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A Study on the Safe Position from the Local Fire in the Ship's Engine Rooms

Mann-Eun Kim† · Kyoung-Woo Lee* · Young-Ho Lee**

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Abstract : Control devices for fire safety systems located in a engine room are to be arranged at a safe position which is easily accessible during a fire. To develop an interpretation for the safe position in engine rooms, calculation and experiments are carried out to determine a correlation between radiant heat and distance from fire in this paper. On the basis of results of this research, the control devices for a main engine are to be installed in the behind side of an obstruction to reduce radiant heat from the fire of the main engine. In case of other control devices, they are also to be provided in the same manner of control devices for the main engine or are to be placed with 5 meters far from fire hazards.

Key words : Safe position, Local fire, Local application fire fighting system, Multi-engine installations, Heat flux

1. Introduction

SOLAS[1] stipulates measures to ensure that the fire protection system can be used even in case of fire. Taking that into account, a number of requirements on the fire safety matters have been established. These include compartment segregation, insulation, fire door, etc. However, many of these requirements call for the separation of control positions for fire safety equipment and the machinery space.

The local controls for fixed local application fire fighting system (MSC/Circ.913[2], paragraph 3.13) and the manual isolation valves on fuel service line for multi-engines installations (SOLAS regulation II-2/4.2.2.5.5) are fire safety equipment in the machinery spaces. Since the control panel and isolation valves are manually operated, they need to be placed in a position considered safe for the operator in case of local fire. However, there is no interpretation on such safe places and consequently, many recognized organizations and ship designers are applying their own set of requirements

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† Corresponding Author(Energy & Industrial Technology Center, Korean Register of Shipping, E-mail : mekim@krs.co.kr, Tel : 042)869-9350)

* Senior Engineer, Energy & Industrial Technology Center, Korean Register of Shipping

** Professor, Division of Mechanical & Information Engineering, Korea Maritime University

causing confusion and misunderstanding. In this paper, the results of performed calculations and experiments to provide clear interpretation on the safe manual operating position from local fire was introduced.

2. Requirements and approach concept

According to the requirements of SOLAS, the fire extinguisher, the local application fire fighting system and the total flooding fire extinguishing system shall be provided in the engine rooms. And, the local application fire fighting system shall be provided in the engine rooms where the fire risk is the highest. For the local application fire fighting system, the MSC/Circ.913, paragraph 3.13, states that the operation controls should be located at easily accessible positions inside and outside the protected space and the control which are arranged inside the space should not be liable to be cut off by a fire in the protected space.

Furthermore, SOLAS regulation II-2/ 4.2.2.5.5 also requires that in multi-engine installations which are supplied from the same fuel source, the means of isolating the fuel piping to individual engines shall be provided and the means of isolation shall be operable from a position not rendered inaccessible by a fire on any of the engines.

When a fire breaks out, radiant heat produced by the fire prevents a person from approaching the ignition point. Consequently, the degree of radiant heat impact on a person and the amount of radiant heat at certain distances should be identified to pinpoint which area would be safe for manual operation of fire safety equipment.

The Fig. 1 shows the schematic diagram of local operation controls for local application fire fighting system and the Fig. 2 shows schematic diagram of fuel isolation valve for the multi engine installations.

Considering the values given in table 1, it is safe to assume that a person without donning the fireman's outfit can safely perform simple work such as manipulation of valve or switch of control panel at $0.7\ W/cm^2$.

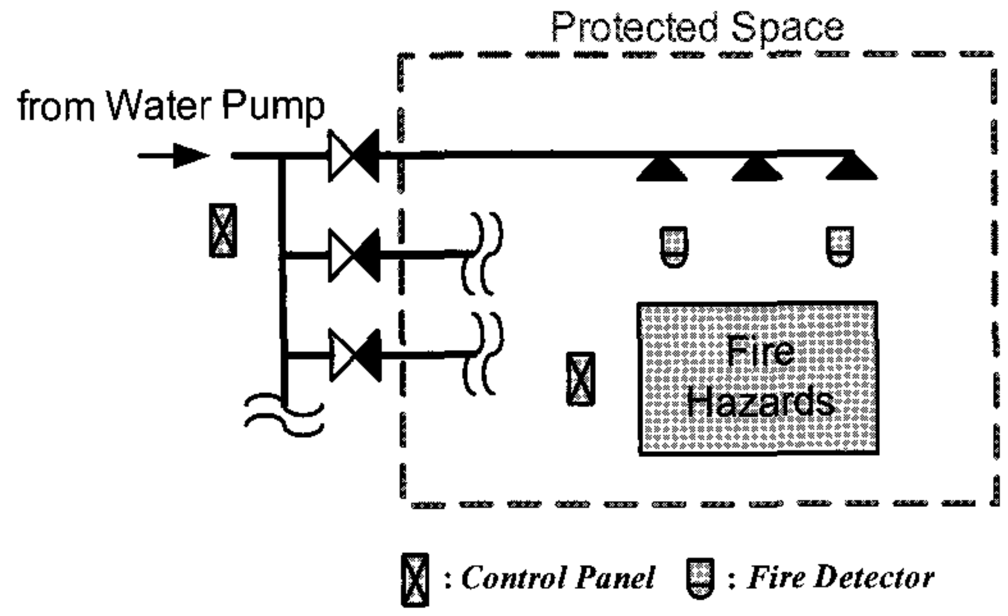


Fig. 1 Schematic diagram of local operation controls for local application fire fighting system

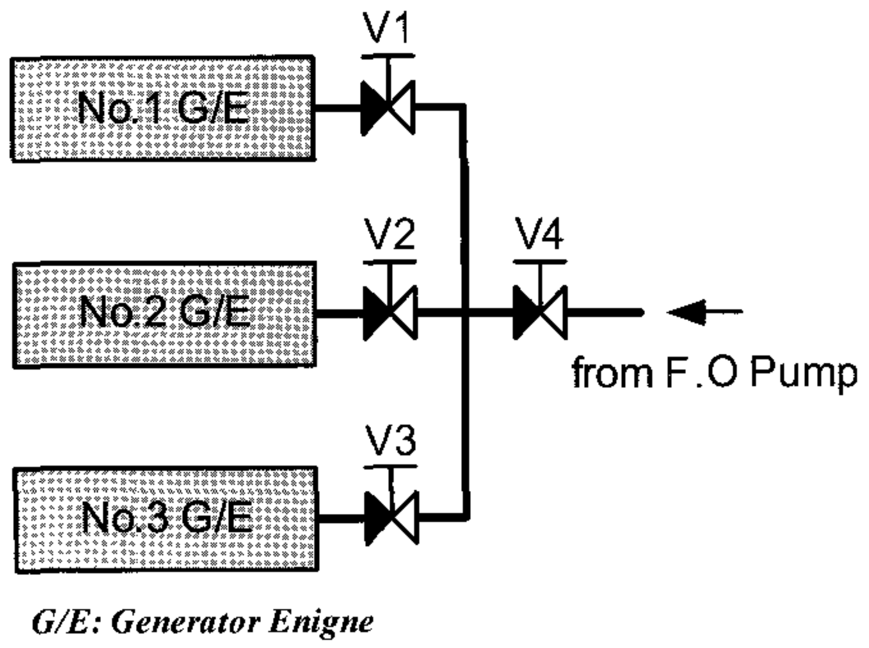


Fig. 2 Schematic diagram of fuel isolation valve for multi engine installations

Table 3 Heat flux and related level of heat flux[3]

Heat Flux	Related Level of Heat Flux
0.025 W/cm^2	Heat flux radiating from a human body on a cold winter day.
0.14 W/cm^2	Heat flux from the sun on a clear day in the tropics.
0.64 W/cm^2	Heat flux 10 cm away from a 100 W incandescent light bulb.
1 W/cm^2	Causes burn to human skin after 10 seconds.
5 W/cm^2	Causes burn to human skin after 1 second.
10 W/cm^2	Heat flux from a propane torch at the flame tip.
100 W/cm^2	Heat from an oxy-acetylene torch at the flame tip.
6500 W/cm^2	Heat flux on the surface of the sun (radiation only).

3. Calculation for Heat Flux

In order to calculate the heat influx at various distances from the fire, a fire model is required. For this purpose, a fire model of the annex to document FP 44/INF.4[4] was used.

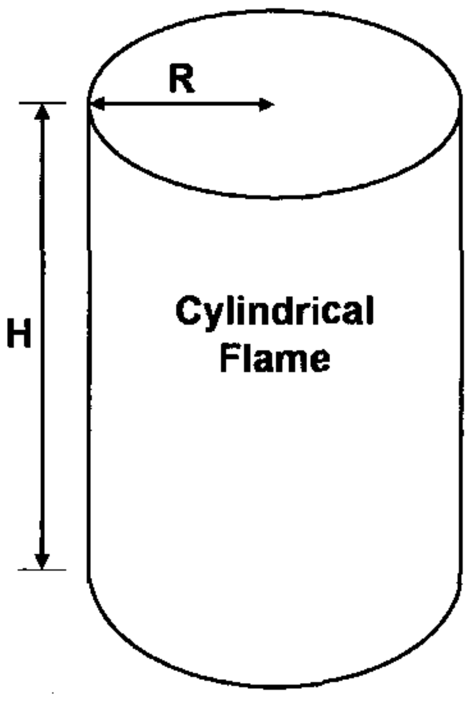


Fig. 3 Cylindrical Flame

In the document FP 44/INF.4, the fire is represented as a cylindrical flame as shown in the Fig. 3. The heat flux(E) at various distances from the centre of cylindrical flame shown in the Figure. 1 can be calculated using the equations (1), (2), (3) and (4).

$$E = \alpha R_f \tag{1}$$

where,

α : shape coefficient determined by equation (2)

R_f : radiant heat ratio, 2000 $kcal/m^2h$

$$\alpha = \frac{1}{\pi n} tan^{-1}\left(\frac{m}{\sqrt{n^2-1}}\right) + \frac{m}{\pi}\left\{ \frac{a-2n}{n\sqrt{ab}} \tan^{-1}\left(\sqrt{\frac{a(n-1)}{b(n+1)}}\right) - \frac{1}{n}\left(\sqrt{\frac{n-1}{n+1}}\right) \right\} \tag{2}$$

where,

$a = (1+n)^2 + m^2$

$b = (1-n)^2 + m^2$

$n = L/R$

$m = H/R$

L : distance from the center of the flame, m
R : radius of flame, m
H : height of flame, m, 3R

$$S = \pi R^2 = \frac{0.2^2 A V_0}{V_B} \tag{3}$$

where,

S : section area of flame, m^2
A : section area of pipe, m^2
V_0 : velocity of leakage, m/sec
V_B : combustion velocity, 0.28×10^{-4} m/sec

$$V_0 = C_d \sqrt{\frac{2P}{\rho}} \tag{4}$$

where,

C_d : discharge coefficient, 0.6
P : internal pressure of pipe, Pa
ρ : density of fluid, 950 kg/m^3

The above formulas are based on an assumption that the fire is caused by the leakage in the flange or union of a pipe. The heat flux at various distances were calculated for the pipes 20A ~ 65A (schedule 40), which are used in the fuel oil service system on board ships, under the inside pressures of 5 bar, 8 bar and 12 bar. The graphics in the Fig. 4 and Fig. 5 show the results of such calculations.

However, the results of calculations are not sufficient to reflect actual situations since calculations are based on many assumptions. The actual fire does not form a perfect cylinder shape and it is difficult to confirm that the height of cylinder flame is three times the radius. Especially, the radiant heat ratio R_f, which decides the value of heat flux, is not 2000 kcal/m^2h in all fires.

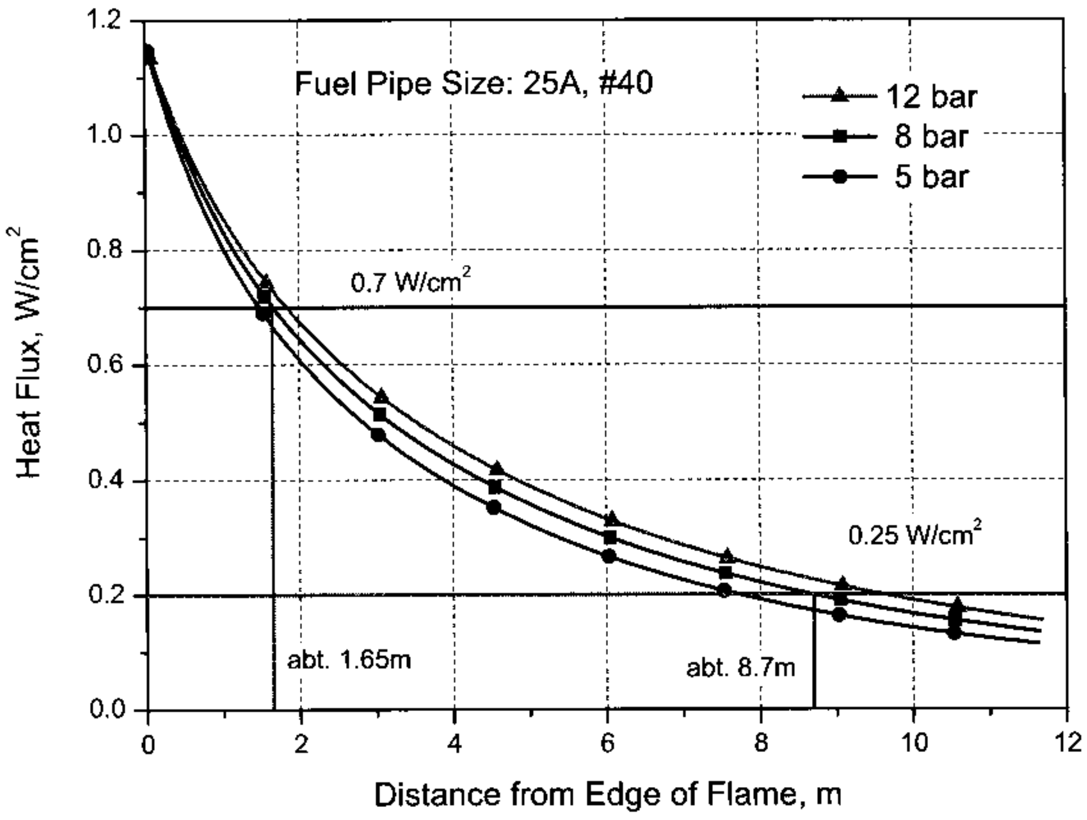


Fig. 4 Calculated heat flux at various distances (25A, Sch.40)

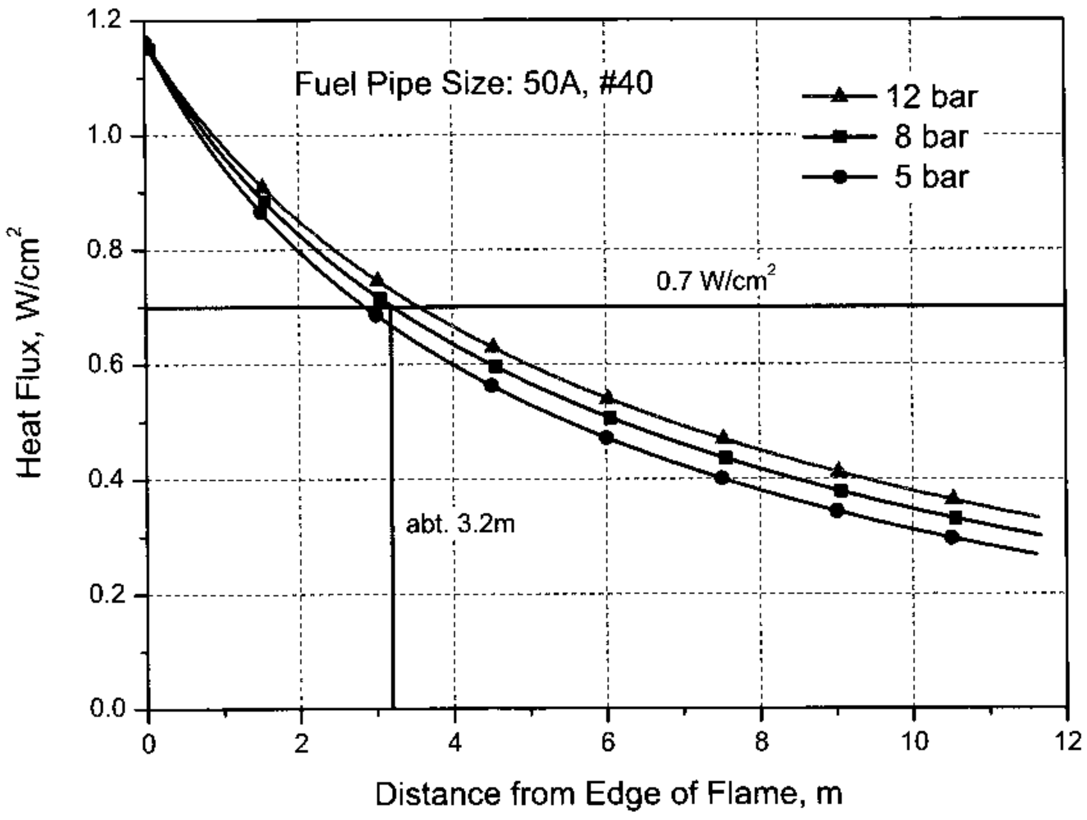


Fig. 5 Calculated heat flux at various distances (50A, Sch.40)

Consequently, the above calculation results need to be compared with the results of the experiment to identify the general tendency.

4. Experiment for heat flux and temperature

The experiment was carried out inside a 20m × 15m fire test shop and the spray fire and pool fire were used as a fire source. The positions of heat flux meter, thermocouple and fire were as in the Fig. 6 and the fire scenario and experimental conditions were as in the Tables 2 and 3.

Additionally, an approved type water mist nozzle (table 4) was set up on the upper side of fuel spray nozzle to find out the influence of water mist on the heat flux. The specification of the nozzle is described in the Table 4.

As shown in the Table 2, the fire scenarios of MSC/Circ.913 and MSC/Circ.1165 were used for the spray fire and

Table 2 Fire scenario for experiment

No.	Source of fire	Firing direction	Position of heat flux meter	Kind of fuel
6MW	6MW F.O nozzle[1)]	To Mock-up	6	Diesel oil
1MW-1	1MW F.O nozzle[1)]	To Mock-up	6	Diesel oil
1MW-2	1MW F.O nozzle[1)]	To Mock-up	10	Diesel oil
Pool	Square box[2)]	-	4	Heptane[3)]

1) Refer to IMO MSC/Circ.913, Annex, Table 3.2.2.1

2) 770 mm x 770 mm x 300 mm(Height) × 5 mm(Thickness) Steel Box

3) Height of water: 65 mm, Height of Heptane: 10 mm

Table 3 Experiment condition

Heat flux meter	64-5SB-20, MEDTHERM corp.
Amplifier for Heat Flux Meter	H-201, MEDTHERM corp.
Thermocouple	K type
Installation of heat flux meter & thermocouple	1m above from ground
Size of test shop	20m(L)×15m(B)×13m(H)
Ambient temperature	About 20℃

Table 4 Specification of water mist nozzle

Approval standard	MSC/Circ.913
Model no.	MistWin-T10(WIN Corp.)
Working pressure	40 ~ 80 bar
K-factor	2.4
Max. horizontal nozzle spacing	2.5 × 2.5 m
Min./Max. vertical distance from object	0.5 m / 4 m
Actual vertical distance from fuel nozzle	1 m
Actual vertical distance from center of pool	2 m

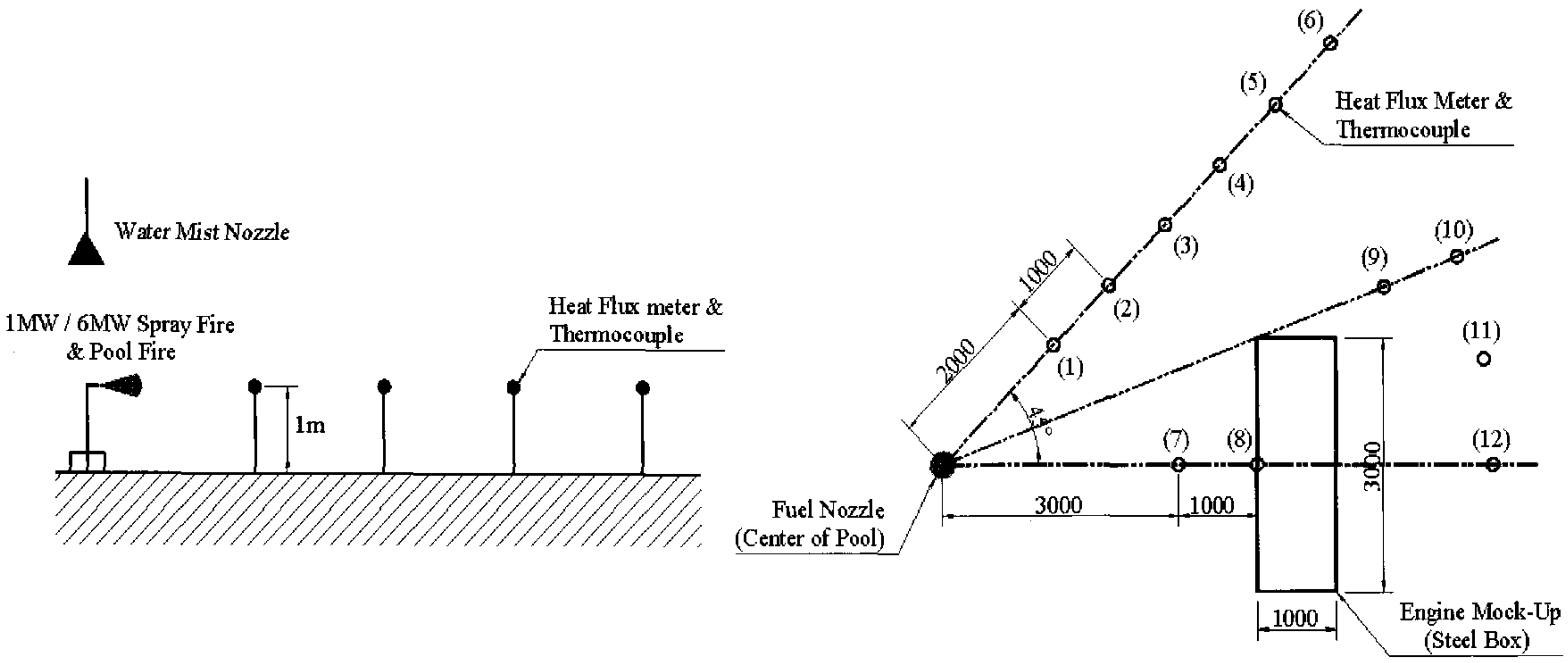


Fig. 6 Arrangement of experiment for heat flux from fire

pool fire, respectively. Although the types of fire provoked in the actual machinery space would be more complicated and wide-ranging than the fire scenario described in the Table 2, the fire scenario for the experiment was set based on the nominal heat release for the purpose of measuring heat flux at various distances from the fire. The test was carried out based on the spray fire according to MSC/Circ.913, since MSC/Circ.1165, annex, appendix B, table 3 states the nominal heat release to be 6.4 MW maximum.

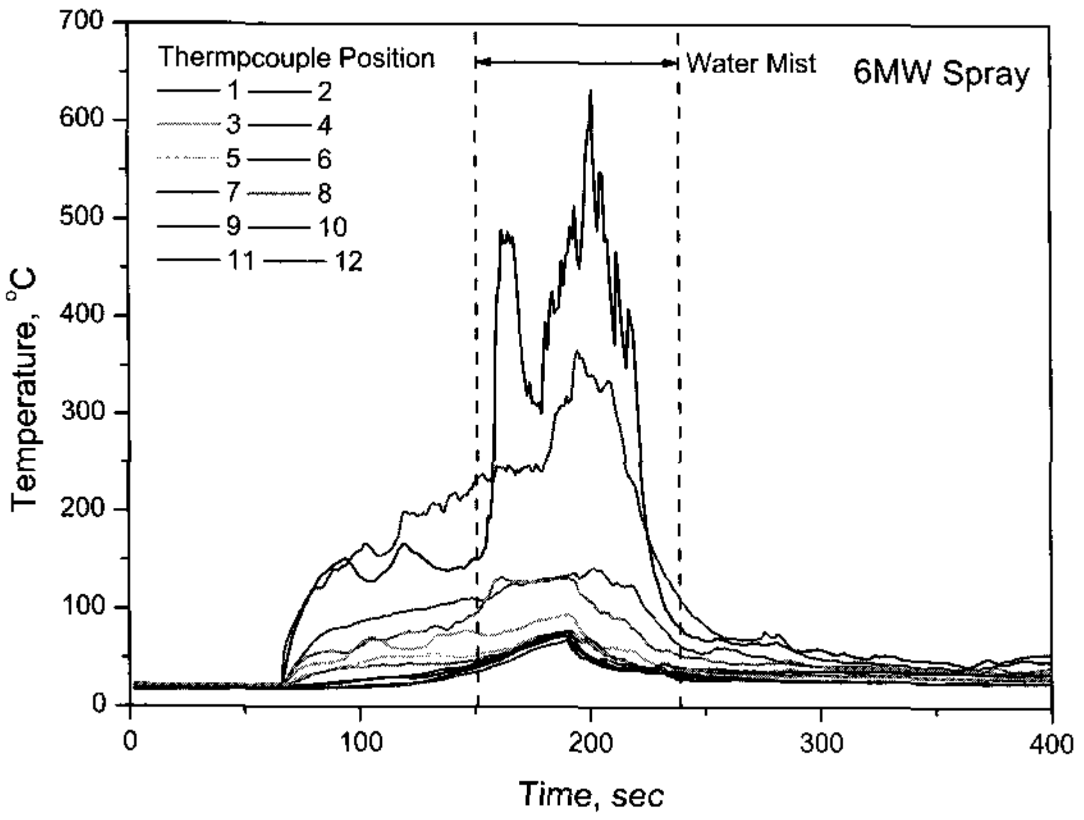


Fig. 7 Test result - 6MW Spray

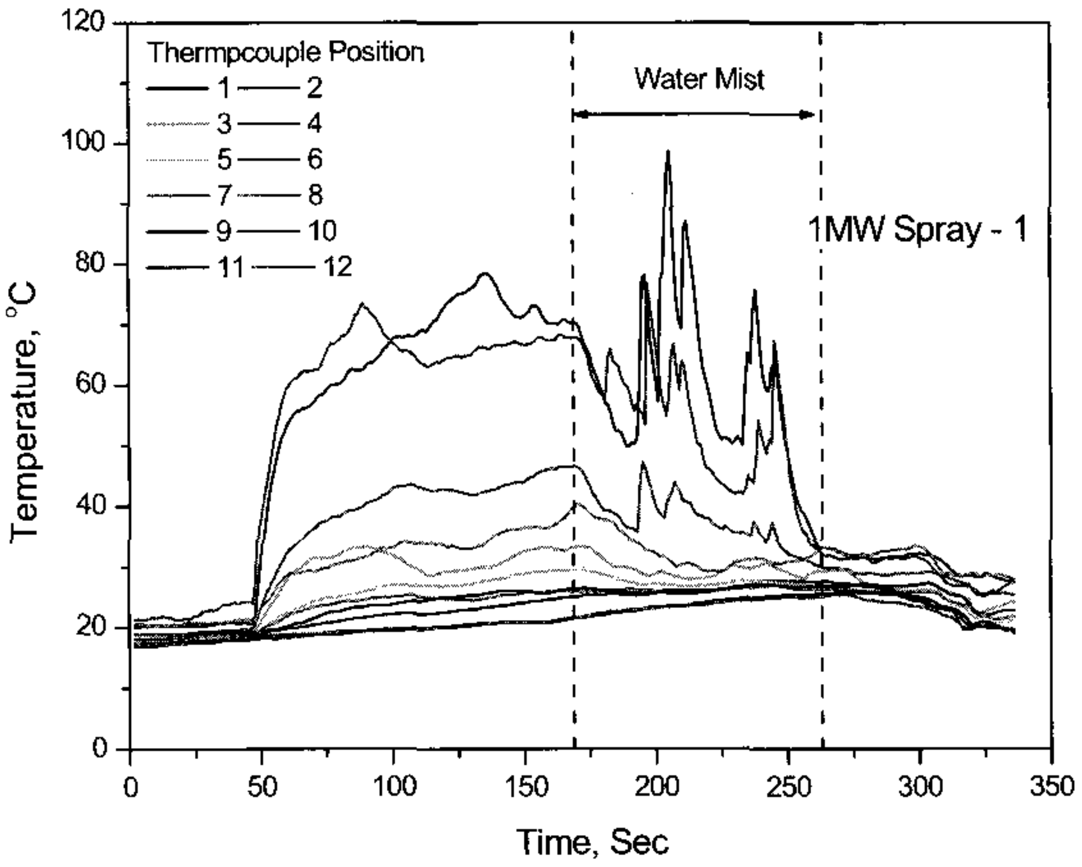


Fig. 8 Test result - 1MW spray-1

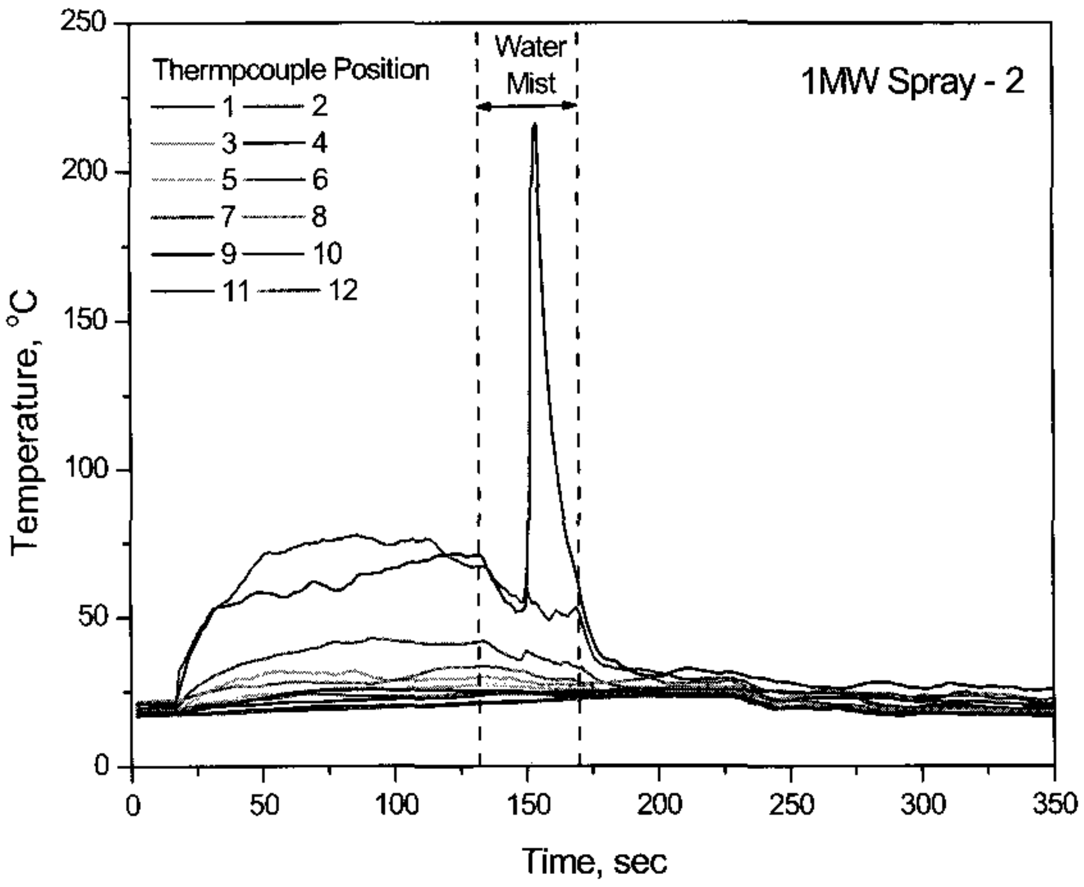


Fig. 9 Test result - 1MW spray-2

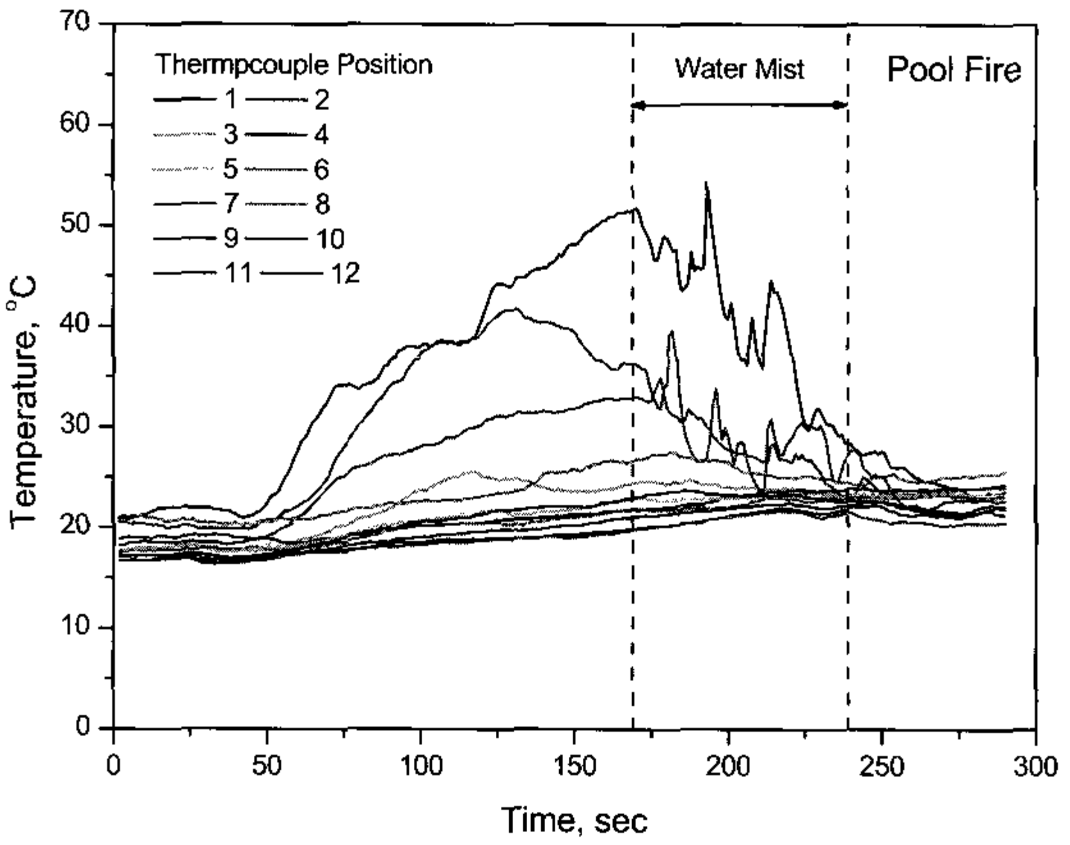


Fig. 10 Test result - pool fire

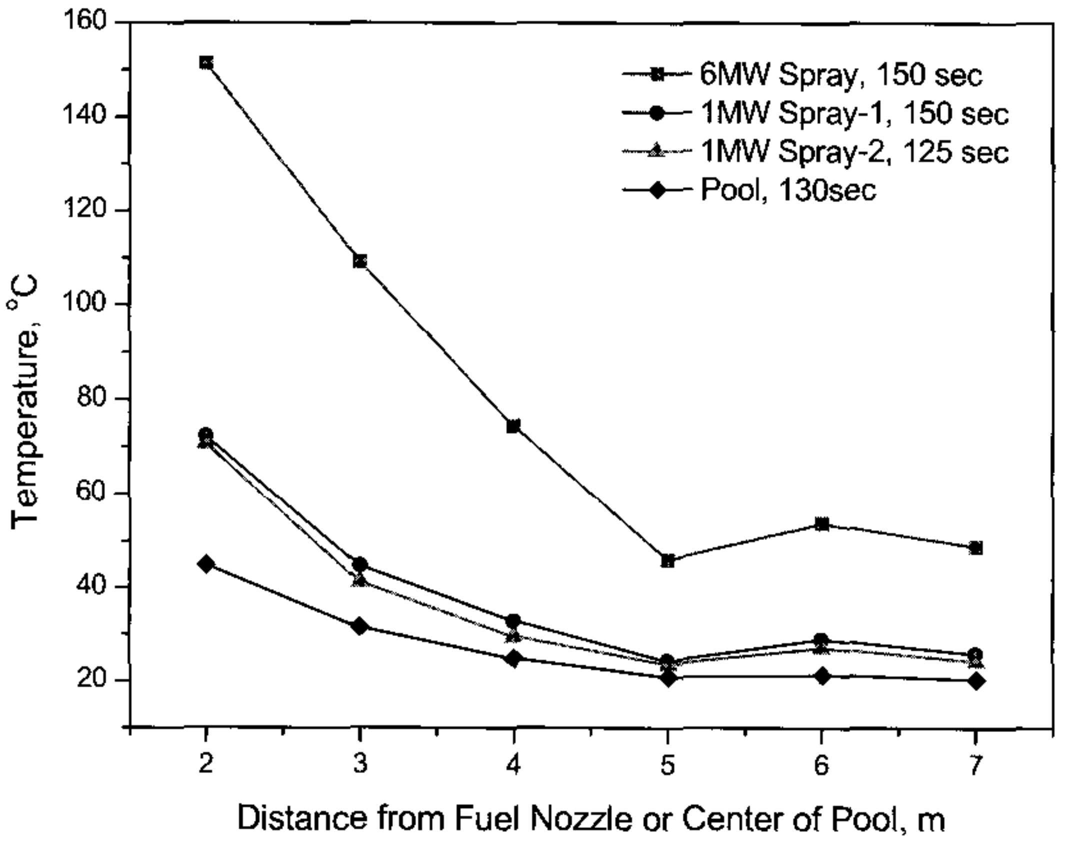


Fig. 11 Temperature distribution regarding to distance from fire source

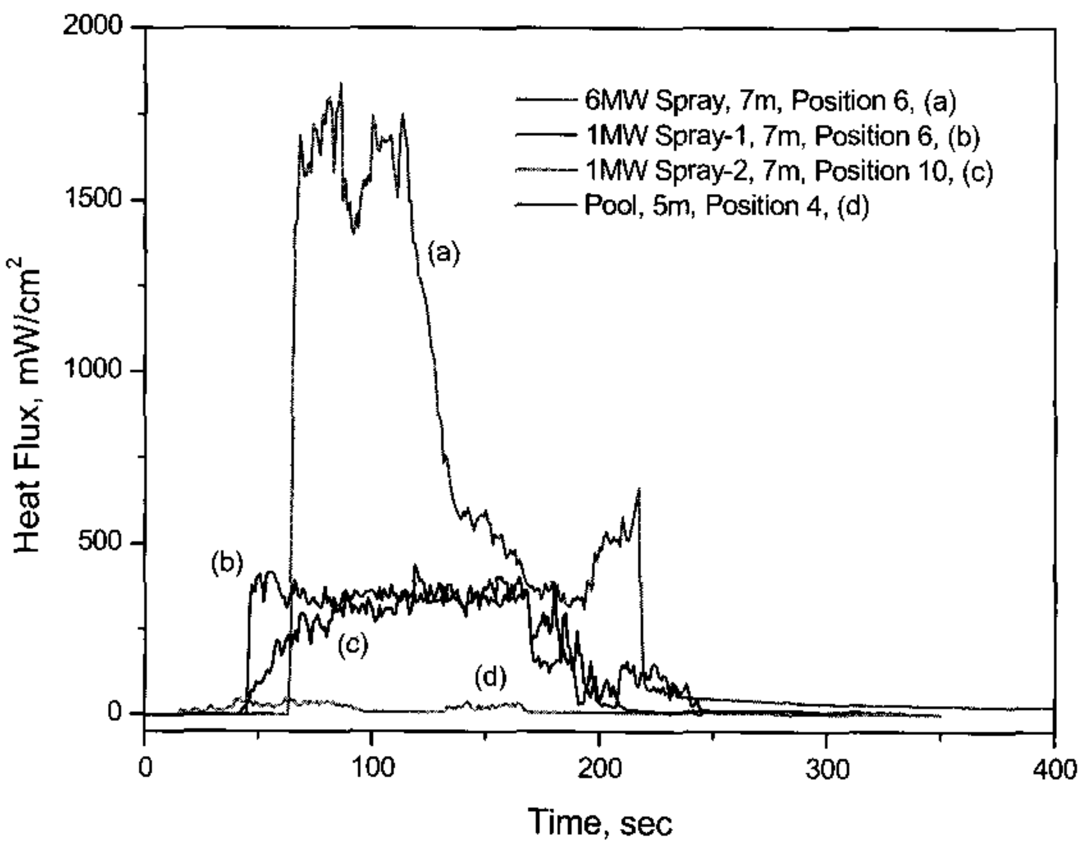


Fig. 12 Measured heat flux

The temperature and heat flux measuring points were arranged as shown in the Fig. 6 after considering the actual engine room arrangement. The positions 1 to 6 simulated open space, while positions from 7 to 12 simulated various forms of actual obstructions.

The experiment was carried out with all doors in test shop closed. The temperature and heat flux were measured by allowing the fire to fully develop and by activating the water mist system.

The Fig. 7 to Fig. 12 shows that the temperature of the area surrounding the fire varies greatly with the size of fire. Also, in Fig. 11, it was found that the temperature decreases with the increased distance from the fire source and that the decreasing gradient becomes greater as the size of fire becomes larger.

After the activation of water mist system, the temperature of area near the fire increased temporarily. When the fire occurs, most of its heat tends to move upwards. It is thought that at that moment the water mists spurting out gets in contact with the fire causing them to evaporate. This state of mixed flux works to influence the surrounding heat flux.

It is considered that a person can operate control panel at a position where the heat flux is less than 0.7 W/cm^2. However, in case of 6 MW spray fire considered as M/E fire scenario, the level of heat flux transmitted to a position of 7 m away from the fire source was too high for a person to safely operate the fire safety equipment.

In case of 1 MW spray fire which is

considered as a G/E fire scenario, in Fig. 12, heat flux was measured to be about 0.4 W/cm^2 at 7 m distance from the fire source, making the manual operation possible at a distance of 4 to 5 m from the fire.

In case of pool fire which may be considered as a fire in the bilge area or at oil coaming, the temperature and heat flux measured were lower than 1 MW spray fire. Consequently, the location of manual operation should be considered for the spray fire only.

Among the results of the figures, the result for 1 MW spray-2 should be discussed in more details. Normally, an engine room has many obstructions which interfere with the heat flux. To consider the actual engine room condition, the heat flux was measured from a position 10 which is a point located in a straight line from the fire source and the edge of obstruction (engine mock-up). According to the measurement, the heat flux was only too little transmitted. Consequently, it is safe to assume that the heat flux at position 9, 11 and 12 is lower than the value measured at position 10.

Based on the result of experiment, it is clear that the manual operation position should be located at a position having an obstruction from the fire.

5. Conclusions

On the basis of result of foregoing experiment, the design of manual operation position should consider the following items.

(1) local control panel for fixed local application fire fighting system for main engine should be located at a position protected by an obstruction to reduce high heat flux.

(2) local control panel for fixed local application fire fighting system for generator engine, boiler burner, incinerator burner, etc. should be located at a minimum distance of 5 m from the fire source and a position protected by an obstruction.

(3) manual isolation valves for multi-engine installation, when used for generator engine fire, should be located at a minimum distance of 5 m from the fire source and a position protected by an obstruction.

(4) local control panel for fixed local application fire fighting system should not be arranged on the upper deck floor from the protected area without a perfect obstruction.

6. References

[1] International Convention for the Safety of Life at Sea, International Maritime Organization, 2006 consolidated edition, IMO, 2006

[2] "Guidelines for the approval of fixed water-based local application fire-fighting systems for use in category a machinery spaces", MSC/Circ.913, IMO, 1999

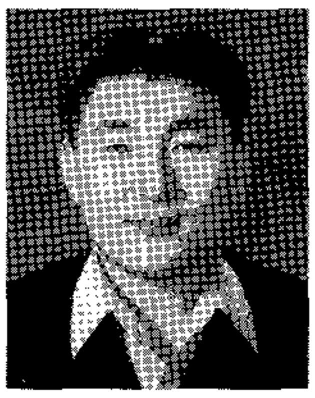
[3] Vatell Co. Ltd., "How Much Heat Flux is That?", Thermateq"-nology Newsletter, pp.2, March.

[4] "Result of the research on applicability of Formal Safety Assessment to comprehensive review to SOLAS chapter II-2", FP 44/INF.4, IMO, 1999

Author Profile

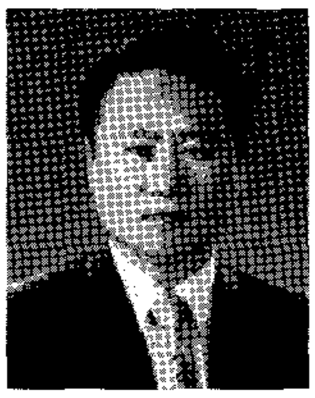
Mann-Eung Kim

He received the B.S, M.S and Ph. D. degrees from Korea Maritime University in 1980, 1998 and 2005. He is currently a general manager of Korean Register of Shipping.



Kyoung-Woo Lee

He received the B.S, and M.S and Ph.D. degrees from Korea Maritime University in 1996, 1999 and 2008. He is currently a senior engineer of Korean Register of Shipping.



Young-Ho Lee

He received the B.S and M.S degrees from Korea Maritime University in 1980 and 1982 and his and Ph. D. degree in 1989 from Tokyo University in Japan. He is currently a professor of Division of Mechanical & Information Engineering at KMU in Busan, Korea.