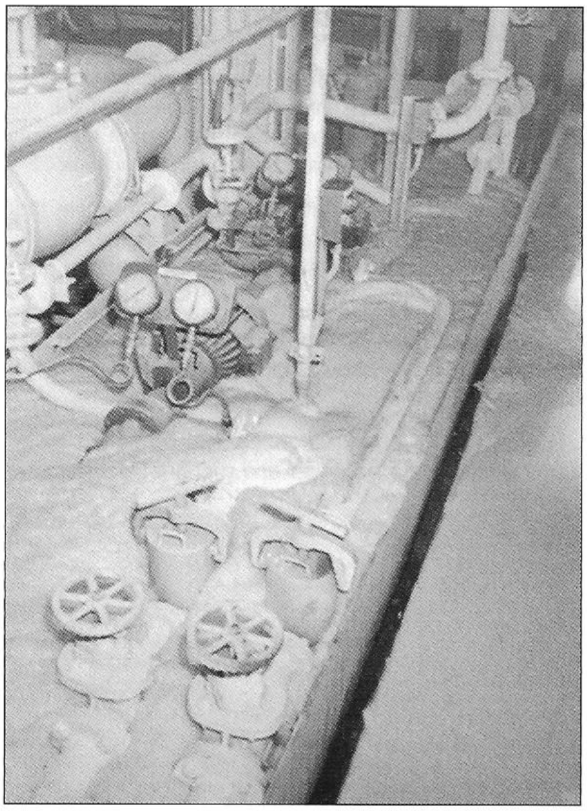

Figure 5 Machinery space after discharge of a foam system

Steam

Steam systems are no longer a real option due to the fall from grace of the steam turbine and the limited availability of steam from auxiliary boilers.

Inert waste gas

Conventional inert gas systems are not an option on vessels other than tankers which have inert gas generators.

Dry powder and aerosol particulates

Dry powder systems are used extensively for industrial fire suppression but in their traditional configurations, have found little use in the marine environment.

Aerosol particulate systems such as Micro-K and Pyrogen have been developed from dry powder technology to provide compact and rapid discharge systems in a modular configuration.

Neither dry powder nor aerosol particulate systems have been subjected to the IMO test regime although Micro-K and Pyrogen have been subjected to smaller scale testing and have been granted approval by various Authorities for small vessel systems.

Water spray

Water spray systems designed under the SOLAS application rates can only be effective when designed specifically to target anticipated fire sources. Accordingly water spray has not been subjected to the IMO fire test regime, as it would likely fail.

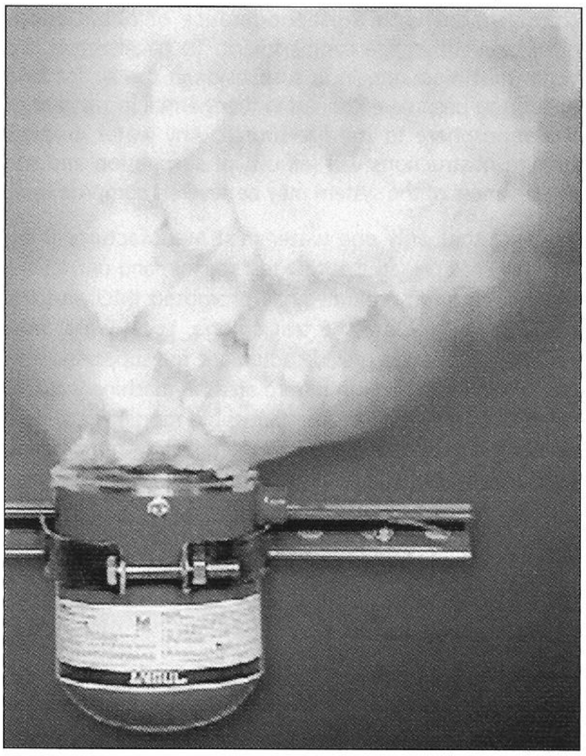

Figure 6 Aerosol particulate system

Water mist

There are three fundamentally different methods of water mist technology generally available that are unlike traditional water spray which uses considerably lower discharge pressures of around 275kPa.

- Low Pressure – in the order of 10 to 15 bar (approximately 1.0 to 1.5MPa)
- High Pressure – in the order of 30 to 200 bar (approximately 3.0 to 20MPa)
- Atomising – in which water at a relatively low pressure of 5.0 bar (0.5MPa), is mixed with compressed air.

In the IMO test regime the physical configuration of a relatively small engine mock-up and floor plate in the large test enclosure leaves a significantly large overhead and annular space around the "engine". This relatively large ratio between open void and engine volumes is typical of large commercial vessel machinery spaces, substantiates the test protocol and enables the water mist to thoroughly mix with the atmosphere and permeate shielded spaces

A typical small vessel machinery space is usually relatively small with the installed machinery occupying most of the

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compartment with a preponderance of obstructions elsewhere within the compartment. To be effective, the water mist must remain in suspension in the air for long enough to become entrained in the thermal movement of the atmosphere to the fire source. Any water droplets striking obstructions will fall out of suspension and the effectiveness of the system may be severely compromised.

The fact that only one water mist manufacturer (high pressure) has passed the IMO test regime, and only at the 500m^3 maximum volume, has prompted IMO and the USCG to re-evaluate the test criteria. Local water mist systems designed to provide automatic fire suppression on and around specific high hazard areas in machinery spaces to combat fire at the earliest possible moment are now considered to be one answer to the difficulty in protecting very large spaces with a single water mist system.

A number of other small water mist systems have been subjected to smaller scale testing and have been granted approval by various authorities for small vessel systems.

Costs and availability

Initial installation costs will vary according to vessel size and system type. Figure 7 shows the relationship between typically available popular systems for a 75m^3 space. Note the disparity between installation and recharge costs.

An important consideration is the long-term availability of agents. Unlike halocarbons and manufactured chemicals, water and natural gases such as CO_2 and Inergen will never be subject to environmental restrictions.

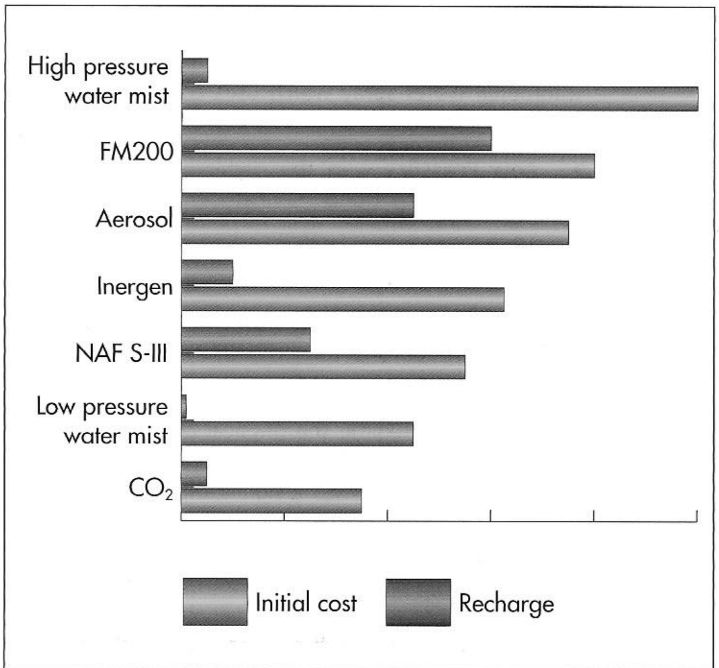

Figure 7 Relative installation and recharge costs for various agents based on protecting a 75m^3 space

CONCLUSION

Despite prescriptive regulations, vessels owners and builders must recognise that the performance of the fire extinguishing system needs to have a demonstrably satisfactory performance for the intended application.

This may be achieved by either selection of a system that has passed IMO or other acceptable tests or is designed in accordance with acceptable Australian Standards.

System safety is of paramount importance considering the obligations under occupational health and safety legislation and crew should not be relied on to carry out duties beyond their skills and training.

Vendors should be experienced and be called on to demonstrate tested, approved and supportable systems.

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