FSS 0000019 R

WATER MIST FIRE SUPPRESSION WORKSHOP
National Institute of Standards & Technology
Gaithersburg, MD 20899 USA - March 1-2, 1993

WATER MIST IN MARINE APPLICATIONS

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SUMMARY

This paper is designed to present an up-to-date picture of practical applications for water mist / fog fire fighting technology in marine markets. The paper will introduce the reasons for the development of the technology, discuss the test program undertaken by Marioff and highlight the insights this has provided concerning the firefighting capability of water fog systems. Practical applications in the marine markets for accommodation areas, engine rooms and other spaces will be given with reference to the actual ships on which Hi-fog systems have been fitted. Land based uses will also be discussed, with references to systems installed or on order.

1. INTRODUCTION

Marioff have for eight years specialised in the development and supply of innovative high pressure hydraulic products to the offshore and marine markets. Service companies within the group have been responsible for testing, flushing and commissioning high integrity systems such as subsea control packages and complete offshore platform oil piping systems.

The high incidence of arsonist fires on passenger ships culminating in the "Scandinavian Star" disaster off Denmark, when over 150 people lost their lives, recently prompted the International Maritime Organisation (IMO) to require all passenger ships to have sprinkler systems fitted in the accommodation areas by 2005 or earlier. The need to quickly develop a lightweight sprinkler system that could be practically retrofitted to a passenger ship was apparent, and in 1991 Marioff became involved in the development of a high pressure water fog sprinkler system specifically designed for this application. Due to the small pipe sizes of a high pressure system, installations including the water filled pipework have typically been 10% of the weight of a conventional sprinkler system according to current SOLAS rules, and installation is much quicker and less expensive.

The rapid phasing out of Halon use for environmental reasons prompted IMO to prohibit the installation of Halon on new vessels since July last year. The need to develop alternative safe and environmentally friendly fire extinguishing methods for ships' engine rooms led Marioff to develop a suitable water fog extinguishing system for machinery spaces.

Two years of intensive development work, including over 400 fire tests at internationally recognized testing laboratories, has resulted in approval of Hi-fog systems by European Authorities including the UK Department of Transport and major Classification Societies including Lloyds Register and American Bureau of Shipping. Systems have been, and continue to be, installed in Europe and Scandinavia. (See Table 1.)

The development of this technology for marine applications has also recently led to many practical uses on land based special hazard situations. (See Table 2.)

2. BACKGROUND

The efficient fire suppressing effect of fine water fog or mist has been recognized for many years. This suppression is due to the large total surface area of the droplets and the high rate of speed at which they turn to steam, thus absorbing the energy of the fire. The average droplets contained in a water fog yield a total surface area at least 100 times greater than conventional sprinkler drops for the same water volume. Therefore much smaller amounts of water are required by fog to absorb energy from the fire. See Table 3.

Practical use of water fog / mist in fire protection has been restricted to very few applications such as extinguishing fires in chimneys. One of the reasons for not bringing water fog systems to the market has been the difficulty in combining the small water droplet size with efficient penetration of flue gases. Although water fog or mist is extremely efficient at air cooling (and therefore absorbing energy in the combustion area) compared to conventional sprinklers or water spray systems, the light weight of the droplets has made it impossible to penetrate the flue gases produced by even a moderate combustion source.

Marioff has overcome this problem by using experience gained with high pressure hydraulic technology. By forcing water at high pressure through specially developed nozzles arranged on spray or sprinkler heads, a water fog is propelled at a speed high enough to penetrate the flue gases of even a flashover fire.

As well as fire tests, droplet size measurements have been made, which suggest that droplet size distribution is an important factor.

The combination of correct water droplet size, distribution and high speed of penetration are the factors which we believe, through the testing undertaken, to be the key to fast suppressing and extinguishing capability even in adverse ventilation conditions. In the engine room hydrocarbon fire tests carried out in Sweden and Finland, extinguishing times were so fast that an additional effect was suspected. It was realized that in addition to the cooling effect, in a high temperature fire the water fog turning to steam causes an inerting effect and drives out the oxygen from the combustion area.

As a manufacturing and systems supply company, Marioff has concentrated on carrying out practical fire tests to prove fire suppression and extinguishing capability, test components and establish design and installation criteria in order to satisfy the regulatory authorities in Europe.

3. WATER FOG SPRINKLER SYSTEM FIRE TESTS

A series of tests was undertaken at SP, the Swedish National Testing & Research Institute from November 27th to December 12th 1991 and also on February 18th 1992. The purpose of the test program was twofold. Firstly, Marioff needed to evaluate alternative head designs, locations and spacing in the different fire scenarios. Secondly, it was necessary to ensure that the Hi-fog system installed on board a passenger ship would provide at least an equivalent level of fire protection for life and property as a traditional sprinkler system designed according to Chapter II-2 Regulation 12 of the SOLAS convention.

More than 60 different tests were performed in order to study the effects of the system against fires in cabins, large rooms, and in public open spaces on board a passenger ship.

3.1. Cabin / Corridor Tests

Location: SP, Swedish National Testing & Research Institute

Date: November - December 1991

Report: 91 R30141

Figure 1. shows the layout of the test cabin / corridor mock up. The cabin was equipped with standard polyether mattresses in a pullman type bunk bed. In most of the tests the lower beds were made with a backrest of the same material as the bed itself. The amount of burning material was enough to create a flashover in the cabin. The tests were performed in the SP fire hall which is equipped with large-scale measuring equipment making it possible to simultaneously measure the rate of heat release from the fire.

The temperatures in the cabin and in the corridor as well as smoke production and rate of heat release were measured during the tests. The air supply to the cabin was arranged by a ventilation unit placed in the ceiling of the cabin. The air supply was 40 L/sec (1.41 ft^3/sec). Tests were carried out with the cabin door open and closed, and included simulated arsonist fires and flashover fires of over 1 MW.

Figure 2. shows the temperature in the cabin during Test 1.9 with automatic activation and the door closed. Figures 3 & 4 show the temperatures and rate of heat release in Tests 1.34, simulating a flashover fire with manual activation.

SP Observations:

"The tests showed that the Hi-fog extinguishing system gives equivalent or better reduction in fire hazard for the cabin fire compared with conventional sprinklers."

3.3. Open Space Fire Tests

Location: SP, Swedish National Testing & Research Institute

Date: December 1991

Report: 91 R30141

In this test series the intention was to verify the results from previous tests which were made under a fire calorimeter hood. A number of tests were carried out against a simulated restaurant or other public space fire. Tests were performed with Hi-fog sprinkler and spray heads fitted to a suspended ceiling with a size of 10 x 10 m (1076 ft^2). The configuration was open and thus there were no restrictions in air supply to the fire. As it was important to study the influence of the ceiling height on the sprinkler performance, tests were performed with one and two deck ceiling height 2.5 m (8'2") and 5 m (16'4") ceiling height.

SP Observations:

"For the open areas the result from the tests showed that it is possible to control a fire in a group of furniture if a deluge system with a minimum area of operation of 100m^2 (1076 ft^2) floor area is used."

3.2 Closed Room Fire Test

Location: SP. Swedish National Testing & Research Institute

Date: February 18, 1992

Report: 91 R30141 (Tests 2.21 & 2.22)

In addition to the main test series, two additional tests were performed in a room 9.6 x 6.0 m (623 ft^2), with ceiling height 3,10 m (10'2"). The ceiling was fitted with five 5 Hi-fog sprinklers. Two sofas made of cold foam were placed in the room, and a fire was started on one. The sprinklers activated automatically.

SP Observations:

"The result showed that the Hi-fog system is able to control a furniture fire in a relatively large confined room with only two heads operating."

3.5 ISO 6182-1.2 Wood Crib Fire Test

Location: SP, Swedish National Testing & Research Institute

Date: 10-11th April 1992

Report: 91 R30189A

After the SP test report was issued it was decided to carry out four wood crib fire tests generally to ISO 6182-1.2 based on UL 199 standard. A group of Hi-fog heads was positioned in the ceiling according to Marioff's installation guidelines based on room size of 100m^2 (1076 ft^2). The test should run for 30 minutes after which the wood crib is dried and weighed. Weight loss should be maximum 20%.

SP Observations:

"The main impression from the tests with the Hi-fog system was the rapid extinction of the wood crib and the heptane spray including the ignition torch (38 seconds). It was not possible to run the test for the 30 minutes test period because of the extinction of the heptane spray and the ignition torch."

4. MACHINERY SPACE SYSTEM FIRE TESTS

In order to provide alternative protection to Halon in ships' engine rooms, a water fog system for machinery spaces should successfully complete a fire test program which simulates the worst case fire conditions that can occur. The Marioff Hi-fog machinery space system uses low pressure water fog as a cooling and controlling medium, and high pressure fog for extinguishing. In order to extinguish a hydrocarbon fire, it is necessary to propel the water droplets into the space at very high speed so that they will penetrate the flue gases and reach the combustion area. With the Hi-fog machinery space system, this is done by using a stored energy system consisting of accumulators loaded with high pressure water. The activation of the Hi-fog nozzles at high pressure ensures that the fog is blasted into the combustion area and the continuation of the low pressure gives continuous cooling so reignition cannot occur.

4.1 Prototype Machinery Space Fire Tests

Location: Upinniemi, Palokoulutuskeskus, Finland

Date: 15-16 July 1991

A series of tests was carried out in Finland for the Marine Directorate of The Department of Transport, United Kingdom. The tests were carried out to demonstrate the capability of the Marioff Hi-fog sprinkler system in extinguishing high temperature hydrocarbon fires in a simulated ship's engine room. The tests were carried out in a purpose built fire test engine room of 261 m^3 (9,217 ft^3) at Upinniemi, Palokoulutuskeskus, a Naval Base 40 km (25 miles) from Helsinki, Finland over two days. The temperatures were measured by VTT Fire Technology Laboratory.

Nine gas burners (400 KW) were ignited to heat a steel plate simulating a split oil pipe or filter housing. When the temperature reached aprox. 600 deg C. (1,112^0 F.), oil flow of 10 L/min (2.56 gal/min) at 130 Bar (1,185 psi) was sprayed over the hot steel plate to ignite and flow into the bilges. After several minutes the system was manually activated.

In the five official tests, extinguishing time was between 6 and 35 seconds, and between 6 - 34 litres of water was used for the extinguishing.

4.2 Machinery space development fire tests

Location: SP, Swedish National Testing & Research Institute
Upinniemi, Palokoulutuskeskus, Finland

Date: April - June 1992

Report: 91 R30189

A series of full scale tests were carried out to evaluate the performance of the Hi-fog fire protection system against pool and spray fires in a simulated ship's engine room. The tests were carried out by SP, the first and second series in SP's fire hall in a 8 x 10m (861 ft^2) room with 4.8 m (15'8") ceiling height (13,561 ft^3). The third and fourth test series were carried out in the simulated engine room at Upinniemi under SP's control. In all tests the same engine mock-up was used with Hi-fog heads positioned above and over the bilge area. (See Figure 5).

Fuel Oil, diesel oil and lubrication oil pool fires varying from 2 to 11 m^2 (21.5 to 118 ft^2) were used in the tests. Spray fires of the same liquids and combination spray and pool fires with different preburn times were used.

Approximately 150 different tests were performed with the Hi-fog high pressure fire protection system to study the effect of the system against fires in a ship's engine room. A large number of the tests incorporated modifications and improvements as the system evolved. Extinguishing time for tests in Series 3 and 4 was between three and seven seconds.

SP observations:

"The tests show that the Hi-fog Fire Protection System is able to extinguish large engine room fires with pool and spray fires combined with natural ventilation from open doors and hatch.
Previous tests at SP have shown that a water spray system with 5 $l/m^2/min$ (0.12 gal/ft^2) according to to regulation SOLAS chapter II-2 Regulation 10 has a very limited extinguishing capacity against pool and spray fires compared with the Hi-fog system."

4.3 Large engine room fire tests

Location: VTT Fire Technology Laboratory, Helsinki, Finland

Date: November 5 and 6, 1992

Report: PAL 2210/92

Eight full-scale suppression experiments were carried out in the big test hall of the Fire Technology Laboratory at VTT.

The same engine mock-up as used in previous tests was constructed in the test hall to simulate a large ship's engine room with diesel oil as the fuel. The most intense fire in the tests consisted of four pool fires under the mock-up, one pool fire on top of it, total 11 m^2 (118 ft^2) and a spray fire beside it. The order of magnitude of the maximum heat release rate was estimated to be 20 MW.

The preburn time in each test was about two minutes from time of lighting the spray, after which the Hi-fog system was manually activated. Different water pressures were used in different tests.

The tests demonstrated the ability of the Hi-fog system to extinguish a 20 MW oil fire even in an unenclosed large space.

5. OTHER TESTS

5.1 Electric switchgear Tests

Location: ABB Strömberg Research Centre, Vaasa, Finland

Date: August 3 1992

Report: 9 AFX92-98

The objective of the tests was to find out if the operation of a Hi-fog fire protection system causes disruptive discharges in the main circuits of some typical electrical switching apparatus.

Main circuits of following apparatus were tested:

- low-voltage (690v) switchgear MDF including a frequency converter SAMI R3
- medium-voltage (24 Kv) switchgear MH
- medium-voltage (24 Kv) disconnector OJON 3-20
- busbar of low-voltage (690v) switchgear MDF supplied with DC current

Even with the Hi-fog heads spraying normal tap water directly into the open cabinets there were no disruptive discharges in eight of nine tests. The test which resulted in discharges was successfully repeated with deionised water, and later with tap water when heads were moved 30 cm (12") to the side of the cabinet.

5.2 Computer room smoke activated fire tests

Location: VTT Fire Technology Laboratory, Espoo, Finland

Date: July 2-3, 1992

Report: PAL 2196/92

A set of 11 experiments was performed in the smoke sensitivity room of the Fire Technology Laboratory at VTT. The experimental arrangement, i.e. the fire itself, the computer in the room and the Hi-fog sprinkler arrangement, was varied between the experiments. The two main objectives were:

1) to observe the performance of a Hi-fog system in extinguishing a computer room fire, and
2) to find out whether the combination of smoke from a polyvinylchloride (PVC) fire and fog from Hi-fog sprinklers cause any damage to computers that are not participating in the fire.

In all function tests the Hi-fog system was successful in extinguishing the test fires.

An independent smoke contaminations expert present at these tests commented: "It appears that the Hi-fog has the ability to "wash out" contaminates from the smoke thus greatly reducing the overall smoke damage effect."

5.3 Enclosed space fire suppression tests

Location: VTT Fire Technology Laboratory

Date: October 9 and 12, 1992

Report: PAL 2206/92

A series of sixteen tests were carried out to simulate fires in a typical small room as follows:

1) ticket stand (wood crib/heptane)
2) paint storage (paint/heptane)
3) transformer room (hydraulic oil)

All the experiments were performed in the fire test room 2.4 x 3.6 x 2.4m high (630 ft^3) of the Fire Technology Laboratory at VTT. The door of the room was kept closed during the experiments with a gap of variable size under the door. One Hi-fog sprinkler head was fitted in the ceiling and connected to a self-contained pressure bottle. Activation was either automatic or manual. Maximum amount of water used for each test was 6 litres (1.6 gal).

In all cases the fires were extinguished and reignition did not occur.

5.4 Postflashover fire suppression tests

Location: VTT Fire Technology Laboratory

Date: September 4, 1992

Report: PAL 2204/92

A series of 4 experiments were performed in a fire test room inside the big test hall of the Fire Technology Laboratory at VTT. Chipboard plates and wooden sticks were used. After ignition the fire was allowed to develop past flashover. Manual extinguishing with a Hi-fog head on the end of a lance was started at different times after the flashover.

VTT observations:

"All the postflashover fires were completely suppressed during the experiments. Fire control of a postflashover fire can be achieved with only a few litres of water and - strongly dependent on the amount of fuel - fire suppression requires more water, from 0 to the order of 100 litres in the present experiments."

6. WATER FOG SYSTEMS

6.1 General

In order to provide a working system which could be used in the marine market, system design and installation criteria had to be developed, based on the reports provided by the testing organisations, which were acceptable to the regulatory authorities. However as the use of high pressure piping and associated equipment is quite normal in ships, existing rules and standard components could be used which often were already approved. In some cases additional components had to be developed or modified for the power and control functions, and these have had to be tested and approved before being included in the systems.

6.2 Filtration

The question of cleanliness is vital for a high pressure water fog sprinkler or spray system which uses smaller orifices than conventional low pressure technology. The filtration philosophy which Marioff has adopted has been determined by Marioff's experience in cleaning and certifying high pressure hydraulic systems (such as subsea control systems) which require extremely high levels of cleanliness. Only stainless steel piping and compatible corrosion resistant materials are used and the system is primed and run with fresh water (although it can run on seawater in an emergency). The water is filtered through strainers before entering the system and as a final safeguard all Hi-fog sprinkler and spray heads have filters behind each nozzle.

6.3 Hi-fog sprinkler system

The Hi-fog sprinkler system consists of sprinklers, spray heads, section valves and a pump unit, together with alarm panel, piping and electric wiring. The piping is normally at a pressure of 10 - 20 bar (145 - 290 psi). Only when a sprinkler is activated is the high pressure 100 bar (1,450 psi) system started.

The lightweight pump unit now consists of several electrically driven pumps and a water tank, and is designed to provide minimal loading on the vessel electrical supply. The Hi-fog section valve incorporates a test and stop valve according to SOLAS requirements and is integrated into the automation system, which incorporates a control panel and alarm unit showing the position of all sections.

6.4 Hi-fog machinery space system

The Hi-fog machinery space system is simple and failsafe being based on standard hydraulic principles. It consists of a number of Hi-fog spray heads connected by stainless steel piping to a stored energy power unit, which places a minimal loading on the vessel's electrical supply. Activation can be manual or remote. On activation the stored energy is released to give a rapid high pressure blast of fog for fire extinguishing. This gradually reduces to a continuous low pressure fog for cooling to prevent reignition on hot metal surfaces.

The Hi-fog spray heads are positioned according to installation criteria determined by the testing results: above bilges, tank tops and other areas over which oil fuel is likely to spread and also above other specific fire hazards in the machinery space.

The Hi-fog power unit is lightweight and modular. It consists of one or more banks of gas/water pre-charged accumulators combined with an electrically driven low pressure water pump. The power supply automatically switches from main to emergency supply.

All main branch pipes are fitted with 'pipe break valves', which close automatically in the event of damage to the pipe by a fire or explosion, ensuring that pressure will not be lost for the rest of the system. As well as the fire alarm function, the system is provided with automatic alarms to signal if the pressure is lost in the power unit or the air supply.

6.5 Hi-fog self-contained system

The Hi-fog self-contained water fog system is designed for use where manual and/or automatic fire suppression is required in closed rooms or for local special risk protection.

The system consists of sprinklers, spray heads, accumulators,activating valves connected by stainless steel piping. Systems can consist of one accumulator assembly and one sprinkler or multiples of accumulator assemblies and combinations of spray heads and sprinklers.

Activation of system can be electrical, heat or manual or a combination of all three.

An addition to the self-contained system can be a low pressure water pump and break tank to supply cooling fog to an area after high pressure fog has been exhausted and additional cooling is required.

The accumulator is manufactured and tested to pressure vessel regulations and body material is steel internally coated with an epoxy paint to prevent corrosion. The accumulator valve incorporates a pressure gauge, burst disc to prevent over pressurisation, and nitrogen charge/vent connection, and water fill port.

6.6 Hi-fog lance extinguishing systems

Hi-fog heads and lances suitable for portable manual extinguishing with pumps or pressure accumulators are also currently being developed.

7. REFERENCES

1. Swedish National Testing & Research Institute, Borås, Sweden, 91 R30141, Cabin and public space fire tests with Marioff's Hi-fog fire protection system. February 19, 1992.

2. Swedish National Testing & Research Institute, Borås, Sweden, 91 R30189A, Crib fire test in principal accordance with ISO/DIS 6182-1.2. April 30, 1992.

3. Swedish National Testing & Research Institute, Borås, Sweden, 91 R30189, Tests in simulates ship's engine rooms with Hi-fog Fire Protection System. July 28, 1992.

4. VTT Fire Technology Laboratory, Helsinki, Finland, PAL 2210/92, Fire suppression tests in simulated ship's engine room with a Hi-fog fire protection system. November 16, 1992.

5. ABB Strömberg Research Centre, Vaasa, Finland, 9 AFX92-98, Withstand voltage of switchgears in the presence of operating Hi-fog fire extinguishing system. August 3, 1992.

6. VTT Fire Technology Laboratory, Espoo, Finland, PAL 2196/92, Extinguishing tests of simulated computer room fires by a Hi-fog sprinkler system. August 11, 1992.

7. VTT Fire Technology Laboratory, Espoo, Finland, PAL 2206/92, Enclosed space fire suppression tests. October 23, 1992.

8. VTT Fire Technology Laboratory, Espoo, Finland, PAL 2204/92, Manual suppression of a postflashover fire with Hi-fog nozzles. September 11, 1992.

TABLE 1. MARIOFF MARINE REFERENCE LIST

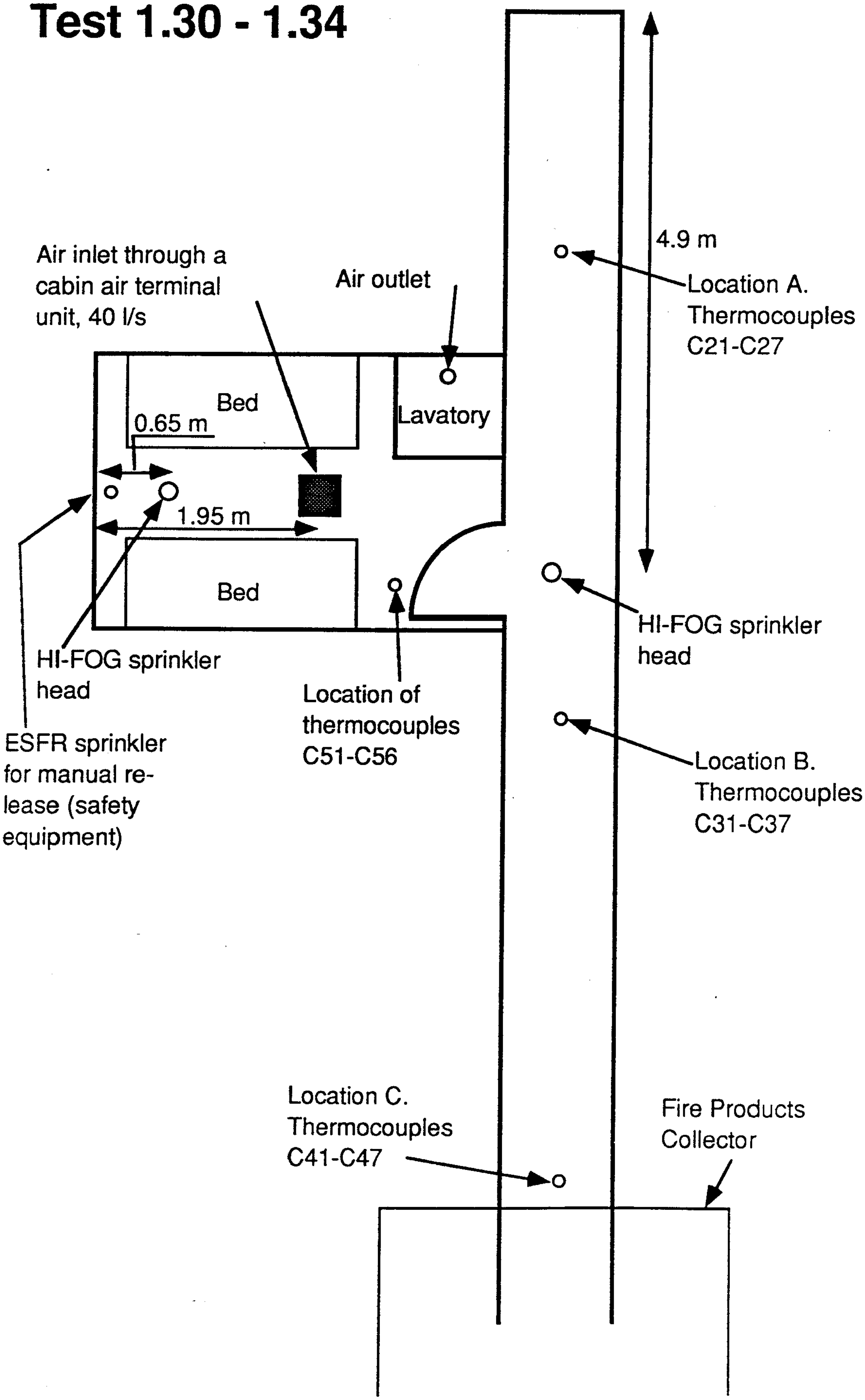
Vessel	*Type*	*Operator/Yard*	*System*	*Progress*
'Olympia'	Cruise ferry	Viking	Galley system	Installed
'Mariella'	Cruise ferry	Viking	Duty free store	Installed
'Franz Suell'	Cruise ferry	Euroway	1200 sprinklers	Installed
'Festival'	Cruise ferry	Silja	2200 sprinklers	Installed
'Karneval'	Cruise ferry	Silja	2200 sprinklers	Installed
'Kalypso'	Cruise ferry	Slite	Galley system	Installed
'Europa'	Cruise ferry	Slite	2340 sprinklers	Installed
'Topaz'	Seismic vessel	GECO	160 sprinklers + engine room	Installed
'Diamond'	Seismic vessel	GECO	160 sprinklers + engine room	Installed
'Linden'	Sailing ship	Linden	30 sprinklers	Pending
NB 373	Cruise ferry	Euroway	1200 sprinklers	Pending
'Robin Hood'	Cruise ferry	TT-Line	1200 sprinklers	Installing
'Athena'	Cruise ferry	Slite	Galley system	Installing
'Bergen'	Ferry	Askøy	750 sprinklers + engine room	Installing
8821	Surface effect ship	Polyship Belgium	24 sprinklers + engine room	Start March 93
Nils Dacke	Cruise ferry	TT-Line	1200 Sprinklers	Start April 93

TABLE 2. MARIOFF LAND BASED REFERENCE LIST

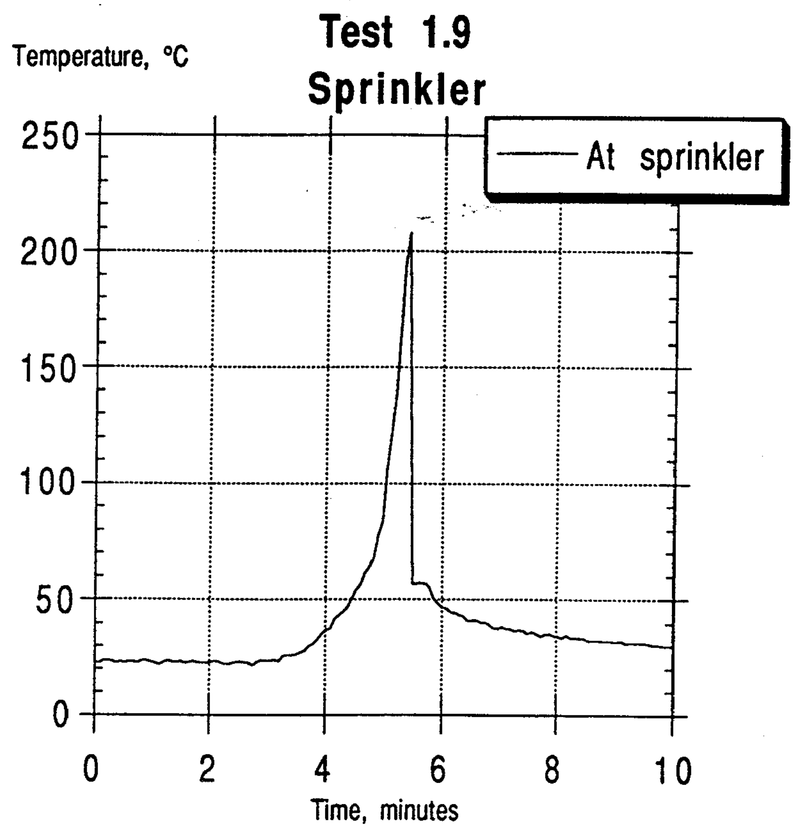
Customer / Project	*Protection*	*System*	*Progress*
London Underground	Store rooms Kiosks	Self-contained	Installed /Installing
London Transport	Paper archives	Self-contained/pump	March install
Agrekko/Shell	Generator room	Self-contained	Commissioning
Polarcup, Finland	Printing machinery	Sprinkler/pump	Commissioning
BMW, Germany	Test room	Self-contained	Ordered

FIGURES

Test 1.30 - 1.34



SP 511


Test 1.9
Sprinkler
Temperature, °C
At sprinkler
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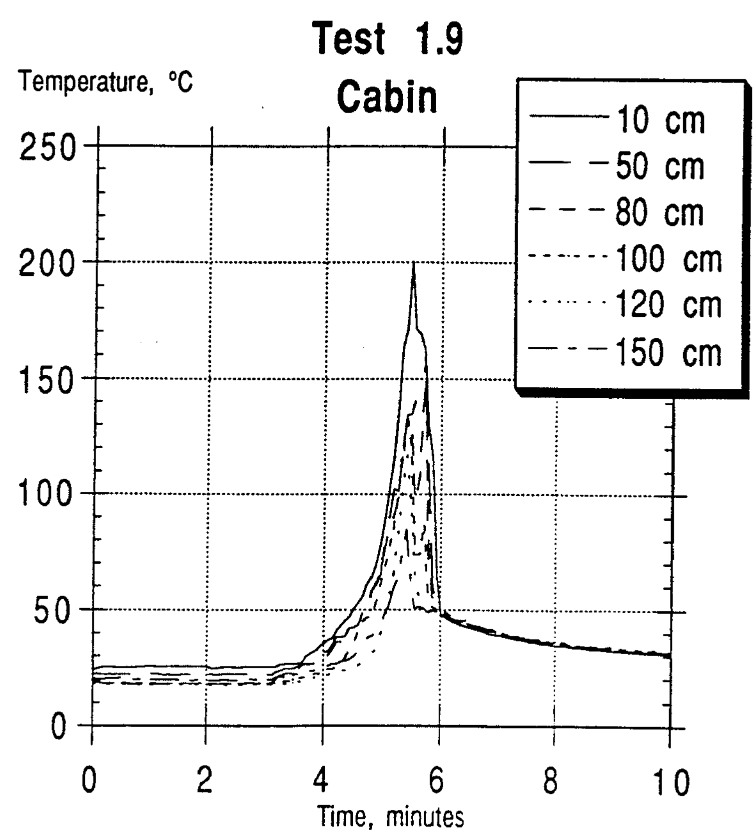
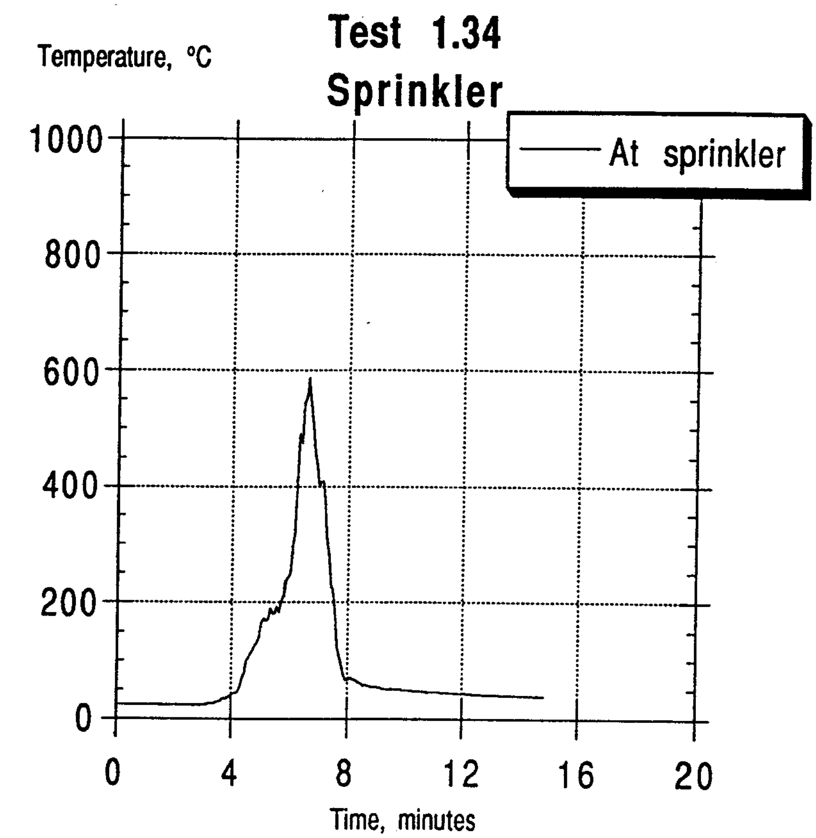
200
150
100
50
0
0
2
4
6
8
10
Time, minutes


Test 1.9
Cabin
Temperature, °C
10 cm
50 cm
80 cm
100 cm
120 cm
150 cm
250
200
150
100
50
0
0
2
4
6
8
10
Time, minutes


Test 1.34
Sprinkler
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600
400
200
0
At sprinkler
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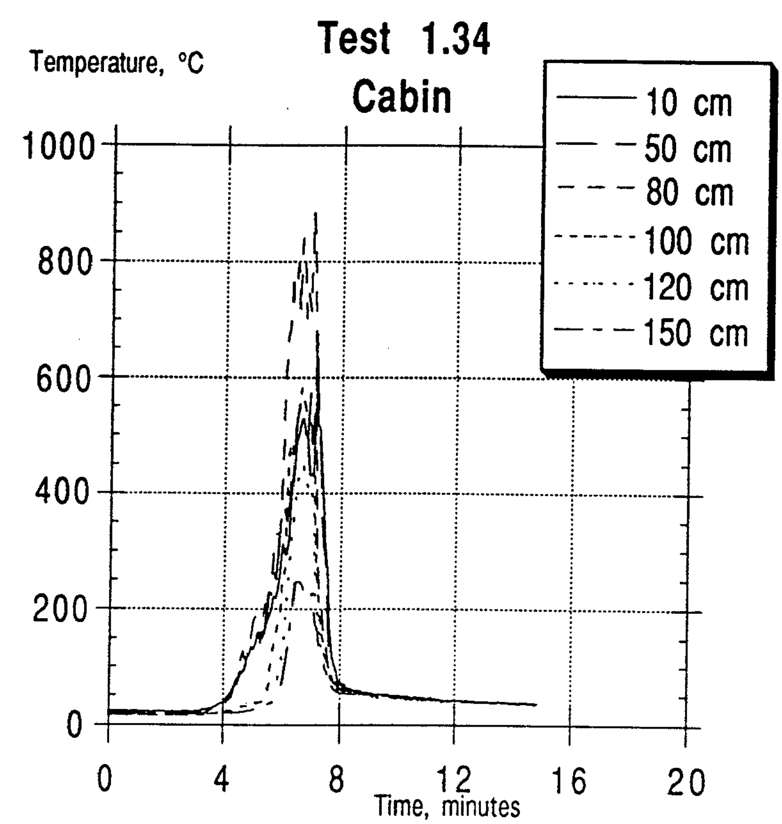
4
8
12
16
20
Time, minutes


Test 1.34
Cabin
Temperature, °C
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800
600
400
200
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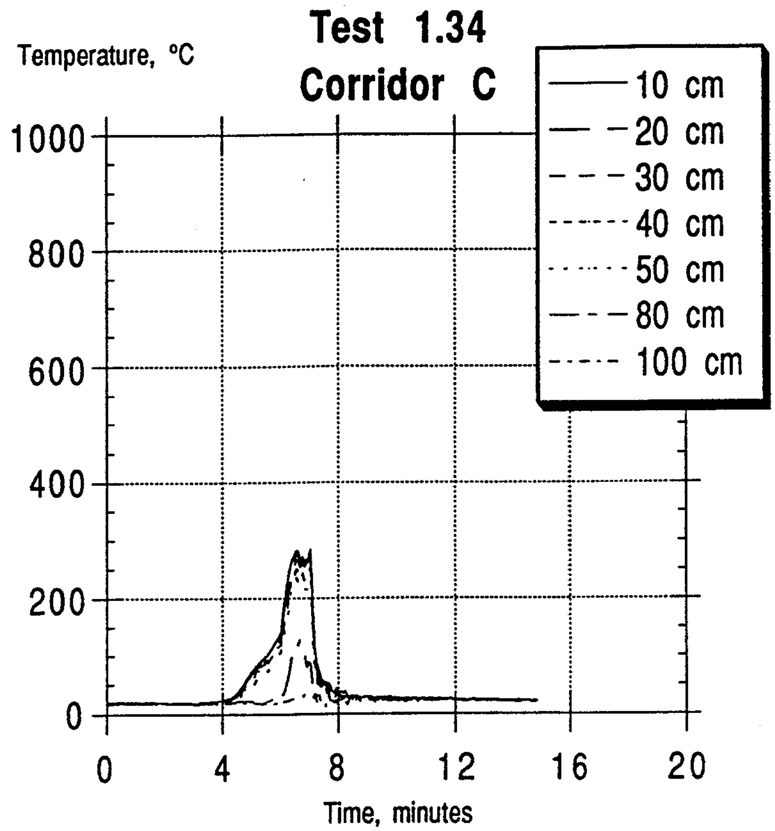
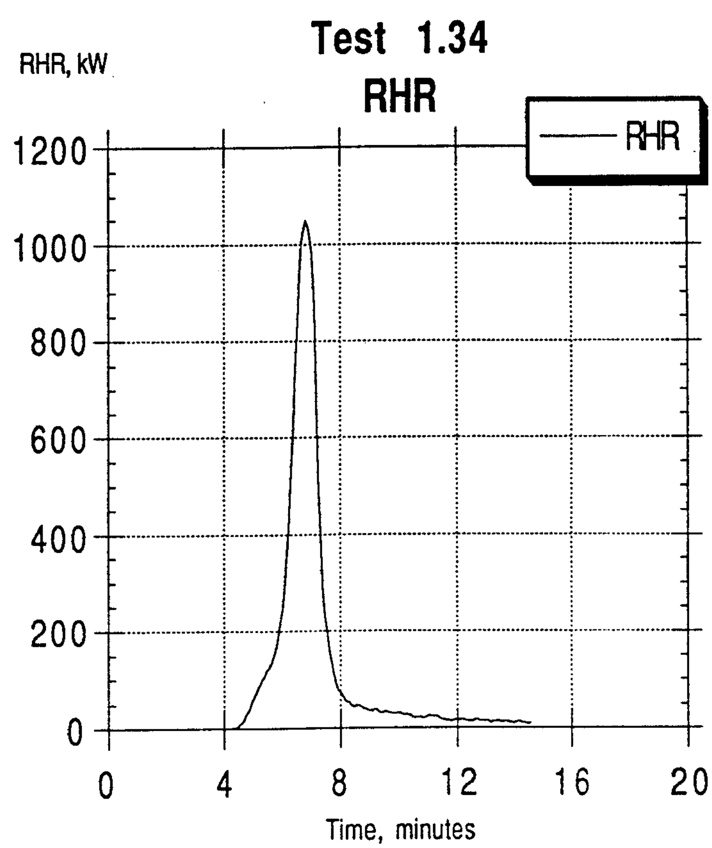
10 cm
50 cm
80 cm
100 cm
120 cm
150 cm
0
4
8
12
16
20
Time, minutes


Test 1.34
Corridor C
Temperature, °C
10 cm
20 cm
30 cm
40 cm
50 cm
80 cm
100 cm
1000
800
600
400
200
0
0
4
8
12
16
20
Time, minutes


Test 1.34
RHR
RHR, kW
RHR
1200
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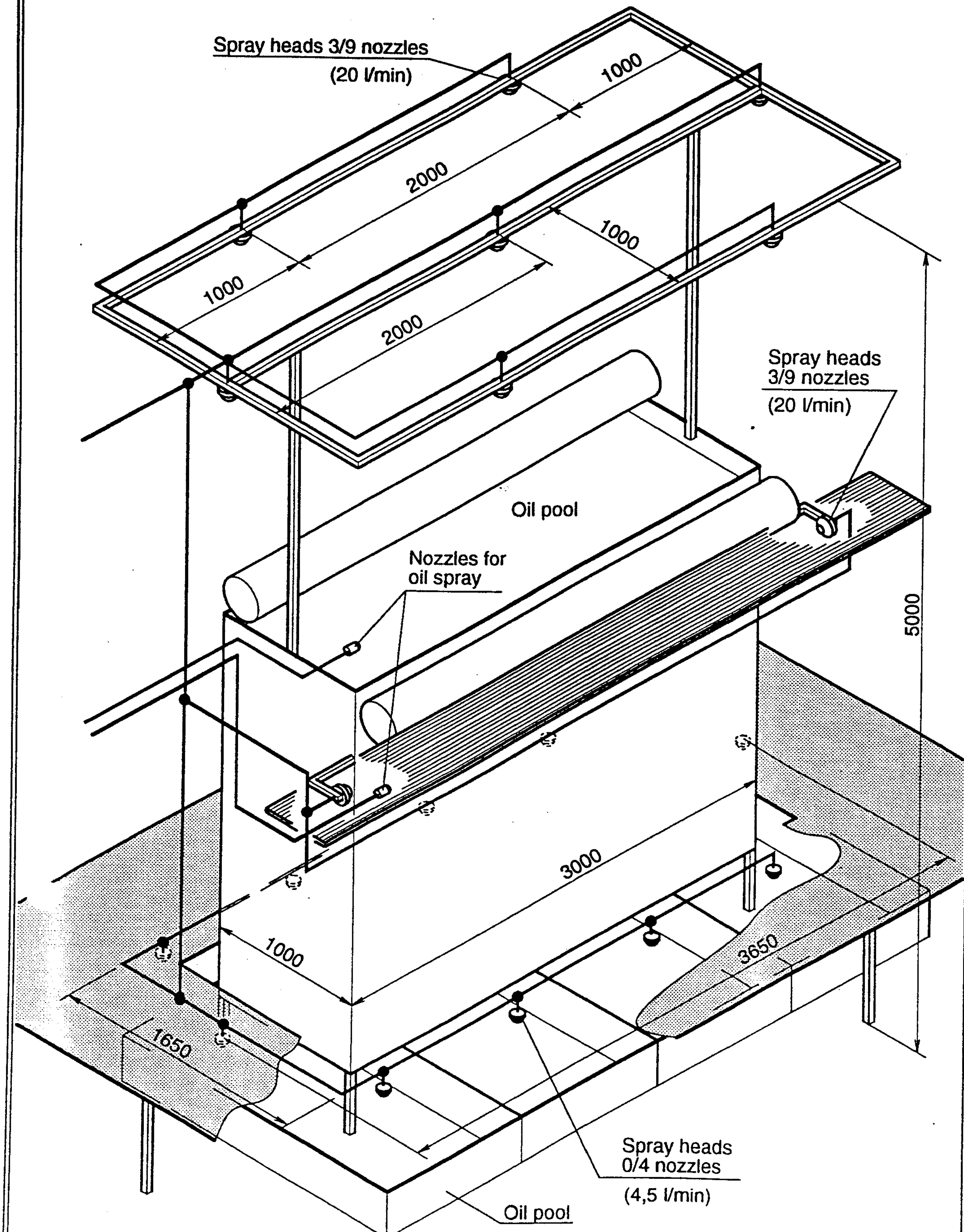
800
600
400
200
0
0
4
8
12
16
20
Time, minutes



Drawing no. ***4-101-07***

Hi-fog	***Head layout - engine room tests*** *SP report R30189 - test series 3 and 4*	MARIOFF