MARINE FIRE EXTINGUISHING SYSTEMS - YACHT FIRE SAFETY & PREVENTION

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ABSTRACT

Ships carry fuel, batteries, propane, alcohol, wood, plastic, fabric, etc. When these materials burn, special types of fire extinguishers are required to suppress the fire.
This study includes fire extinguishing systems used in the maritime industry, the area of use, and the application of two fire extinguishing systems. Using different fire extinguishing systems, developments, and the systems that can be directed in the future are also described. Water-based-sprinkler, gas-based, foam-based and powder-based systems have been studied and some regulations have been reviewed for the prevention of sea and yacht fires and their impact on safety.

Key Words: *Sprinkler, safety at sea, yacht fire protection, fire extinguishing system.*

1. Introduction

Many situations can cause loss of life and property on ships. One of these reasons is the occurrence of a fire on the ship. Fire extinguishing systems are created in a way to reduce the loss of life and property with certain criteria and rules determined by the authorities which class and flag state. Fire extinguishing systems have different rules and applications in private, commercial, and military ships. Especially ships used for personal and small commercial purposes are subject to rules by class authorities and flag states, exempted from many rules or at certain points, the rules are more flexible. On the other hand, commercial ships subject to some flag states may be subject to additional rules and practices compared to a class and other flag states.

2. Marine Fire Extinguishing Systems

Marine Fire Extinguishing Systems can be classified as into three categories [1].

1. Portable fire extinguisher.
2. Semi-portable fire extinguisher
3. Fixed type firefighting equipment onboard ship

These systems provide water, gas, foam and powder base protection.

2.1 Water Based Fire Fighting Systems

Water based fire-fighting protection systems protect machinery category A and special cargo spaces, local protection of machineries, accommodation spaces, vehicle areas and cargo holds. Multiple spaces can be protected by one water based system (see Figure 1).
Water based fire-fighting system is designed according to related code in FSS Code, such as MSC Circ. 265(84) should be followed when accommodation and service spaces are protected. Water-based systems are usually manually operated and fresh water should be used in the first-place exempt car deck protection.

Figure 1. Water protection in Engine Room.

2.2 Gas Based Fire Fighting Systems

Gas based fire-fighting system protects machinery spaces category A and closed deck vehicle areas. System is designed according to related code in FSS Code. Gases like CO2, Novec1230, FM200 and Inergen use in gas based fire-fighting system (see Figure 2).

The main issue of the design of a gas based protection system is human safety. Most of European countries prefer to use clean agent gases like Novec1230, Inergen, etc. Unfortunately, using clean agent gas is not enough for human safety. Therefore, Concentration of gas should be between Lowest Observed Adverse Effect Level (LOAEL) and No Observed Adverse Effect Level (NOAEL). No Observed Adverse Effect Level calculated on the net volume of the protected space at the maximum expected ambient temperature without additional safety measures [2]. Lowest Observed Adverse Effect Level, inert gas is used at gas concentrations above 52% calculated on the net volume of the protected space at the maximum expected ambient temperature [3].

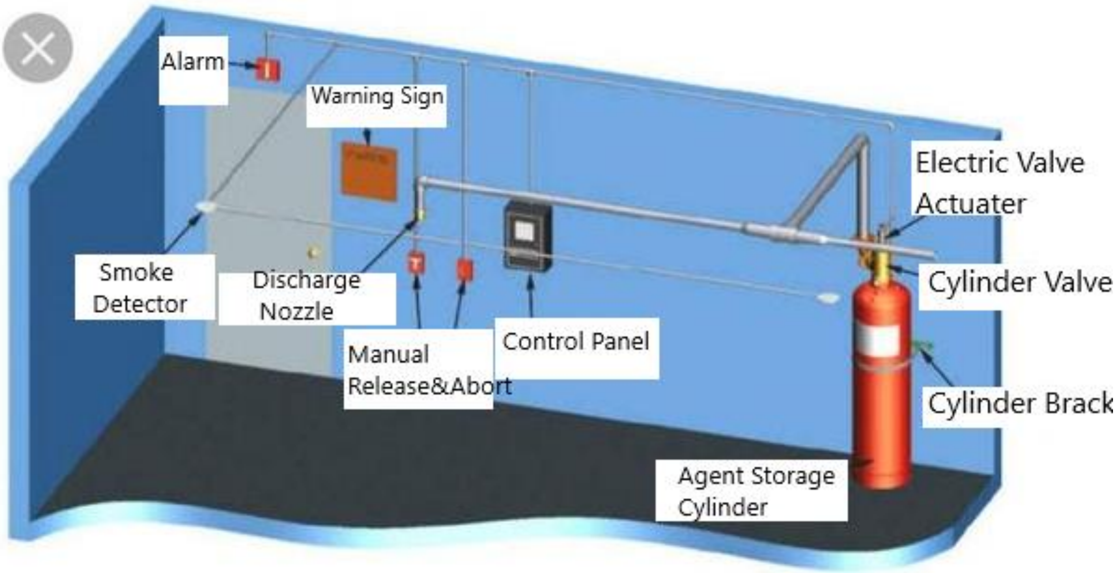

Figure 2. Gas Based Protection

2.3 Foam Based Fire-Fighting Protection

Foam based fire-fighting system protects helideck area and bilge areas in machinery spaces when these spaces protected by water mist and deck foam systems.

Helideck protection is designed according to CAP437 depends on D-value of the design helicopter [4]. This system can be designed in two ways. The first system is designed with a fire monitor system. The other one is called Deck Integrated Fire-fighting System (DIFFS) which consists of pop-up nozzles protection.

2.4 Powder Base Fire Fighting Protection

Powder base systems are usually used in Bunker Stations production. They are used for fires with solid, liquid or gaseous substances and for metal fires, thus, they are used for fire classification A, B, C and D. These systems are used as fixed and portable on ships. Although the most common use of dry powder is portable fire extinguishers, it can also be used for tank protection in private boats operating at special fueling stations and LNG terminals, which are also referred to as fixed systems.

3. FIRE EXTINGUISHING SYSTEM ON YACHTS

Fire protection systems requirements on yachts are classified by gross tonnage and length. There is no specific fire protection system classification for yacht types and hull materials.

3.1 Water Based System

Yachts are protected by water based fire-fighting system can be used in machinery and accommodation spaces on yachts. Automatic sprinkler system is used in yachts because they have more accommodation space than commercial ships. This system is activated only if the heat sensitive glass bulb is broken. Only broken nozzles lets spraying.

3.2 Gas Based Systems

Gas based system protects engine rooms and cargo pomp rooms. Gas system, even though the clean agent gas does not directly affect human health, it is not preferred in accommodation areas. Halon 1211, 1301, 2402 and perfluorocarbons are prohibited to use of protection of machinery spaces.

Gas based system is preferred for engine rooms in small yachts since system weight will be lighter than water based system. Addition to this, if engine room is very small, system can be automatic.

4. COMPONENTS AND EXAMINATION OF SPECIAL SYSTEMS USED ON YACHTS

In this study, water and gas based fire-fighting systems were evaluated for two yachts. The review of the systems is given below, respectively.

4.1 Water Mist System

A water mist system is applied to a 30 m length yacht which is built in Turkey, under RINA. Accommodation space is protected. System is included pump, nozzles, butterfly valve with electrical actuator, zone valves, control system. Nozzle arrangement is given in Figure 3. System P&ID is given in Figure 4.

System capacity is calculated based on the number of nozzles, k-factor of nozzles and working pressure of nozzles (Table 1).

$$Q = n.k.\sqrt{pressure} \quad (1)$$

where,

n= number of nozzle, k=k-factor of nozzle.

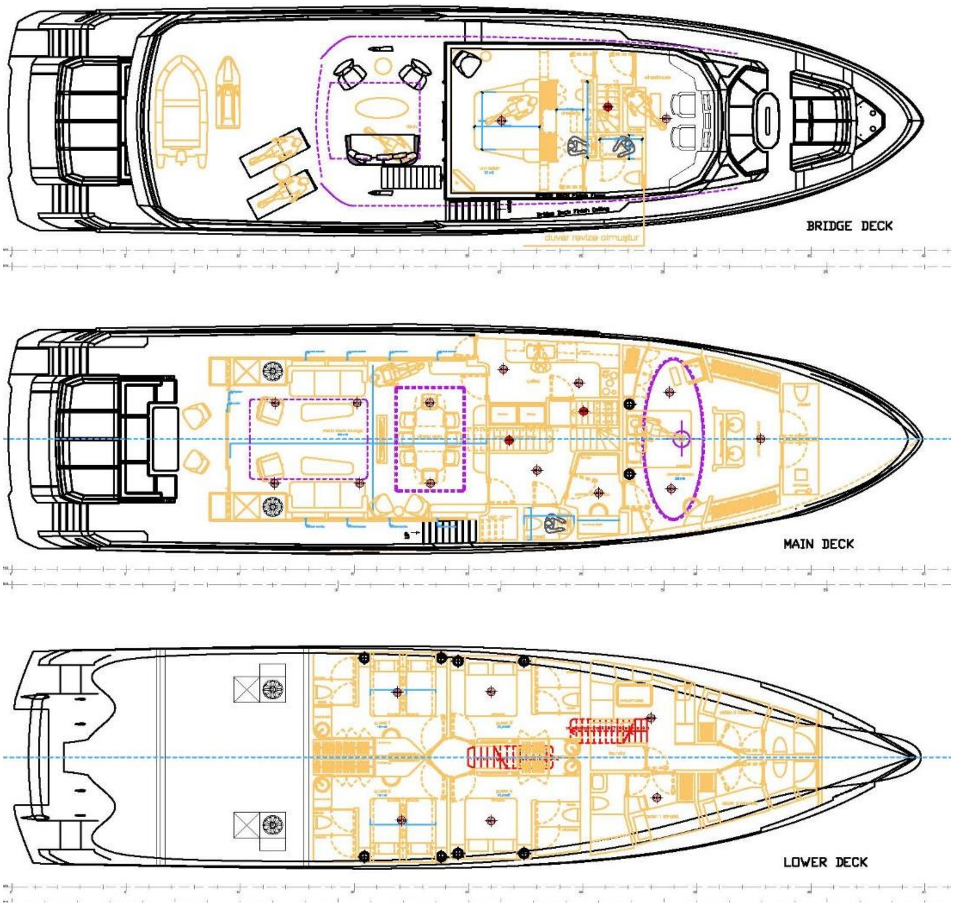

Figure 3. Nozzle Arrangement.

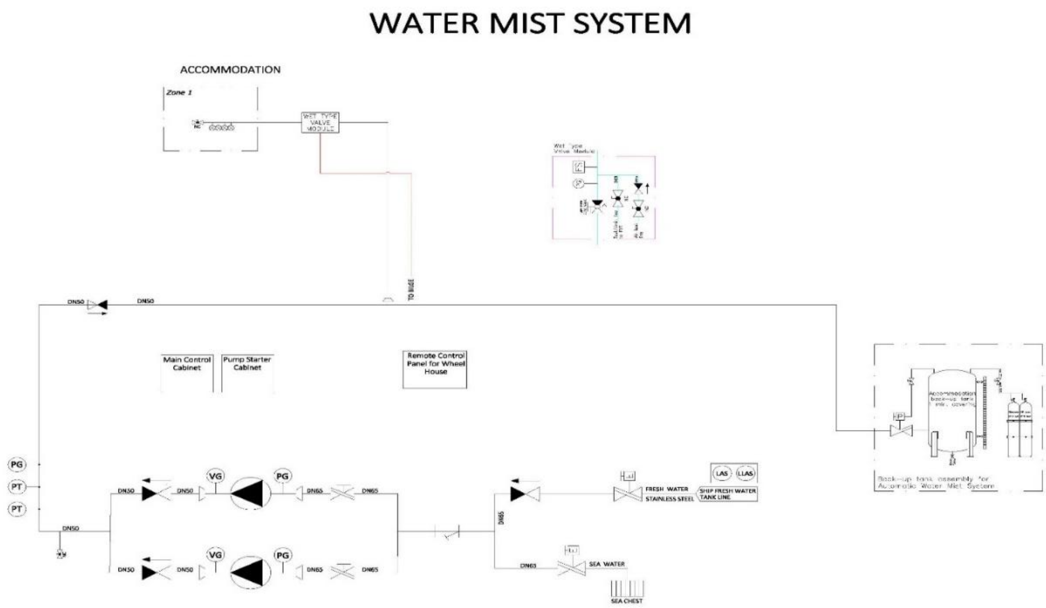

Figure 4. P&ID of System.

Table 1 Calculation of system capacity.

Protected Space	Number of Nozzle	K-factor	Pressure	Capacity (with loss)
Accommodation Space (OH-L1)	20	13,5	6	708
Accommodation Space (OH-CO)	3	15,5	6	122
			TOTAL CAPACITY	830

After placing the nozzles in the protected area, Equation (1) is used taking into account the pressure and capacity loss caused by the pipes. The capacity is calculated as 830 l / min @ 10 bar. According to this calculation, the pump capacity should be selected as 50 m3 / h @ 10 bar. After the pump capacity selection, design details and technical data are obtained from the pump supplier (Table 2).

Table 2 Design details and technical data belongs to pump.

DESIGN CRITERIA				
Fluid :	**Flange Standard:**		**Pressure Class:**	
Fresh Water / Sea Water	Suction	Discharge	Suction	Discharge
	DN65	DN50	PN 16	PN 16

According to Table 2, the pump's suction flange and discharge flange dimensions are DN65 and DN50, respectively. When designing the system, the water flow rate should be between 4 - 6 m/s.

$$\text{Valve size} = \sqrt{((Q \times 60/1000) \times V/(3600 \times \pi^4))} \times 1000 \qquad (2)$$

According to Equation (2), valve size should be 66.34-54.2 mm and 1 DN50 PN16 wafer type check valve should be used in the discharge line of the pumps.
Since the pump suction flange is DN65 PN16, a DN65 PN16 wafer type butterfly valve is used in the suction line of the pumps.
The system should be fed from freshwater and seawater. Two DN65 PN16 lug type butterfly valves with electric actuators - the same size as the pumps' suction valve - are used for water suction from the freshwater tank and the sea chest. The system should be first fed from freshwater. If freshwater cannot be sufficient to extinguish the fire, system should be automatically changeover the seawater. The system comprises an accommodation zone. Therefore, 1 flow switch is used in accommodation zone lines to detect water velocity flow and wet type zone valve. One main control panel is mounted an appropriate place in engine room. Automatic nozzles are should be in under pressure. One pressure tank is used for to hold automatic nozzles under pressure. Pressure tank capacity should be bigger than accommodation water mist system capacity. In this study, the water mist system capacity is 830 l/min and the pressure tank capacity is taken as 900 liters.
Automatic sprinkler system design as nozzles can be broken when temperature is higher than their capacity and system works automatically. However, that does not mean all nozzles broke and extinguish the water in protected spaces. Only broken nozzles are extinguished.
Finally, one remote control panel which includes Emergency stop button, selector switches and buzzer. In this panel, end user can control fire pump operation and zone valves.

4.2 Gas Based System

A gas based system is applied to a 56m motor yacht which is built in Turkey under RINA. FM200 System was used. Flooding factors were calculated and given in Table 3.

Table 3. Flooding Factors.

Flooding Factors FM-200																				
Design Temperature (of the Hazard)		Specific Vapor Volume (m^3/kg)	Design concentrations for the different standards as marked below may be subject to changes.																	
			6.00 %	6.20 %	6.40 %	6.50 %	6.70 %	6.80 %	7.00 %	7.20 %	7.40 %	7.60 %	7.90 %	8.00 %	8.40 %	8.50 %	8.70 %	9.00 %	10.00 %	11.00 %
			Agent Quantity Requirements per Volume of Protected Hazard (kg/m^3)																	
-20 °C	-4.0 °F	0.11664	0.548	0.567	0.587	0.597	0.616	0.626	0.646	0.666	0.686	0.706	0.736	0.746	0.787	0.797	0.817	0.848	0.953	1.060
-15 °C	5.0 °F	0.11920	0.536	0.555	0.574	0.584	0.603	0.613	0.632	0.651	0.671	0.691	0.720	0.730	0.770	0.780	0.800	0.830	0.933	1.037
-10 °C	14.0 °F	0.12177	0.525	0.543	0.562	0.571	0.590	0.600	0.619	0.638	0.657	0.676	0.705	0.715	0.754	0.763	0.783	0.813	0.913	1.015
-5 °C	23.0 °F	0.12433	0.514	0.532	0.550	0.560	0.578	0.587	0.606	0.625	0.643	0.662	0.690	0.700	0.738	0.748	0.767	0.796	0.894	0.995
0 °C	32.0 °F	0.12690	0.503	0.521	0.539	0.548	0.566	0.575	0.594	0.612	0.630	0.649	0.676	0.686	0.723	0.733	0.751	0.780	0.876	0.974
5 °C	41.0 °F	0.12947	0.494	0.511	0.529	0.537	0.555	0.564	0.582	0.600	0.618	0.636	0.663	0.672	0.709	0.718	0.737	0.764	0.859	0.955
10 °C	50.0 °F	0.13203	0.484	0.501	0.518	0.527	0.544	0.553	0.571	0.588	0.606	0.623	0.650	0.659	0.695	0.704	0.722	0.750	0.842	0.937
15 °C	59.0 °F	0.13460	0.475	0.492	0.509	0.517	0.534	0.543	0.560	0.577	0.594	0.612	0.638	0.647	0.682	0.691	0.708	0.735	0.826	0.919
20 °C	68.0 °F	0.13716	0.466	0.482	0.499	0.507	0.524	0.532	0.549	0.566	0.583	0.600	0.626	0.634	0.669	0.678	0.695	0.722	0.811	0.902
25 °C	77.0 °F	0.13973	0.457	0.474	0.490	0.498	0.514	0.523	0.539	0.556	0.572	0.589	0.614	0.623	0.657	0.665	0.682	0.708	0.796	0.885
30 °C	86.0 °F	0.14229	0.449	0.465	0.481	0.489	0.505	0.513	0.529	0.546	0.562	0.579	0.603	0.612	0.645	0.653	0.670	0.696	0.781	0.869
35 °C	95.0 °F	0.14486	0.441	0.457	0.473	0.480	0.496	0.504	0.520	0.536	0.552	0.568	0.593	0.601	0.634	0.642	0.658	0.683	0.768	0.854
40 °C	104.0 °F	0.14742	0.433	0.449	0.464	0.472	0.488	0.495	0.511	0.527	0.543	0.558	0.582	0.590	0.623	0.631	0.647	0.671	0.754	0.839
45 °C	113.0 °F	0.14999	0.426	0.441	0.456	0.464	0.479	0.487	0.502	0.518	0.533	0.549	0.572	0.580	0.612	0.620	0.636	0.660	0.741	0.825
50 °C	122.0 °F	0.15256	0.419	0.434	0.449	0.456	0.471	0.479	0.494	0.509	0.524	0.540	0.563	0.571	0.602	0.609	0.625	0.649	0.729	0.811
55 °C	131.0 °F	0.15512	0.412	0.427	0.441	0.449	0.463	0.471	0.486	0.501	0.516	0.531	0.553	0.561	0.592	0.599	0.615	0.638	0.717	0.797
60 °C	140.0 °F	0.15769	0.405	0.420	0.434	0.441	0.456	0.463	0.478	0.493	0.507	0.522	0.544	0.552	0.582	0.590	0.605	0.628	0.705	0.784
65 °C	149.0 °F	0.16025	0.399	0.413	0.427	0.434	0.449	0.456	0.470	0.485	0.499	0.514	0.536	0.543	0.573	0.580	0.595	0.618	0.694	0.772
70 °C	158.0 °F	0.16282	0.393	0.406	0.420	0.427	0.442	0.449	0.463	0.477	0.491	0.506	0.527	0.535	0.564	0.571	0.586	0.608	0.683	0.760
75 °C	167.0 °F	0.16538	0.386	0.400	0.414	0.421	0.435	0.442	0.456	0.470	0.484	0.498	0.519	0.526	0.555	0.562	0.577	0.599	0.672	0.748
80 °C	176.0 °F	0.16795	0.381	0.394	0.408	0.414	0.428	0.435	0.449	0.462	0.476	0.490	0.511	0.518	0.547	0.554	0.568	0.589	0.662	0.736
85 °C	185.0 °F	0.17051	0.375	0.388	0.402	0.408	0.422	0.428	0.442	0.456	0.469	0.483	0.504	0.510	0.538	0.545	0.559	0.581	0.652	0.725
90 °C	194.0 °F	0.17308	0.369	0.382	0.396	0.402	0.415	0.422	0.435	0.449	0.462	0.476	0.496	0.503	0.530	0.537	0.551	0.572	0.642	0.715
							NFPA 2001 Surface Class A / UL			NFPA 2001 Class C / Pyrochem			EN 15004 ISO 14520 Surface Class A		VdS 2381 'Special Hazards'	EN 15004 ISO 14520 Higher H. Class A	NFPA 2001 Class B Heptane	EN 15004 ISO 14520 Class B Heptane		

FM200 gas system is designed according to NFPA 2001 and working temperature is 0 ºC - 50 ºC. Due to flooding factor table, agent quantity requirement per volume of protected hazard is 0.751 [5].

Net volume is here 35 m^3, and the capacity is calculated using the following formulation.

$$Capacity = net\ volume \times agent\ quantity\ requirement\ per\ volume\ of\ protected\ hazard$$

Capacity $= 35 \times 0.751 = 26.23$ kg and this is the amount of gas required.
One piece 32 liter FM200 container with 27 kg filling is needed. Gas is supposed to discharge in 10s in a protected zone. 2.7 kg / sec flow is needed for the protected area. According to Table 4, it can be used 25 mm nozzle for protected to zone.
After selecting the use of 25 mm nozzle and 32l FM200 cylinder to use, one electric and one manual actuator are needed for the active FM200 cylinder.
If a user wants to see gas pressure in cylinder, a supervisory pressure switch can be used on cylinder to show FM200 gas pressure in cylinder. This request usually comes from the Navy on Navy projects. On the other hand, if a user wants to see gas pressure in cylinder on panels, a discharge pressure switch can be added in the system. This request usually comes from the Navy on Navy projects too.

Table 4. Flow in Schedule 40 Pipe

Pipe Type	Pipe Diameter	Internal Diamter (mm)	Min Flow (kg/sec)	Max Flow (kg/sec)
40T	10 mm	12.52	0.272	0.907
40T	15 mm	15.8	0.454	1.361
40T	20 mm	20.93	0.907	2.495
40T	25 mm	26.64	1.588	3.855
40T	32 mm	35.05	2.722	5.67
40T	40 mm	40.89	4.082	9.072
40T	50 mm	52.5	6.35	13.61
40T	65 mm	62.71	9.072	24.95
40T	80 mm	77.93	13.61	40.82
40T	100 mm	102.3	24.95	56.7
40T	125 mm	128.2	40.82	90.72
40T	150 mm	154.1	54.43	136.1

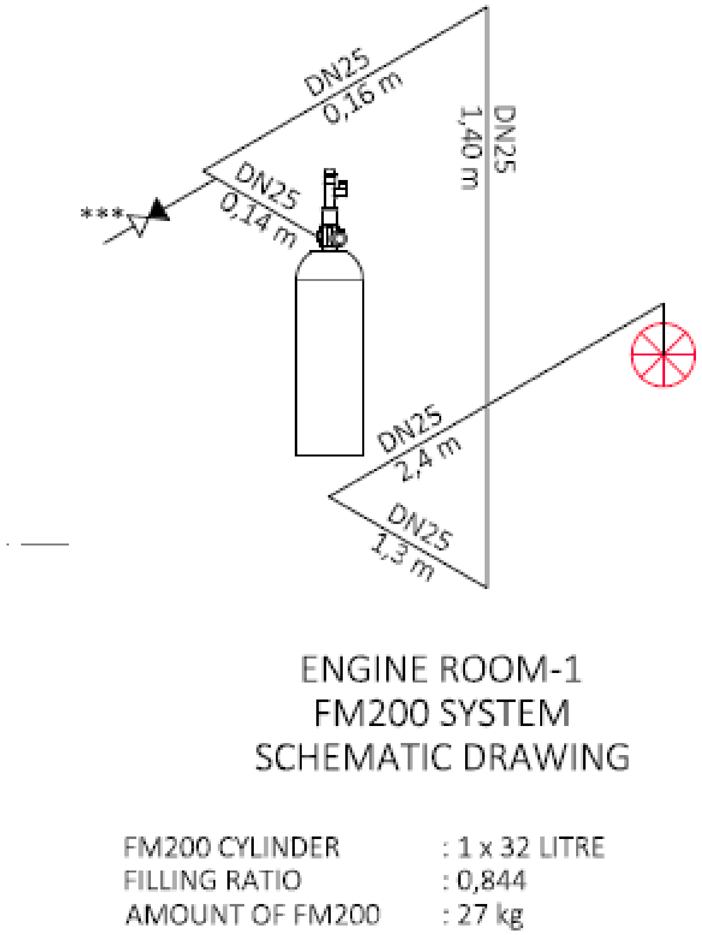

Figure 5. Nozzle arrangement

Finally, after yard send the isometric diagram for piping, nozzle arrangement is drawn and nozzle drilling can be calculated with supplier application. According to drilling size, nozzle can be manufactured. The related nozzle arrangement is given in Figure 5.

5. Conclusion

Fire extinguishing systems are developing with the investments made, developments in engineering and technology, environmental awareness and customer demands. With the use of environmentally friendly fuels in ships, the systems used are also changing accordingly. Although it is pleasing that the use of environmentally friendly gases is so common in both commercial and military ships however, there are problems caused by the single use of these systems.

It seems the same that the reduction of fossil fuels used day by day will reduce the foam-based protection, as the dry powder fire extinguishing system has very little usage area today. On the other hand, although the water-based fire extinguishing system is often the definitive solution in extinguishing the fire, there are some negative situations it brings. In the system to be used for the protection of living spaces, there is a need for a fresh water tank to feed the system for half an hour or a pressure tank to keep the system under constant pressure. Such negative effects can be minimized by being revised by both the flag and the classification organization with the correct information provided by sub-suppliers during the design phase of the project. Also, small ships such as a yacht or non-classification ships are mostly exempt from rules and authority controls. This fact leads shipbuilders and owners to the cheapest possible protection. But this situation will result in loss of life and property when a fire breaks out. For this reason, the necessary rules to prevent fires that pollute the environment and cause loss of life and property should be applied to any type of ships without flexibility.

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