UNITED STATES COAST GUARD

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NAVIGATION AND VESSEL INSPECTION CIRCULAR 6-72 CHANGE 1 INCLUDED

Subj: Guide to Fixed Fire-Fighting Equipment Aboard Merchant Vessels

1. Purpose. The purpose of the attached guide is to explain the basic characteristics of fixed fire-fighting equipment installed aboard merchant vessels. This is accomplished by discussing how the various fire extinguishing agents function, and by enumerating the important element which must be considered when designing a system. By explaining the principles of system operation it is hoped that design and review of installations will be simplified.

2. Cancellation. This circular and the enclosed guide supersedes the information previously issued as NVIC:14-65.

3. Objectives. The guide is intended to disseminate to Coast Guard technical units, Coast Guard marine inspectors, equipment manufacturers, vessel owners, and shipyards a supplement to and clarification of regulation governing installation of fixed fire-fighting equipment aboard merchant vessels. It is intended to be explanatory only; nothing herein shall be taken as amending the applicable regulations, nor as prescribing nor limit mg the authority or responsibility of the Officer in Charge, Marine Inspection in the exercise of his good judgment.

4. Revisions. It is expected that these notes will require modification in light of their use in the field. Comments and suggestions are welcome, and revisions will be issued as necessary.

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End: (1) Guide to Fixed Fire-Fighting Equipment Aboard Merchant Vessels

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GUIDE TO FIXED FIRE-FIGHTING EQUIPMENT

ABOARD MERCHANT VESSELS

i. INTRODUCTION

The purpose of this guide is to enlarge upon the standard. for the design, installation, and testing of fixed fire extinguishing equipment aboard U.S. flag merchant vessels. It is not intended to modify or in any way change the applicable regulations, rather to supplement and clarify them. The discussion of the various systems is intended to be explanatory only and not meant to indicate preference for a system or systems to be installed on a given vessel. Specific regulations should be consulted to determine protection required in each vessel environment, especially with respect to hazardous or dangerous cargoes.

Fire extinguishing systems should be reliable and capable of being placed into service in simple, logical steps. The more sophisticated the system is, the more essential that the equipment be properly designed and installed. It is not possible to anticipate all demands which might be placed upon fire extinguishing systems in event of emergency. However, potential casualties and uses should be considered, especially as related to the isolation of equipment, controls, and required power from possible disruption by a casualty. Fire protection systems should, in most cases, serve no function other than fire fighting. Improper design or installation can lead to a false sense of security, and can be as dangerous as no installation.

Fixed extinguishing equipment is not a substitute for required structural fire protection. These two aspects have distinct primary functions in U.S. practice. Structural fire protection protects passengers, crew, and essential equipment from the effects of fire long enough to permit escape to a safe location. Fire fighting equipment, on the other hand, is for protection of the vessel. Requirements for structural fire protection vary with the class of vessel and are the most detailed for passenger vessels. However, approved fixed extinguishing systems are generally independent of the vessel's class.

Automated vessels require additional consideration of required extinguishing equipment where a reduced manning scale presents a reduction in number of available fire fighting personnel. Control of all systems or functions relating to fire protection of the machinery space should be centralized in a single accessible location outside the machinery casing. This station should be able to control the fixed fire extinguishing system, the machinery space ventilation, fuel pumps and fuel tank valves subject to a fuel head pressure, the remote fire pump, and the bilge system. (NVC 1-69, H.l.b)

Where fire-extinguishing systems are not required, but are installed, the system shall be in accordance with the applicable regulations.

This guide is divided into six parts, corresponding to the major types of carbon dioxide fixed fire extinguishing systems: (I) firemain, (II) (III) mechanical foam, (IV) water spray, (V) manual sprinkling, and (VI) bromotrifluoromethane. Each portion contains, (a) a discussion of the basic concepts of the system and explanation of the regulations, (b) a check-list guide for use in system design and review, and (c) notes on initial and subsequent tests and inspection of the installation. The part describing each system is contained as a separate portion of the guide, so that the guide may be used as a single booklet form or so that individual portions may be detached and used separately.

I. FIRE MAIN SYSTEM

A. DISCUSSION

A.1. GENERAL

The fire main system is the backbone of all fire-fighting systems on a ship. Water has the greatest heat absorbing capacity of any extinguishing medium in use. It is versatile; it can be used as a straight stream for combating deep-seated fires; it can be applied as a spray for combating combustible liquid fires where cooling and minimum agitation is desired; it can be used as a back-up for protection of personnel where cooling is the primary effect desired. As it absorbs the heat of a fire it may be vaporized to steam, which tends to smother the fire in enclosed spaces. Aboard ship, the quantity of water available for fire fighting is limited only by the capacity of the fire pumps. The disadvantages of water for combating fires aboard vessels are: (1) excessive quantities may impair the vessel's stability, and (2) it should not usually be used on live electrical equipment.

Any fire main installation must be capable of delivering and adequate supply of water to any portion of the vessel quickly for the purpose of combating fires.

The requirements for fire main apply irrespective of other fire protection equipment which may be required. In the case of special design vessels, as nuclear ships, exceptions to this requirement may be granted when it is shown that in certain locations the fire main would act as a detriment. Such proposals must specially be considered during design and plan approval stage.

The regulations specify fire pump capacity, pipe sizes, hydrant locations, hose lengths, etc., usually based upon a performance specification of the final installation. This makes design and review of the system to assure compliance with the regulations more difficult, but no less necessary. Adequate effort at the design, stage is absolutely essential. This is the period in which the size of the pumps, size of the piping, runs of piping, number of fittings, etc. are determined. Once the installation is made, changes to comply with the regulations are almost impossible to effect. Sole reliance should not be placed upon operational tests to determine compliance with the regulations.

A.2. FIRL PUMIPS

A.2.l Fire Pump Location

Most vessels are required to have two fire pumps with all suctions, sources of power, etc. located in separate spaces so that one casualty will not put all pumps out of operation. The alternative of installing both pumps in the same space and protecting the space with carbon dioxide is a deviation , permitted only in unusual circumstances where the separation of pumps will not increase safety - usually accepted for small vessels only. Such an arrangement is a poor substitute for separation of the pumps.

One important objection is that pumps are not required to be controlled from outside of the space. If a fire occurs in the space containing the pumps, the space will become untenable. Even upon discharge of CO_2 and extinguishment of the fire, the spaces will remain untenable, delaying the availability of the pumps. There is a strong probability that when the pumps do become available, they will be inoperable.

As a basis for application of the requirement to separate fire pumps, a fire in one space is considered to be of such magnitude that the entire space, including the machinery space casing, is inaccessible and all equipment therein is made inoperable.

When a pump powered by the emergency electrical system is to be used as one of the independent fire pumps, compliance with this requirement can be deceptive. Complete independence of fire pumps may be lost due to interdependence between electrical Systems and boilers, because runs of electric cable may be vulnerable to fire in several spaces, and because of non fire-proof boundaries of machinery spaces. Some examples of aspects which must be considered are:

(1) A steam fire pump in the boiler room in combination with an electric fire pump in the engine room supplied from the emergency electrical system may not comply with the regulation. If the boilers are dependent on electrically driven auxiliaries, a fire in the engine room may affect not only the electric fire pump, but also the normal electric supply to the boiler auxiliaries required for operation of the steam fire pump.

(2) An electric fire pump located remotely from the main machinery spaces and supplied from the emergency electrical system in combination with another fire pump in a main machinery space may not comply with the requirement. If the cable supplying the remote pump passes through either the boiler or engineroom a fire in that space will affect the machinery space fire pump and may damage the power supply cable to the remote fire pump.

(3) An electric fire pump located outside the main machinery spaces and supplied from the emergency electrical system by a cable and motor starter attached to a machinery space boundary or casing may not be independent of the machinery space. In this situation it is possible for heat from a fire in the machinery space -to be conducted through the boundary or casing and damage the power supply to the fire pump.

(4) An electric pump is located outside of the main machinery spaces and is supplied from the emergency electrical system, the power for which is an independent diesel-drive generator. Location of the fuel supply to the independent diesel-driven generator in the machinery space or casing may nullify the fire pump separation. A machinery space fire could disrupt fuel to the driver for emergency electrical power, thereby putting both fire pumps out of operation.

One additional aspect which must be considered in the arrangement of fire pumps to comply with this requirement concerns "separation" of the spaces. For the purpose of determining compliance with this requirement, the following condition must be met in order for the spaces to be considered "separate."

(1) Any common boundaries between the spaces must be an effective "A" Class fire division.

(2) To insure that a fire in one pump space does not spread rapidly to an adjacent pump space, doors in common boundaries between the spaces shall be either:

(a) Remotely operated Class II watertight doors, or

(b) Remote release, self-closing fire doors (installed alone or in tandem with dogged watertight doors)

However, doors on the same level as and in close proximity to continuously manned control stations need not be of the self-closing type.

(3) The spaces shall have independent access.

In the advent that there is only a single engine space, it becomes increasingly difficult to find a suitable location for the second fire pump. There are three acceptable solutions to this problem of which the latter is acceptable only in very unusual circumstances. Listed in general order of preference, they are:

(1) <u>Deep well pump</u> - Installation of a deep well pump located in the accommodation and service space area above the machinery space would be acceptable. The suction shaft would pass down through the machinery apace where it would take suction from a sea chest. All electrical components and valving would be located inside of the pump room, providing complete independence from the machinery space. Such an arrangement allows simple rapid operation of the system. Some of the problems which must be considered in such a design are:

(a) Provision of a flexible connection between the pump suction shaft and the pump to avoid undue stresses both at the connection and at the sea chest.

(b) Strength of the sea chest or suction shaft support.

(c) Provisions of fire insulation if the pump space immediately adjoins the machinery space.

(2) <u>Forward pump</u> - If a bow thruster is provided, the fire pump may be located in the forward portion of the ship with power provided by the bow thruster prime mover. Such an arrangement would possibly involve a considerable time delay before the pump could be actuated and remote control of the pump and valves from the accommodation area would be necessary.

(3) <u>A separate enclosure</u> - Building a small separate enclosure inside the machinery space with access from outside the machinery space has several drawbacks.

(a) To assure that a fire in the engine space will not affect operation of the second fire pump, water supply, source of power, power cables, etc. should be independent of the machinery space.

(b) Despite all precautions the space may tend to become a "forgotten space," lacking maintenance, collecting debris, etc.

(c) Access to the space is difficult at best and could be a potential safety hazard due the long distance which must be transversed by a vertical ladder.

(d) There would likely be a considerable time delay before the pump could be started in the advent of a fire in the machinery space.

A.2.2 Fire Pump Capacity

The size of the required fire pumps depends upon the vessel's size and service. It also depends upon the arrangement of the particular fire pump and piping aboard the vessel. In general, pumps are required to be sized as follows:

(I) For passenger vessels, the combined fire pump capacity must be equal to 213 of the required bilge pump capacity. For cargo and tank vassals the capacity of a single fire pump must be at least 2/3 of the capacity of a single required bilge pump, while delivering water through the fire main at the nozzle pitot pressure.

(2) The capacity of an individual fire pump shall not be less than 80% of the total required combined capacity divided by the required number of pumps.

(3) Each individual pump must be capable of supplying the two (three for tankers over 650 feet) hose streams incurring the greatest pressure loss[1] at 50 psi pitot tube pressure (7S psi Pitot pressure for tankers).

When 2 1/2" hydrants are required, the hose discharge as stated in (3) above is assumed to be from 2 1/2" hydrants. If two-l 1/2"[2] hydrants are installed in lieu of one-2 1/2" as permitted by regulation it is assumed that both 1 1/2" hydrants are used. In cases where both 1 1/2" and 2 1/2" hydrants are installed aboard a single vessel, the system should be designed to meet the following conditions:

(1) Combination of required number hydrants (1 1/2" and 2 1/2") incurring the greatest pressure drop, when flowing simultaneously, between the fire pump and the nozzle, and

(2) Combination of required number of 2 1/2" hydrants incurring greatest pressure drop, when flowing simultaneously, between the fire pump and the nozzle.

[1] Passenger & Largo Regulations say two highest, this can be interpreted to mean "incurring greatest pressure loss" if length of the vessel becomes significant (in which case the "friction-head" loss in long piping runs would exceed the "elevation-head" loss of high hydrants).
[2] The combined discharge from two-I 1/2" hydrants is roughly equivalent to that from one-2 1/2" hydrant. (see Paragraph A.7.l Nozzle Discharge).

The stipulation "while flowing simultaneously" is necessary since a combination of the nozzles incurring the greatest pressure drop while flowing individually may not represent the most severe design condition. This can be seen in the following diagram.

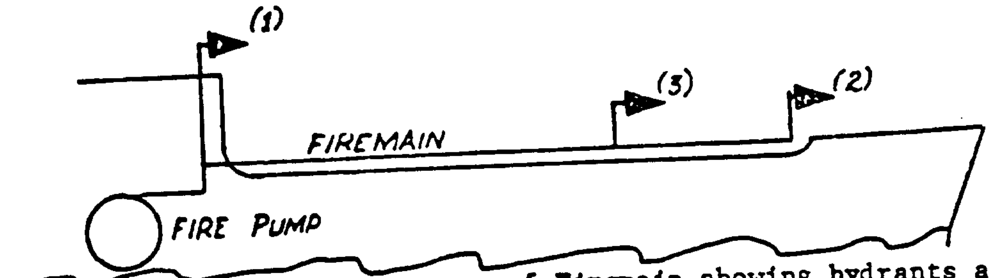


Fig. I.A.1 - Diagrammatic Arrangement of Firemain showing hydrants at which greatest pressure drop may occur.

Assume nozzle (1) incurs the greatest pressure drop alone and (2) incurs the second greatest individual pressure drop. However, the simultaneous flow of nozzles (2) and (3) could produce & combined pressure drop greater than that incurred by the combination of nozzles (1) and (2). If pumps are used for other fire fighting purposes see subsequent discussion in section 5.2. Pump characteristic (capacity vs. head) curves should be provided and examined for all fire pumps. This is the only method by which the adequacy of the pumps may be determined during the design stage. When two pumps are required, their approximate combined capacity should be examined.

2.2.1. <u>Fire Pump Capacity - Example I</u>

Determining the required capacity of fire pumps is perhaps best illustrated by examples. Assume a passenger vessel is required to have the following:

(1) Minimum number of pumps = 2

(2) Required bilge pumping capacity = 1000 gpm

(3) Minimum Pitot tube pressure at two outlets flowing simultaneously = 50 psi

Apply the design conditions noted in paragraph A.2.2:

(1) The combined capacity of fire pumps for passenger vessels must equal 2/3 of the bilge pumping capacity, or in this case:

1000 x 2/3 = 667 gpm, required combined capacity at adequate pressure to produce 50 psi Pitot pressure at nozzle.

(2) Each pump must be capable of supplying 2 hose streams at 50 psi Pitot pressure, which means each pump must produce:
2 x 160 gpm[3] = 320 gpm, at adequate pressure to produce 50 psi Pitot pressure at nozzles.

[3] 160 gpm is flow through one 7/8" diameter nozzle, see derivations in Section 7

Since a minimum of two fire pumps is required, the minimum combined capacity based on (2) above is:

2 x 320 gpm = 640 gpm

So in this case, criteria (1) determines the minimum required combined capacity (667 gpm).

The minimum capacity of any one pump, as determined by (2) above is 320 gpm. However, there is another criteria for the minimum capacity of a single pump which must be tested; this criteria is listed in paragraph A.2.2(2). Applying this criteria, the minimum capacity of a single fire pump would be:

$\frac{667\,gpm}{2} \times 80\% = 266.4$[4] gpm (note: This is less than the minimum of 320 gpm required for 50 psi Pitot pressure).

We now have calculated the minimum combined capacity (667 gpm) and the minimum individual capacity (320 gpm) of all fire pumps. It now remains only to select the number and capacity of pumps to be installed. If the minimum of two fire pumps is installed, the each pump should be at least equal to:

$$\frac{667\,gpm}{2\,pumps} = 333\,gpm / pump$$

However, if three pumps are installed when only two are required the capacity of each pump based on the necessary combined capacity is:

$$\frac{667\,gpm}{3\,pumps} = 222\,gpm / pump$$

This is less than the required minimum of 320 gpm per pump deter-mined previously. So if -three pumps are installed to meet the 667 gpm combined requirement, they must each produce 320 gpm, or the three pumps would have a minimum combined capacity of:

$$3\,pumps \times 320\frac{gpm}{pump} = 960\,gpm$$

A second example: *****

Assume a cargo vessel is required to have the following:

(a) Minimum number of pumps = 2

(b) Required bilge pump = 600 gpm

[4] Divided by required number of pumps

(c) Mininu.m Pitot tube pressure at two outlets flowing simultaneously = 50 psi.

Apply the design conditions noted in paragraph A.2.2:

(1) The capacity of a single fire pump must be at least 2/3 of the capacity of a single required bilge pump, or in this case:

600 x 2/3 = 400 gpm, required capacity at adequate pressure to produce 50 psi Pitot pressure at nozzle.

(2) Each pump must be capable of supplying two hose streams at 50 psi Pitot pressure, which means each pump must produce:

2 x 160gpm = 320 gpm, at adequate pressure to produce 50 psi Pitot pressure at nozzles.

Therefore, in this example 2/3 of the single bilge pump capacity is the governing criteria.

A.2.3. Availability of Fire Fighting Water

The General Assembly of the Inter-governmental Maritime Consultative organization agreed on a number of fire safety improvements to be required of passenger vessels operating on an international voyage. These improvements were put into force for U.S. vessels by amendments to Subchapter II - Passenger Vessels, Chapter I, Title 46 CFR. Among the amendments is addition of a new section 76.10-3, which requires ready availability of fire fighting water for passenger ship on an international voyage. A number of questions have arisen regarding interpretation of this section. The objective of the section is to insure that fire fighting water is available in the shortest possible time, either by maintaining water pressure in the fire main or by installing convenient remote controls for fire pump operation. Specific acceptable means for providing water availability are:

(1) Maintenance of Water Pressure - Water pressure may be maintained in the fire main at all times that passengers are on board. The pressure may be maintained by one of the required fire pumps. This would provide an immediately available quantity of water adequate for initial fire fighting efforts. Alternatively, another suitable pump such as a salt water service pump may be used to maintain the pressure. This pump should have a capacity of at least 75 gpm at 50 psi pressure. If such a pump is used, an alarm shall be fitted in the engine service pump may be used to maintain the pressure. This pump should have a capacity of at least 75 gpm at 50 psi pressure. If such a pump is used, an alarm shall be fitted in the engineroom which will sound upon a pressure drop in the system. This arrangement would provide a limited quantity of water for immediate use, with the assurance that more water will be available within a reasonably short period.

(2) Remote Control of Fire Pumps - If ships were not originally designed for maintenance of pressure on the firemain, it may be practicable to convert them to such service. When pressure is not maintained, at least two of the required fire pumps shall be capable of remote operation. The fire pumps capable of remote operation shall be effectively separated so that a single fire will not put both pumps out of operation. Thus, in any emergency at least one fire pump can be rapidly placed into service from a normally manned or readily accessible location. Remote operation shall consist of the following:

(a) If located in a normally manned machinery space, the fire pump and all valves requiring operation for effective delivery of water to the fire main shall be capable of operation from the manned operating platform within that machinery space. This will permit water to be delivered to the firemain very shortly following sounding of the fire alarm or special crew alarm. Valves required to be remotely operable include not only the inlet valve to the fire main but also valves to other systems supplied by the fire pump. Control of these valves is necessary to insure that fire fighting water is not inadvertently misdirected.

(b) If located in a normally unmanned machinery space, the fire pump and associate valves shall be capable of control from outside that machinery space. Spaces considered suitable for location of the controls include:

(i) The fire control station, if any;

(ii) The bridge, if there is no fire control station; or

(iii) A readily accessible position outside of the machinery space, near the ventilation shut-down, the remote fuel oil stops, and the release for the installed fire extinguishing system.

Control locations shall be clearly and conspicuously marked. Control of fire pumps located in unmanned spaces in the fore-going manner is intended to provide ready availability of fire fighting water in event of a fire in the normally manned machinery space.

The foregoing are intended as illustrations of acceptable means for providing ready availability of fire fighting water. Other arrangements may be accepted, on an individual basis, providing availability of water is equivalent to that specified in the preceding paragraphs

Means of providing the ready availability of water specified for U.S. ships may also be used as a guide in interpreting Regulation 86(b) of Enclosure (1) to NVIC 2-68, for foreign flag passenger ships.

A.3 PIPE SIZING

One requirement for pipe sizing is a performance criterion. Firemain systems must be so designed and the piping so sized that when performance-tested the piping will deliver a quantity of water sufficient to meet the minimum nozzle pressure requirements previously discussed. Briefly, again, these are:

(1) Deliver water at minimum required Pitot tube pressure to the required number of nozzles flowing simultaneously.

(2) Simultaneously supply other systems which are connected directly to firemain.

The National Fire Protection Association Handbook[5] has numerous friction loss tables for piping which may be used in approximating pressure losses in the firemain. Other tables may be equally acceptable if the source of the data is identified.

The firemain must be capable of delivering the quantity of water produced by two fire pumps operating simultaneously. This quantity of water must be delivered to a number of adjacent hydrants at a minimum Pitot tube pressure of 50 psi. For example, assume a single fire pump is required to supply 2-2 1/2" hydrants at 50 psi Pitot pressure. By referring to A.7, we know this is the same as saying the pump must produce 320 gpm at 50 psi Pitot pressure. Then the firemain must be of sufficient diameter to deliver $\frac{320 gpm}{pump} \times 2(pumps)$ = 640 gpm from a number of adjacent hydrants. The number of hydrants will usually be twice the number required to be supplied by a single pump, or in this example: $\frac{2 hydrants}{pump} \times 2 pumps = 4 hydrants$.

A.4. VALVES

The tank vessel regulations require a sufficient number of Valves to isolate damaged sections of piping. This requirement, read in conjunction with the statement that "operation of the foam system shall not interfere with simultaneous use of the fire main", should be taken to require block valves in the deck fire main at least at intervals which accommodate or correspond to the spacing of block valves in the deck foam main. All parts of the fire Rain located on exposed decks shall either be protected against freezing or be fitted with cut-out valves and drain valves so that the entire exposed parts of such piping may be shut off and drained in freezing weather. Except when closed to prevent freezing, such valves shall be sealed open.

Fire Rain root shut off valves not required in the fire main at each deck level. However, installation of such valves for isolation of individual decks may be of positive value at some locations.

A.5. USE OF FIRE PUMPS FOR OTHER PURPOSES

Fire pumps Ray be used for purposes other than supplying water to the fire main provided one of the required pumps is kept available for use on the fire Rain at all times. "Available

[5] Superscripts refer to references.

for USC" means that any or all of the required pumps Ray be used for non-vital services. With control valves for other services at a manifold adjacent to the pump, in event of fire any other service may be readily secured as the valve to the fire Rain is opened. Availability does not mean that the pump must be reserved exclusively for the fire main. Reliability of fire pumps is probably improved if they are used for other services, ensuring proper pump maintenance.

A.5.l. Other than Fire-Fighting

The fire main is a tempting source of "free" water; it is already installed in most spaces. However, injudicious use quickly reduces the reliability of the system. Connections to the fire main for purposes other than fire-fighting, deck wash (and tank cleaning on tankers) should be only from a discharge manifold near the pump unless specific exceptions are granted.

Connections to the fire main for low water-demand services in the forward portion of the vessel (such as anchor wash, forepeak educator, or chain locker educator) have frequently been permitted. In such cases, each fire pump must be capable of meeting the hose stream requirements with the other-service connection open. This prevents the inadvertent opening of the other-service connection from destroying the effectiveness of the fire main system.

The specific purposes for which use of the fire Rain is permitted by regulation, i.e. deck wash and tank cleaning, have one important factor in common: Someone knows that the system is in use and is usually in attendance. Such usage should not be left unattended.

A.5.2. Fire Fighting

Connections to the fire main for other fire-fighting purposes are permitted. Sizing the fire pumps depends on what other system is installed and where it connects to the fire main system. If fire pumps are used for other fire-fighting systems, they must be sized as follows:

A.5.2.1. Foam System

(1) When the foam system is connected at the fire pump manifold, one fire pump may supply the foam main and one pump the fire main.

(2) When the foam system is connected to the fire main at other than the fire pump manifold. one pump must meet the requirements of both systems simultaneously.

A.5.2.2. Sprinkling System

(1) Regardless of where connected, combined capacity of all fire pumps must be capable of supplying the sprinkler system while meeting hose stream requirements. Great care must be taken when arranging more than one fire pump to discharge into a single fire

main. Unless the pump curves are identical, each pump will not discharge at its rated capacity. For example, two pumps rated individually at 250 gpm may only deliver 400 gpm when used in combination.

A.5.2.3. Water Spray

(1) The objective is rapid operation of the system; pump room fires may easily reach temperatures of 2000^{0}F within 3 minutes. A pump must be reserved exclusively for the spray system or one of the required pumps increased by the capacity of the spray system. However, this assumes that the water spray system is connected to the fire main at other than the fire pump manifold. On tankers, if the water spray system connection is at the fire pump manifold, and so arranged that operation of the water spray system does not interfere with simultaneous use of the firemain, this would be acceptable. Such an arrangement is similar to what is required for foam systems.

For further clarification of acceptable pumping arrangements see sketches at end of this part (Subpart D - Pumping Configurations). The difference between the water supply requirement for a water spray system versus a 5prinkler system lies in the nature of the hazard protected. It is essential for water spray systems to be actuated quickly. This is more fully discussed in the parts on WATER SPRAY and on SPRINKLER systems.

A.6. RELIEF VALVES

Relief valves are required on the discharge side of all fire pumps. Discharge of the relief valve should be to a safe location. The relief valve piping should be without shut-off valves, so that the purpose of the relief valve is not defeated. Relief valves should be set to operate at l25[6] psi or 25 psi in excess of the pressure necessary to meet the hose stream requirements, whichever is greater. The required relief valve setting is determined by the following factors:

(1) Design pressure of the piping

(2) Maximum pressure to which a hose should be subjected, and

(3) Maximum hose nozzle pressure that can be safely handled by personnel.

The 125 psi limitation apparently Stems from the accepted service pressure for cast iron and galvanized steel fittings, formerly common in firemain use. This accepted service pressure has more recently been increased to 150 psi.
In event that pump pressures higher than 100 psi are required to meet hose stream requirements, the relief valve should be set to operate 25 psi in excess of the required pump pressure. This is intended to allow for aging of pumps and pipe, decreasing the over-all efficiency of the system. It also permits the use of a single hose at higher pressures.

[6] If the shut-off head of the pump does not exceed 125 psi, no relief valve is required.

Besides protecting the fire main from excessive pressure, the relief valve setting prevents excessive reactions to personnel holding the nozzle. Systems can be designed for pitot pressures up to 100 psi at the nozzle without fear of excessive reaction. The required SO psi pitot pressure gives only marginal fire-fighting capability. higher pressures provide more effective hose streams, particularly when spray applicators are used. Reactions experienced by personnel holding straight Stream nozzles are directly proportional to the pressure (see Paragraph A.7.2 Nozzle Reaction).

The relief valve requirement should not preclude the installation of higher pressure fire-fighting appliances, providing such appliances are not hand held. For example, high pressure monitors are acceptable. When a fire pump is used for services requiring a higher discharge pressure than the fire main, the relief valve should be installed in the fire main near the fire pump manifold, and not at the discharge of the pump. A diagrammatic of such an arrangement is shown in Subpart D - PUMPING CONFIGURATION #1.

A.7. NOZZLES

A.7.l. Discharge

Smooth bore nozzles shall be of bronze or equivalent metal. These nozzles are not type-approved or listed in CG-l9O, Equipment Lists. Nozzle orifice sizes are required to be as sized per table 76.10-5(a) & 95.10-5(a). The characteristics of water discharge from smooth bore nozzles may be described by

$$Q = K\sqrt{P}\ ,$$

where: Q = flow (gpm)
K = constant
P = pressure (psig)

For 5/8" nozzle K = 11.70 (1 ½" hydrant)
For 7/8" nozzle K = 22.78 (2 ½" hydrant)

It will be noted that at 50 psi pitot pressure,

$$Q\left(\tfrac{5}{8}\right) = 11.70\sqrt{50} = 82.7 gpm$$
$$Q\left(\tfrac{7}{8}\right) = 22.78\sqrt{50} = 161.0 gpm$$

or the discharge from one-2 1/2" hydrant with 7/8" nozzle is approximately twice that from one-l 1/2" hydrant with S/S" nozzle.

A.7.2. Reaction

The reaction force experienced by personnel holding a smooth bore nozzle is due to the acceleration of water through the nozzle (Fm ma). It 'may be calculated by the equation:

F = $1.57D^2p$[7]

[7] NFPA Fire Protection Handbook, Thirteenth Edition (p. l2-39)

where F = reaction force (pounds)
D = orifice diameter (inches)
p = pitot pressure (psig)

The reaction of spray nozzles or applicators is considerably less. Combination nozzles and applicators are required to be approved and listed in the Equipment Lists (CG-190). Where combination nozzles are required for protection against class B fires, clips should be provided on the bulkhead near the nozzle for holding the applicator. Be certain that the applicator is of a size and type to fit the nozzle provided.

A.8. HYDRANT SPACING

Hydrants must be so located that two effective hose streams may be directed into all portions of the vessel accessible to passengers and crew as the vessel is being navigated; one[8] of the streams shall be from a single length of hose. It is essential that the hose is long enough to direct water into all portions of the apace and not just long enough to let the nozzle to the door. Increased lengths are not permitted for compliance with this requirement[9]. All hose of the same diameter should be of game length. Once the hoses are removed from the hydrants for testing or cleaning, there is no assurance that the proper length hose will be restored to the required location.

The effective horizontal reach of 5/8" smooth bore nozzle in still air is just under 1 foot per psi nozzle pitot pressure, being about 47 feet at 50 psi. The effective, horizontal reach of a 7/8" smooth bore nozzle in still air is about 52 feet at 50 psi. If combination nozzles are installed for class 3 (flammable liquid) protection, the spacing should be based upon the assumption that the spray pattern is used (spray pattern range is about 20-25 feet in still air).

A.9. AUTOMATION

In addition to the foregoing information for all vessels, the following data for automated vessels is as follows:

(1) Controls for fire pumps located within the engineroom should be included at the engineroom control station. Sufficient controls should be provided to enable the watch to charge the fire main from the engineroom control station.

(2) Controls for fire pumps located outside the engineroom may be included at the engineroom control station. Damage to these controls should not prevent operation of the pumps from the pump location.

(3) On ships with unattended machinery spaces at least one of the fire pumps shall be controlled from the bridge as well as one controlled from the engineering control station. This control station shall include control of the associated pump suction and discharge valves. Instrumentation shall be provided at or adjacent to the fire

[8] For portions of machinery spaces, two streams must be from single lengths of hose.
[9] On the weather deck of tank vessels, the length of the hose may be increased if necessary to allow a single length of hose to be goosenecked over the side of the vessel. If two fire mains are installed, the length of the hose shall be such that a single length of hose may be goosenecked 5rom the nearest fire main.

pump controls to indicate that adequate fire main pressure is available. Inadequate fire main pressure shall be alarmed at the control station and bridge.

B. DESIGN AND REVIEW OP SYSTEM

This subpart provide. a check-list type of outline for essential items which should be considered in designing and reviewing fire main systems. For interpretation of individual items reference should be made to the preceding subpart. In case of any doubt, the applicable regulations should be consulted for exact wording of requirements.

Application: Passenger and Cargo - All fire main installations contracted for on or after November 19, 1952.

Tank - All fire main installations contracted for on or after January 1, 1962.

Tire pumps, piping, hydrants, hose and nozzles are required to be installed on all self-propelled vessels[10]. In addition, they are required on all passenger barges with sleeping accommodations for more than six persons, and all cargo barges with sleeping accommodations for more than 12 persons.

Numbers in parentheses refer to applicable regulations.

B.1. Determine number of pumps required according to size of vessel (tables 34., 76., and 95.10-5(a)).

B.2. Determine location of pumps. On vessels with oil fired boilers, either main or auxiliary, or with internal combustion propelling machinery, pumps, sea suctions, and sources of power must be arranged so that one fire will not eliminate all pumps (34.10-5(f), 76.10-5(h) and 95.10-5(h)). CO_2 protection may be substituted for separation of pumps in very special cases on small vessels only.

B.3. Determine required sizing of pump. On passenger vessels, must (A) meet hose stream requirements (tables 76., and 95.10-5(a)) and (B) total capacity must equal 213 of required bilge pump capacity, for cargo and tank vessels capacity of single fire pump must equal 2/3 of required bilge pump (34., 76., and 95.10-5(b)). Pumps to be used for other fire systems (than fire main) must be sized accordingly. Fire pump characteristic (capacity vs. head) curve should be required.

B.4. Pump sizing must be sufficient to meet hose stream requirements (table 34., 76., and 95.10-5(a) and (c)). This is a performance requirement. Additional pipe sizing requirements are contained in the previous section.

B.5. Fire pumps may be used for other purposes providing at least one pump is available for use on the fire main at all times (76. and 95,10-5(f), 34.10-5(e)).

B.6. Connections to fire main for purposes other than fire-fighting or deck wash (and tank cleaning on tankers) must be from a manifold near the pump (76., and 95.10-5(f), 34.10-5(e)) unless it can be shown that the pump still meets the capacity requirement over and

[10] Excepting tank vessels less than 100 feet in length.

above extraneous Use. Valves must be near the pump and so arranged that the pump may be put on the fire main quickly in event of an emergency.

B.7. Fire pumps shall be fitted on the discharge side with a relief valve set to relieve at either 125 psi (Passenger & Cargo only) or 25 psi greater than necessary to meet the hose strewn requirements, whichever is greater (76., and 95.10-5(d), 34.10-5(c)). If the shut off head of the pump does not exceed 125 psi no relief valve is required (Passenger & Cargo only). This can be interpreted to mean protection for the fire main if the pump is used for other purposes. See further discussion in previous subpart.

B.8. Locate relief valve at discharge of fire pump. Should be through a line that is not valved lest the purpose of the relief valve be defeated.

B.9. Fire pumps are required to be fitted with a gauge on the discharge side of the pump.

B.l0. Determine hydrant spacing. Hydrants must be sufficient in number and so arranged that all portions of tile vessel accessible to passengers or crew, except machinery spaces, while the vessel is being navigated, may be reach with two hose streams, one of which is required to be from a single length of hose (76., and 95.10-10(d), 34.10-10 (b)). Size of hose and nozzles indicated in tables 34., 76., & 95. L0-5(a). On passenger vessels all watertight doors, doors in MVZ's, and stairway enclosures shall be assumed closed in checking compliance with this requirement. Spacing should be checked to scale on the plan, but due to obstructions, and arrangement of vessel, final determination should be left to the OCMI on the actual vessel. Where combination nozzles are installed for class B (flammable liquid) protection, discharge should be assumed to be from the <u>spray</u> pattern.

B.11. Fire stations should be numbered sequentially as required by regulation on all vessels to be certificated by the Coast Guard. See 37, 40-15, 78.47-20, and 97.37-15.

B.12. Provide shore connections. Cargo, Passenger, and Tank vessels over 1000 gross tons are required to be fitted with a shore connection on both sides of the vessel, with suitable adapters and cut-out valves.

B.13. The outlet at the fire hydrant shall be any position from the horizontal to vertical downwards to minimize the possibility of the hose kinking (76., and 95.10-10(f), 34.10-10(c)).

B.14. Suitable shut-off valves are required to be installed in the firemain on tankers to assure continued operation in event of damage (34.10-15 (b), and 34.20-5(e)).

B.15. All parts of the fire main located on exposed decks shall be protected against freezing or fitted with suitable cut-out valves and drains so that the piping may be drained in cold weather (76., & 95.10-10(e)).

8.16. Use of fire hose for purposes other than fire extinguishing and fire drills is prohibited (76.10-10(i), 34.10-10(j)).

8.17. Hose is required to bear tile Underwriters Laboratory label or comply with Federal Specification JJ-II-571 or ZZ-II-451a (34., 76., & 95.10-10(1)).

8.18. Provide acceptable nozzles. Smooth bore nozzles shall be of good grade bronze or equivalent metal (76.10-10(j), 95.10-10(i)). Smooth bore nozzles shall be of a size required by tables 76., and 95.10-5 (a), but proprietary approval by the Coast Guard is not required. Where combination nozzles are required, they are to be of an approved type listed in Equipment Lists, CG-190 (76.l0-10(j)(3), 95.10-10(i) (3), 34.10-10(e)). Applicator should be stowed on bulkhead near nozzle and be of a size and type to fit the nozzle.

8.19. Fire hose shall be carried connected to the hydrants at all times except where the hose may be damaged by heavy weather or when it interferes with handling of cargo (76., and 9S.10-l0(g), 34.10-10 (k)). Hoses shall be stowed in accordance with 76., and 95.10-10(h), 34.10-10(e)) which states that they must be adjacent to the hydrant and conspicuously marked.

C. TESTING AND INSPECTION

C.l. <u>INITIAL INSPECTION</u>

C.1.l. Test system to determine that pumping capacity is sufficient to adequately supply the required number of hose streams. For cargo and passenger vessels, this can be determined by using a single pump and simultaneously flowing the two highest.2 1/2 inch outlets. For tank vessels, this can be determined by using a single pump and simultaneously flowing the two-2 1/2" (three for tankers over (650') hydrants giving the greatest pressure drop between the hydrants and the pump. For cargo and passenger vessels the Pitot tube pressure should be not less than 50 psi, for tank vessels should be not less than 75 psi.

After checking capacity of the individual pumps, two pumps should then be operated simultaneously. Systems which are connected to the fire main, and which might be used at the sane time as the fire main, should be tested simultaneously. -

C.1.2. Review valve and piping arrangement near pump to make Certain that the fire pump may be put on the system quickly. All manifold valves should be near the pump.

C.l.3. Assure that pumps, sea suctions, power supply, and cable are segregated so that one casualty will not put both pumps out of operation.

C.l.4. Hydrant locations should be examined to determine that all portions of vessel accessible during voyage may be reached with two streams of water, one of which shall be from a single length of hose.

C.l.5. Examine hose to assure proper diameter, length, and marking.

C.l.6. Determine that hose is properly stowed, and connected to fire main. hose shall be visible or stowage clearly marked.

C.l.7. If combination nozzles are required, assure that they are of an approved type. Check stowage 6f applicator, should be on bulkhead near nozzle and be of a size and type to fit the nozzle.

C.l.8. Determine that fire stations are legibly marked and numbered as required.

C.l.9. Check shore connections and arrangement.

C.1.10. Assure that relief valve is set to operate properly, and discharges to an acceptable location.

C.1.11. Check to be certain that no connections, other than those specifically permitted, are made to the fire main.

C.2. PERIODIC INSPECTION

C.2.l. Assure that pumping capacity has not seriously deteriorated. This can be done by flowing the required number of hoses and checking Pitot pressure in accordance with C.1.1.

C.2.2. Check hose, stowage, marking, etc. of hose. Pressure test hose at 100 psi or the maximum pressure to which it will be subjected in service, whichever is greater.

C.2.3. Operate valves, pumps, etc. to assure firemain system is in good working order.

C.2.4. If vessel employs control starting of fire pumps check by operating pump from all remote control 8tations.

C.2.5. If vessel requires pressure alarm$_1$ check by flowing enough hydrants to reduce pressure on fire Rain to point where alarm should sound.

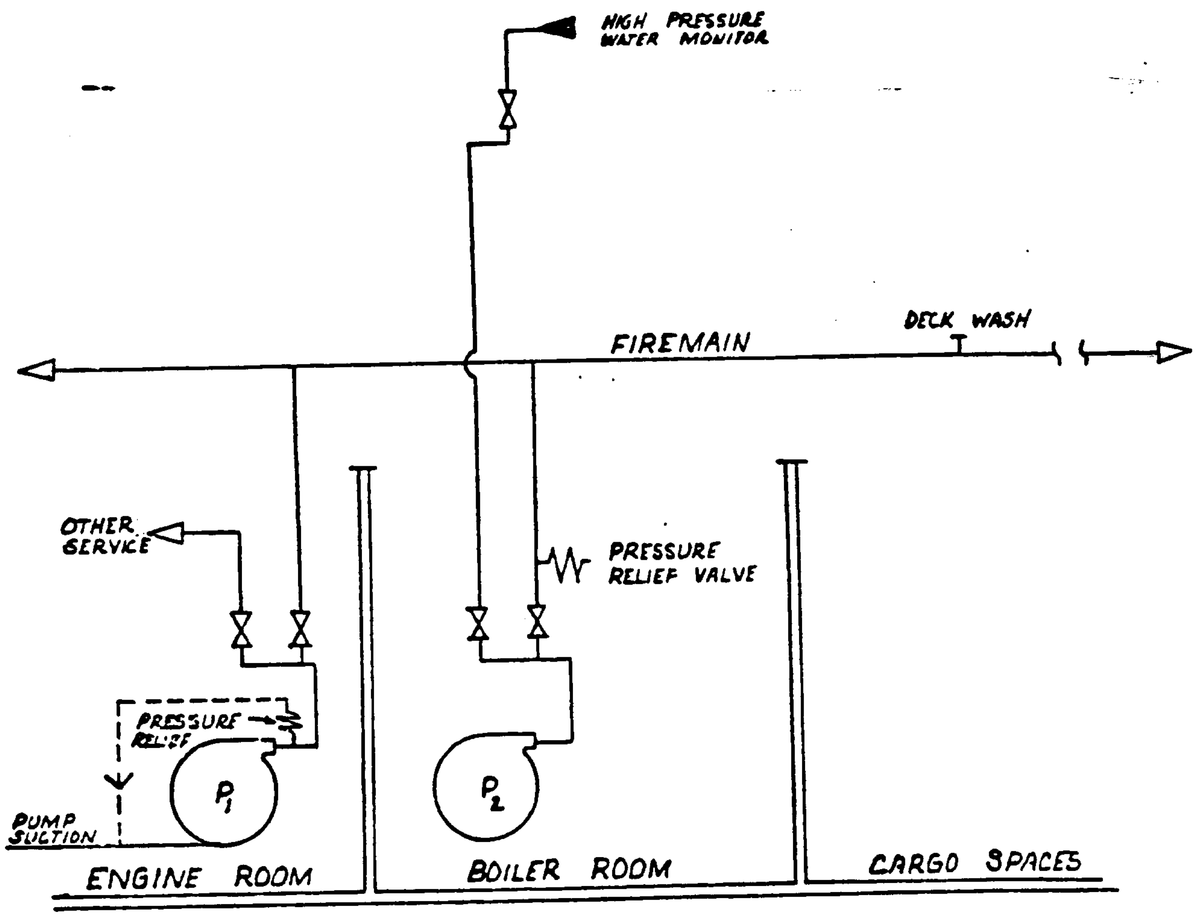
C.2.6. Check items (1.7), (1.10) and (1.11) above.

D. PUMPING CONPIGURATIONS

The following drawings are diagrams of acceptable fire pump piping arrangements. Schematics are intended to represent general piping runs only and should not be construed as showing the number of hose streams for which the system is required to be designed. Included are notes regarding required capacity of pumps with each configuration.

The drawings are intended for guidance only. Acceptable arrangements are not limited to those shown.

Figure I.D.1 - Acceptable Pumping Configuration No. 1



TYPICAL FIREMAIN SYSTEM AS MIGHT BE INSTALLED ABOARD PASSENGER OR CARGO VESSEL - WITH HIGH PRESSURE WATER MONITOR INSTALLED AS EXCESS EQUIPMENT.

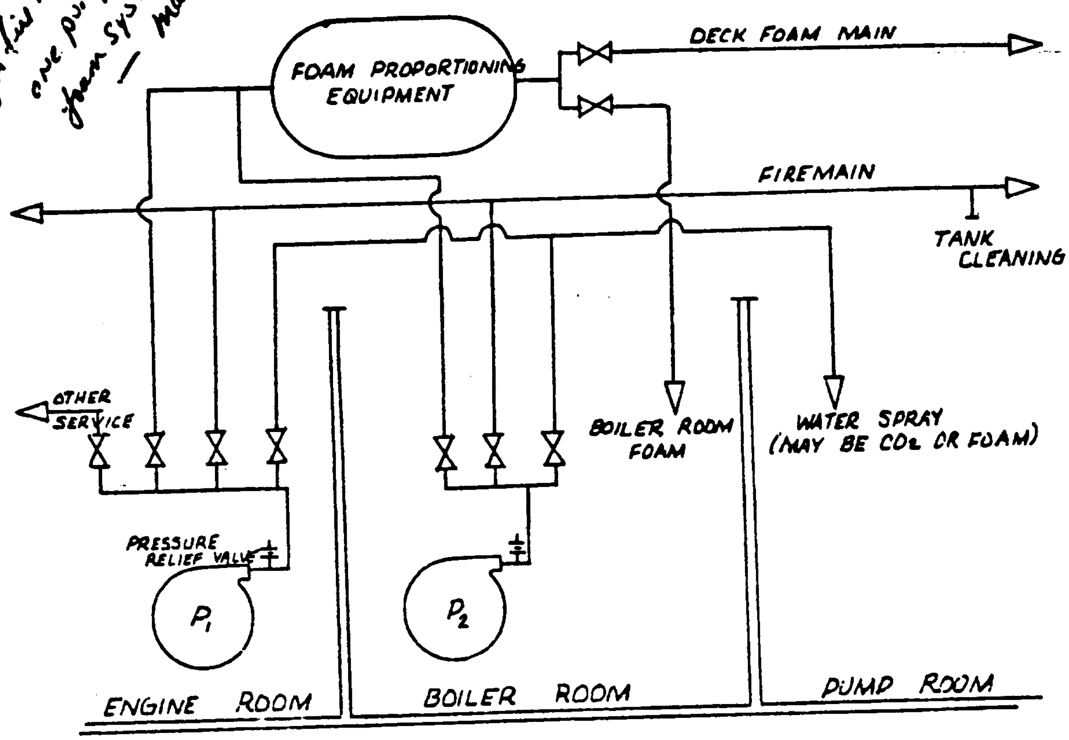
NOTES :

1. PRESSURE RELIEF FROM P_1 IS SHOWN DISCHARGING TO THE PUMP SUCTION. THIS IS A RECOMMENDED DISCHARGE ARRANGEMENT.

2. THE PRESSURE RELIEF VALVE FOR P_2 IS SHOWN ON THE SYSTEM SIDE OF THE FIRE MAIN SHUT OFF VALVE IN LIEU OF AT THE PUMP DISCHARGE. THIS IS TO PERMIT INSTALLATION OF THE HIGH-PRESSURE MONITOR. SEE SECTION A.6.

– One pump sized for fire main
one pump sized for foam system –
manifold connections

Figure I.D.2 - Acceptable Pumping Configuration No. 2

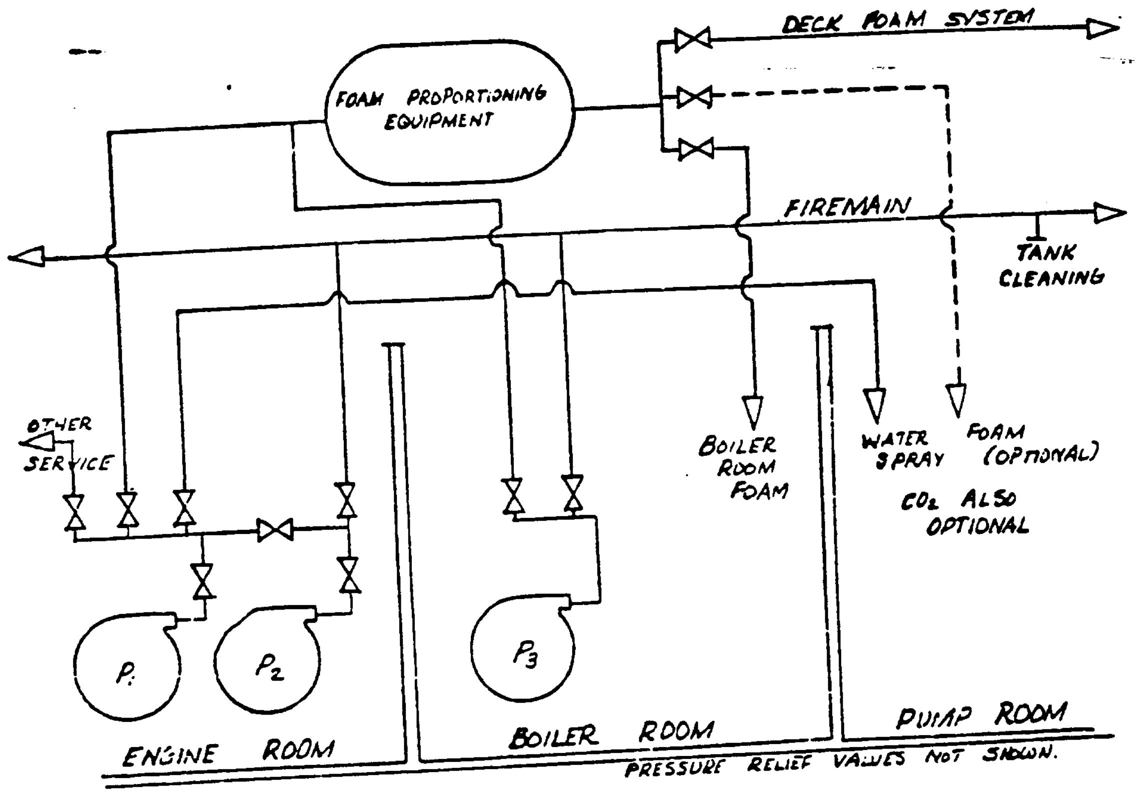


TYPICAL FIREMAIN SYSTEM AS INSTALLED ABOARD TANK VESSEL WITH ALL CONTROLS VALVES LOCATED AT MANIFOLD NEAR PUMP.

DESIGN CONDITIONS:

(1) Fire on Deck:	P_1 on Foam Main P_2 on Firemain	(May be reversed)
(2) Fire in Pump Room:	P_2 on Firemain P_1 on Water Spray	(May be reversed)
(3) Fire in Boiler Room:	P_1 on Foam Main & Then Firemain - However, it is strongly recommended that P_1 be capable of supplying the foam system and firemain system simultaneously. P_2 out of Service	
(4) Fire in Eng. Room:	P_1 out of Service P_2 on Firemain	

Figure I.D.3 - Acceptable Pumping Configuration No. 3

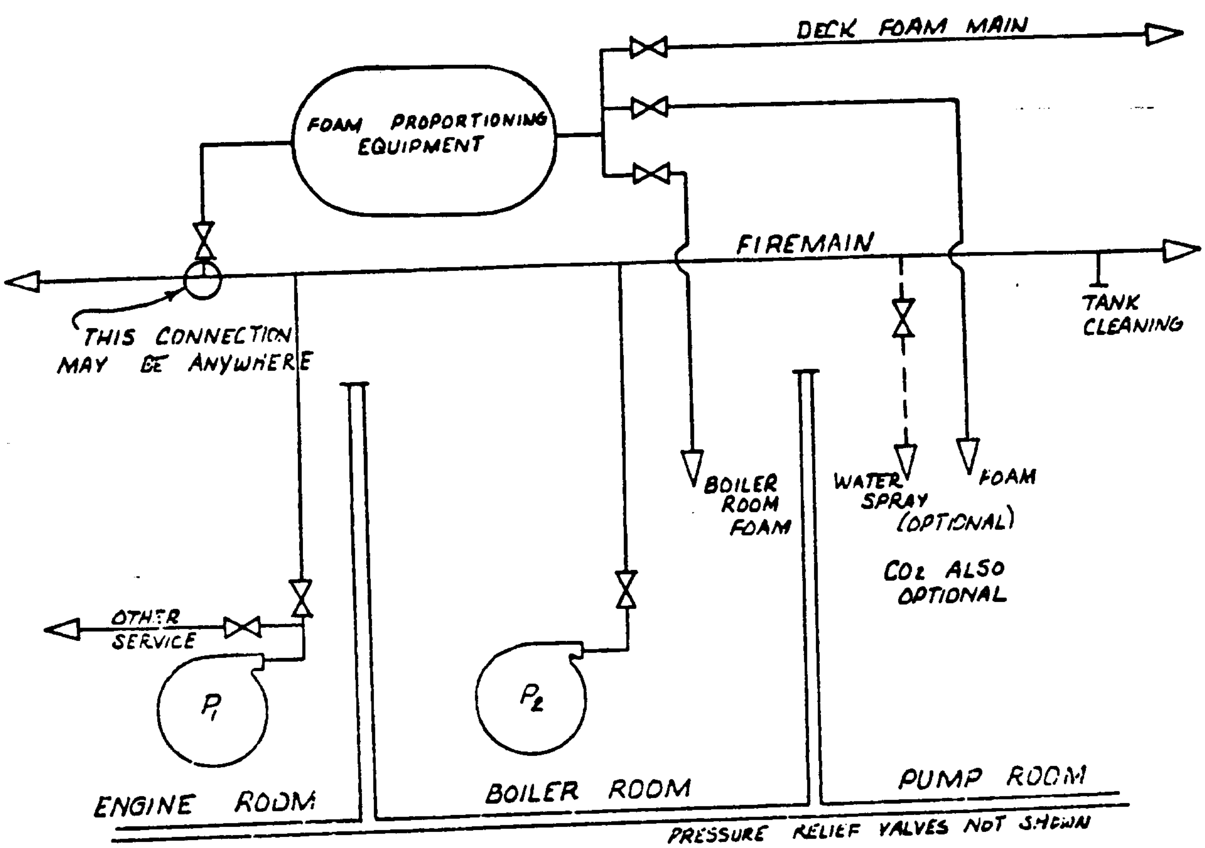


TYPICAL FIREMAIN SYSTEM AS INSTALLED ABOARD TANK VESSEL - ALL CONTROL VALVES NEAR PUMP & EXTRA PUMPING CAPACITY AVAILABLE.

DESIGN CONDITIONS:

(1) Fire on Deck:	P_3 on Deck Foam P_2 (P_1 on Firemain)	(May be other combination
(2) Fire in Pump Room:	P_1 on Water Spray P_3 (P_2) on Firemain	
(3) Fire in Boiler Room:	P_2 on Firemain P_1 on Boiler Foam	
(4) Fire in Eng. Room:	P_3 on Firemain	

Figure I.D.4 - Acceptable Pumping Configuration No. 4



TYPICAL FIREMAIN SYSTEM AS
INSTALLED ABOARD TANK VESSEL
ALL VALVES NEAR EQUIPMENT

DESIGN CONDITIONS:

(1) Fire on Deck:	P_1 (P_2) on Firemain and Deck Foam
(2) Fire in Pump Room:	P_1 (P_2) on Firemain and Pump Room Foam (Water Spray)
(3) Fire in Boiler Room:	P_1 on Firemain and Boiler Room Foam P_2 out of Service
(4) Fire in Engine Room:	P_2 on Firemain

NOTE: P_1 & P_2 should have identical pump characteristics.

II. CARBON DIOXIDE

A. DISCUSSION

A.1 GENERAL

Carbon dioxide as an extinguishing agent has many desirable properties. It will not damage cargo or machinery and leaves no residue to be cleaned up after a fire. Even if the ship is without power a charged CO_2 system can be released. Since it is a gas, CO_2 will penetrate and spread to all parts of the space. It does not conduct electricity and therefore can be used on live electrical equipment. It can be effectively used on most combustible materials.

There are two disadvantages to carbon dioxide. It has little cooling effect on materials that have been heated by the fire, and the quantity available in a system is limited.

Carbon dioxide extinguishes fires by reducing the oxygen concentration to a point where the atmosphere will no longer support combustion. The CO_2 concentration must be maintained for a sufficient period to allow the maximum temperature to be reduced below the autoignition temperature of the burning material. Carbon dioxide is most effective against flammable liquid fires. In enclosed spaces, burning class A combustible (wood, paper, etc.) fires may not be completely extinguished but may be controlled. For most flammable liquids, reduction of the oxygen concentration to 15% (from the normal 21%) will be sufficient to extinguish the fire. For class A combustibles, a reduction to 15% will control the fire. Some materials, such as acetylene and ethylene oxide, require a greater reduction of oxygen concentration for extinguishment. Still other materials, such as cellulose nitrate and metal hydrides, which do not require environmental oxygen as they burn, cannot be extinguished by use of carbon dioxide.

A.2. TYPES OF MARINE SYSTIMS

There are two basically different systems for the protection of spaces with carbon dioxide, depending upon the hazardous material involved. These two systems may be classified as "cargo" systems and "total flooding" systems.

A.2.l. Cargo System

Fires in class A combustibles carried in cargo holds generally start with some smoldering and production of large quantities of smoke. Only when sufficient heat is developed to reach the "flash over" temperature (temperature at which solid combustibles give off sufficient gases to support continued rapid combustion) will rapid burning occur. Until this time the rate of burning is relatively slow. Time to flash-over for ship's holds would perhaps be at least 20 minutes depending upon oxygen available and other circumstances. This allows tine to prepare fire fighting operations and techniques. Carefully 5ealing the hold prior to release of CO_2 is extremely important. Cargo Systems are intended for use against this type of fire. The correct fire fighting technique with a cargo system is to secure all openings to the space and manually release an initial charge of CO_2 (this quantity will be contained in the instruction book carried aboard the vessel - the instruction book should be prepared in accordance with Coast Guard recommendations, and submitted for Coast Guard approval) until sufficient concentration is developed to bring the fire under control. The hatch covers are maintained in place and additional CO_2 released from time to time (according to the system instruction booklet) to maintain the concentration. This method also allows control of the amount of CO_2 released depending upon how much and what type of cargo is in hold. Extinguishment of a class A type fire with carbon dioxide is difficult due to the thermal insulating properties of the material. Therefore, the hold is kept closed until the vessel reaches a port or other convenient facility where the hold can be opened, cargo removed, and final extinguishment accomplished. Usually such an operation involves removing cargo from spaces not involved in the fire while retaining an inert blanket on the portion of the hold involved. The fire-space is then opened, with charged firemain nozzles and water spray applicators at the ready. The cargo, e.g. baled cotton, is unloaded, cooled with water or broken open if necessary to extinguish the fire.

A.2.2. Cargo Tank System

Cargo tanks aboard cargo and passenger vessels may be protected by a type of cargo system. No specific requirements are enumerated in the passenger and cargo regulations for these systems. Installation requirements should be based upon the subparagraph 34.l5-90(a)(3) of the Tank Vessel Regulations. This regulation calls for discharge of the required quantity of carbon dioxide within 5 minutes. The quantity of carbon dioxide required to protect a given space is based upon a volume factor of 30 (one pound of CO_2 per 30 cubic feet of space). Operating instructions should state the minimum number of carbon dioxide bottles to be released as related to the amount of cargo in the tank.

A.2.3. Total Flooding System

Fires in machinery and similar spaces are generally class B (flammable liquids). In this type of fire the heat build-up is rapid. -The safety of the ship depends to a great extent upon the contents of the machinery space. For this reason, it is important to introduce the extinguishing gas quickly. This also prevents heat from possibly causing failure of bulkheads, making it impossible to maintain CO_2 concentration. Quick release keeps structural members from reaching high temperatures. It also prevents heat updraft from the fire from carrying away the carbon dioxide, as well as limiting damage to equipment. discharge of 35% of the required quantity of CO_2 in these systems should be completed within two minutes; slow release might result in no extinguishment. The separate and deliberate operations are required to avoid unintentional release of the gas. one control shall release at least the required amount of CO_2. Another control is required to operate the stop valve or direction valve.

Systems protecting enclosed ventilation system for motors and generators of electric propelling machinery are of the total flooding type. In addition, the required concentration of CO_2 must be maintained until the machinery can be stopped; this may require release of additional gas at delayed intervals. Such systems are described as "delayed discharge, total flooding" systems.

A.2.4. Special Suitable Space System

Ordinary cargo vessel fire extinguishment systems are not designed for protection against flammable liquid type of fires. To protect against the possibility of releasing the required quantity of CO_2 within a relatively short period. This would result in an increase over ordinary cargo vessel extinguishment system requirements by requiring an increased amount of piping and carbon dioxide nozzles. The amount of CO_2 required is based upon the gross volume of the largest “tight” space divided by a volume factor of 22 (one pound of CO_2 per 22 cubic feet of space). The “tight space” allows for small openings in hatches. Therefore, in designing a system for a volume factor of 22 for the “tight space” in 2 minutes, there is sufficient CO_2 available for a volume factor of 30 for the whole hold. The discharge of the required CO_2 is to be completed within 2 minutes.

A.3. CARBON DIOXIDE CONCENTRATION

Reduction of oxygen content to 15% is sufficient to extinguish most fires. Developing a CO_2 concentration of 28.5% in the atmosphere will reduce the oxygen content to 15%. The volume of carbon dioxide required to develop a given concentration in the atmosphere, assuming free efflux[11], is expressed by

$$x = \frac{\log_{10}\left(\frac{100}{100 - \%CO_2}\right)}{.434}$$

(NFPA No. 12 - Carbon Dioxide Extinguishing Systems, page 12-64)

where x = volume of CO_2 added per volume of space. Although Coast Guard regulations were actually developed empirically, it is of interest to see how this relates to Coast Guard requirements. To apply this formula, assume that one pound of carbon dioxide expands to 9 cubic feet when released and apply a volume factor of 22 (from Coast Guard regulations for machinery spaces over 50,000 ft^3) to determine the pounds of CO_2 required. The concentration of C02 developed in such a space (per 100 ft^3) may be calculated as follows:

$$100\,ft^3 \times \frac{lbCO_2}{22\,ft^3} \times \frac{9\,ft^3}{lbCO_2} = 40.9\,ft^3 CO_2\ /\ 100\,ft^3 space = x$$

$$\frac{40.9}{100} = \frac{\log_{10}\left(\frac{100}{100 - \%CO_2}\right)}{.434} \qquad \%CO_2 = 33.5\%$$

This concentration is sufficient to reduce the to approximately. 13.9%.

For cargo spaces, a volume factor of 30 (based upon gross volume of largest hold) is used to determine the quantity of CO_2 required. This is equivalent to

$$100\,ft^3 \times \frac{lbCO_2}{30\,ft^3} \times \frac{9\,ft^3}{lbCO_2} = 30\,ft^3 CO_2\ /\ 100\,ft^3 space = x$$

$$30 = \frac{\log_{10}\left(\frac{100}{100 - \%CO_2}\right)}{.434} \qquad \%CO_2 = 25.9\%$$

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[11] “Free efflux" means application of carbon dioxide in which the displaced atmosphere is exhausted freely through various small openings as carbon dioxide is injected. Some carbon dioxide is therefore lost with the vented atmosphere. The loss is greater at higher concentrations.

Because shipboard installations generally have fewer openings (portholes, etc.) than land installations, and they are at higher levels in the space, the carbon dioxide is not readily diluted but tends to remain near the bottom of the space where burning is likely to occur. This is a preferred condition.

Introduction of this percentage of carbon dioxide will reduce the oxygen Content of the space to 15.5%. It might appear at first glance that the oxygen content cannot be reduced enough, using a factor of 30, to extinguish the fire. However, i~ computing the volume of the space protected 110 reduction in volume is allowed for items of bulk which may be stowed in the space. As fires in cargo holds ordinarily occur with some stowage in the hold, the actual volume of atmosphere to be inerted is less than the gross volume of the hold. In addition, and most importantly, no consideration is given to the fact that once a hold is sealed up, the fire itself will consume a portion of the oxygen, thereby reducing the 02 concentration of the atmosphere prior to C02 release. Consequently, the oxygen content of the atmosphere actually in the hold would be reduced considerably below 15%. In the case of cargo tanks, it may be desirable to require sufficient C02 to reduce the oxygen content to l5'~. The above discussion is not applicable to machinery spaces as reduction in the volume of the protected space is allowed for boiler casings, etc. which extend into the space.

A.4. VOLUME FACTOR

As the volume of a space increases the proportional amount of CO_2 required to protect that space decreases (the volume factor in Coast Guard regulations increases). The smaller the volume of a space the greater the ratio of surface area to volume and consequently the greater the ratio of access openings to volume. Therefore, for smaller spaces there is a relatively greater chance of CO_2 leakage from the space. An additional factor is that of ventilation. While mechanical ventilation Systems are required to be shut down and ventilators closed upon actuation of a system, the presence of a ventilation system allows loss of some extinguishing gas.

A.5. NOZZLE SPACING

Coast Guard regulations state that nozzles should be spaced to give a “relatively uniform” discharge. In enclosed spaces, such as aboard ship, the location of nozzles is not so critical as for foam and water spray Systems. The carbon dioxide will disperse to all portions of the hazard within a relatively short period. Spacing the nozzles in some uniform pattern simply reduces the time necessary for the gas to mix with the air and completely inert the space. In a machinery space location of nozzles at a height equal to one-third to one-half the height of the space is adequate. since CO_2 is heavier than air it will tend to remain in the lower portions of the space and the air forced out the top will contain little CO_2.[12] Nozzles should not be located near ventilation or other openings as there is a relatively greater chance of CO_2 being forced out of the opening.

A.6. NOZZLE DESIGNATION

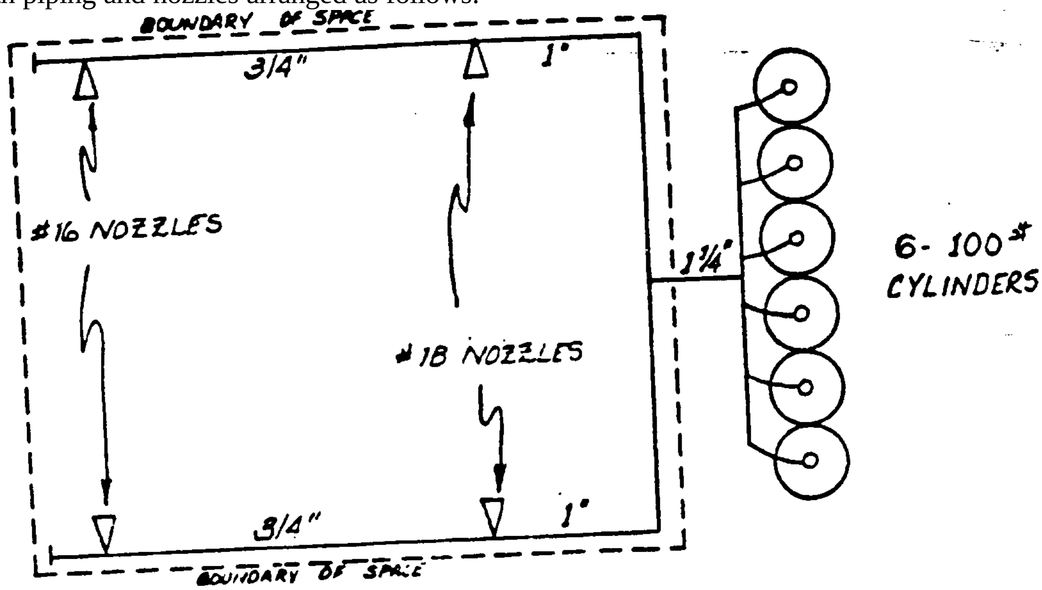
Discharge nozzles should be permanently marked to identify the nozzle and show the equivalent single orifice diameter. This equivalent diameter refers to the orifice diameter of the "standard" single orifice having the same flow rate as the nozzle in question. The equivalent orifice code number refers to the "standard" orifice diameter in 1/32" increments. For example a #16 nozzle has a discharge equivalent to a "standard" orifice 16/32" or 1/2" in diameter. A plus sign following the code number indicates equivalent diameters 1/64" greater than that indicated by the numbering system. For example, an 8+ nozzle has the equivalent discharge of a 17/64" standard orifice. See NFPA No. l2[4] for complete listing.

A.7. PIPE SIZING, NOZZLE SIZING, DISCHARGE TIME

[12] During fire conditions, updraft from fire will tend to carry CO_2 away, making prompt action and closure of openings essential.

If the pipe and nozzle sizes are in accordance with the regulations for machinery and similar spaces, the required quantity of carbon dioxide will be discharged in less than two minutes. A satisfactory method for estimating the flow in branch lines is to assume that the gas will flow through the nozzles in direct proportion to the nozzle areas.

For example, assume a 12,000 ft^3 (12000 ft^3 / 20 ft^3 / lb = 600 lb CO_2 rqd) machinery type space with piping and nozzles arranged as follows:



The nominal cy1inder area is: 600 x .0022 = 1.32 in^2.
The area of 1 1/4 of extra heavy main supp1y pipe is: 1.283 in^2.

Since the area of the main supply pipe is smaller, the nozzle orifice area should be based upon this area. The total equivalent orifice area is:

#16 = .1964 in^2 x 2 = .3928 in^2
#18 = 2485 in^2 x 2 = .4970 in^2
TOTAL .8898 in^2
.8898 in^2 / 1.283 in^2 = 69.9% of pipe area.

Since this is between 35% (40% for cargo) and 85% of the pipe area the nozzle orifice size is satisfactory.

The flow through individual nozzles may then be approximated to be proportional to the orifice area, or:

$$flow\#16 = 600lb \times \frac{.1964}{.8898} = 132.4lb$$
$$flow\#18 = 600lb \times \frac{.2485}{.8898} = 167.6lb$$

The carbon dioxide passed through the 3/4" pipe is then 132.4 lb vs. 225 lb allowable, flow through the 1 inch pipe is 300 lb vs. 300 lb allowable, and flow through the 1 1/4" pipe is 600 lb vs. 600 lb allowable. Pipe sizing is, therefore, also satisfactory.

A.8. PRESSURE INCREASE

A simple and reasonably accurate method for estimating the pressure increase due to the release of carbon dioxide into very tight spaces is as follows:

Assumptions:

(1) Carbon dioxide expands to 9 ft^3 for each pound of CO_2 in bottle (this is at 86^0F).

(2) Constant enthalpy for expansion from 3000 psia to 14.7 psia for CO_2.

(3) Complete and instantaneous mixing of CO_2 and air.

A.8.1 Determine the following conditions:

Weight of CO_2 = $\dfrac{Vol.ofVoid\left(ft^3\right)}{Vol.\,factor\left(ft^3\ /\ lbCO_2\right)}$

For CO_2:

$$V_b = 9\,ft^3\ /\ lb \times wgtofCO_2 = \left(volumeCO_2\right)$$
$$T_b = -180^0 F + 460 = 280^0 R$$

For Void:

P_1 = 14.7 psia

V_2 = Volume of void

T_a = Temp. of void prior to release of CO_2. If not known, estimate to be 150^0F. (610^0R).

A.8.2. Calculate T_2 for mixture of air and CO_2 in void:

$$T_2 = \frac{KT_a + T_b}{K+1}, \qquad \text{where} \quad K = \frac{volumefactor}{13.14}$$

A.8.3. Calculate partial pressures (P_2CO_2 & P_2 air)

$$P_2CO_2 = \frac{P_1V_bT_2}{T_bV_2} \qquad\qquad P_2air = \frac{P_1T_2}{T_a}$$

A.8.4 Sum of partial pressures equals total absolute pressure in the space (P_T).

$$P_T = P_2 CO_2 + P_2 air$$

A.9. FREE VENTING

For very tight enclosures, the area necessary for free venting nay be calculated from the following formula, assuming the expansion of carbon dioxide to be 9 ft^3/lb.

$$X = \frac{RA}{1.3\sqrt{P}}$$

where: X = free venting area in square inches.
R = rate of injection in lbs/min/in^2 of orifice area (use 1400).
P = allowable strength of enclosure in lbs/ft^2 (use 25 if not known).
A = total orifice area in square inches.

A.l0. CYLINDER LOCATION

Cylinders shall be located outside the protected space and shall not be subject to being cut off in event of fire. The only exception to this rule is that a total-flooding system of 300 pounds or less, with approved automatic release, may be installed in the protected space. Spaces containing the cylinders shall be designed and ventilated so as to preclude an ambient temperature in excess of 130^0F. This is to prevent the carbon dioxide pre-sure in the cylinders from rising, and possibly breaking the rupture disc which protects the cylinder from over-pressure.

A similar over-pressuring situation might arise if cylinders are located immediately adjacent to the space which they protect. Heat from a fire in the protected space might readily be conducted through the bulkhead, over-pressuring the cylinders. This situation could occur if the fire has gained a considerable bead start before discovery. In such a situation, rupture of the over-pressure disc would fill the cylinder room with CO_2, leaving none to fight the fire. To avoid such a situation, the CO_2 cylinder bank 8hould be located in a space that is not contiguous with the space protected. If this is impossible9 the common bulkhead(s) between the spaces should be protected with A-60 structural insulation.

A.11. REMO TE RELEASE

When remote stations ire installed which will control either release of the required amount of carbon dioxide, or which will operate a direction valve to direct Co2 into the proper compartment, design of the remote control system design should be carefully considered. Usually the remote control operation is accomplished by a cable system. A lever is pulled at the remote station, and this force is transmitted via the cable to the cylinder location where cylinders or valves are operated. Operation of the remote pulls should not require more than 40 pounds pull nor more than 14 inches movement to accomplish its purpose. Although the system may operate satisfactorily when new, kinks in the cable due to being kept in one position, or possible deterioration of pulleys, etc. may make the system more difficult, or impossible, to operate in the future. For this reason, excessive lengths of control cable should not be used, and cables and other operating mechanisms should never be installed in locations where they will be subject to the weather.

A.12. AUTOMATION

On automated vessels a centralized engineroom control station is provided. If the control station is enclosed, there are at least two major areas of concern:

(1) If a fixed carbon dioxide extinguishing system is installed for protection of the machinery space, the predischarge warning alarm should be capable of being heard inside of the control station as well as in the machinery space.

(2) The remote operating controls located at the engineroom" exit for the fixed extinguishing system should be duplicated within the control station enclosure.

B. DESIGN AND REVIEW OF SYSTEM

Application: Passenger & Tank Vessels contracted for on or after January 1, 1962

Cargo Vessels contracted for on or after November 19, 1952

Note: Numbers in brackets refer to applicable subparts of the regulations. (Passenger - Part 76; Cargo - Part 95; Tank - Part 34, unless otherwise noted)

In case of any doubt, applicable regulations should be consulted for exact wording of requirements.

B.1. Check space to be protected and determine type of system to be installed (See chart, Subpart C).

B.2. Check volume of protected space(s). Be certain boundaries are sufficiently tight to maintain CO_2 concentration (.l5-5(e)(2), .15-5(c)(2)). M additional amount of one pound of CO_2 for every square foot of opening which cannot be closed at the time of extinguishing (clear door opening) is required Very tight spaces such as paint lockers, etc. may require pressure relief (.15-40(a)). (For estimate of pressure increase, see Subpart A, Discussion).

B.3. Determine volume factor for space(s) and determine quantity of CO_2 required (see chart, Subpart C).

B.4. Compare amount of CO_2 required for space requiring greatest amount, to quantity of CO_2 to be provided (.15-5(b).

B.5. Control and cylinder location shall be outside of the protected space and in an accessible location (control .15-l0(a), cylinder .15-20(a)). In systems of 300 pounds or less, cylinders may be located inside of protected spaces if automatic discharge is provided (.15-20(b)). Such installations should also have a manual release operable from outside of the space, and not subject to being cut off.

8.6. Cylinders should be securely mounted (.15-20(d)) and easily removable for weighing (.15-20(e)). They should not be subject to an ambient temperature in excess of l30^{0}F.(.15-20(c)). They should also be protected from excessive temperatures in event of fire in the protected space.

B.7. Each cylinder must be provided with a safety device (rupture disc) to relieve excessive pressure. Similarly, where a distribution manifold is used, a pressure relief device is required (.15-15(d)) to protect the piping in event all branch line shut-off valves are closed.

8.8. Check whether nozzle locations will give a relatively uniform discharge (76., and 95.15-5(e)(S), 34.lS-S(e)(6)).

8.9. Compare nozzle outlet area (total) with main supply pipe size or nominal cylinder outlet area, whichever is smaller (7b., and 95.15-5 (e)(6), 34.15-5(e)(7)). The nominal cylinder outlet area (in square inches) is equal to the quantity of CO_2 required (in pounds) times 0.0022.

8.10. Compare the carbon dioxide flow in each section of piping to the maximum allowable by the pipe size tables (76., and 95.l-5(e)(3), 34.l5-5(e)(4)). For method of estimating carbon dioxide flow in branch lines, see discussion, Subpart A.

8.11. For machinery and similar spaces and specially suitable spaces, discharge of the required amount of carbon dioxide must be completed within 2 minutes (76., and 95.15-S(e)(7), 34.l5-5(e)(8)). This requirement will be met if nozzles and pipes are size according to (8) and (9).

8.12. Piping must extend at least 2 inches beyond the last orifice to reduce the danger of clogging the nozzle (.l5-15(i)).

8.13. Piping passing through living quarters shall not be fitted with drains or openings in such spaces (.15-l5(i)).

8.14. Location of controls must be outside of the protected space (.l5-l0 (a)) and convenient to one of the main means of escape (.15-10(c)).

8.15. CO_2 distribution piping shall be controlled from not over two stations (.15-10(c)). If cylinders are capable of remote release, provisions shall also be made for local release at the cylinders (.15-10(e)).

8.16. At least 2 pilot cylinders are required in systems of 3 or more cylinders (one pilot cylinder in two cylinder systems), which depend upon gas pressure for release of rest of cylinder bank (.15-10(e)). Manual controls shall require a pull of not more than 40 pounds (force) nor a movement greater than 14 inches. Estimate about 10 pounds per cylinder.

8.17. Machinery space shall have one control to operate the valve to the space and a separate control to release at least the required amount of CO_2 (.l5-l0(d)).

8.18. Complete but simple operating instructions should be located near the release control (.15-l0(h)).

8.19. Check ventilation arrangement and shutdown. Mechanical ventilation requires automatic shutdown (.l5-35(a)). Means must be provided for closing all natural ventilation openings (.l5-35(b)). Canvas is satisfactory.

8.20. A delayed discharge and predischarge alarm shall be provided for systems protecting spaces normally accessible to persons on board except lamp rooms, paint rooms, and similar spaces (.15-30(a)). The 20 second delay period prior to discharge of the carbon dioxide specified in, the regulations is the minimum delay period. In large or unusually arranged spaces, the delay period should be sufficient to allow escape from all portions of the protected space.

B.21. The predischarge alarm must be marked with a warning sign (78.47-9,97.37-9, 35.40-7). predischarge alarm shall depend upon no source of power other than C02 flow (.15-35(a)). The alarm should be located so as to be audible throughout the space, while all machinery is operating.

B.22. Check list of component part numbers as shown on the drawing against the Coast Guard approved parts list (.15-10(g), 15-15(a), (b) & (c), must be supplied by the same manufacturer. This will assure that the parts are compatible and will result in an effective system.

8.23. Pipe and fittings should be provided in accordance with the Coast Guard approved pipe drawing of the manufacturer. Where reference is made to specific approved drawings of piping and/or installations which are on file, additional copies must be provided for the use of the inspector in the field. In instances where pipe and fittings are provided by organizations other than the system vendor, a complete bill of materials for the system must be submitted.

C. SPACES PROTECTED BY CARBON DIOXIDE & TYPE OF SYSTEM REQUIRED

ABBREVIATIONS:
R - Required
O - Optional in lieu of other systems
RII - CO_2 only system permitted, but not required
e - Some exceptions see regs

Type of Vessel	Space Protected by Carbon Dioxide	Type of System (For definition of systems Subpart A)	Flooding Factor	Required or Optional
CARGO & MISC.	Cargo Compartments	Cargo System	30	R*
	Spaces Specially Suitable for Vehicles	Total Flooding	22	R**
	Cargo Tanks	Cargo Tank System	30 (see Subpart A)	O
	Lamp & Paint Lockers & Similar Spaces	Total Flooding	See Table 95.15-5 (e)(1)	R
	Oil Fired Boilers and Associated Equipment	Total Flooding	See Table 95.15-5(e)(1)	O
	Internal Combustion Propelling Machinery	Total Flooding		RII R^{e}
	Enclosed Ventilation Sys. for Motors & Generators of Elec. Propelling Mach.	Delayed Discharge Total Flooding	10(2000 ft^3 or less)° 12(over 2000 ft^3)°	R
TANK	Dry Cargo Compartment	Cargo System	30	O
	Lamp & Paint Lockers & Similar Spaces	Total Flooding	See Table 34.15-5(e)(1)	O
	Pump Rooms	Total Flooding		O
	Boiler Rooms	Total Flooding		O
	Machinery Spaces	Total Flooding		R-If Flash Pt. Less than 110°F
	Internal Combustion Installations	Total Flooding		RII R^{e}
	Enclosed Ventilation Sys. for Motors & Generators of Elec. Propelling Mach.	Delayed Discharge Total Flooding	10(2000 ft^3 or less)° 12(over 2000 ft^3)°	R

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II(CO)

Type of Vessel	Space Protected by Carbon Dioxide	Type of System (For definition of systems Subpart A)	Flooding Factor	Required or Optional
PASSENGER	Paint & Lamp Lockers & Similar Spaces	Total Flooding	See Table 76.15-5(e)(1)	R
	Boiler Spaces	Total Flooding		O
	Machinery Spaces (Internal Comb. & Gas Turbine)	Total Flooding		R
	Auxiliary Spaces (Internal Comb. & Gas Turbine)	Total Flooding		R[e]
	Cargo Spaces (Accessible During Voyage)	Not Permitted		
	Cargo Spaces (Inaccessible During Voyage)	Cargo System	30	R
	Cargo Oil Tanks	Cargo Tank System	30 (see Subpart A)	O
	Cargo Spaces Containing Autos with Gasoline	Total Flooding	22••	R
	Enclosed Ventilation Sys. for Motors & Generators of Elec. Propelling Mach.	Total Flooding	10(2000 ft^3 or less)• 12(over 2000 ft^3)•	R

* If accessible during voyage <u>may</u> be considered living space and sprinklers required.
** If space partially open, sprinklers may be required.

• In addition, must maintain 25% concentration until equipment can be stopped.

••If the deck is open at either or both ends, as found on ferry vessels, it is called a "vehicular deck" and a manual sprinkling system is required.

D. INSPECTION AND TESTINIG
(Carbon Dioxide)

D.1. <u>INSTALLATION TEST</u>

ddition to determining that the system is installed in accordance with the regulations and approved plans, the following checks are suggested:

.1. Piping should be pressure tested in accordance with paragraph 34.9 76., and 95.15-15(j).

D.l.2. Remote controls for release of carbon dioxide equipment should be operated. Excessive pull (over approximately 40 pounds) or movement (over approximately 14 inches) should not be permitted.

D.l.3. Protection of cylinders and controls from damage should be verified.

D.l.4. Operation of discharge delay and alarm should be checked. Discharge of gas into spaces that may be occupied should be delayed for a period sufficient to allow escape from any portion of the space. Thought should be given to the audibility of CO_2 alarms in the engine room especially whole the vessel is underway. It has been observed on occasion that the alarm could not be heard over the noise of an underway engineroom. The alarm must be audible over all operating machinery to afford adequate protection to the crew.

D.l.5. Operating levers, selector valves, etc. should be properly identified. Operating instructions should be examined.

D.l.6. Switches for automatic shut down of ventilation should be operated.

D.l.7. It should be verified that all openings into the space are capable of being secured.

D.l.8. Check operating instruction book.

D.2. INSPECTIONS FOR CERTIFICATION

D.2.l. Weigh cylinders. Recharge if weight loss exceeds ten percent of charge.

D.2.2. Predischarge alarm should be checked and test operated if necessary. The alarm should be audible throughout the space with the machinery operating.

D.2.3. Compliance with items (1.2)) (1.6) and (1.7) above should be assured.

D.2.4. Operating instructions should be in place and legible.

D.2.5. Determine age of cylinders. If over 12 years old, cylinder should be discharged and hydrostatically tested. See 46 CFR 147.04-1(a). However, if cylinders are 5 years old or older and found underweight by D.2.l, then hydro must be conducted at the time cylinders are removed for recharging. Owners often have service contracts with carbon dioxide equipment manufacturers for maintenance of the system. A joint inspection is desirable, but does not relieve the Coast Guard of responsibility.

D.2.6. If under D.2.5. any cylinders or piping are required to be inspected, then all flexible connections between the cylinders and the piping shall be renewed or subject to a pressure test of 1,000 pounds per square inch.

D.2.7. Visually check all distribution lines for disformation, missing discharge heads, blanks, and breaks.

III. MECHANICAL FOAM SYSTEMS

A. DISCUSSION

A.1. DEFINITIONS

A.1.1. Foam
A fire extinguishing agent which is a fluid aggregate of small air filled bubbles that will float on the surface of most flammable liquids. It is formed by mixing foam concentrate and water (foam solution) and expanding it by agitation with air.

A.l.2. Foam Solution
A homogeneous solution of foam concentrate in water. The term "water rate" is used in the Coast Guard regulations; its meaning is synonymous with that of "foam solution rate" for 3% and 6% concentrate systems.

A.l.3. Foam Concentrate
An aqueous solution of concentrated liquid (usually protein-base) with a stabilizer added which when mixed with water and air forms a fire extinguishing foam which is highly resistant to breakdown.

A.2. FOAM, CHARACTERISTICS & APPLICATIONS

Mechanical foam is produced by introducing foam concentrate in proper proportions into a flowing stream of water and aspirating with air. Aboard ship the foam concentrate is normally introduced by means of proportioning equipment near the foam concentrate storage container at some central location on the vessel. The foam solution thus formed is pumped through fixed piping to foam nozzles, monitors, etc. at the area to be protected. Air is mixed with the foam solution at the nozzle and foam produced.

Foam extinguishes a flammable liquid fire by forming a continuous blanket over the burning liquid, separating the combustible vapors from the oxygen (air) necessary for combustion. Because foam contains water dispersed in very thin film, it also has cooling properties. Once formed the blanket has the ability to reseal itself should it be broken. It is not readily dissipated by heat. The intended use of foam is against flammable liquid tires where a surface area is present which may be blanketed.

It is of limited use on most class A (wood, paper, etc.) fires due to its inability to effectively cover other than horizontal surfaces for long periods of time, its limited cooling ability, and its inability to penetrate deep seated fires. Foam may also be used to blanket flammable liquid spill8 which are not burning to prevent the escape of combustible gases and subsequent ignition.

The foam concentrate normally supplied is suitable for use with most, but not all, flammable liquids carried aboard tankers. For example, it is impossible for this foam to form a blanket on alcohol’s, esters, ketones, or ethers (commonly called water-soluble or polar liquids).

An approved (Coast Guard) "polar solvent" foam concentrate is available, which is also suitable for hydrocarbon fires. Unlike other available alcohol foams, it is not necessary to spread thi8 product gently on the surface. Rather, it can be applied through hose nozzles or monitors. In addition to the 20% "foaming concentrate", this system has a 3% catalyst, which further reacts the polymer in the concentrate. The "polar solvent" foam is further strengthened upon application to the solvents, where regular foams are quickly broken down. The application rate must be determined for each individual vessel.

A.2.l. High Expansion Foam

Presently under consideration, is a new concept in fire extinguishing foams. High expansion foam is capable of producing vast volumes of foam with a small quantity of water and a very small amount of suitable foam concentrate. Where the expansion ratio of low expansion foam is about 8:1, the expansion ratio for high expansion foam is about 800:1. This type of foam system has some possible use for large volume spaces, where the quantity of CO_2 required would be excessive. This system has not yet been approved by the Coast Guard (although it has been accepted on an experimental basis for a single roll-on/roll-off vessel) and is not further discussed in this guide.

A .2.2. Light Water

An aqueous film forming foam called light water is also being investigated. This new synthetic foam forming concentrate has been developed for flammable liquid fires. Chemically the foam is a perfluorinated surfactant capable of enabling water to float on petroleum products. Even though the agent shows promise, such characteristics as burnback resistance, corrosiveness, sea water suitability, and adaptability to currently approval marine type foam systems have yet to be evaluated by the Coast Guard.

A .3. NCENTRATE

A.3.1. Rate of Application

Regular foam concentrate is available as either 3% or 6% liquid. The usual ratio of foam concentrate, water, and air to produce a foam with good fire extinguishing properties is as follows:

3% concentrate - 3[13] parts concentrate, 97 parts water, 900 parts air
6% concentrate - 6[1] parts concentrate, 94 parts water, 900 parts air

The 3% concentrate is usually used in new installations since it requires about one-half the quantity of concentrate to produce an equivalent volume of foam. Cost far equal protection is comparable.

For "polar solvent" systems the proper proportions are as follows:

(20% concentrate type) - 3 parts catalyst, 20 parts foaming concentrate, 77 parts water, and 900 parts air.

The first fire-fighting foams available were the "chemical" type which depend upon a chemical reaction to form the foam. It was found by testing that a six inch blanket of chemical foam would

[13] In operation foam proportioning equipment usually introduces foam concentrate into water in proportions exceeding the minimum required (e.g. 3.05%). The amount of foam concentrate introduced varies with the water flow through the proportioned. The actual percentage may be determined by referring to the appropriate manufacturers' instruction booklet.

extinguish fires and be sufficiently resistant to beat breakdown. When the mechanical foams were first developed, this same criterion was applied (6" blanket) to determine what quantity of foam would be required. This has, over the years, become an acceptable design requirement, providing sufficient foam to remain intact for periods long enough to suppress vapor release and cool the liquid surface and adjacent ignition sources to prevent reignition. The requirement for a blanket of this thickness appears in the Coast Guard regulations as a minimum foam solution rate (water rate) for a specific period of time. This allows more uniform system design procedures. For example, for a boiler flat the required foam solution application rate is 1.6 gpm per 10 square feet for a period of 3 minutes. Assuming a conservative ratio of expansion of 8 (volume of foam to volume of foam solution) it will be seen

$$\frac{1.6 gal / \min}{10 ft^2} \times 3\min \times \frac{ft^3}{7.48 gal} \times \frac{12 in}{ft} \times 8(\exp ansion) = 6.16 in$$

Note: One cubic foot of water contains 7.48 gallons that a 6.16" blanket of foam will be formed over the area protected.

For deck foam systems, the required foam solution rate differs from the required rate for fixed foam systems. The required rate is 0.016 8pm per square foot of the entire tank surface for 15 minutes. Entire tank surface is defined as the maximum beam of the vessel times the total longitudinal extent of tank spaces. The rate for deck foam; Systems is based on the following typical tanker configuration:

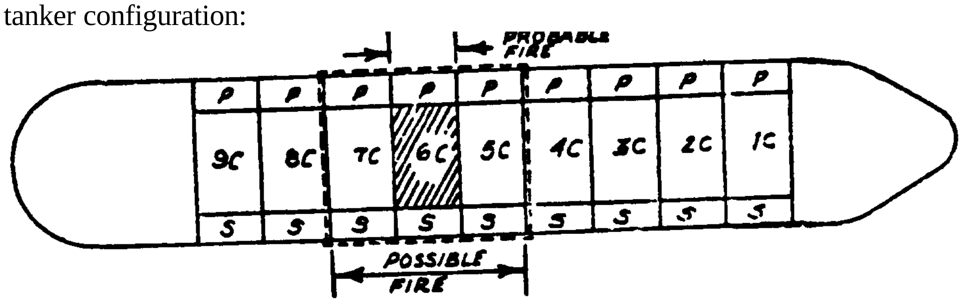


Figure III.A.1. Typical T-2 Tanker

It is a generally known fact that the effectiveness of a foam fire extinguishing system in controlling a flammable liquid fire depends upon the rate at which the foam is applied. Most systems are designed to deliver 0.16 gpm for each square foot of protected hazard. The figure of 0.16 gpm/ft^2 of protected hazard is used in Coast Guard regulations governing installation of foam extinguishing systems in boiler rooms. For deck foam systems, however, the rate of 0.16 gpm/ft^2 of protected hazard is expressed in a different way, i.e,, deck foam Systems are required to deliver 0.016 gpm per square foot of the <u>total</u> tank area of a vessel's cargo tanks. The figure of 0.016 gpm/ft^2 of total area was derived from the rate of 0.16 gpm/ft^2 of protected hazard, based upon the design of a T-2 tanker and the probable area of fire spread aboard the vessel. Calculating the required foam system rate for a T-2 tanker using the rate of 0.016 gpm/ft^2 of total tank area, one finds the resulting system would be capable of delivering about 0.16 gpm/ft^2 of area to any series of adjacent port-centerline-star-board tanks extending the breadth of the vessel. Thus, for a T-2 tanker, the accepted rate of 0.16 gpm/ft^2 of protected hazard is still available. Again, using the 0.16 gpm/ft^2 of total tank area to design the deck foam system aboard a T-2, one finds the resulting system will deliver 0.252 gpm/ft^2 of any <u>single</u> cargo tank. As design of tank vessels evolved, however, the trend has been toward fewer and fewer tanks. It can be seen from the foregoing explanation that using the rate of 0.016 gpm/ft^2 of total tank area for design of the deck foam system for a vessel having fewer tanks than a T-2 would mean any single tank aboard that vessel would be protected by a lower application rate. Thus, with no change in the method of calculating foam application, fewer tanks means a lower foam application rate for each tank with a resultingly serious compromise in the effectiveness of the foam system. Therefore to correct this situation a dual method of calculating deck foam system application rate is used. For usual petroleum products the water rate shall be at least 0.016 gpm for each square foot of the cargo area or 0.24 gpm for each square foot of the horizontal sectional area of the single tank having the largest such area, whichever is greater. The quantity of foam shall be sufficient for 15 minutes of operation. The cargo area is defined as the maximum beam of the vessel times the longitudinal extent of the tank spaces.

The rate was arrived at as follows:

(1) Assume fire in no. 6C as shown.

(2) The probable fire and possible fire areas would also be as shown.

The total possible fire area is seen to be approximately one third of the total tank area of the vessel. The requirement for application of the required rate for 15 minutes was based upon two consideration:

(a) If the fire burned beyond 15 minutes$_1$ it is improbable that it could be contained and extinguished by the vessel's crew, and

(b) Previous requirement for fixed-systems in cargo tanks was to apply the tam solution for 5 minutes for one tank across. Since the possible fire area covers three tanks across, the required application time would be 3 x 5 = 15 minutes.

Thickness of foam blanket, per se, has no meaning. What is important is an ability to extinguish a fire and maintain an effective vapor-tight cover. Some foams require thicker blankets to accomplish this. Other foams can do an equally effective job with blankets of lesser thickness. Thus rate of application$_1$ related to some standard test rate, is the important factor and not thickness of blanket.

Actual small scale fire tests conducted for Coast Guard approval of foam concentrate and associated equipment were conducted at a rate of 0.06 gpm/ft^2, these fires were extinguished. Thus the required rate of 0.16 gpm/ft^2 (compared to 0.06 gpm/ft^2 test rate) provides an adequate safety factor to account for large scale fires and/or larger preburn for shipboard installations.

A.3.2. Quantity Required

The amount of foam concentrate required to be supplied depends upon the type of installation. Systems designed to protect machinery and similar interior locations where the foam blanket will be contained within the space require calculation of the quantity of foam concentrate by one method. neck foam systems protecting outside areas where the foam blanket may not be contained require calculation by second method.

A.3.2.l. Fixed Foam Systems

The quantity of foam concentrate required for protection of machinery spaces must be sufficient for 3 minutes discharge at the required foam solution rate. If the actual rate of flow exceeds the required rate of flow, no increase in quantity of foam concentrate is necessary because this means only that the 6" blanket will be produced in less than 3 minutes. The following example is a typical calculation of foam solution rate, and quantity of foam concentrate required for a machinery-type space.

Assume area to be protected is 3000 ft^2. Then the required minimum foam solution rate (R_{FS}) is:

$$R_{FS} = 300 ft^2 \times \frac{1.6 gpm}{10 ft^2} = 480.0 gpm$$

Assume that the foam proportioned introduces a 3% foam concentrate into the water stream at a rate (P_R) of 3.05% of the foam solution rate.

The quantity of foam concentrate (F_C) required for 3 minutes operation at the required foam solution rate may be calculated as follows:

$$F_C = R_{FS} \times \frac{P_R}{100\%} \times 3 \min utes$$

$$F_C = \frac{480 gal}{\min} \times \frac{3.05\%}{100\%} \times 3 \min utes$$

F_C = 43.92 = 44 gallons foam concentrate required.

If the system supplies foam solution at a rate of 500 gpm (in lieu of required 480 gpm), the quantity of foam concentrate required is still only 44 gallons.

A.3.2.2. Deck Foam System

Time is the critical feature of deck foam type systems. It is assumed that if a fire is not under control within 15 minutes, that it cannot be extinguished by the ship's crew. Therefore, the quantity of foam concentrate is required to be sufficient for 15 minutes operation at the actual foam solution rate. In determining the actual foam solution rate, no regulation of the water pump to reduce the rate of discharge is permitted. The following is a typical calculation.

Assume tile deck area to be protected is 40,000 ft^2 and largest tank is 2500 ft^2. The required minimum foam solution R_{FS} rate is:

$$R_{FS} = 40{,}000 ft^2 \times \frac{0.016 gpm}{ft^2} = 640 gpm$$

or $R_{FS} = 2500 ft^2 \times \frac{0.24 gpm}{ft^2} = 600 gpm$

Now, assume that hydraulic calculations show that the actual foam solution rate (R_A) is 680 gpm (in lieu of 640 gpm required). The quantity of foam concentrate (F_C) must then be sufficient for 15 minutes operation at 680 gpm, and may be calculated as follows:

$$F_C = R_A \times \frac{P_R}{100\%} \times 15 \min utes$$

where P_R = proportioning rate (assumed to be 3.05%.)

$$F_C = \frac{680gal}{\min} \times 0.0305 \times 15 \min utes$$

F_C = 311.1 = 312 gallons foam concentrate required.

For a "polar solvent" system the following is a typical calculation.

Assume the deck area to be protecte4 is 10,000 ft^2. The required minimum foam solution (foaming, concentrate and catalyst) R_{FS} is:

$$R_{FS} = 10{,}000 ft^2 \times \frac{0.032gpm}{ft^2} = 320gpm$$[14]

Now, assume that hydraulic calculations show that the actual foam solution rate (R_A) is 400 gpm (in lieu of 320 gpm required). The quantity of foam concentrate (F_C) must be sufficient for 15 minutes operation at 400 gpm, and may be calculated as follows:

F_C = F_C (concentrate) + F_C (catalyst)

$$F_C(concentrate) = R_A \times \frac{P_R}{100\%} \times 15 \min utes$$

where P_R = proportioning rate

$$F_C(catalyst) = \frac{P_R}{100\%} \times 15 \min utes$$

(1) $$F_C(concentrate) = \frac{400gal}{\min} \times 0.205 \times 15 \min$$

F_C(concentrate) = 1230 gallons foam concentrate

(2) $$F_C(catalyst) = \frac{400gal}{\min} \times 0.0206 \times 15 \min$$

F_C(catalyst) = 123.6 = 124 gallons catalyst

A.4. FOAM SYSTEM DESIGN

A.4.l. Fixed System

[14] Higher rates may be required on certain products.

In boiler rooms and similar spaces piping., and nozzles are fixed; nozzles must be so located as to spread a blanket of foam over the entire area protected. In general, no point of the area protected should be over 30 feet from a nozzle. If obstructions to the flow of foam are present, additional nozzles nay be required.

Nozzles protecting boiler flats should normally be installed to spread the foam under the floor plates (on the lower boiler flat). Foam will usually follow the path of a fuel oil spill in such arrangements, providing the maximum distance from the nozzles is not too great. In machinery spaces the nozzles should be designed to deliver foam to the engine room bilges. The distance from the bilge nozzles to the bilge should be no less than 6 inches. Residual fires above the floor plates in machinery spaces may be extinguished by the additional fire hydrants required. When the foam system is used to protect an oil-fired boiler installation on a boiler flat that can drain to the lower engine room, both spaces should be protected simultaneously. Nozzles should be located near the boiler flat and near the floor plates.

Nozzles may be located at either the deck (boiler rooms) or arranged to spray from the ceiling (pump rooms), depending upon the hazards present in the protected space.

A.4.2. Deck Systems

Deck Foam Systems were first required by the 1962 Tank Vessel Regulations in lieu of fixed pipe inert gas smothering systems led to the cargo tanks. This change was invoked to provide an improved fire protection system. With fixed pipe inert gas systems, rupture of a key inert gas line would make it impossible to get inert gas to the fire. Rupture of a tank would Rake it impossible to maintain an inert gas concentration.

The deck foam system is intended to protect any deck area with the required rate of flow from foam stations (monitors or hose stations) aft of the area. At least 50 percent of the required rate of application shall be from mounted devices. Mounted appliances have greater capacity, greater range, require fever people to operate and can be put into operation in a much shorter time than hand held devices. However, at least one hand held device shall be provided at each foam station for flexibility during the final stages of extinguishment. Piping and foam stations must be so arranged that ruptured sections of piping in way of a fire may be isolated. With this arrangement, wherever fire occurs, it will be possible to effectively fight the fire by working forward from the after house. (Assuming machinery and foam pumping and proportioning equipment is aft.)

A.5. PUMPS

Use of deck foam main is not to interfere with simultaneous use of the fire main. Specific provision is made to use the fire pump for operation of the foam main providing, in fixed systems, that the pump is located outside of the protected spaces. If the foam system supply is taken directly from the fire main a single fire pump must be capable of meeting the hose stream requirements while simultaneously providing the required foam solution rate. Such a system is frequently encountered in partial installations. See typical diagrams included in Part l - FIRE MAIN.

The foam main piping shall be used for no other purpose. To permit other use would require quite complex operating instructions, and destroy the concept of a versatilefire protection system which can be brought into immediate use. In addition, there would always be the possibility of pumping all of the foam out through the (say) ballast connection instead of to the fire.

B. DESIGN AND REVIEW OF SYSTEM

The following is a check-off list procedure for use in the design and review of mechanical foam systems. In case of any doubt, applicable regulations should be consulted to determine exact wording of the requirements.

Applications: Passenger & Cargo Vessels contracted for on or after 19 November 1952

Tank Vessels contracted for on or after 1 January 1962. Mechanical Foam Systems only.

Abbreviations: FX - Fixed Systems
DK - Deck Systems
PASS - Passenger Vessels
CAR - Cargo Vessels
TK - Tank Vessels

Foam solution, as used in this text, means a mixture of foam concentrate and water before air is introduced and the foam expanded. The term "water rate" is used in the Coast Guard regulations; its meaning is synonymous with that of "foam solution rate," for 3% and 6% concentrate system.

Numbers in brackets refer to the applicable subparts of the regulations.

B.1. A complete submittal for a foam system should contain the following information:

- B.1.1. Manufacturer's name and identification of each principal component by model or part number so that Coast Guard approval may be determined.
- B.1.2. Tabulation of areas (both total cargo and largest tank) protected by foam with supporting area calculations.
- B.1.3. Calculations of foam solution rate and amount of foam concentrate required to protect the above areas.
- B.1.4. A line pressure diagram showing the calculated operating pressure and flow at each foam outlet, at the inlet of the foam proportioner, and at the fire pump outlet. (May be included on system diagram.)
- B.1.5. Tabulated data supporting conditions calculated under (B.l.4) above.
- B.1.6. Detailed arrangements, sections, and elevations of the piping system.
- B.1.7. Fire pump capacity vs. head curve. Source of electric power for foam concentrate pump, if required.

B.2. Determine area of spaces to be protected (see chart, Subpart C).

B.3. For fixed systems, nozzle spacing and piping arrangements shall be such as to give a reasonably even distribution of foam over the entire area (34, 76 & 95.17-5(a)). If there are obstructions to foam flow from the nozzles, additional foam outlets may be required.

B.4. For deck systems, foam hydrants and nozzles should be located so that any portion of the open deck cargo area is protected with the required rate of flow (34.20-15(c)). Hydrants and monitors protecting a given area should be arranged so that a fire will not isolate outlets providing the required rate of flow to that area. Sufficient portable foam nozzles and hoses shall be provided for house aft structures to outfit two complete foam stations. The intent is to provide a hack-up station, not to reduce the total number of required stations. For split house configurations sufficient nozzles and hoses shall be located in each house.

B.5. Determine the foam solution rates required for the areas protected (see chart, Subpart C). In this regard a list of products to be carried shall be submitted for "polar solvent” cargoes.

B.6. Check line pressure calculations (flow and pressure at each outlet) to assure that the system will meet the requirements of (B.3) above. (See approved sample calculations in foam system design instruction book, e.g. National Foam Instruction Sheet #620 or #626 or Pyrene Design Data Book, JF-17S8 or R~~-36, Rev. 2). A minimum pressure of 50 psi is required at all foam producing outlets.

B.7. Calculate amount of foam concentrate (3~ or 6~) required to meet the discharge time requirements (see chart). It should be noted that foam concentrate required for fixed systems (boiler rooms, etc.) is based on the <u>required</u> rate while the foam concentrate for deck systems is based upon t e <u>actual</u> rate of foam solution flow. In determining this quantity for the deck foam system no manipulation of the fire pump discharge will be permitted.

B.8. Separate quantities of foam concentrate need not he provided for each space protected, hut only for the space requiring the greatest amount (76.17-S(e)(3); 9S.17-S(d); 34.17-5(d); 34.20-5(d)).

B.9. Compare fire pump characteristic curve(s) to conditions calculated under (D.5) above to determine if adequate to meet the required flow conditions.

B.10. Operation of the deck foam system shall not interfere with the simultaneous use of the fire main system (34.20-5(e)). Fire pumps may be used for other purposes providing one pump is kept available for use on the fire main at all times (34., 76., 95.10-5(e)). See Subpart A for discussion of pump requirements.

B.11. Controls, valves, foam concentrate container (34., 76., 95.17-10(b), 34.20-10(b)) and .pumps (76.17-5(c)(3), 34. & 95.17-5(e)(1)) shall be located outside of the space protected, and be accessible in event of fire in the space protected.

B.12 Control spaces shall he located convenient to one of the main escapes from the space (34., 76., & 95.17-10(b)), with complete but simple instructions located near the controls (34., 76., & 95.17-10(c)).

B.13. Deck foam Systems require sufficient block valves to effectively isolate the system in event of damaged piping in way of fire (34.20-15(c)).

8.14. Drains and dirt traps shall be fitted where necessary to prevent the accommodation of dirt or moisture (34., 76., 1 95.17-15(d), 34.20-15 (c)).

8.15. Two additional fire hydrants are required outside of machinery spaces to extinguish residual fires above the floor plates (34., 76., & 9S. 17-25(a)).

8.16. Check part numbers of system components to verify Coast Guard approval. (Piping: 34., 76., & 9S.17-lS(a), 34.20-15(a); Controls, foam concentrate I container: 34., 76., & 9S.17-l0(a), 34.20-10(a); Discharge outlets: 34.. 76., I 95.17-20(a), 34.20-20(a)). Model numbers of approved system components are listed in the design instruction booklets of the manufacturers (e.g. National Foam Instruction Sheet No. 620 or 626, Pyrene Design Data Book, JF-1753 or RTM-36, Rev.2) as listed in the Equipment Lists, CG-190. Approved components of more than one manufacturer may not be used in a single installation, except that foam concentrates of more than one manufacturer may be used in a single system if so listed in the approved manufacturer's instruction booklets.

C. SUMMARY OF AREAS PROTECTED AND FOAM SOLUTION RATES REQUIRED

(For Petroleum-type Cargoes Only)

SPACE PROTECTED	TYPE OF SYSTEM	AREA TO BE PROTECTED	FOAM SOLUTION RATE	DISCHARGE TIME
Boiler Rooms (O) (CAR, PASS, TK) Pump Rooms (O) (TK)	Fixed	Entire Bilge or Tank Top*	1.6 GPM/10 FT^2 (.17-5(b)(1))	3 Minutes @ Required Rate (.17-5(c))
Cargo Tanks (O) (CAR & PASS)	Fixed	Entire Liquid Surface Within Usual Range of Trim (.17-5(a)(3))	1.0 GPM/10 FT^2 (.17-5(b)(2))	5 Minutes @ Required Rate
Cargo Tanks (R) (TK)	Deck	Cargo Area, Defined as Maximum Beam Times Longitudinal Extent of Tanks (.20-3) or single largest tank	.016 GPM/FT^2 (entire cargo area)** or 0.24 GPM/FT^2 (area of largest tank)	15 Minutes @ Actual Rate (.20-5(c))
Enclosed Spaces (TK)	Deck	Actual Area of Space	1.6 GPM/10 FT^2 (.20-15(c))	5 Minutes @ Required Rate (.20-15(c))

(O) - Optional in Lieu of Other Systems
(R) - Required

*When Used to Protect Oil Fired Boiler Installation on Flat That Can Drain to Lower Engine Room, Both Spaces Shall be Protected Simultaneously (.17-5 (a)(2)).

**Deck System Assumes 10 Tanks Per Ship With One Tank on Fire, Flow Rate Then Becomes:

$$\text{Flow Req} = \frac{1.6\ \text{GPM}}{10\ \text{FT}^2} \times \frac{1\ \text{Tank}}{10\ \text{Tanks}} = 0.016\ \text{GPM/FT}^2$$

D. INSPECTION AND TESTING

D.1. INSTALLATION INSPECTION

In accordance with (71.20-15, 31.10-18 etc.) fire extinguishing installations are required to comply fully with the applicable regulations and be in accordance with approved plans.

As with any fire extinguishing system, the foam system should be installed so as to go into operation quickly. During plan review it is attempted to assure that rapid and simple operating is possible. However, there is no substitute for witnessing the actual operation of equipment.

Service contracts for maintenance of foam equipment are not as common as contracts for maintenance of carbon dioxide systems. This makes the Coast Guard inspection particularly important.

To assure that the foam system is properly installed, the following checks are recommended:

D.1.1. Deck Foam System

D.1.1.1. Foam outlets (nozzles), proportioners, and foam concentrate shall be Coast Guard approved as listed on the approved plan or in the Equipment Lists, CG-190. Hoses for the foam system should meet the sane requirements as fire hose.

D.l.l.2. It should be determined that operation of the foam system will not interfere with simultaneous use of the fire main.

D.l.l.3. The deck foam system should be operated, using water only, to assure that the fire pump and piping system are adequate to deliver at least the required rate of flow at a minimum Pitot pressure of 50 psi. If a foam monitor is installed, due to its high capacity it should be one of the pieces of equipment in this test.

D.l.l.4. The actual rate of flow obtained under (D.l.l.3) above should be determined. The quantity of foam concentrate should be approximately what is needed for 15 minutes operation of foam system at the actual rate.

D.1.1.5 Foam should be produced at least at one outlet to observe quality of the foam produced. Production of foam will also assure that the proportioning equipment is functioning properly Good quality foam should usually be rather fluid, but yet stable enough that it does not drain out into a solution quickly. The appendix of NFPA No. 11[3] gives a more complete description of foam. quality. Caution should be used to be certain that water will not get in the foam container to contaminate the foam during testing. It may not be possible to produce test foam in all systems because of contamination problems.

D.1.1.6 Controls should be clearly marked. Operating instructions should be postcd near the control equipment. These instructions should be simple, but must contain sufficient information for proper operation of the system. A diagram of the system is usually essential.

D.l.l.7. Determine, if possible, age of foam concentrate, and suitability for use with equipment installed. Recording batch number of foam concentrate should be sufficient for manufacturer to determine the age if this is not readily available. If in doubt, a sample should be submitted for test as per paragraph 31.10-18(d) of the regulations.

D.l.2. <u>Fixed System</u>

D.l.2.l. Items 1.1.1, 1.1.6 and 1.1.7 should be checked as for deck systems.

D.l.2.2. To assure that the foam piping and outlets are free of obstruction, the system should be flow tested with either air or water. Outlets may be temporarily capped, if necessary, to allow testing of one or two outlets at a time. Water is the preferred test medium as this will give the best indication of the systems efficacy. Water can be directed overboard by hose connections or allowed to flow to the bilges. Again the minimum outlet pressure must be 50 psi. Air can be used to give an indication that pipes are free of total obstruction. However, this will not give an indication of pressure or quantity available. Neither will it pick up smaller obstructions that could eventually clog nozzle when system is brought into use.

D.l.2.3. Each outlet of a mechanical foam system must have a device (foam maker) for introducing air near the nozzle to produce foam. Since test of the fixed system by making foam is not required, absence of these devices will not be readily apparent during testing, and should be carefully verified by visual inspection.

D.1.2.4 When the system protects a boiler flat or similar space, even through there is protection of the lower level, there should be a 9 inch coaming around the flat to assure that a foam blanker will be retained.

D.2. <u>Periodic Inspection</u>

D.2.l. Paragraph 31.10-18(d) outlines the testing procedure for testing deck foam systems biennially. Block valves in the deck foam main should be operated and left in the open position.

D.2.2. A water test of the fixed foam system should also be made.

D.2.3. The foam proportioner (and associated driving equipment if installed) should be operated.

D.2.4. operating instructions and valve markings should be conspicuously located At the tine of inspection it is suggested that operation of the system be reviewed with the Chief Engineer to assure his familiarity with equipment.

D.2.5. Check quantity of foam concentrate in tank. Also check quality.

D.2.6. Hose should be tested at a pressure of 100 psi or the maximum pressure to which it will be subjected in service.

IV. <u>WATER SPRAY</u>

A. DISCUSSION

A.1. GENERAL

Spray Systems take advantage of the principal advantage of water for fire-fighting purposes: its cooling, ability. breaking the water into small droplets allows it to vaporize more readily and more completely, thus absorbing more of the fire's heat. Water spray systems may be designed to perform any of a number of functions, such as extinguishment of fire, control of fire, or exposure protection. The objective of shipboard installations is complete extinguishment of the fire. In special purpose spray systems, as nay be installed aboard LPG carriers for the protection of tanks and house fronts, the function may be to reduce the quantity of heat absorbed by the tank or surrounding structure. These special purpose Systems are discussed later in this chapter.

Water spray is often preferred for protection of pump rooms because there is no danger of asphyxiation as with CO_2 and no mop-up as with foam. The supply of water is inexhaustible.

A.2. CHARACTERISTICS

There is no fine line of demarcation between sprinkler systems and water spray systems. The differences are primarily in water discharge pattern, water velocity, density of water application, and water droplet size.

Sprinklers have only one basic water discharge pattern, based upon the Underwriters Laboratories requirements. There are well designed rules for sprinkler spacing and size of supply piping, geared to this standard distribution pattern. Aboard ship sprinkler systems may be used to:

(1) Extinguish fires in Class A (wood, paper) combustibles.

(2) Protect the structural integrity of the vessel, or

(3) Confine flammable liquid (Class H) fires in small containers (e.g. automobile tanks) to the location of origin).

All of the above are based upon the minimum water application rate of 0.12 gpm/ft^2 for sprinklers, as required by regulation.

Water spray nozzles, on the other hand, may have any water capacity and discharge pattern. Pipe sizing and nozzle location must be individually engineered, based upon the nozzle characteristics. Water spray nozzles discharge water at a lower velocity and in smaller drop sizes. Nozzles are approved by the Coast Guard upon the basis of tests conducted in mock pump room installations using, diesel oil fuel. Water spray systems are installed aboard vessels to extinguish pump room fires. The rate of water application is considerable higher than for a sprinkler system ranging from 0.21 gpn./ft^2 to 0.46 gpm/ft^2 depending upon the nozzle used.

A.3. <u>APPLICATION</u>

Water spray is most effective on flammable liquid fires with flash points above the temperature of the water being applied. however, even gasoline fires may be controlled and sometimes extinguished by its use. The extinguishing mechanism of water spray in any fire situation depends upon the type of product burning, degree to which fire has developed, etc. Water spray extinguishes a fire by cooling, smothering, emulsification, or dilution, or by a combination of these factors. Normally, with fuel oils, and similar high flash point flammable liquids, water reduces the temperature of the burning liquid to below the flash point. This is accomplished by causing a surface emulsion (small drops of water suspended in non-water soluble compounds) of the liquid and by reducing heat transfer back to the liquid surface from the base of the flame. Thus, a fire nay be extinguished even before the entire body of the liquid is cooled below the flash point. In addition water applied in a fine spray to hot fires is vaporized as it absorbs the fire's heat, forming steam which tends to smother the fire in enclosed spaces. The spray also cools surrounding structural members reducing the danger of reignition once the fire has been extinguished. Against fires involving water soluble flammable liquids, tile water may dilute the liquid, raising its flash point.

A.4. DISADVANTAGFS

There are two disadvantages of water spray:

(1) The system is subject to malfunction if not properly tested and maintained, and

(2) Water spray should not usually be applied directly to live electrical hazards.

A.5. EFFECT'IVFNESS AND APPROVAL

According to numerous articles written on water spray systems, effectiveness of water spray depends upon (1) drop size, and (2) thrust of the spray. The combined drop size and thrust must be sufficient to penetrate through the tremendous "updraft" of tile fire to the surface of the burning liquid. Cooling the hot fire gases has little effect, instead the burning surface should be cooled. At the sane tine, the drop size must be small enough to allow complete vaporization of the water. The smaller the droplets, the more effective their cooling action because of their proportionally greater surface area and resultant higher rate of heat absorption. Coast Guard approval does not take these items into consideration directly, as by a system specification. Rather, approval is based upon actual extinguishment of fires in mock pump rooms.

The manufacturer requesting approval is permitted to arrange nozzles in any way desired, using any rate of application. If the fires are extinguished, the nozzles are approved, the approved application rate to be at least the minimum rate tested. The nozzle pattern and the height of the nozzle above the surface can be no greater than the maximum tested. Data on approved nozzles are included in Section 9 - NOZZLE CHARACTERISTICS.

In any design, at least 50 psig must be available at the most remote outlet.

Mock tests were conducted in 35' x 30' x 25' high pump rooms. Simulated catwalks were installed. It was found that open gratings did not materially reduce the effectiveness of the spray. However, fires under solid partial decks or catwalks low in the space, although suppressed, continued to burn. Additional nozzles under such obstructions are required. In the test arrangement it was found that a temperature of 2000^0F was reached within 3 minutes before the spray system was activated. Fires were extinguished in less than one minute.

A.6. SPECIAL PURPOSE STSTEM

For foreign flag vessels entering U. S. ports, and U. S. flag liquefied flammable gas vessels, a water spray system is required for protection of the cargo tanks extending above or mounted on the weather deck. In addition a water curtain shall be provided to screen the cargo area from the deck house where the crew is normally berthed or employed. The rate of discharge shall be at least 0.25 gpm per square foot of protected surface area. If a deck foam system, required for some other products, is arranged such that an effective water spray could be provided over the tank area, a separate water spray system will not be required. The system shall be designed to the capability of supplying water simultaneously to the deck house screen and the cargo tank area.

This system, it must be remembered, is basically for control and exposure protection. It is not designed to extinguish a fire.

A.7. PIPING

There are no specific regulations to govern the site of supply piping or the number of nozzles which may be installed on a single system for water spray systems, as there are for manual sprinkling or carbon dioxide systems. Each installation must be individually engineered. NFPA No. 15 contains sample hydraulic calculations which give reliable results in determining the water demands of spray systems. The hydraulic engineering method contained in that publication is recommended for designing water spray systems aboard ship. Designers should provide detailed hydraulic calculations for each installation to assure that 50 psi will be available at the most remote outlet. Spray system piping shall be of a corrosion resistant material. In addition, since the system is of the "dry pipe" type, piping must withstand temperatures up to 2000-2200^0 F until water can be supplied to the system. The following piping materials are acceptable for water spray installations:

(1) wrought iron, with 300 lb. malleable iron fittings

(2) Cupro nickel

(3) Aluminum bronze

(4) hard aluminum. brass

(5) Admiralty metal

Dissimilar metals should not be used in these piping systems. There are cases on record where the unauthorized use of dissimilar metals caused electrolysis and subsequent failure of the system.

Threading compound should not be used. The use of threading compound increases the possibility of clogging strainers by foreign material.

A.8. PUM1PING CAPACITY

Regulations require that the pump supplying water for the system be reserved exclusively for the system or that one of the required fire pumps be increased by the capacity of the system. These requirements are based upon two assumptions:

(1) That the water spray system is taken directly from tile firemain near the water spray installation, and

(2) That the water must be available quickly and not be jeopardized by, or jeopardize, the simultaneous use of the fire main system.

However, there is an additional, equally acceptable alternative for supplying the water spray system. This is done by taking the water supply from the fire pump manifold and locating the water spray system control valve near the pump. A separate supply line is then run to the water spray system, similar to a foam system arrangement. This permits supplying water quickly without interfering with the fire main. This arrangement spay even be superior to supplying water from the fire main and locating control valve near the system, since remote starting of fire pumps is not required.

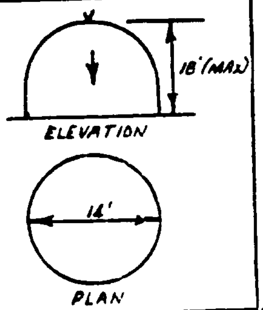
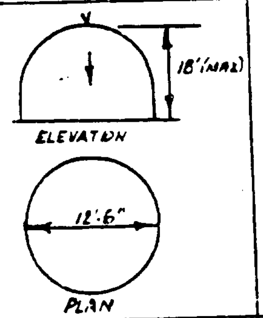
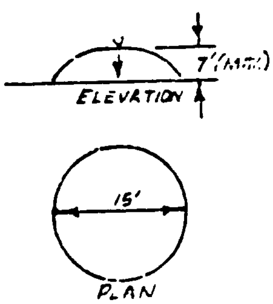
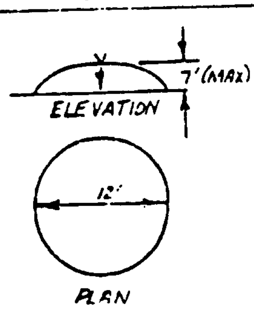
A.9. NOZZLE CIIARACTERISTICS

The following tables give nozzle characteristics for various manufacturers.

A.9.1 Bete Fog Nozzle, Inc.

Discharge Characteristics of CG Approved
Water Spray Nozzles

— Test spacing of Bete nozzles was 8'-0" between nozzles, 12'-0" between lines. Maximum distance from nozzle to wall, 10'-0", one line only.

WATER DISCHARGE PATTERN	MODEL	NOZZLE CAPACITY
	MODEL N5S	Nozzle Capacity: 37 GPM @ 50 PSI 52 GPM @ 100 PSI Application Rate (Min.)* 0.42 GPM/FT^2
	MODEL N3S	Nozzle Capacity: 18.4 GPM @ 50 PSI 26.1 GPM @ 100 PSI Application Rate (Min.)* 0.21 GPM/FT^2
	WIDE SPRAY MODEL N5WS	Nozzle Capacity: 37 GPM @ 50 PSI 52 GPM @ 100 PSI Application Rate (Min.)* 0.46 GPM/FT^2
	WIDE SPRAY MODEL N3WS	Nozzle Capacity: 18.4 GPM @ 50 PSI 26.1 GPM @ 100 PSI Application Rate (Min.)* 0.23 GPM/FT^2

* Application rates are the minimum (Avg.) for which nozzles were tested in mock pump room tests using diesel oil fuel. Design rates should not be less than the test rate. (Minimum rates not included in test data, but derived from test results). IV([illegible]

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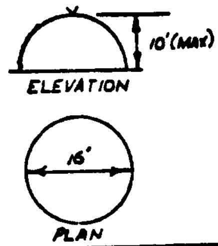
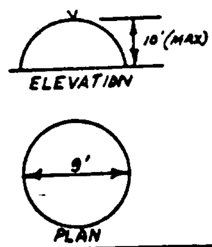
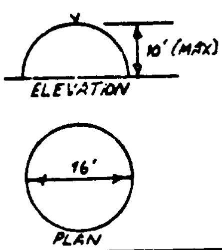
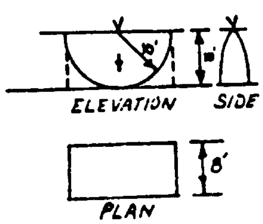
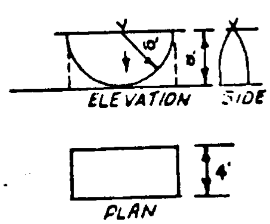
A.9 .2 Akron Brass Mfg. Co.

Discharge Characteristics of CG Approved
Water Spray Nozzles

WATER DISCHARGE PATTERN	MODEL	NOZZLE CAPACITY
	MODEL 1" - BM - 54	Nozzle Capacity: 54 GPM @ 100 PSI 37 GPM @ 50 PSI Application Rate (Min.)* 0.46 GPM/FT^2
	MODEL 1/2" - BM - 15	Nozzle Capacity: 15 GPM @ 100 PSI 9 GPM @ 50 PSI Application Rate (Min.) 0.27 GPM/FT^2
	MODEL 1/2" - DM - 34	Nozzle Capacity: 34 GPM @ 100 PSI 24 GPM @ 50 PSI Application Rate (Min.) 0.32 GPM/FT^2
	MODEL 1" - DM - 24	Nozzle Capacity: 24 GPM @ 100 PSI 17 GPM @ 50 PSI Application Rate (Min.) 0.26 GPM/FT^2 Test Spacing - 15' O.C.
	MODEL 1/2" - DM - 15	Nozzle Capacity: 15 GPM @ 100 PSI 10 GPM @ 50 PSI Application Rate (Min.) 0.32 GPM/FT^2 Test Spacing - 10' O.C.

* Application rates are the minimum rates (Avg.) for which nozzles were tested in mock pump room tests using diesel oil fuel. Design rates should not be less than the test rate. (Minimum rates not included in data, but derived from test results).

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B. DESIGN AND REVIEW OF SYSTEM

This is a check-off type of procedure, listing items which should be considered in designing and reviewing water spray Systems... For interpretation of individual items, reference should be made to the preceding discussion section. In case of any doubt, applicable regulations should be consulted for exact wording of the requirements.

Application: TANK - Contracted for on or after 1 January 1964.
PASSENGER & CARGO - Contracted for on or after 19 November 1962.
BULK DANGEROUS GOODS -

Where permitted: TANK - Pump Rooms, Lamp and Paint Lockers.
CARGO - Oil-fired Boilers[15], Lamp and Paint Lockers.
PKSSENGER - Oil-fired Boilers
BULK DANGEROUS GOODS - Tanks above deck and deck house fronts

Note: Only carbon dioxide type extinguishing Systems are permitted to be installed for protection of spaces containing internal combustion propelling machinery.

Due to the above, this subpart is written for the protection of pump rooms, where the system is used almost exclusively. Proposals for other installations should follow this subpart as well as SOIAS, 19608 (Chapter II, Regulation 62) as applicable.

(Numbers in parentheses refer to applicable regulations)

B.1. Select nozzles to be used: must be Coast Guard approved (34.25-20) and (153.32-20). Approval also designates minimum pressure (50 psi) and maximum height that nozzle may be installed above the protected area.

B.2. Capacity and arrangement of the system must be such as to effectively blanket the area protected (34.25-5(a)) and (153.32-5). Compliance with this requirement is related to which approved nozzles are used, and includes the following factors:

(1) Minimum rate of water application for which nozzle was tested.

(2) Spray pattern of the nozzle, and

(3) Height of the nozzle above the protected area (34.25-5(b)) and (153.32-5(b')).

These factors are more fully discussed in the preceding subpart.

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[15] Recent changes to the regulations eliminate the specific requirements for fixed water spray systems from the Passenger and Cargo Vessel regulations. This is because:

(1) No installations of water spray systems for protection of oil-fired boilers on the vessels have been proposed, and

(2) The 1960 SOLAS Convention increases the requirements for such systems protecting oil-fired boiler installations. Under 1960 SOLAS, the System is required to be charged to the necessary pressure at all times with the provision that a pressure drop in the system shall automatically start the pump.

B.3. To check the pattern, show the nozzle locations on plan and elevation views and sketch in water distribution pattern of the nozzles. Obstructions to distribution nay require additional nozzles (34.25-5(b)) and (1S3.32.5(b)).

B.4. In the event that considerable piping or pumping requirement is installed above the highest spray nozzle, it nay be necessary to provide additional nozzles to protect this equipment (see NFPA No. l5, 25.40).

B.5. Water supply must be from outside of space protected and in no way dependent upon power from the space protected (34.25-5(c)).

B.6. Pumps supplying water for the system shall be reserved exclusively for the system or the capacity of one of the <u>required</u> fire pumps, as set forth in 34.10, shall be increased by the required capacity of the system so that this system may be used simultaneously with the fire main system (34.25-5(c)) and (153.32-5(d)). however, if the water spray system is supplied from the fire pump manifold in such a way that it would not interfere with simultaneous use of the fire main system, and in such a way that it can be put into service quickly, this would be acceptable.

B.7. The control valve shall be outside of the space protected and as convenient as possible to one of the escapes from the space (34.25-10) and (153.32-10). However, if the water spray system is supplied from. the fire pump manifold, as described in (B.6), the control valve nay be near the pump. It is not necessary to be able to start the pumps from the control station.

B.8. Complete, but simple, operating instructions shall be posted near the controls (34.25-10). Controls shall be marked as required by 35.40-18.

B.9 Piping shall be of a heat and corrosion-resistant material (34.25-15(a) and (b)) and (153.32-15(a) and (b)). See discussion section for list of acceptable materials. Threaded joints should be metal to metal; no threading compound should be used.

B.10. Drains and dirt traps shall be fitted where necessary to prevent accumulation of dirt and moisture (34.25-15(d)) and (153.32-l5(d)). Line strainers are required to have a total clear area equal to five times the area of the pipe in which it is installed. Approval of spray nozzles also includes approval of the associated strainer, if require(1.

B.11. Water distribution and water supply for the system should be verified by hydraulic calculations. Good engineering is not a complete substitute for testing the installation, but it is important to resolve system deficiencies in the design stage.

C. INSPF.CTION AND TESTING

C.1. Water spray nozzles shall he Coast Guard approved, and 'mist be the same type as indicated on the approved drawing.

C.2. Water supply (pump capacity) should be checked by operating water spray system and firemain simultaneously. Minimum pressure at the most remote spray nozzle should be 50 psi.

C.3. Water distribution pattern of the spray system should be checked. This may be done by entering space as the system is operated. If the system is operating properly, the space should be filled with a dense water fog. (Flush with fresh water after testing).

C.4. Following flow tests of the system, the line strainer and all nozzle strainers should be checked and determined to be free of obstruction.

C.5. Check location of control valves. They must be near the fire pump or convenient to one of the main escapes from the spaces.

C.6. Complete, but simple, operating instructions shall be posted near the controls.

V. MANUAL SPRINKLING SYSTEM

A. DISCUSSION

A.1. GENERAL

Aboard U. S. vessels, sprinkler systems are employed in only very limited locations. In method I (SOLAS), primary dependence is placed upon structural fire protection rather than automatic sprinkler protection. This is in contrast to the British method (method II) in which combustible construction is permitted in combination with a complete sprinkler system. (Method II employs an automatic in lieu of a manual sprinkler system).

A sprinkling system will accomplish two things:

(1) It will extinguish fires in class A (wood, etc.) combustibles, as well as high flash point (above 200^{0}F) combustible liquids.

(2) It will control the heat output from flammable liquid (e.g. gasoline) fires and at the same time offer protection to the overhead of the protected space.

In installations protecting vehicular decks the system should be designed to protect the structural integrity of the vessel, confine the fire to the location of origin, and wash the flammable liquid to a safe location. Installation on vehicular decks, such as aboard ferry vessels, is the primary marine use of sprinkler systems in this country.

There is no sharp line of demarcation between sprinkler Systems using standard sprinklers and water spray systems. The primary differences are in water discharge pattern, water velocity, density of water application, and water droplet size.

Sprinklers have one basic discharge pattern and must distribute water in accordance with a standard distribution pattern established by Underwriters Laboratories. There are well developed standards for pipe sizing and sprinkler head spacing based upon this standard discharge pattern. Regulations require a minimum application of 0.12 gpm/ft^2. Sprinkler systems, as installed aboard vessels, are primarily for protecting the structural integrity of the vessell limiting the spread of fire, and controlling the amount of heat produced.

Water spray nozzles are of different sizes and distribution patterns. These systems are usually designed to provide greater water densities in smaller drop sizes than are sprinkler systems. Pipe sizes, nozzles and nozzle spacing must be selected for each installation so as to effectively distribute the required quantity of water. Water spray systems are more effective in extinguishing fires in low flashpoint flammable liquids.

A.2. TYPES OF SPRINKLERS

When the regulations were written, what is now termed the ”old-type” sprinklers were then in common use. Coast Guard regulations were written around such sprinklers.

The old-type sprinklers were designed to spray a portion of the water against the over head for the purpose of cooling it.

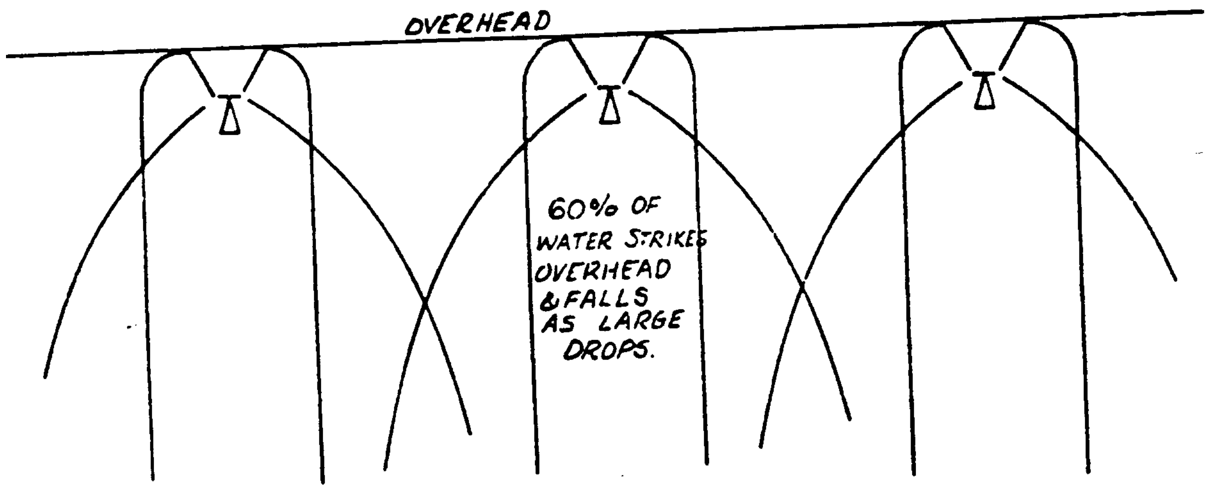


Figure V.A.1 Discharge Pattern of Old-Type Sprinklers

This was the basis upon which the "effectively spray the overhead" provision of the regulations was developed.

Subsequent to publication of these regulations, however, the "standard" sprinkler head was developed This sprinkler does not direct any water against the overhead. Tests have proven that with standard sprinklers the water distribution is more uniform and the system is more effective. The overhead is given equivalent protection.

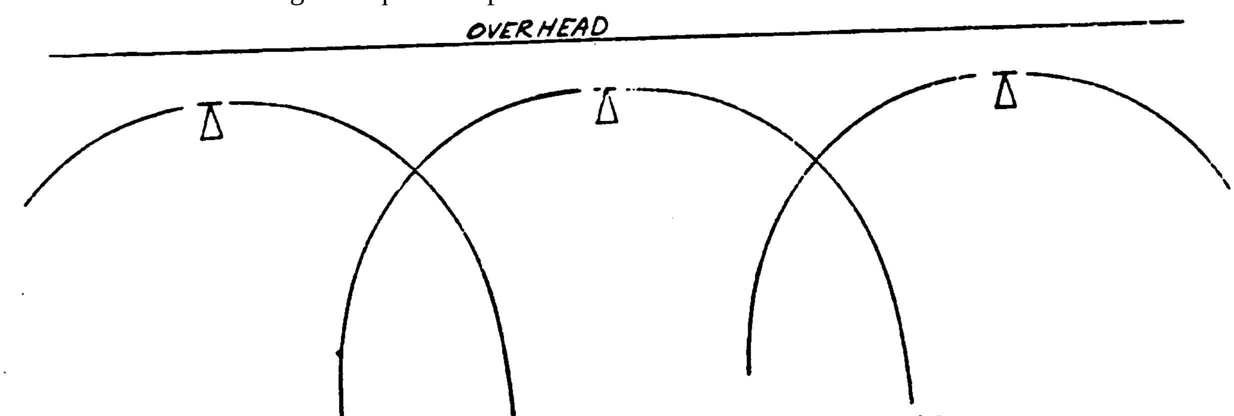


Figure V.A.2 Discharge Pattern of Standard Sprinklers

Use of "standard" sprinklers should be encouraged in lieu of the "old-type" because they afford batter protection at similar spacings. Since the regulations were written in contemplation of "old-type" sprinklers, their use is permitted. "Old-type" sprinklers may be installed in either upright or pendent position. If "standard" sprinklers are installed in the pendent position, they must be so designed; the designation "pendent" will be marked on the deflector. Distinction between "old-type" and "standard" sprinklers may be made by examining the manufacturer and model designations stamped on the frame or deflector of the sprinkler. Reference to underwriters Laboratories Fire Protection Equipment List will indicate sprinkler type. In installations, "standard" sprinklers " may be used to replace the "old-type;" but "old-type" replacement of "standard" sprinklers should not be permitted.

A.3. <u>SPACING OF SPRINKLERS</u>

No portion of the overhead shall be more than 7 feet from a sprinkler.

A.3.l. Old-Type Sprinklers

Spacing of "old-type" sprinklers should be based on one sprinkler to not more than 100 ft^2 of deck area, regardless of Pitot pressure at the sprinkler head (15 psi Pitot is, of course, the minimum). Greater spacing should not be allowed since the major portion of the water is directed against the overhead.

If sprinklers on alternate lines are not staggered,

the seven feet from sprinklers is controlling, and the arrangement must be such that $\sqrt{A^2 + B^2}$ is 14 feet or less.

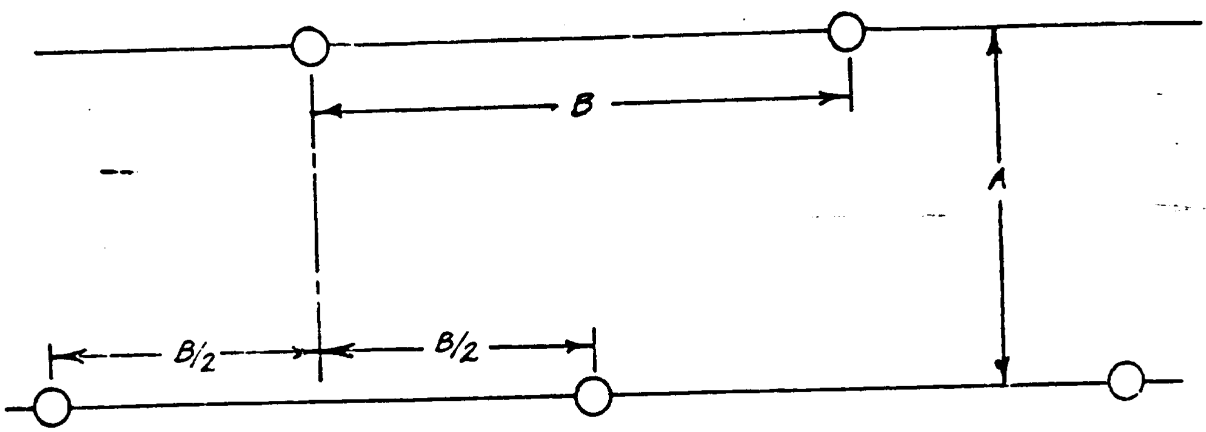


Figure V.A.4 Sprinklers on Alternate Lines Staggered

If sprinklers on alternate lines are staggered, the 100 ft^2 limitation becomes the controlling factor, and A x B must equal 100 ft^2 or less.

Staggered spacing is preferred; it gives better water distribution. If the spacing is other than full staggered, the sprinklers should be considered non-staggered. Regulations were developed in contemplation of non-staggered or fully-staggered arrangements. With 15 psi Pitot at the head, the 5/8" diameter sprinkler will deliver l2 gpm, meeting the 12 gpm/l00 ft^2 requirement.

A.3.2. Standard Sprinkler

Due to the superior water distribution of "standard" sprinklers, the "maximum of seven feet from a sprinkler" criteria may be applied in all instances. With staggered spacing, this would permit one sprinkler to cover an area greater than 100 ft^2. If this is done, the minimum Pitot pressure at the most remote outlet must be increased such that the required 12 gpm per 100 square feet is still applied to the deck area. The Pitot pressure necessary to deliver the required quantity of water through a 3/8-inch diameter sprinkler Ray be estimated in accordance with the following section.

A.3.2.1. Sprinkler Characteristics

$$Q = 29.83cd^2\sqrt{P}$$

where Q = flow (gpm)
C= coefficient of discharge (0.75)
d = orifice diameter 9inches)
P = Pressure (psi)

$$Q = K\sqrt{P}$$

where K = 3.15

at 15 psi Pitot pressure, Q = 12.2 gpm.

If a standard sprinkler is designed to protect 120 ft^2, the lowest Pitot pressure required would be:

$$Q = 120\,ft^2\left(\frac{.12\,gpm}{ft^2}\right) = 3.15\sqrt{P}$$

or $$P = \left(\frac{14.4}{3.15}\right)^2 = 20.9\,psi\,(\min imum)$$

Similar calculations can be made for any individual design.

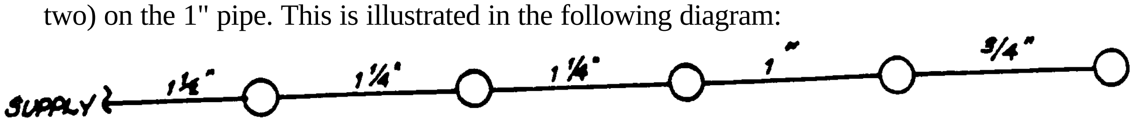
End sprinklers may be a distance from the bulkhead equal to one half of the line distance between heads. Reference should be made to NFPA No. l3 for standard spacing of end sprinklers on alternate lines and spacing of lines adjacent to bulkheads.

Care must be taken in referring to NFPA No. 13 as criteria for vessel installations. Sprinklers for land installations have a ½” diameter opening; the Coast guard specifies a 3/8” diameter opening.

A.4. PIPE SIZING

The pipe-sizing schedule listed in the Coast Guard regulations is arranged so that if 15 psi Pitot pressure is available at the most remote sprinkler head, it will be available at every head in the system. This is true providing there is no appreciable difference in elevation head between the sprinkler heads.

The number of sprinkler heads listed in the piping schedule which may be served by a given diameter of pipe refers to the total number of sprinklers. The table states that a 3/4" pipe may serve one sprinkler, a 1" pipe may serve two sprinklers, etc. For example, assume the end pipe of a system is 3/4" in diameter and serves one sprinkler. The next length of piping must be 1" in diameter. The two sprinklers served by the 1" pipe means the one on the 3/4" pipe plus one (not two) on the 1" pipe. This is illustrated in the following diagram:



Detailed hydraulic calculations are usually not required. However, in systems of unusual design or where there is a question regarding the system's adequacy hydraulic calculations demonstrating that 15 psi will be available at all outlets should be prepared.

A.5. DRAINAGE

Consideration should be given to drainage of water from sprinkled Spaces. Gasoline will float on the surface of the water and, although suppressed, will continue to burn. Drainage should be to a safe location such as over-board drains which will not allow the burning liquid to flow into openings below. Drainage must also be adequate so as to preclude a stability problem.

A.6. RELIABILITY

As with water spray systems, the greatest drawback of a sprinkler system is its unreliability. Sprinkler lines and sprinkler heads have a tendency to clog with foreign matter if not tested frequently and flushed with fresh water after testing. Fire pump suction seachests for sprinkler pumps have become so clogged as to cause the fire pump motors to burn up due to lack of testing. If properly designed and maintained, a sprinkler system can be among the most effective fire fighting mediums aboard a vessel. However, long experience has demonstrated that because of the difficulty of testing without damaging the interior and finishings, that proper maintenance is seldom performed and the system will not operate as designed.

A.7. NAVY SPRINKLER SYSTE~S

Frequently on MSC and missile resupply ships a magazine-type sprinkling system of Navy design is proposed for protection of missiles, ammunition lockers and similar spaces. The systems proposed generally cover rather large areas and are highly automated. In addition, standard Navy equipment such as nozzles, etc. are used in these systems. The water sprinkling rate for these systems is generally equal to or slightly less than the required rate for systems contemplated by the Coast Guard. Due to the extremely sensitive nature of spaces protected, the systems are designed to operate automatically within a period of a few seconds.

Coast Guard regulations do not contemplate these high capacity, automatic sprinkler systems, nor hazards of the nature which they are designed to protect. For these reasons, Navy design Systems, including Navy (or Mil Spec) equipment, and sprinkling rates may be accepted on special service vessels, the nature of whose contents are not contemplated by Coast Guard regulations without a compromise of vessel safety. This is providing that (1) accessible manual valves are available to open or close the system manually should this be necessary, and (2) that operation of the Navy-type sprinkler system does not interfere with simultaneous operation of the vessel's firemain. In other words, the fact that the system is basically, of Navy design does not reduce any requirements considered necessary for the safety of other portions of the vessel.

In these designs special consideration should be given to the quantity of water discharged from the sprinkler system, as excessive quantities may seriously impair the vessel's stability.

Navy type automatic detection Systems may also be accepted in conjunction with these Systems.

When sprinkler Systems are proposed in areas required to be so protected by Coast Guard regulations, a Coast Guard approved system must be installed. A Navy system is not acceptable.

B. DESIGN AND REVIEW OF SYSTEMS

This procedure is an outline of essential items which should be considered in designing and reviewing sprinkler systems. For interpretation of individual items, reference should be made to the preceding discussion section. In case of any doubt, applicable regulations should be consulted for exact wording of requirements.

Application: PASSENGER VESSELS - Contracted for on or after 19 November 1952[16]

CARGO VESSELS - No provisions, if permitted or required under equivalency paragraph, apply passenger vessel rules

TANK VESSELS - No application

Where Required: (1) Vehicular decks (defined as a deck designed for the carriage of automobiles with fuel tanks containing gasoline, with one or both ends open, such as is found on ferry vessels).

(2) Cargo spaces which are accessible during the voyage. (This may also include protection of automobiles in specially designed automobile carriers providing special considerations are given to drainage.

Numbers in parentheses refer to applicable subparts of the regulations.

B.1. Check over-all arrangement of vessel to determine number and arrangement of sprinkler zones required.

B.2. The following guidelines should be used in determining required zoning:

(1) Separate zones may be used for each deck (76.23-5(a)).

(2) On any particular deck, spaces separated by "A" or "B" class bulkheads may be zoned separately.

(

(3) In common areas (that is, a large space on a single deck that is -not subdivided by "A" or "B" class bulkheads) the number of zones shall be as required by table 76.23-5(b).

B.3. Zones in common areas shall be approximately the same size. Zones of this type shall be arranged to overlap so that the end heads of adjacent zones cover an identical area (76.23-5).

B.4. Layout the sprinkler arrangement. Sprinklers must be arranged such that:

(1) No portion of the overhead is more than 7 feet from a sprinkler head (76.23-10(b)(l)), and

(2) At least 12 gpm is applied to each 100 ft^2 of deck area (76.23-10 (a)).

The requirement appearing in the regulations that the overhead is to be effectively sprayed is applicable only if "old-type" sprinklers are used.

For a more complete discussion of item B.4. see preceding Subpart A.3.

[16] Passenger Vessel Regulations also have provisions for automatic sprinkling systems, but they are seldom, if ever, installed aboard U. S. vessels.

B.5. Sprinklers shall be so located that there is no obstruction of the distribution of water by frames or girders. At the same time the sprinklers should be located close enough to the overhead to afford protection to the overhead. A maximum distance of 16 inches below the frames is recommended. (See NPPA No. l3 (7110 and 7120) as reference).

B.6. Check pipe sizing based upon number of sprinklers served. (Table 76. 23-10(e)). If piping is sized in accordance with the schedule (that is one sprinkler on a 3/4" pipe, two[17] on a 1" pipe, etc.) and 15 psi Pitot pressure is available at the end sprinkler head, it will be available at every head in the system (providing there is no appreciable difference in elevation heads).

B.7. Locate control valves for system. Must be outside of space protected and accessible in event of fire in the protected space (76.23-15(a)). The control shall be marked as required by 78.47-15.

B.8. Determine pumping requirements. Pumps must be sufficient to operate all sprinklers in a single zone at a minimum Pitot pressure of 15 psi (see item #B.6). In addition, on vessels over 750 gross tons, the capacity shall also be sufficient to operate the second largest zone (76.23-10(d)(i)). Fire pumps may be used to supply water to the sprinkler system as described above, providing the combined pump capacity is sufficient to simultaneously meet the hose stream requirement of 76.10-5(c) in addition to the sprinkler system.

B.9. Pipes shall be securely supported, and where necessary, protected against injury (76.23-20(c)).

B.10. Pipe and fittings shall meet the applicable requirements of Subchapter F (Marine Engineering).

B.11. Drains and dirt traps shall be fitted where necessary to prevent accumulation of dirt or moisture (76.23-20(d)).

B.12. Piping shall be used for no other purpose (76.23-20(e)).

B.13. Sprinkler heads are to be of the open-type, 3/8 inch in diameter (76. 23-10(b) (1)).

8.14. Provide sprinklers of an approved type (76.23-2S). However, the Coast Guard does not specifically approve sprinklers. Sprinkler heads listed by Underwriters Laboratory are accepted as meeting this requirement. "Standard" sprinklers are preferable to "old-type" sprinklers. See preceding Subpart of further discussion. Part numbers of approved components should be listed on the drawings(s) for ease of identification during plan review and inspection.

C. INSPECTION AND TESTING

It is difficult to perform effective tests of sprinkler system installations due to the nature of the spaces which they protect. Water damage can easily be incurred within accommodation or storage areas. However, it is essential that the system be tested as thoroughly as possible at regular intervals. Installation of the sprinkler equipment is of little value if it does not function properly in time of emergency. The following testing procedure is recommended.

[17] The number of sprinklers that may be supplied by a given size pipe refers to the total number of sprinklers. For example, it the end pipe is 3/4" diameter, it may serve one sprinkler. If the next section of pipe is 1" in diameter, it may serve a maximum of one additional sprinkler, making a total of two sprinklers (one on ¾” and one on 1") served by the 1" diameter pipe.

C.1. INITIAL INSPECTION

C.1.1. Determine adequacy of pumping capacity to supply the largest (or two largest) sprinkled zones. Preferably this test should be made prior to the installation of easily damaged equipment by actually pumping water through the largest sprinkled zone(s) and measuring the Pitot tube pressure at the most remote outlet. This pressure must be a minimum of 15 psi. If the fire pumps are used, the required number of fire hoses must be operated simultaneously with the sprinkler system. If performing an actual system test is not possible, the water demand for the sprinkler system may be approximated. A rough estimate of the water demand would be:

(1) Approximately 14 gpm per head in the largest zone if separate pumps are installed or

(2) Approximately 18 gpm per head plus required number of hose streams if the fire pumps are used.

The pump(s) should be capable of delivering this quantity of water through a number of hose streams at a minimum Pitot tube pressure of 25 psi plus the difference in elevation head, if any, between the hose stream and the highest sprinkler(s) in case (1) or a minimum Pitot tube pressure of 50 psi in case (2). (Flush with fresh water after testing). If separate pumps are provided, and it is not possible to cross-connect the pump with the firemain to test as described above, a alternate means of measuring pump capacity must be devised.

C.l.2. Review valve and piping arrangement to assure ease of system operation. Control valves should be so located that they are accessible in event of fire in protected space. Fire pumps must also be accessible in event of fire in protected space.

C.l.3. Review sprinkler spacing and location. Sprinklers should be located as shown on the approved plans and such that there is no obstruction to water distribution. Sprinklers should usually be not lower than 16" below deck frames.

C.l.4. Check pipe sizing based upon the number of sprinklers served. Pipes should be securely supported.

C.l.5. Determine that approved sprinkler heads are used. Coast Guard regulations call for 3/8" orifice diameter sprinklers. Other, including larger, diameters should not be accepted unless specifically approved on plans. Large diameters may mean that the pumping capacity is inadequate and the over-all effectiveness of the system is reduced. Open-type sprinklers are required.

C.l.6. Drains and dirt traps should be installed to assure proper maintenance of the system.

C.l.7. Assure that control valves are properly marked to identify zone which they control.

C.2. PERIODIC INSPECTIONS

C.2.l. If practicable operate the system with water. If this is not possible, remove a sprinkler or flushing connection near the most remote sprinkler in the system. All other sprinklers must be plugged to prevent damage. More than one connection or sprinkler my be removed if deemed necessary. Connect suitable hose etc. to flow water overboard or to other safe location from the selected outlets. Systematically remove other sprinklers and plug other openings to further test the zone as necessary. operate pumps, discharging water through the selected outlets, to assure that the lines are free of obstruction. (Flush with fresh water after testing).

C.2.2. Visually inspect all open sprinklers to determine that they are free of obstruction.

C.2.3. Operate control valves and verify that they are properly marked.

C.2.4. Open drain traps to eliminate any water trapped in system.

C.2.5. Verify that dirt traps are not clogged or obstructed.

If the system shows signs of excessive corrosion, has not been tested for a considerable period of time, or does not function properly in the partial discharge test described in 2.1, an actual operational test is recommended. The performance record of sprinklers aboard vessels has been poor at best. Further information on the maintenance and cleaning of sprinkler systems is contained in NFPA, No. 13A - Care and Maintenance of Sprinkler Systems, the Handbook of Industrial Loss Prevention (Factory Mutual), and the NFPA Fire Protection Handbook.

VI Halon Systems

A.1. General

Total flooding halon fire extinguishing systems are appropriate for enclosed spaces where fires involving electrical equipment or gaseous and liquid flammable materials may occur. The extinguishing agents used in these systems are halogen substituted hydrocarbons. Several different halon agents exist with variations in the amounts of carbon, chlorine, bromine, and fluorine in the compound. The accepted nomenclature system for these compounds describes the molecular composition of the agent. Each agent is given a number, the first digit represents the number of carbon atoms, the second fluorine, the third chlorine, the fourth bromine, and the fifth iodine. Terminal zeros are dropped. The three most common halogenated extinguishing agents at present are: Bromochlorodifluoromethane (Halon 1211), Bromotrifluoromethane (1301), and Dibromotetrafluoroethane (Halon 2402). Halon 1301 is the only halogenated agent currently accepted by the Coast Guard for fixed shipboard fire extinguishing systems. Other halons are unacceptable because they are either highly toxic themselves, or they can form unacceptable amounts of toxic products of decomposition when exposed to fire. portable fire extinguishers widely used in the past contained Halon 104 (Carbon Tetrachloride) or Halon 1011 (bromochloromethane). Due to the toxicity of both these agents, their marine use was banned by the Coast Guard in 1958. Currently, both Halon 1301 and Halon 1211 portable extinguishers are available, which carry Coast Guard marine approval.

Halon 1301, even though acceptable for shipboard use, is somewhat toxic; however, if discharged properly, the toxic effects are minimal. Halon 1301 is a colorless, odorless gas which chemically interacts with the combustion process to inhibit combustion. Although it is similar to carbon dioxide in application and storage, its extinguishing action is produced by an entirely different process. Halon 1301 chemically interrupts the process which produces combustion, while carbon dioxide extinguishes flames by displacing the atmosphere to effectively reduce the oxygen content below a point where combustion can occur. Halon 1301 should not be used to protect hazards involving chemicals capable of rapid oxidation in the absence of air, combustible or reactive metals, and metal hydrides. Additionally, the use of Halon 1301 on Class A materials has not been thoroughly researched by the U. S. Coast Guard at present and is therefore not acceptable for the protection of cargo holds when carrying general cargoes.

Halon 1301 systems are designed to limit the production of toxic products of decomposition. If Halon 1301 is heated above 900^0F (482^0C), it breaks down to form hydrogen fluoride, free bromine and carbonyl halides. Full scale tests involving flammable liquid fires, conducted at the Coast Guard Fire and Safety Test Facility have shown that if Halon 1301 is discharged into a burning machinery space in 10 seconds or less, the amount of toxic decomposition products formed are of less consequence than the normal combustion products such as carbon monoxide.

A.2 Coast Guard Approval of Halon 1301 Systems

At present, Title 46 of the Code of Federal Regulations does not contain any provisions for the design or requirements of Halon 1301 systems aboard commercial vessels. In essence, the approval of these systems is based upon a provision within the Code of Federal Regulations that grants to the Commandant of the Coast Guard the authority to allow new or unique systems, if it is adequately demonstrated that the proposed system is equivalent to the existing system required by the regulations. Carbon dioxide total flooding fire protection systems are the systems to which Halon 1301 systems must prove equivalence. Therefore, Coast Guard approved Halon 1301 systems are required by Federal Law to be designed with an equivalent degree of fire protection capability and reliability. Where basic deviations in design occur due to the use of the Halon 1301 agent, specific adaptation to the regulations have been developed.

The basic design philosophy of carbon dioxide systems, however, has been retained for halon systems:

a. The protected space must be evacuated before the system is discharged. Pre-discharge alarm is required.

b. The agent storage containers must be located outside of the protected space, except for spaces less than 6000 ft^3 and modular type halon systems.

c. Two separate and distinct actions must be performed to discharge the agent.

d. Manual type release devices are required; automatic release is permitted only for spaces less than 6000 ft^3.

e. Detailed instructions must be provided at the remote release station to explain alternate means of discharging the system.

A.3 Specific Areas of Concern Involving Halon Agents

1. One feature of halon fire extinguishants that must be kept in mind is the possible hazard they may present to personnel. The agents have a certain degree of inherent toxicity; however, if designed and handled properly, the halon agents and systems present no greater risk than carbon dioxide extinguishing equipment and usually much less. Of the current halon agents, 1301 is considered the only halon fire extinguishant which may be used for total flooding applications onboard vessels. The Coast Guard requires a minimum 6% by gross volume concentration (volume 1301/volume air) of the agent for fire extinguishing Systems. At this concentration, toxic effects are minimal; however, personnel should not be exposed to a 7% concentration for more than one minute and a 10% concentration may well be regarded as unsafe for human exposure.

   To adequately protect personnel from these hazards, the Coast Guard requires the protected space to be evacuated before Halon 1301 discharge. Additionally, a warning sign is required at each entrance to the protected space, warning personnel that re-entry of the space, after the system is discharged, should not be attempted without self-contained breathing apparatus.

   Toxic products of decomposition are formed when Halon 1301 is exposed to flames. If Halon 1301 is discharged in 10 seconds or less, causing rapid extinguishment of flames, the amount of toxic products formed is of little or no consequence. The amount of these toxic products of decomposition formed can be minimized by discharging the halon system as soon as possible after fire discovery. More halon breakdown will occur if the fire has the opportunity to burn freely and heat the metal structure within the protected space. This would seem to suggest that automatic detection and release of the halon agent would be desirable. In buildings, this concept is viable; however, onboard vessels, automatic release is not practical in all cases. To properly extinguish a fire, operating machinery within the protected space must be shut down prior to agent discharge. If a vessel were navigating in a high density shipping channel, an automatically released fire extinguishing system could shut down the main propulsion plant and ship's service generators when needed most.

An engineering trade-off has therefore been made, requiring for all spaces greater than 6000 ft3, manual release of agent, and evacuation of the protected space to protect personnel from potential toxic products of decomposition of the halon.

2. A second problem that may be encountered with Halon 1301 concerns the protection of diesel engines. If carbon dioxide is injected into a running diesel engine, the engine will stop. This has not been observed with Halon 1301; in fact, the engine may even speed up. It is possible that if a diesel engine were to scavenge Halon 1301, toxic products of decomposition from the Halon 1301 breakdown under the high cylinder pressures within the diesel could be released through the diesel exhaust system. Coast Guard design requirements mandate the automatic shutdown, prior to halon discharge, of all diesel engines which receive intake air from the protected space.

A.4 system Types

The purpose of this guide is to explain the requirements for engineered type Halon 1301 systems. There are two other types of Halon 1301 systems which are reviewed by the Coast Guard. Both of these are approved as pre-engineered type systems. The approval for these systems will indicate factors such as maximum-permissible pipe lengths, number of elbows, etc. These systems are as follows:

Approval Number - 162.035/1/1 - Bromotrifluoromethane Systems for Hydrofoil Craft.

These systems are for limited installation in unmanned spaces up to a maximum volume of 2250 cubic feet.

Approval Numbers - 162.029/1/0
162.029/3/0
162.029/4/0
162.029/7/0
162.029/8/0
162.029/9/0
162.029/10/0

Halon 1301 systems for installation in uninspected pleasure craft.

B.1 General Arrangements

The basic arrangement for Halon 1301 systems is similar to approved carbon dioxide systems. The agent cylinders are manifold together and located outside of the protected space. A releasing control should operate one or two pilot cylinders and a stop valve control must be provided to prevent agent discharge if the pilot cylinders are accidentally tripped. The agent is in turn piped to the protected space and discharged through nozzles. The general arrangements shown in Appendix A are acceptable.

Currently, there are no Halon 1301 systems which resemble low pressure carbon dioxide systems. Several manufacturers, however, are currently vending a "modular" type system, which consists of a number of agent containers mounted in various locations throughout the protected space. The containers are not connected to a manifold, but are arranged to discharge individually. The releasing mechanisms are either electric or pneumatic. The review of these systems is done by Headquarters, because of the complex nature of the system control hardware. A very detailed review is done to insure that control and supervisory circuitry will function in the marine environment. A reliability study is also conducted on most electrical components.

B.2 Halon 1301 Concentration

The extinguishing effectiveness of Halon 1301 is highly dependent upon the concentration of the agent in the protected space. Tests conducted by the Coast Guard have shown that for normal shipboard protection, a 6% concentration of Halon 1301 of the total or gross volume of a machinery or other space can effectively extinguish flammable liquid fires in that space. The amount of agent necessary to form this concentration must be calculated for the lowest range of temperature expected in that space. Basically, this is because the specific volume (ft^3/lb) of Halon 1301 vapor varies with the ambient temperature

A 6% halon design concentration calculated at the lowest ambient temperature expected in the space with no deductions being made for machinery could cause the concentration in the protected space to be as high as 7% - 7.4% under actual conditions because temperatures within most machinery spaces are usually greater than 700F under normal operating conditions.

It is felt that this concentration is justifiable for shipboard halon systems for the following reasons:

1. Evacuation of the protected space is required- Automatic release of machinery space halon systems is not permitted because vital ships navigating and propulsion equipment could be stopped at inopportune times. This may cause higher temperatures to be reached within the protected space before agent release which inturn could form unacceptable amounts of toxic halon decomposition products.

2. A 7% concentration is approximately the inerting concentration required for most marine fuels - According to NFPA Standard l2AD the inerting concentration should be used where large amounts of fuel are available which could be atomized or sprayed from broken fuel lines or fittings.

B.3 Determination of Necessary Quantity of Halon 1301

The minimum design concentration of Halon 1301 for machinery spaces, turbine enclosures, or pump rooms containing diesel fuel, gasoline, or crude oil and other similar petroleum products is 6% of the gross volume of the space. If other flammable or combustible materials are present in the protected space, higher concentrations of halon may be needed.

To calculate the necessary weight of Halon 1301, the volume of the protected space must first be determined. This volume is the gross volume, i.e. no deductions are made for machinery or any other contents.

The gross volume is then multiplied by the mass flooding factor. The mass flooding factor in pounds per cubic foot is calculated from the specific volume of the halon vapor at a given temperature. when the mass flooding factor is multiplied by the volume of space, the result is the quantity of Halon 1301 in pounds necessary to give a 6% concentration. The mass flooding factors are dependent upon the temperature within the protected space. Standard mass flooding factors have been determined for specific areas. These values should always be used unless circumstances require some special consideration. The mass flooding factor for pump rooms is .0289 lb/ft^3 (0^0F) and for machinery spaces and turbine enclosures is .0270 lb/ft^3 (32^0F).

If unique conditions arise, the necessary quantity of Halon 1301 may be calculated as follows:

$$W = \frac{V}{s} \qquad \frac{C}{100 - C}$$

W = weight of Halon 1301 required, lbs.

C = Halon 1301 Concentration, % by volume

V = Volume of protected space (ft^3)

s = Specific volume of the Halon 1301 vapor. This value is calculated with the following formula:

s = 2.2062 + .005046T
T = Design Temperature, ^{0}F

B.4 Effects of Ventilation

The extinguishing potential of total flooding Halon 1301 Systems depends upon the "tightness" of the Space, and any leakage of agent from the space will reduce this effectiveness. If there are any openings to the space which cannot be completely closed, a discharge test of the system may have to be conducted to ascertain if an extinguishing concentration can be reached and maintained.

In spaces where power ventilation is installed, the ventilation system must be shut down prior to agent discharge, The shutdown of the ventilation must be automatically accomplished by the operation of the halon system releases. Sufficient time for the rundown of the ventilation must also be allowed before the release of halon.

In the event that ventilation cannot be expediently shut down, an additional quantity of agent must be provided to compensate for the effects of ventilation. The following formula should be used to determine the necessary total amount of agent:

$$Q = \frac{0.01CET}{s\left[1 - e^{\frac{-ET}{V}}\right]}$$

Q = Lbs of halon

C = Halon 1301 Concentration % by volume

E = Ventilation rate, ft^3/sec.

T = Time in sec. (10 sec. max.)

V = Volume of protected space, ft^3

S = Specific volume of Halon 1301 vapor, ft^3/lb. (See Section B.3)

e = Natural logarithm base, 2.71828

B.5 Overpressurization of Protected Space

Due to the high speed discharge of the superpressurized Halon 1301, it will almost always vaporize as it leaves the discharge nozzle, resulting in adiabatic cooling of the protected space and causing a temporary pressure drop. This pressure drop has a tendency to counteract the pressure rise expected because of the partial pressure of the added 6% halon concentration. The halon-air mixture will eventually cause a pressure rise, as heat is transferred into it from the surrounding bulkheads and decks, but this pressure rise is gradual and can usually be vented through any available small openings.

B.6 Agent Storage Containers

Halon 1301 is stored in metal containers in liquid form, and is superpressurized with dry nitrogen to one of two pressures (at 70^0F): 360 or 600 psig. The quantity of Halon 1301 that is stored in each container varies among manufacturers and generally ranges up to a maximum of 250 lbs.

All containers on a common manifold must be of the same size and must contain the same quantity of Halon 1301 to insure an equal rate of flow into the manifold from each container. Manifolded cylinders must be secured with a substantial mounting bracket to prevent damage.

Cylinders should be located as near to the protected space as possible, and the following criteria must also be met:

1. The cylinders must be located outside of the protected space, except for spaces less than 6000 ft^3.

2. The temperature range the cylinders may be exposed to is between 130^0F and -20^0F. Spaces containing Halon 1301 cylinders must be ventilated or heated to maintain the ambient temperature within these limits.

3. Halon 1301 cylinders are fitted with an overpressure relief device (normally a frangible disc) which will allow the relief of excessive pressure within the cylinder. If the cylinders are located adjacent to the protected space, enough heat may be conducted through bulkheads or decks to rupture the overpressure disc. Should this occur, the halon storage room would be filled with agent, and very little, if any, would be available to extinguish the fire. Therefore, common bulkheads and decks between halon storage rooms and protected spaces must be constructed to A-60 class.

B.7 Controls

The releasing mechanisms for halon systems are similar to those used for CO_2 systems. The usual type of mechanical releases are cables. The pull handles of these cables should not require a pull of more than 40 pounds nor a movement of greater than 14 inches to release the contents of the halon containers. Also, the cables as well as the remainder of the releasing mechanism must be protected from the weather. Pneumatic releases are also acceptable on certain systems.

Instructions explaining the system operation and containing a schematic diagram of the piping layout should be posted at each pull box or stop valve control, and in the halon storage room. The instructions should be as follows:

1. The instructions should give specific locations and instructions of where system components are located in relation to where the person attempting to operate system is standing.

2. The instructions should also be easy to comprehend in a brief period of time.

3. At each pull box, two sets of instructions should be posted. The first set of instructions should state in some form --- In case of fire in (<u>protected Space</u>) operate extinguishing system by pulling lever, operating valve, etc. --. The second set of instructions should state in some form ---If the extinguishing system fails to operate, go to (<u>some specified location</u>) and follow instructions posted there ---. A map or plan should be included with this instruction, showing the operator exactly where he must go to find the secondary release.

4. The instructions should be printed in letters large enough to be read from a distance of several feet.

5. In the cylinder st3rage room, a general schematic of the entire system should be posted showing the various sections of the system. To facilitate rapid comprehension of the arrangement, each section should be numbered, color coded, or named. Each pilot valve and stop valve should in turn be numbered, named, or color coded. An instruction list should be posted with a heading stating in some terms --- Alternate means of operating fire extinguishing system in case of failure of remote release devices Each protected space should be listed with appropriate instructions for each space, e.g.

   Boiler Room: operate blue stop valves (3) and blue cylinder valves (2)

   Cargo hold #3: operate stop valve number seven and release 14 CO_2 cylinders.

   These instructions should state which valves to operate and how many should be operated. If stop valves are located remote from the cylinder storage room, the instructions should also explain <u>where</u> to find the valve.

6. The instructions should be securely mounted and should be permanently inscribed on metal or plastic plates. Temporary paper instructions which are sealed in plastic may be posted until inscribed instructions can be fabricated.

   These guidelines are general in nature, exact wordings and descriptions on nameplates are left up to the manufacturer.

   A remote release and control for appropriate stop valves or direction valves must be located as near as possible to at least one exit of the protected space.

B.8 <u>Warning Devices</u>

Alarms which depend on no source of power other than pressure must be installed to signal the impending discharge of the Halon 1301 system. These devices are arranged to sound an alarm when the system release is operated but prior to agent discharge. A discharge delay mechanism must be installed in the halon piping to allow an escape period after the discharge alarm begins sounding. The alarm must be audible throughout the entire protected space while machinery is running. A sign must be posted immediately adjacent to the alarm explaining its purpose.

A warning must be posted at each entrance to the protected space warning personnel not to enter the space without self-contained breathing apparatus after the halon system has been discharged.

B.9 Hydraulic Calculations of Agent Flow

The flow of Halon 1301 through piping requires careful evaluation. Because both liquid and gaseous halon are flowing simultaneously, a condition of two-phase flow can exist. Unlike the calculation of carbon dioxide flow, the calculation of halon flow is very critical.

All Halon 1301 systems should be balanced, i.e., all branches should be roughly of equal length and similar flow rates. This is particularly important if the system is designed to discharge simultaneously into several spaces. when splitting the halon flow at tees, an exact determination of how much agent flows in each direction cannot be guaranteed through unbalanced branches. If a tee and unbalanced piping is used to divide the halon flow into two separate spaces, it is possible to have an insufficient concentration in one of the spaces.

For all submittals, the percent of agent in piping should be evaluated. This is the ratio of the internal volume of the entire discharge piping network to the volume of the Halon 1301 in the storage containers. If the percent of the agent in piping ratio exceeds 100%, there will not be a sufficient amount of agent to completely fill the piping during discharge. The accuracy of flow calculations depends upon having the discharge piping completely filled with agent. If the ratio exceeds 125%, a discharge test should be conducted to evaluate the performance of the system.

Example #1

A tank vessel has a pump room with a volume of 130,000 cubic feet and which is normally unmanned. The installed ventilation system operates at the rate of one complete air change per minute and when shut down, requires an approximate rundown time of 35 seconds. Good engineering practice would suggest that one would design the system to shut down the ventilation with the actuation of the system, and by means of the time delay prevent the discharge of the agent into the hazard area until the ventilation has completely run down. However, for the purposes of illustration of the calculation technique, the time delay is designed for 25 seconds, with the ventilation system operating at full capacity during the 10 seconds of agent discharge.

Under the above conditions, the Halon 1301 quantity required to produce a 6% concentration at 0^0F (Section B.3 for pump rooms) at the end of a discharge -.period of 10 seconds with a ventilation rate of 130,000 cubic feet/minute is calculated using the formula in section B.4:

$$Q = \frac{0.01CET}{s\left[1 - e^{\frac{-ET}{V}}\right]}$$

At 0^0F., s = 2.2062 + 0.005046(T) = 2.2062 $\frac{ft^3}{lb}$

E = 130,000 $\frac{ft^3}{\min}$ = 2166.6 $\frac{ft^3}{\sec}$

T = 10 seconds

$$Q = \frac{0.01(6)\left(2166.6\frac{ft^3}{\sec}\right)(10dec)}{2.2062\frac{ft^3}{lb}\left[1 - e^{\frac{-2166.6(10)}{130,000}}\right]} = \frac{1299.9}{2.2062 \times (0.1535)} = 3838 pounds$$

Example #2

A system is to be installed in a floating nuclear power plant located off the coast of Key West, Florida. The temperature in the protected space will not normally drop below 70^0F. Determine the required quantity of halon needed to protect a volume of 37,000 ft^3.

$$W = \frac{V}{S}\left[\frac{C}{100 - C}\right]$$

where S = 2.2062 + .005046T
T = 70^0F
S = 2.2062 + .35322
S = 2.55942 ft^3/lb

$$W = \frac{37,000\,ft^3}{2.55942}\,\frac{6\%}{100 - 6\%} = 923lb$$

C.1 Review of Systems

The following information is required for the complete review of a Halon 1301 submittal:

a. General schematic of system and description of space~to be protected.

b. Piping and fitting schedule.

c. Drawings of components to include:
   i. Storage containers and DOT rating

   ii. Discharge heads

   iii. Release mechanisms

   iv. Any detection system parts

v. Nozzles

vi. Alarms

vii. Valving

viii. Warning and instruction signs

ix. Any other component part (e.g. ventilation shutdown, time delay, etc.)

d. Calculations verifying the following:

i. Design concentration 6 percent at lowest possible temperatures anticipated within the protected areas.

ii. Hydraulic calculations to demonstrate discharge within 10 seconds at ambient temperature not to exceed 70^0F.

e. System manual containing:

j. Operation instructions

ii. Maintenance instructions

To eliminate a complex review for each system submitted, a standard parts list will be developed by Headquarters. This will eliminate the need for the vendors to submit component drawings with each system. The standard review procedure will be to check, first of all, the appropriateness of the system for the protected space, then the design temperature, Halon 1301 concentration and quantity. The hydraulics of the system should be checked with the procedures outlined in NFPA standard 12A. Each of the part numbers should be checked to see if they are listed on the standard parts list. Should any problems arise, they may-be referred to Headquarters.

D.1 Design and Review of System

1. Check protected space and determine if total flooding Halon 1301 system is correct application. Halon should not be used to protect Class A materials.

2. Check volume of protected space. If volume exceeds 6000 ft^3, automatic release is not permitted.

3. Check boundaries of protected space to ascertain if the halon concentration can be maintained. Note if ventilation systems can be shut down prior to agent release.

4. Determine quantity of Halon 1301 needed. Extra halon must be supplied to compensate for unclosable vent openings or operating ventilation systems. Check if quantity of Halon 1301 supplied is sufficient.

5. Divide quantity of halon in-pounds by 10 seconds to get required flow rate in lb./sec. Check the sum of flow rates of nozzles to determine if provided system has an adequate flow rate.

6. Check cylinder location. Cylinders must be located externally to protected space except for automatic systems and certain specially approved systems. Cylinder storage room must have temperatures between -20^0F and 130^0F. Automatically released systems may have cylinders within protected space.

7. Cylinders must be securely mounted, and must be removable for weighing. Each cylinder must have a pressure gage. If cylinders are mounted adjacent to protected space, common bulkhead or deck must be A-60.

8. A pressure relief device must be installed in each cylinder, and the manifold.

9. Check nozzle arrangement to determine if uniform distribution is provided.

10. Piping must be schedule 40 or heavier, and must be galvanized. Piping must extend 2 inches beyond the last nozzle of each branch line to prevent clogging. Pipe exceeding 4 inches in diameter must be schedule.60. Fittings must be 300 lb class malleable iron or other acceptable as listed in 46 CFR Parts 50 to 63.

11. Check piping supports to determine that piping is securely fastened. Aluminum piping supports are unacceptable.

12. Check manual release devices. Two distinct and separate actions should be required to operate the system. A schematic diagram of the system and a procedure for discharging the system if the remote release devices are non-functioning should be posted by each release Station.

13. Check ventilation and other operating machinery in protected space. Devices must be provided in the Halon 1301 system to shut down ventilation before agent release. Diesel engines which intake air from the protected space must be shut down automatically prior to agent release.

14. Check to determine if discharge delay allows adequate time to evacuate protected space before agent is released. The pre-discharge alarm must be loud enough to be heard in the protected space while machinery is running.

15. Check component part numbers with the Coast Guard approved parts list.

16. Check hydraulic calculations according to NFPA Standard 12A. Certain manufacturers use different methods to compute flow. A deviation of 15% of the required nozzle pressures is acceptable.

17. Determine percent of agent in piping. This should not exceed 125%.

D.2 <u>Halon 13Q1 Systems Inspection Procedures</u>

1. The weight of each cylinder must be checked. If a weight loss of more than 5 percent is noted, the cylinder must be replaced or recharged.

2. The pressure of each cylinder must be checked. If a pressure drop (adjusted to temperature) of more than 10 percent is recorded, the cylinder must be replaced or recharged. Cylinder pressures will vary with temperature; the following chart is provided as a guide:

	360 psi system	600 psi system
Temperature	Pressure	Pressure
40^0F	275 psig	500 psig
50^0F	300 psig	530 psig
60^0F	330 psig	565 psig
70^0F	360 psig	600 psig
80^0F	395 psig	640 psig
90^0F	430 psig	680 psig
100^0F	470 psig	730 psig

3. Predischarge alarm must be checked and operated with dry air or nitrogen if necessary. The alarm should be audible throughout the space with machinery operating.

4. Remote release mechanisms must be checked to insure that cables and pulleys are free to move and that the mechanism operates properly.

5. Switches for automatic shutdown of equipment must be checked and tested if necessary.

6. Check to see if all openings to the space can be completely closed.

7. Legible operating instructions detailing release and alternate method of release must be posted at each entrance to the protected space.

8. Visually check all piping for breaks, corrosion, obstructions, etc. If necessary, blow out piping with pressurized air.

9. Check all mounting brackets for proper support.

10. Check date of last hydrostatic test; cylinders must by hydrostatically tested every 12 years.

D.3. <u>Installation Test Requirements</u>

1. Halon 1301 piping systems should be tested as outlined in 46 CFR 76.15-15 (J). The test pressures used shall be equal to one and one half times the design pressure of the system.

<u>REFERENCES</u>

(1) "An Investigation into the effectiveness of Halon 1301 (Bromotrifluoromethane CBrF) as an extinguishing agent for Shipboard Machinery Space Fires." D.F. Sheehan, March 1972, U.S. Coast Guard, Office of Research and Development.

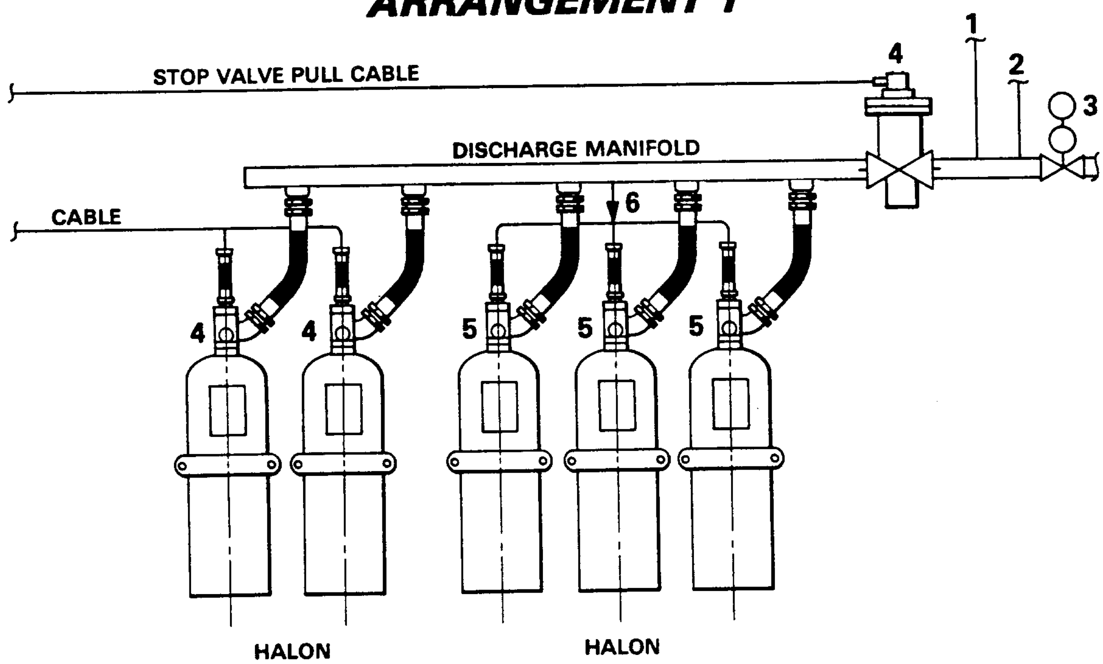
(2) N.F.P.A. Standard *12A

Approved General Arrangements for Halon 1301 Systems

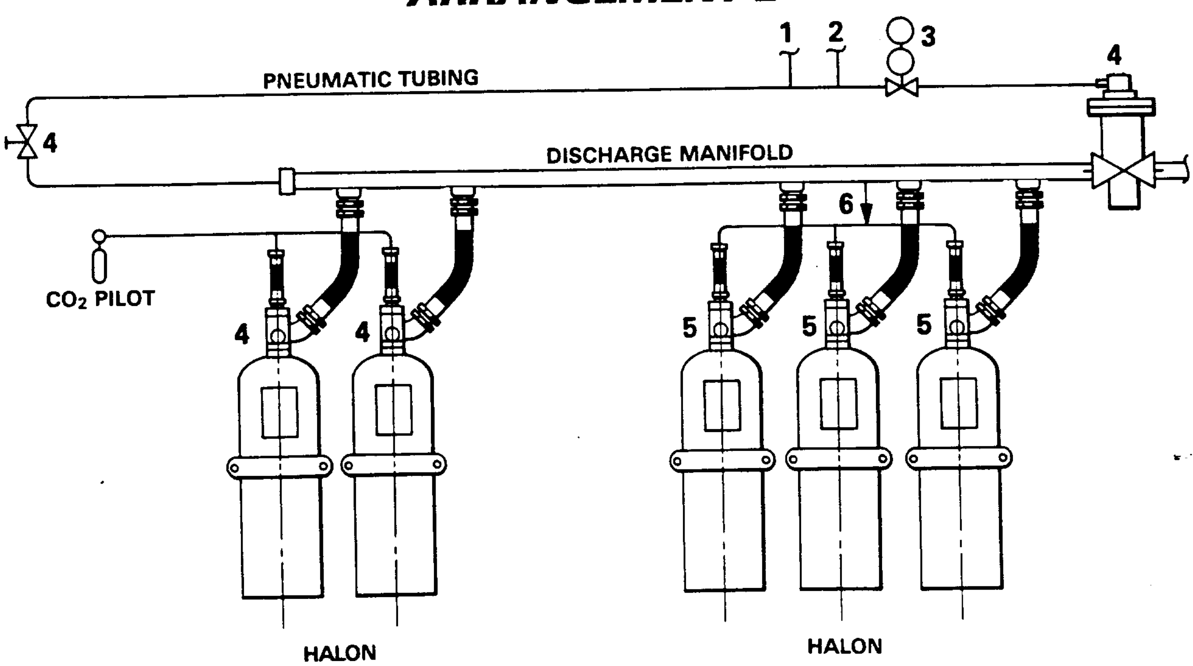
KEY

1. TO PRESSURE OPERATED ALARM.
2. TO PRESSURE OPERATED SWITCHES.
3. TIME DELAY.
4. VALVE CAPABLE OF MANUAL OPERATION.
5. PRESSURE OPERATED VALVE. NO MEANS OF MANUAL OPERATION.
6. CHECK VALVE.

ARRANGEMENT 1



ARRANGEMENT 2



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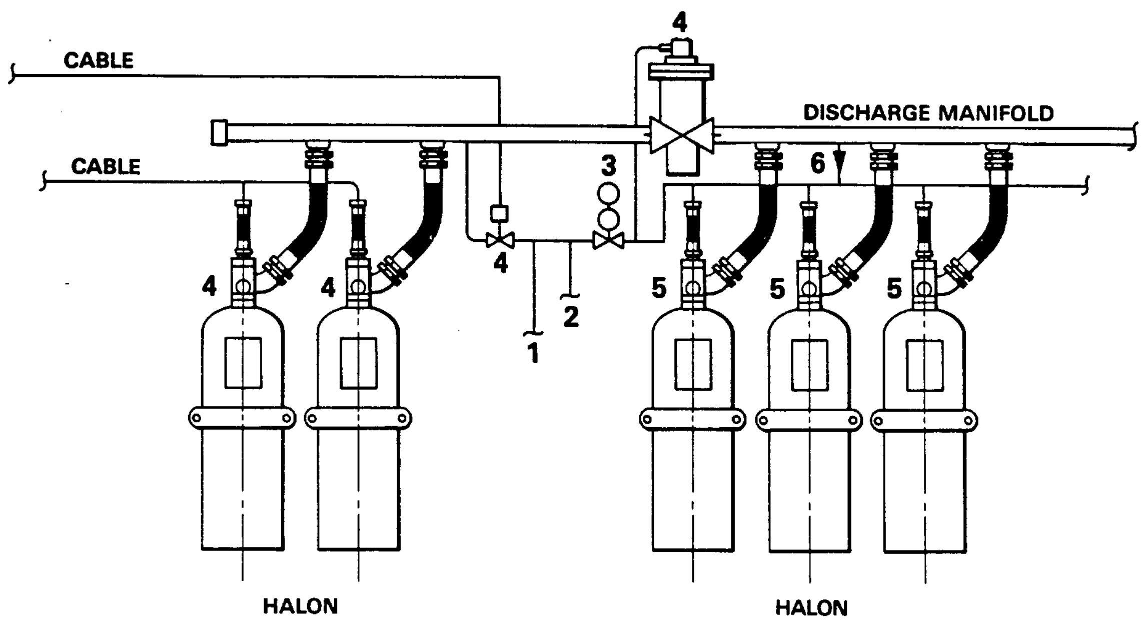
ARRANGEMENT 3



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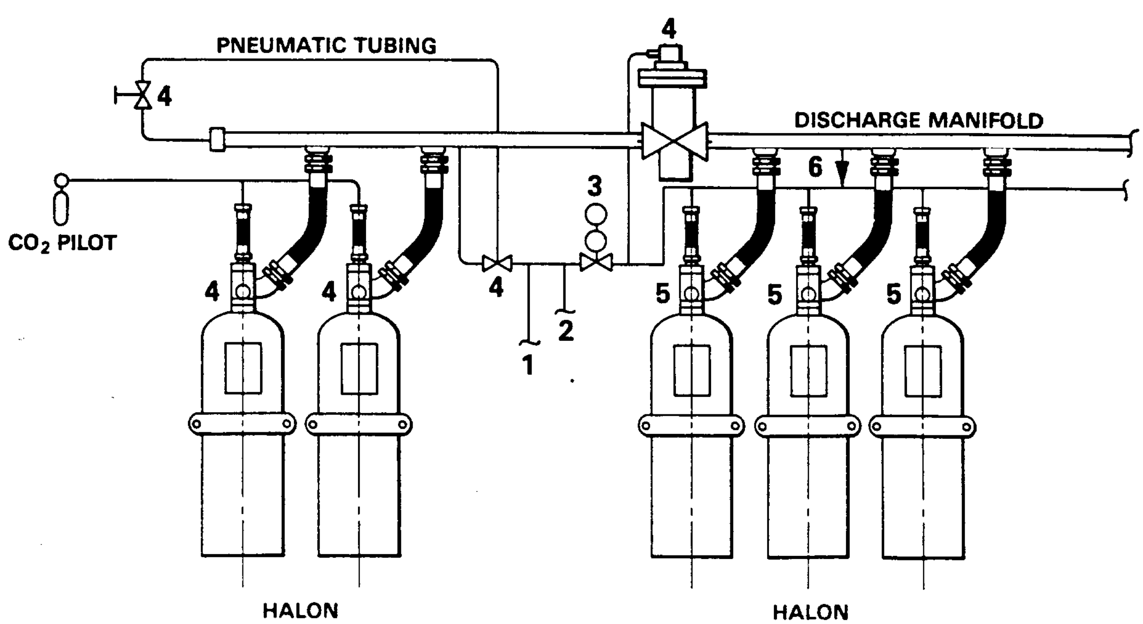

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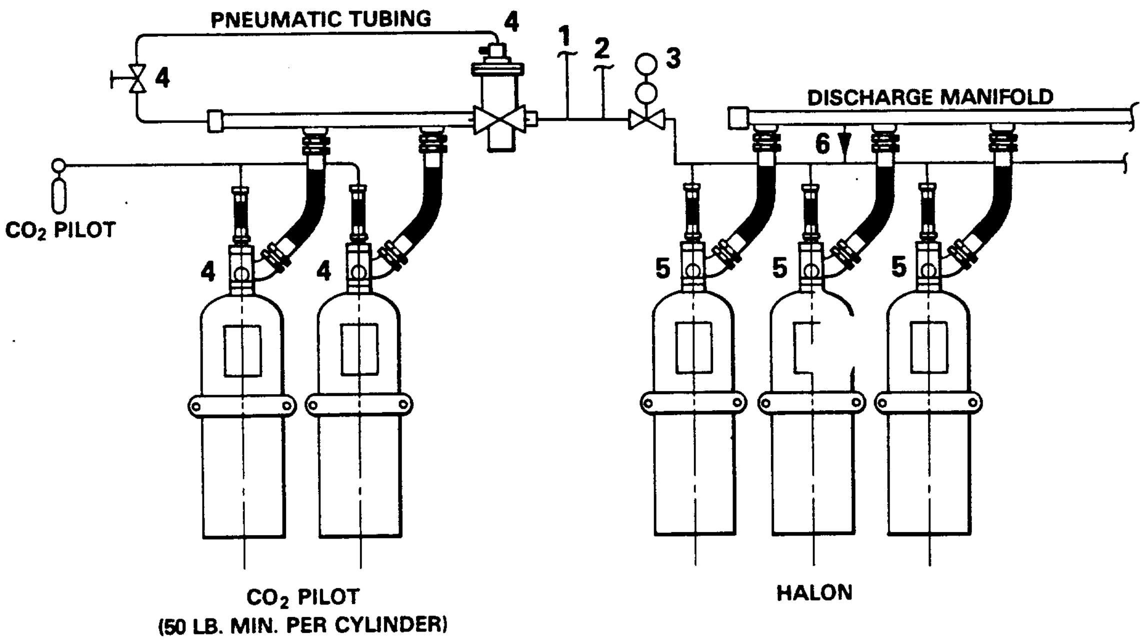
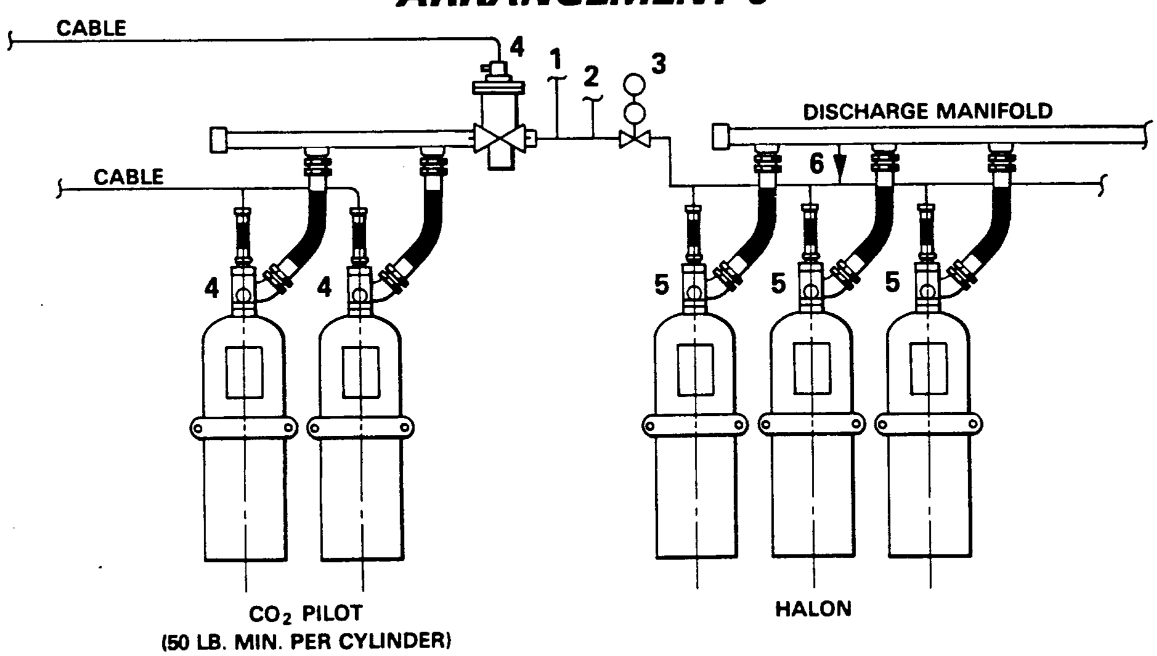
ARRANGEMENT 5



ARRANGEMENT 6



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