FURTHER EVALUATION OF WATERMIST FOR THE ROYAL NAVY

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ABSTRACT

In 1993 the Royal Navy's firefighting section, ME225, instigated a programme of work to research the principles of watermist and develop its application as a possible replacement for halon in warship machinery spaces. Since that time the programme has progressed from initial experiments to examine the interaction between mist and flame, through trials in an unenclosed rig designed to investigate 'zoned' protection[1], to further tests with the rig enclosed. The earlier work was described in a previous *Journal* article[2]. The latest phase of work has involved two projects. At the Loss Prevention Council, trials have been carried out with the aim of identifying the capabilities and limitations of typical high and low pressure watermist systems against small 'difficult' fires in a strictly controlled environment. A separate programme of trials was conducted at the Fire Research Station and involved a selection of low and high pressure nozzles, a range of typical naval fuels and various fire obstruction scenarios. This phase has involved enclosing the original rig to enable the nozzles to act in a 'total flood' manner while also allowing the simulation of typical ventilation characteristics for a scaled down machinery compartment in both the normal and damaged conditions.

Introduction

The Royal Navy uses Halon 1211 and 1301 in primary fire extinguishing systems on over 100 vessels including surface warships, Royal Fleet Auxiliaries and some submarines. Following the ban on Halon production by the Montreal Protocol, ME225 has been researching alternatives as replacements for existing equipments and for specification in future designs. It is of primary importance that such systems do not compromise the fire fighting effectiveness currently afforded by Halon or introduce unacceptable safety risks when used. Support to current, essential use Halon systems is from a Halon bank.

Background

The assessment of Halon alternatives has concentrated on the two areas considered most appropriate for warship compartment protection; gaseous agents and watermist systems. With many of the range of current chemical alternatives there are increasing concerns over: toxicity, environmental implications, inability to remove heat from hot surfaces and importantly the potential to release significant quantities of toxic combustion breakdown products. This final point has serious implications in a warship, where compartments must be re-occupied and become operational again as soon as possible. It is for these reasons that the main area of research and development continues to be watermist. The best of these systems have good potential to satisfy all of the above criteria while offering effective firefighting performance.

Scope of trials

Two parallel series of trials have been performed to investigate different aspects of watermist performance. The first involved a joint venture between the MoD and the Technical Development Group of the Loss Prevention Council (LPC). The second was a continuation of earlier work with the Building Research Establishment's Fire Research Station (FRS). At the LPC, the highly controlled environment of the test compartment has allowed strictly controlled but relatively small scale trials. At the FRS, trials can be carried out with relatively large fires and the flexibility of the rig has allowed different obstruction and ventilation scenarios to be tested.

LPC trials

The aim of the LPC trials was to test the performance of two systems representative of low and high pressure types in the same conditions and against the same fuels as used in the LPC's work on comparison of gaseous halon alternatives[3]. This will enable comparisons to be made between the performance of watermists and gaseous agents (the subject of a forthcoming report). Full details of the latest work carried out are contained in the full LPC report[4].

Test chamber

(Fig. 1) shows the LPC test compartment which measures 8m × 4m × 3m giving an internal volume of $96m^3$. The 3m ceiling height is representative of a smaller warship machinery compartment although these particular trials were not aimed at replicating such a scenario. Ventilation was reduced to two 100mm diameter drainage holes at the floor to give a relatively well sealed environment. Provision was made for 4 satellite fires in the corners of the room, two high up and two at floor level. These provided an indication of the distribution of the extinguishing system and its ability to tackle very small, awkwardly sited fires. Each was monitored by separate thermocouples.

Fuels and trials procedure

The fuels used are shown in Table 1 and were the same as in the gaseous agent tests but with the addition of three fuels used specifically in Naval applications:

- Dieso F-76,

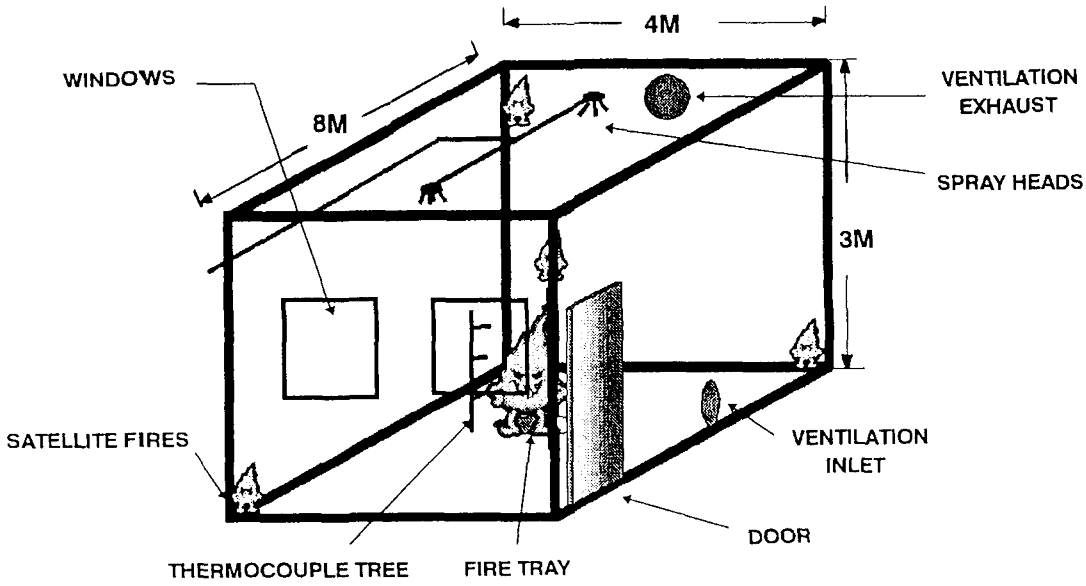

FIG. 1—LPC TEST CHAMBER

- Avtur F-34
- Dieso Soaked Fibres (DSF, a combination of polycarbonate pipe insulation and mineral fibre board soaked with fuel designed to represent a deep seated lagging fire).

Sufficient fuel was used to allow a free burn time of about 10 minutes. The trials procedure involved igniting the fire followed by a pre burn period prior to mist application. Extinguishment was confirmed by temperature drop and

TABLE 1—*Fuel Data*

Fuel class	Fuel type	Trials used	Description and Typical uses	Flash Point °C	Auto-Ignition Temp °C	Approx Fire size/output
A	Small wood crib	LPC	Redwood 24 in No. (25 × 25mm sticks)	—	—	0.20 Mw
	Large wood crib	LPC	Redwood 24 in No. (50 × 50mm sticks)	—	—	0.40 Mw
	PVC cable crib	LPC	6mm^2 PVC sheathed flat mains cable 72 × 280mm strips in crib	—	—	1.1 Mw
B	Heptane	LPC	Commercial n-Heptane	—	215	1.75 Mw
	DIESO F-76	LPC/ FRC	Petrol Distillate. Diesels/ Gas Turbines	61	240	FRS 1.75 Mw
	AVTUR F-34	LPC/ FRC	Kerosene Derivative Aircraft Turbines	38	220	FRS 2.0 Mw
	OM-33	LPC/ FRC	Mineral hyd. oil/naval hydraulic systems.	160	N/A	FRS 1.5 Mw
HYBRID A/B	DSF	LPC/ FRC	Dieso soaked insulation/ mineral fibre board	N/A	N/A	FRS 1.0 Mw

visually through a viewing tube into the fire area. The data logger recorded inputs from all instrumentation simultaneously throughout the tests. Fire position was varied during the programme from directly under a nozzle to an offset position. This tested the ability of each system to extinguish fires in a more difficult location. It should be noted that the fire sizes used at the LPC are relatively small compared to those used for most watermist trials and by their nature may be more difficult to extinguish than larger fires. This facility provides very comprehensive instrumentation for temperature, pressure and particularly gas analysis. However it should be noted that the steam dilution contribution to oxygen depletion, estimated to be around 2–3%, could not be accurately measured due to the drying process required by the analyser. Data collection is handled from all inputs simultaneously by a computer interfaced data logging system with sampling rates up to 2kHz.

Watermist nozzles and systems

Two systems were trialled, one representing a typical low pressure type, the other a high pressure gas driven type. Both are commercially available and already fitted in a variety of applications including some commercial marine environments.

High pressure—gas driven

The system tested is available in high pressure pumped, inert gas driven or compressed air driven versions. The inert gas type was tested in these trials and used nitrogen to propel water held in cylinders through a multi-orifice nozzle head at high pressure. The pressure decays during discharge from approximately 90 to 15 Bar (measured at the nozzle). The system produces a very fine high velocity spray, the characteristics of which are such that as the gas pressure reduces so the droplet size decreases giving a range of 120 to 20 microns. The gas is stored in one or more 50 litre bottles and by varying the number of nitrogen and/or water cylinders varying discharge times can be sustained.

Results—HP gas driven system

Table 2 lists a selection of the test data and results for this system. Definition of the terms used in the results table under comments is:

Rapid extinguishment	—	Less than 30 seconds.
Quick extinguishment	—	Greater than 30 but less than 90 seconds.
Extinguishment	—	Greater than 90 but less than 360 seconds.
Long extinguishment	—	Greater than 360 seconds.

The fastest extinguishment was achieved against Heptane directly under a nozzle head, while a similar test conducted offset from the nozzle head resulted in the extinguishing time increasing by an order of five. Good results were achieved against all Class A and B fuels when under a nozzle head, while times were much longer or not successful at all when offset. This system produces small high velocity droplets in the main phase of its operation, which are able to penetrate a fire plume directly beneath and cool the fuel surface, flame and locally deplete the oxygen. However for more distant fires the droplets appear to have lost most of their energy and are therefore carried away on the fire plume. Extinguishment then appears to be more dependant on 'global' oxygen depletion within the enclosure, predominantly by the fire, to the point of extinguishment. A contributory factor with the gas operated version of this system is the inerting effect of the nitrogen propellant. Tests without a fire indicated that the contribution to oxygen depletion was around 4% in these trials. A further indicator used at the LPC is a tray lip thermocouple. This showed that, if the lip temperature could be reduced to below

TABLE 2—*LPC results for HP gas driven system*

Fire Type		HP System configuration			Exting Time Sec	O_2 Min %	SAT. Fires Ext	Comments
Fuel	Position	N_2 Cyl Nom. Press	$H2_O$ Cyl	Nozzle Heads				
Small Wood	under nozzle	3/175	3	2	301	15.64	1 of 4	Exting.
Large Wood	under nozzle	3/175	3	2	220	15.20	4 of 4	Exting.
PVC Cable	under nozzle	1/175	3	3	80	18.91	0 of 4	Quick Exting.
300mm Heptane	under nozzle	1/175	3	3	9	19.23	0 of 4	Rapid Exting.
445mm Heptane	offset from nozzle	2/175	3	3	455	14.62	4 of 4	Long Exting.
445mm Dieso	under nozzle	1/175	3	3	16	18.85	1 of 4	Rapid Exting.
445mm Dieso	offset from nozzle	1/175	3	3	(580)	16.24	3 of 4	Not Exting. Fuel out
445mm Dieso	offset from nozzle	2/175	3	3	533	15.36	4 of 4	Near to. Fuel out
445mm Avtur	offset from nozzle	1/175	3	3	(1010)	14.19	4 of 4	Not Exting. Fuel out
445mm Avtur	offset from nozzle	2/175	3	3	483	14.46	4 of 4	Long Exting.
DSF	under nozzle	1/175	3	3	N/A	19.10	0 of 4	Not Exting.

Notes:
1. Oxygen measurements do not include steam dilution contribution.
2. 8 Orifice nozzle used for class A fires, 6 orifice nozzle for class B.

the auto-ignition temperature of the fuel, then a successful extinguishment usually followed (provided the cooling could be maintained for long enough). The ability to extinguish satellite fires varied and depended on global oxygen depletion. Other aspects of this systems performance included an ability to scrub smoke from the atmosphere extremely efficiently and a low water consumption rate. Compartment cooling was quite good, the mean enclosure temperature dropping by around 50°C over the first 200 seconds of a typical fire. Overall, this system performed well against fires placed beneath the nozzle heads and less well when offset from the nozzle heads. This would indicate an ability to penetrate the fire and cool the fuel provided the nozzle head is correctly positioned. The long extinguishing times of the offset fires combined with reduced oxygen levels in these circumstances suggests a degree of reliance on 'global' oxygen depletion in these scenarios. When considering this point it is important to remember that relatively small fires were used. With larger fire sizes the fire would make a significant contribution to oxygen depletion and therefore assist the system.

Low pressure—pump driven

The nozzle selected to represent the LP type was the Wormald AM10 (Fig. 2). This has a relatively large central orifice (3mm) with a spherical 'ball bearing' deflector mounted on two supporting arms. The mist droplet characteristics for this nozzle are shown in (Fig. 3). For these tests the nozzles were supplied from a centrifugal pump at the manufacturer's recommended operating pressure of 12 bar. The number and spacing of nozzles was determined by the manufacturer's design information but initial distribution experiments showed the system to be ineffective if a 1.5–2m spacing was exceeded. After initial water distribution problems with the AM10 nozzles, it was decided to increase the number fitted from 6 to either 8 or 11, provision having been made for the extra 3 nozzles which could be introduced via isolating valves if required. This arrangement gave a maximum spacing between nozzles of 2m and a distance of 1m from the walls.

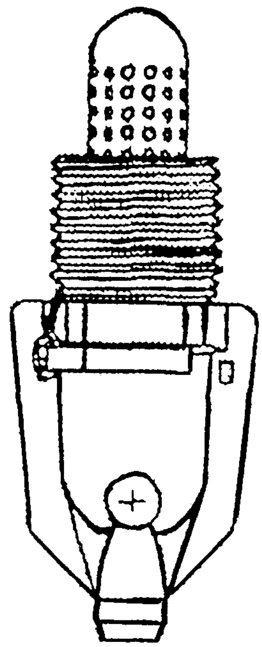

Fig. 2—Wormald AM10 nozzle

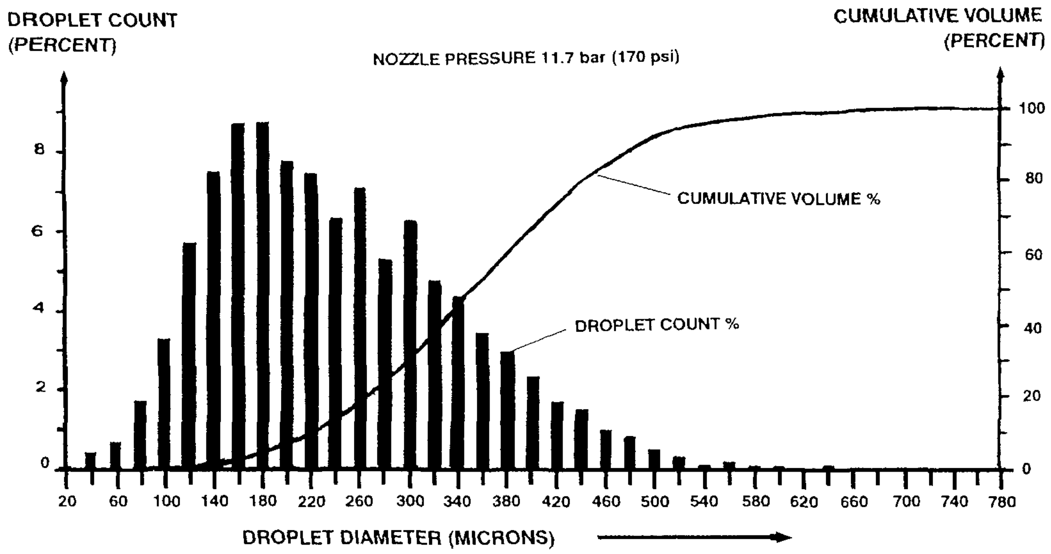

Fig. 3.—AM10 droplet characteristics

Table 3 lists test data for the low pressure pump operated system utilizing this set up. It is clear that global oxygen depletion does not play such an important role in the extinguishing process with this system (although it may still happen local to the flame). The minimum value achieved was around 19% compared to 14% for the HP system. Extinguishing times are also generally longer. Interestingly the two lower satellite fires went out in every test, indicating the surface flooding nature of this nozzle layout. The higher satellites were not extinguished suggesting that the mist was not acting in a true 'total flooding' manner. The nozzle design results in relatively high water consumption, using 11 nozzles typically 400 litres for a 200 second discharge. A benefit of this is enclosure cooling which is excellent, a reduction in mean temperature of 70°C was recorded in the first 200 seconds of a typical discharge onto a Class B fuel. Smoke scrubbing was noted as being quite good, but not as good as for the HP system. Overall, provided the system is

TABLE 3—*LPC results for LP pump driven system*

Fire Type		No of Nozzles	Operating Press (Bar)	Exting. Time Sec	O_2 Min %	Satellite Fires Exting.	Comments
Fuel	Position						
Small Wood	offset from nozzle	11	12	212	20.42	2 of 4	Exting.
Large Wood	offset from nozzle	11	12	309	19.24	2 of 4	Exting.
PVC Cable	offset from nozzle	11	12	110	20.04	2 of 4	Exting.
300mm Heptane	offset from nozzle	11	12	(461)	19.88	2 of 4	Not Exting. Fuel out.
445mm Heptane	offset from nozzle	11	12	263	19.29	2 of 4	Exting.
445mm Dieso	offset from nozzle	11	12	153	20.17	2 of 4	Exting.
445mm Avtur	offset from nozzle	11	12	235	19.96	2 of 4	Exting.
DSF	offset from nozzle	11	12	117	20.49	2 of 4	Exting.

Notes:
1. No fires extinguished with 8 nozzle pattern.
2. Oxygen measurements do not include steam dilution contribution.

engineered correctly, it would seem capable of combating a range of fires efficiently being best suited to applications where rapid control of temperature is important. Also apparent is the simplicity of the nozzle, with a large orifice less likely to block or require as much maintenance as the HP types. On the downside, the system is likely to be more costly to install due to the number of nozzles and amount of pipework required (although through life costs may be cheaper than the HP types) and may use more water (depending upon the extinguishing time taken).

FRS trials

The objective of the FRS trials was to investigate the effects of enclosure and obstruction on system performance. The trials were in two phases:

Phase 1

Tested a range of pump driven high and low pressure nozzles in the enclosed rig representing an 'intact' compartment. Two tests were made with each fuel, one unobstructed and one with a solid table obstruction placed over the fire at a height of 1.5m.

Phase 2

Used an inert gas propelled high pressure mist system with the same fuel and obstruction combinations but in two distinct ventilation scenarios. One, the 'intact' condition as used in the first phase, the other a 'battle damaged' condition representing, for example, a large shell penetration in the compartment.

Full details of the latest trials are contained in separate FRS reports for the gas driven and pumped systems[5]. Due to programme constraints the 'battle damage' phase could not be completed for the pump driven nozzles during these trials. However during a previous phase of trials[1], all of these nozzles were tested in the same rig but in an unenclosed environment. The results of this work give a good indication of how they may perform in a 'battle damage' condition. Notwithstanding this the full 'battle damage' trials will be completed during the next phase of work.

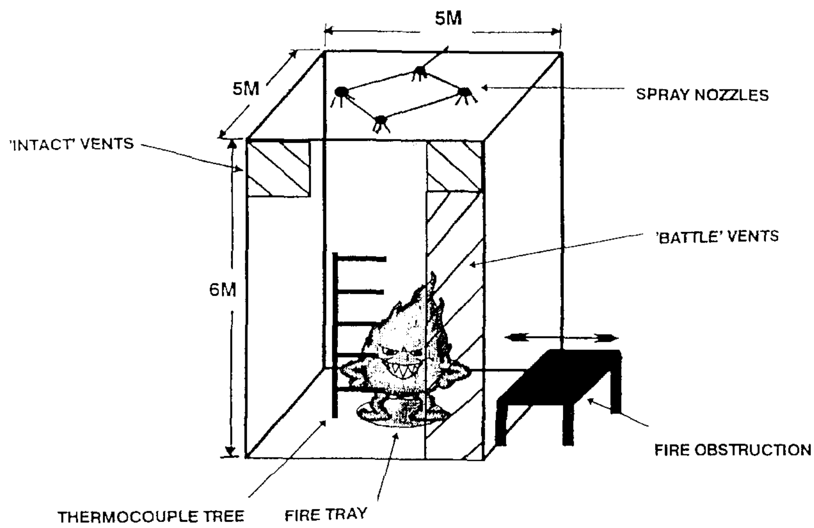

FIG. 4.—FRS TEST RIG

Test rig

The rig arrangement, (FIG. 4), gave an enclosed volume of 150m^3 with three steel walls with the fourth able to be altered to give two states of free ventilation. The trials were planned to approximate the ventilation conditions of a typical frigate machinery compartment following forced vent fan shutdown but prior to manual close down of the external dampers and a 'battle damaged' condition with an increase in the ventilation area from approximately 1m^2 to 3.75m^2. The 6m ceiling height was representative of a large warship/auxiliary machinery compartment. Instrumentation was similar to that used at the LPC, utilizing a thermocouple tree and oxygen analyser; again it is important to note that the steam dilution contribution to oxygen depletion could not be measured accurately but again was estimated to be around 2–3%.

Fuels and trial procedure

For the FRS trials the choice of fuels was restricted to those most applicable to Naval applications:

- Dieso F-76
- Avtur F-34
- OM-33
- DSF.

Sufficient fuel was used to allow a free burn time of about 10 minutes. Trials procedure involved igniting the fire followed by a pre burn period prior to mist application. Extinguishment was confirmed by temperature drop and visually through viewing holes in the rig. A data logger recorded inputs from all instrumentation simultaneously throughout the trials.

Watermist nozzles and systems

Table 4 shows the range of nozzle types used for all trials and details the nominal operating pressures and typical spray droplet diameters.

TABLE 4—*Nozzle information*

Nozzle type	Nominal Operating Pressure (Bar)	Mist Drop Size (Microns)	Comments
HP gas driven	90–15	120–20	Water in cylinders driven by compressed nitrogen.
NRL flooding spraying systems INC 7G-1	70	—	US NRL modified version of 7G1.
NRL Mk3 Modified spraying systems	70	—	US NRL modified version of 7G1 with larger orifices.
Wormald AM10	12	150–600	Pump driven nozzle with spherical diffuser.
Lechler 460-648	7	80–330	Pump driven LP nozzle.

Results at FRS

Table 5 shows the results for the HP gas driven system. Tests without the obstruction and in the enclosed condition were generally very successful. Indeed the fastest time of any test was obtained against Avtur at 7 seconds and all Class B fuels tested were extinguished quickly. Performance with the table obstruction over the fire pan in the enclosed ventilation condition was still quite impressive, the extinguishing times were considerably longer, of the order of 8 times for Avtur and up to 15 times for the Dieso, but this was the only system to consistently extinguish Class B fuels under an obstruction. The difficult DSF was not extinguished, and in this case it appeared that insufficient mist had reached it to provide effective protection or control. In the 'battle damaged' scenario a full set of trials were conducted as before, but the results were very different. In the unobstructed trials, with the system using the same 1 nitrogen/3 water cylinder configuration the only success was against the OM-33 fuel. With the remaining fuels, the extra ventilation appeared to have a significant effect on the fire, not allowing the mist to really penetrate the plume successfully. The oxygen measurements at the plume do not appear to be very different to the enclosed condition. By adding an extra cylinder of nitrogen the ability of this system to cope with the extra ventilation was improved, although only the Avtur was extinguished in addition to the OM-33. It is likely that there were two beneficial effects:

1. Additional nitrogen assistance to the oxygen depletion
2. The discharge pressure being maintained over a longer period.

All results were worse in the obstructed condition with no successful extinguishments being recorded and the DSF receiving little protection. It is clear from these results that a gas operated HP system of this type performs very well in relatively well enclosed conditions and has a good ability to penetrate obstructions from above. More openly ventilated conditions have a significant effect on the performance of such a system, particularly against obstructed fires.

TABLE 5—*FRS trial results for HP gas driven system*

Fuel	Rig Vent Scenario	Fire Scenario	N_2 Cyl. Pressure (Bar)	H_2O Cyl.	No. of Nozzles	O2 Min % at Plume	Time to Exting. Sec	Comment
DIESO	Intact	Unobstructed	1/156	3	2	20.5	15	Rapid Ext.
AVTUR	Intact	Unobstructed	1/175	3	2	20.8	7	Rapid Ext.
OM-33	Intact	Unobstructed	1/158	3	2	20.3	28	Rapid Ext.
DSF	Intact	Unobstructed	1/155	3	2	19.1	—	Min control
DIESO	Intact	Obstructed	1/170	3	2	17.0	225	Ext.
AVTUR	Intact	Obstructed	1/170	3	2	19.5	57	Quick Ext.
OM-33	Intact	Obstructed	1/170	3	2	18.6	149	Ext.
DSF	Intact	Obstructed	1/170	3	2	17.8	—	Min control
DIESO	Battle	Unobstructed	1/151	3	2	16.7	—	No Ext.
AVTUR	Battle	Unobstructed	1/175	3	2	15.6	—	No Ext.
AVTUR	Battle	Unobstructed	2/153	3	2	19.8	41	Quick Ext.
OM-33	Battle	Unobstructed	1/158	3	2	20.5	20	Rapid Ext.
DSF	Battle	Unobstructed	2/155	3	2	19.9	—	Min control
DIESO	Battle	Obstructed	2/160	3	2	17.5	—	No Ext.
AVTUR	Battle	Obstructed	2/157	3	2	16.8	—	No Ext.
OM-33	Battle	Obstructed	2/165	3	2	18.5	—	No Ext
DSF	Battle	Obstructed	2/165	3	2	19.2	—	Min control

HP/LP pump driven system

Table 6 gives the results for HP/LP nozzles systems.

NRL modified spraying systems ¾-7G-1 (NRL 'Flooding' 70 Bar)

Extinguished all the class B fires without the obstruction, times varied from 130 to 480 seconds so were slower than some other systems. With the obstruction in position above the fire, both Dieso and OM-33 fires were put out, although these took a lengthy 469 and 487 seconds respectively and were getting near to fuel exhaustion. Again the DSF was not extinguished in either scenario although some protection was apparent when inspecting the remaining material after the fire.

NRL modified spraying systems 7G1 (NRL 'MK3' 70 Bar)

The most improved nozzles from the previous open rig trials, these were proved to work very effectively in the enclosed rig. All fuels except the DSF were extinguished both unobstructed and covered. Extinction times varied from a quick 15 seconds for the unobstructed Avtur to a more lengthy 327 seconds for the obstructed OM-33. The unobstructed times were all good while the obstructed varied considerably. This was however the only nozzle other than the LP AM10 to put out all the liquid fuel fires in the obstructed condition. Damage limitation to the DSF was reasonable, but not as good as the AM10 nozzle.

WORMALD AM10 (12 Bar)

These nozzles gave an excellent set of results against the Class B fuels. All unobstructed fuels were extinguished in very fast times ranging from 13 to 36 seconds. Even obstructed the fires were all stopped in times ranging between 37 and 236 seconds. In both cases Dieso was the most persistent fuel for this nozzle to combat, this was more usually the Avtur fire for the other nozzles. This nozzle did not fully extinguish the DSF fires whether un-obstructed or obstructed, however inspection of the assemblies post test revealed the greatest degree of control of any of the tested nozzles, more than 20% of the material remained intact.

LECHLER 460-648 (7 Bar)

Gave good results against un-obstructed liquid fires ranging in the most consistent (if not the fastest) extinguishing times of between 70 and 127 seconds. However, the DSF fire was not extinguished in either scenario although a degree of damage control was afforded. The other fires proved more difficult in the obstructed test with only the OM-33 being successfully extinguished in a relatively quick 62 seconds.

TABLE 6—*FRS results for pump driven systems (Intact scenario only).*

Nozzle Type	No. of Nozzles	Fuel	Scenario	Press (Bar)	O_2 Min % at Plume	Water volume used (l)	Time to Exting Sec	Comments
NRL Flood-ing	4	DIESO	Unobstructed	70	17.4	116	199	Exting.
	4	AVTUR	Unobstructed	70	17.2	49	84	Quick Ext.
	4	OM-33	Unobstructed	70	18.8	77	132	Exting.
	4	DSF	Unobstructed	70	18.2	—	—	No Exting.
NRL Flood-ing	4	DIESO	Obstructed	70	17.1	274	469	Long Exting.
	4	AVTUR	Obstructed	70	16.0	—	—	Fuel out
	4	OM-33	Obstructed	70	17.3	284	487	Long Exting.
	4	dSF	Obstructed	70	18.9	—	—	No Esting.
NRL Mk3	4	DIESO	Unobstructed	70	18.0	32	24	Rapid Exting.
	4	AVTUR	Unobstructed	70	18.1	20	15	Rapid Exting.
	4	OM-33	Unobstructed	70	18.7	43	32	Quick Exting.
	4	DSF	Unobstructed	70	18.5	—	—	No Esting.

Nozzle Type	No. of Nozzles	Fuel	Scenario	Press (Bar)	O_2 Min % at Plume	Water volume used (l)	Time to Exting Sec	Comments
NRL Mk3	4	DIESO	Obstructed	70	17.3	213	160	Esting.
	4	AVTUR	Obstructed	70.	17.7	89	67	Quick Exting.
	4	OM-33	Obstructed	70	16.2	436	327	Exting.
	4	DSF	Obstructed	70	18.0	—	—	No Exting.
Lechler 460–648	9	DIESO	Unobstructed	7	17.5	142	127	Esting.
	9	AVTUR	Unobstructed	7	16.2	133	119	Exting.
	9	OM-33	Unobstructed	7	18.4	78	70	Quick Exting.
	9	DSF	Unobstructed	7	18.0	—	—	No Exting.
Lechler 460–648	9	DIESO	Obstructed	7	16.0	—	—	No Exting.
	9	AVTUR	Obstructed	7	15.9	—	—	No Exting.
	9	OM-33	Obstructed	7	18.9	69	62	Quick Exting.
	9	DSF	Obstructed	7	18.2	—	—	No Exting.
Wormald AM10	9	DIESO	Unobstructed	12	18.3	65	36	Quick Exting.
	9	AVTUR	Unobstructed	12	18.5	31	17	Rapid Exting.
	9	OM-33	Unobstructed	12	20.0	23	13	Rapid Exting.
	9	DSF	Unobstructed	12	19.2	—	—	No Exting.
Wormald AM10	9	DIESO	Obstructed	12	16.8	425	236	Exting.
	9	AVTUR	Obstructed	12	17.5	69	38	Quick Exting.
	9	OM-33	Obstructed	12	19.4	67	37	Quick Exting.
	9	DSF	Obstructed	12	18.3	—	—	No Exting.

Note

1. Oxygen measurements do not include steam dilution contribution.

Conclusions

This series of trials utilized two different test compartments each tailored to research particular aspects of watermist performance including:

- Comparison of HP and LP types in controlled conditions
- Performance against small and difficult fires
- Ability to tackle fires offset from the nozzles
- Environment tenability effects

- Effects of enclosure and oxygen depletion
- Effects of obstruction and performance against larger fires.

For the gas driven HP system the main extinguishing process ranges from either rapid fuel/flame cooling and local oxygen depletion when the nozzle is directly over the fire to a dependence on 'global' oxygen depletion by; fire consumption and nitrogen and steam dilution, and therefore on compartment enclosure when the fire is more remote.

For the pumped systems there appears to be much less dependence on 'global' oxygen depletion with performance relying more directly on cooling as a result of the increase water volumes provided by such nozzles. It is clear that careful engineering is required to ensure sufficient mist coverage as these systems do not work in a fully 'total flood' manner. Their ability to combat hidden or obstructed fires is not as good as the higher pressure system tested, but a good degree of control can be afforded to even persistent fires.

High Pressure systems

For

- Better performance against obstructed fires
- Gas driven types use relatively small quantities of water
- Excellent ability to scrub smoke out of the atmosphere
- Good atmospheric cooling ability
- Relatively simple pipework and installation requirements

Against

- Performance may be affected by degree of enclosure
- Use smaller orifice nozzles which may require finer system filtration requiring more frequent maintenance
- Requires compressed gas to be available/stored on board or dedicated pumps

Low Pressure systems

For

- Operating pressures closer to existing ship sea water mains pressures
- Excellent atmospheric cooling ability
- Good smoke scrubbing ability
- Earlier trials indicate less dependence on degree of enclosure and ventilation
- Simple nozzle with large orifice sizes—less fine filtration required and maintenance simplified.

Against

- Less effective at extinguishing obstructed fires
- Requires careful system engineering with large numbers of nozzles and an extensive pipework system
- Can use relatively large amounts of water, may not be suitable in certain applications where free surface effects are important

Overall it is considered that the LP pumped system appears particularly suited to surface warship applications, especially if a system can be designed to operate effectively at nominal and across the range of standard fire main pressures. These systems seem most applicable for total compartment protection with a carefully engineered nozzle pattern tailored to the particular risk being protected. The high degree of cooling afforded and good smoke scrubbing abilities should allow early re-entry for fire fighters even if the fire is not fully extinguished. The HP systems would seem more suited to enclosed conditions or gas turbine/diesel modules. There also seems potential to examine this system for use in submarines where the compartments are enclosed, highly cluttered and where smoke scrubbing is important These systems also have the benefit of not introducing large quantities of water into the vessel.

Future work/way ahead

These trials have greatly increased our understanding of the abilities of watermist as a possible alternative to Halon for warships compartment protection. The capabilities of a range of high and low pressure systems have been explored in a variety of scenarios and against a range of fuels. The trials have also investigated the effect on performance of varying oxygen levels and the ability of different systems to combat hidden fires. Planning for the next phase of work is now well underway. It is intended to examine the abilities of a variety of the latest nozzle designs at ship mains pressures, the effect of additives, sea water and performance against spray fires. Construction of a calorimeter will also allow quantitative data to be taken which may be fed into future computer modelling work. Larger scale work will also be carried out to complete the 'battle damage' condition trials for the nozzles not yet tested and then proceed to examine different nozzle positions, fire positions and sizes in the current rig.

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