



GUIDANCE NOTES ON

FIRE-FIGHTING SYSTEMS

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**American Bureau of Shipping
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Foreword (2017)

Purpose

The ABS Rules incorporate many requirements intended to prevent the onset of a fire. However, even with all the preventative measures taken, shipboard fires still occur. Therefore, the proper design, installation and operation of the vessel's fire-fighting systems are critical to the safety of a vessel and the personnel onboard.

Since fire-fighting systems are so critical, the designs and arrangements of such systems should be carefully evaluated for compliance with the ABS requirements by the designer and ABS Engineering staffs. These Guidance Notes have been developed to assist in a better understanding of the ABS requirements for such systems. They are intended to provide a general overview of ABS requirements that should be considered during technical plan review activities. These Guidance Notes also examine the basic scientific fundamentals of fire, as appropriate for a proper understanding and application of the ABS requirements. Accordingly, this document should be considered as general guidance only and the technical reviews of fire-fighting systems should verify compliance with all ABS Rules applicable to the specific vessel involved.

Note: Rule references in these Guidance Notes (e.g. 4-7-2/1.1.1, etc.) are typically to the requirements found in the ABS *Rules for Building and Classing Steel Vessels*, unless noted otherwise.

Scope

The scope of this document is limited to the review of ABS requirements considered during the technical plan review of active fire-fighting systems onboard ABS-classed vessels. Passive fire protection arrangements, such as structural fire protection, as well as fire detection systems, are outside the scope of this document. Fire-fighting systems of offshore facilities and installations are also outside the scope of this document.

The review of fire-fighting systems for the International Maritime Organization's (IMO's) International Convention for the Safety of Life at Sea (SOLAS) requirements is also not within the scope of this document. However, in many cases, the ABS Rules for fire-fighting systems either incorporate or directly reference IMO SOLAS fire-fighting system requirements. Accordingly, within the discussions of the ABS requirements for various fire-fighting systems, related "interpretations" of the associated SOLAS requirements, as developed by the International Association of Classification Societies (IACS), are identified. These IACS interpretations are called Unified Interpretations (UI). As an IACS member, ABS is obligated to apply these UIs as appropriate interpretations of the SOLAS requirements, unless directed otherwise by the Flag Administration. Interpretations provided in the UIs should be considered when conducting technical plan reviews.

Note: Development of appropriate Unified Interpretations and revision of existing UIs is an ongoing effort within the IACS Working Parties. Therefore, attention is directed to the latest edition of the IACS UI being available on the website <http://www.iacs.org.uk/publications>

In addition to the IACS UIs, IMO MSC Circular 1120 "Unified Interpretations of SOLAS Chapter II-2, the FSS Code, the FTP Code and related Fire Test Procedures" (and its subsequent correction (Corr.1) and amendments per MSC.1 Circulars 1436, 1491 and 1510) also provides guidance regarding SOLAS fire-fighting system requirements. Many of the MSC Circular 1120 interpretations are based upon the IACS UI interpretations, while others provide revised or additional interpretations of the SOLAS requirements. A number of the MSC Circular interpretations have been included in the SOLAS 2000 consolidated edition and subsequently in the SOLAS Consolidated Editions 2004, 2009 and 2014. Consequently, these requirements were also incorporated into the ABS Rules. However, since the MSC Circulars interpretations identify useful information and guidance relative to certain Rule requirements, "selected" IMO MSC interpretations have also been identified.

Note: Regarding classification requirements, MSC Circulars interpretations which are not included within SOLAS have not necessarily been officially adopted by ABS and should only be applied as directed by the ABS Chief Engineer's Office. Further, MSC Circulars interpretations may not be mandatory for any particular Flag Administration, except for those incorporated within SOLAS. Member Governments are only invited to use the annexed interpretations as guidance, and therefore, specific instructions from the ABS Regulatory Affairs Department should be obtained regarding the application of these interpretations on behalf of any particular Administration.



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FIRE-FIGHTING SYSTEMS

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SECTION 1 Basics of a Fire

Fire is a phenomenon with which everyone is familiar. We use it daily to heat our homes and cook our meals. When harnessed, the power and energy from fire serves us well; however, when it is uncontrolled, a fire can quickly consume and destroy whatever lies in its path.

While we are all familiar with fire, few of us are aware of its nature and complex processes. This Section examines the phenomena and various mechanisms at work within a fire and is intended to provide a better understanding of the requirements in fire-fighting scenarios.

1 Chemistry of Fire

1.1 Oxidation

Oxidation is a chemical reaction between the molecules of a substance and the oxygen molecules in the surrounding atmosphere. There are many common examples of oxidation, including the rusting of iron, the tarnishing of silver, or the rotting of wood.

What is known as *fire* is actually a chemical reaction involving the oxidation of the fuel molecules. However, the reaction occurs at a much faster rate and only under certain conditions (e.g., elevated temperatures, proper mixture, etc.). In addition, what is called *burning* or *combustion* is actually the continuous rapid oxidation of millions of fuel molecules. Recognizing that the fire or combustion process is actually a chemical reaction (involving the oxidation of the fuel molecules) is critical to understanding the basics of the fire phenomena.

The oxidation reaction is an exothermic process (i.e., one in which heat is given off). The molecules oxidize by breaking apart into individual atoms and recombine with the oxygen atoms to form new molecules. During this process, a certain amount of energy is released. In the examples of rusting iron or rotting wood, the amount of energy released is minimal since these oxidation processes occur at a very slow rate. However in a fire, the oxidation rate of the fuel molecules is much faster. Because of this rapid reaction, energy is released at a much greater rate. The released energy is actually felt and seen in the form of heat and light. The more rapid the oxidation rate, the greater intensity in which the energy is released. An explosion is, in fact, the oxidation of a combustible media at an extremely fast rate.

1.2 State of Products in “Fire” Oxidation Process

All substances exist in one of three states: as a solid, a liquid or a vapor (gas). For the oxidation process to occur, there must be an adequate intermixing of the oxygen and fuel molecules. For fuel molecules in either a solid or liquid state, the molecules are tightly bound and cannot be effectively surrounded by the oxygen molecules in the atmosphere. Therefore, molecules in either a liquid or solid state are not directly involved in the rapid chemical reaction of oxidation in a fire.

However, fuel molecules in a vapor state are free to mix with the atmosphere. These molecules become effectively surrounded by the oxygen molecules in the atmosphere and are available to become involved in the oxidation process. In fact, only fuel molecules in a vapor state are actually involved in the oxidation process.

While fuel molecules in the solid or liquid states are not directly involved in the oxidation process, when heated, these molecules will move about more rapidly. If enough heat (energy) is applied, some fuel molecules break away from the surface to form a vapor just above the surface. This new vapor can now mix with oxygen and can become involved in the oxidation process. Accordingly, the fuel molecules in a solid or liquid state do serve as the source of additional fuel vapors when exposed to heat.

Note: Usually, molecules in a liquid state can break free more easily than those in a solid state. In many cases, little or no additional heat is necessary for at least some of the fuel molecules in a liquid state to have sufficient energy to break free of the surface and enter the vapor state.

2 Fundamentals of a Fire

The combustion process, or *burning*, is in fact the rapid oxidation of millions of fuel molecules in the vapor form. Once there is sufficient oxygen and the fuel vapor molecules properly mix, an ignition source is typically needed for oxidation to be initiated. However, once oxidation is initiated, it is an exothermic process. If sufficient energy is released during the reaction to maintain the elevated temperature of surrounding oxygen and fuel molecules, and there are sufficient oxygen and vaporized fuel molecules available, then the oxidation process will continue.

The heat released by the oxidation of the fuel molecules is *radiant* heat, which is pure energy, the same sort of energy radiated by the sun and felt as heat. It radiates, or travels, in all directions. Thus, part of it moves back to the seat of the fire, to the “burning” solid or liquid (the fuel).

The heat that radiates back to the fuel is called radiation feedback. This part of the heat serves to release more vapors and also serves to raise the vapor (fuel and oxygen molecule mixture) to the ignition temperature. At the same time, air is drawn into the area where the flames and vapor meet. The result is that the newly-formed vapor begins to burn and the flames increase, which starts a chain reaction. The burning vapor produces heat, which releases and ignites more vapor. The additional vapor burns, producing more heat, which releases and ignites still more vapor. As long as there is fuel and oxygen available, the fire will continue to grow.

For a fuel source with a limited amount of surface area available, the amount of vapor released from the fuel reaches a maximum rate and begins to level off, producing a steady rate of burning. This usually continues until most of the fuel has been consumed.

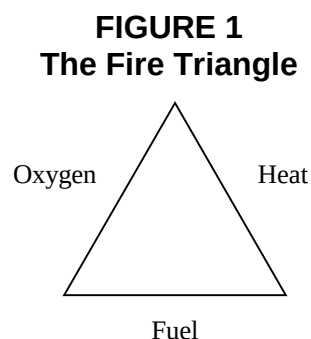
When there is less fuel vapor available to oxidize, less heat is produced and the process begins to die out. A solid fuel may leave an ash residue and continue to smolder for some time, while a liquid fuel usually burns up completely.

3 The Fire Triangle

There are three (3) components required for combustion to occur:

- Fuel – to vaporize and burn
- Oxygen – to combine with fuel vapor
- Heat – to raise the temperature of the fuel vapor to its ignition temperature

The following is the typical “fire triangle”, which illustrates the relationship between these three components:



There are two important factors to remember in preventing and extinguishing a fire:

- i) If any of the three components are missing, then a fire cannot start.
- ii) If any of the three components are removed, then the fire will go out.

It is important to have a clear understanding of these three components and their inter-reactions in a fire. The following Paragraphs examine each of these items in further detail.

3.1 Fuel

Fuel is necessary to feed a fire, and without fuel, the combustion process will terminate. The fuel molecules involved in a fire must be in the vapor (gas) state. However, the initial fuel source may be in a solid, liquid or gaseous state. Many examples of each type of these fuels can be found onboard a vessel.

The following Subparagraphs provide a brief discussion on the various types of fuels and some of the technical issues that impact their involvement in a fire.

3.1.1 Solid Fuels

3.1.1(a) Sources. The most obvious solid fuels are wood, cloth and plastics. These types of fuels are found onboard a vessel in the form of cordage, dunnage, furniture, plywood, wiping rags, mattresses and numerous other items. The paint used on bulkheads is considered a solid fuel.

Vessels may also carry a variety of solid fuels as cargo, from baled materials to goods in cartons and loose materials, such as grain. Metals, such as magnesium, sodium and titanium are also solid fuels that may be carried as cargo.

3.1.1(b) Pyrolysis. Before a solid fuel will burn, it must be changed to the vapor state. In a fire situation, this change usually results from the initial application of heat. The process is known as pyrolysis, which is generally defined as “chemical decomposition by the action of heat.” In this case, the decomposition causes a change from the solid state to the vapor state. If the vapor mixes sufficiently with air and is heated to a high enough temperature (by a flame, spark, hot motor, etc.), then ignition results.

3.1.1(c) Burning Rate. The burning rate of a solid fuel depends upon the rate at which vapors are generated, which depends on a number of criteria, including the configuration of the fuel surface. Solid fuels in the form of dust or shavings will burn much faster than bulky materials (i.e., small wood chips will burn faster than a solid wooden beam).

Finely divided fuels have a much larger surface area exposed to the heat. Therefore, heat is absorbed much faster, vaporization is more rapid and more vapor is available for ignition, allowing the fire to burn with great intensity and the fuel to be quickly consumed. A bulky fuel will burn longer than a finely divided fuel.

Dust clouds are made up of very small particles. When a cloud of flammable dust (such as grain dust) is mixed well with air and ignited, the reaction is extremely quick, often with explosive force. Such explosions have occurred on vessels during the loading and discharging of grains and other finely divided materials.

3.1.1(d) Ignition Temperature. The ignition temperature of a substance (solid, liquid or gas) is the lowest temperature at which sustained combustion will occur. Ignition temperatures vary among substances. The ignition temperature varies with bulk, surface area and other factors. Generally accepted ignition temperatures of common combustible materials in various standardized configurations are provided in various handbooks.

3.1.2 Liquid Fuels

3.1.2(a) Sources. The flammable liquids most commonly found aboard a vessel are bunker fuel, lubricating oil, diesel oil, kerosene, oil-base paints and their solvents. Cargoes may include flammable liquids and liquefied flammable gases.

3.1.2(b) Vaporization. Flammable liquids release vapor in much the same way as solid fuels. The rate of vapor release is greater for liquids than solids, since liquids have less closely bonded molecules. In addition, liquids can release vapor over a wide temperature range. Gasoline starts to give off vapor at -43°C (-45°F). Since gasoline produces flammable vapor at normal atmospheric temperatures, it is a continuous fire risk, even without heating or back radiation. Heating increases the rate of vapor release and therefore the fire risk.

Heavier flammable liquids, such as bunker oil and lubricating oil, release lesser amounts of vapors at atmospheric temperatures. However, the rate of vaporization increases rapidly when heated. Some lubricating oils can ignite at 204°C (400°F). Because a fire reaches this temperature rapidly, oils that are directly exposed to a fire will soon become involved. Once a flammable liquid is burning, radiation feedback and the chain reaction of oxidation quickly increase flame production.

The vapor produced by most flammable liquids is heavier than air. Vapor that is heavier than air is very dangerous because it will seek low places, dissipate slowly and can quickly travel to a distant source of ignition. For example, vapor escaping from a container can travel along a deck and down deck openings until it contacts a source of ignition (such as a spark from an electric motor). If the vapor is properly mixed with air, then it will ignite and carry fire back to the leaky container, resulting in a fire.

3.1.2(c) Burning. Pound-for-pound, flammable liquids produce about 2.5 times more heat than wood when involved in a fire, and the heat is liberated 3 to 10 times faster from liquids than from wood. These ratios illustrate quite clearly why flammable liquid vapor burns with such intensity. When flammable liquids spill, they expose a very large surface area and release a great amount of vapor; therefore, they can produce great amounts of heat when ignited. This is one reason why large open tank fires and liquid-spill fires burn so violently.

3.1.2(d) Flash Point. The flash point of a liquid fuel is the lowest temperature at which the vapor pressure of the liquid is just sufficient to produce a flammable mixture at the lower limit of flammability. The flash points (temperatures) of liquids are determined in controlled tests and are usually reported as a “closed cup” or an “open cup” temperature. The flash point values of liquids are frequently established using the ASTM or Pensky-Martens testing apparatuses and procedures. However, other testing apparatuses are available.

It is important to note that the typical value identified as the flash point of a flammable liquid is based upon atmospheric pressure. However, the value of the flash point for a particular liquid will vary as the atmospheric pressure to which the liquid is exposed increases or decreases.

3.1.3 Gaseous Fuels

3.1.3(a) Sources. There are both natural and manufactured flammable gases. Those that may be found on board a vessel include acetylene, propane and butanes, as well as a number of liquefied gases carried as cargo on LNG and LPG vessels.

3.1.3(b) Burning. Gaseous fuels are already in the required vapor state. Only the proper intermixing with oxygen and sufficient heat are needed for ignition. Gases, like flammable liquids, do not smolder. Radiation feedback is not necessary to vaporize the gas, however, some radiation feedback is still essential to the burning process (i.e., provide continuous re-ignition of the gas).

3.1.3(c) Flammable Range. A flammable gas or the flammable vapor of a liquid must mix with air in the proper proportion to make an ignitable mixture. The smallest percentage of a gas (or vapor) that will make an ignitable air-vapor mixture is called the Lower Flammable Limit (LFL) of the gas/vapor. If there is less gas in the mixture, it will be too lean to burn. The greatest percentage of a gas/vapor in an ignitable air-vapor mixture is called its Upper Flammable Limit (UFL). If a mixture contains more gas than the UFL, it is too rich to burn. The range of percentages between the lower and upper flammable limits is called the flammable range of the gas or vapor. It is therefore important to realize that certain ranges of vapor-air mixtures can be ignited and to use caution when working with these fuels.

The flammability ranges of specific types of fuels are published in various handbooks. Refer to such documentation for the particular product of concern.

3.2 Oxygen

Because the combustion process involves the oxidation of the fuel molecules, the availability of oxygen is vital for the process to exist. Accordingly, the second side of the fire triangle refers to the oxygen content in the surrounding air. Air normally contains about 21% oxygen, 78% nitrogen and 1% other gases, principally argon, and therefore, sufficient oxygen is typically available unless some type of controlled atmosphere (i.e., inerted, etc.) is involved.

3.3 Heat

For fuel molecules to undergo the oxidation process and result in a self-supporting fire, the molecules must be at elevated temperatures (i.e., ignition temperature). Without this elevated temperature, there will be no rapid oxidation or combustion of the fuel molecules. Further, the generation of additional fuel vapors is largely dependent upon feedback radiant heating of the fuel, except for gaseous fuels. Therefore, heat is the third side of the fire triangle. The production of energy from the initial reaction tends to raise the temperature of other molecules to the necessary elevated temperatures and tends to create the self-supporting nature of fire.

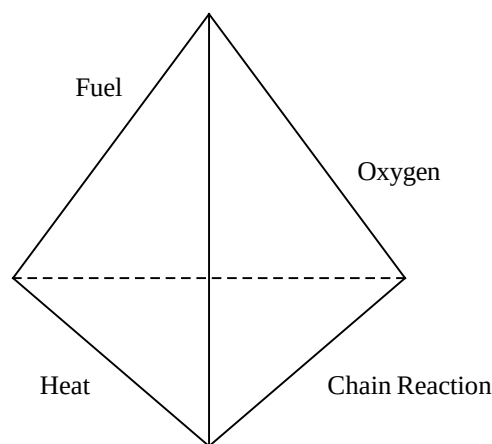
4 The Fire Tetrahedron

The fire triangle (Section 1, Figure 1) is a simple means of illustrating the three components required for the existence of fire. However, it lacks one important element when trying to understand the nature of fire and the effectiveness of extinguishing mechanisms available. In particular, it does not consider the chemical reaction of the oxidation process and the chain reaction needed for a fire to continue to exist.

The fire tetrahedron (Section 1, Figure 2) provides a better representation of the *combustion process*. A tetrahedron is a solid figure with four triangular faces and is useful for illustrating the combustion process because it shows the chain reaction and each face touches the other three faces.

The basic difference between the fire triangle and the fire tetrahedron is that the tetrahedron illustrates how flaming combustion is supported and sustained through the chain reaction of the oxidation process. In a sense, the chain reaction face keeps the other three faces from falling apart. This is an important point, because the extinguishing agents used in many modern portable fire extinguishers, automatic extinguishing systems and explosion suppression systems directly attack and break the chain reaction sequence in order to extinguish a fire.

FIGURE 2
The Fire Tetrahedron



5 Extinguishment Considering the Fire Tetrahedron

A fire can be extinguished if any one side of the fire tetrahedron can be destroyed. If the fuel, oxygen, or heat is removed, the fire will die out. Likewise, if the chain reaction is broken, the resulting reduction in vapor generation and heat production will also result in the extinguishment of the fire. (However, additional cooling with water may be necessary where smoldering or reflash is a possibility.)

5.1 Removing the Fuel

One way to remove fuel from a fire is to physically move it. In most instances, this is an impractical fire-fighting technique. However, it is often possible to move nearby fuels away from the immediate vicinity of a fire, so that the fire does not extend to these fuels.

Sometimes the supply of liquid or gaseous fuel can be cut off from a fire. When a fire is being fed by a leaky heavy fuel oil or diesel line, it can be extinguished by closing the proper valve. If a pump is supplying liquid fuel to a fire in the engine room, the pump can be shut down to remove the fuel source and thereby extinguish the fire; these arrangements are required by the Rules.

5.2 Removing the Oxygen

A fire can be extinguished by removing its oxygen or by reducing the oxygen level in the atmosphere. Many extinguishing agents (e.g., carbon dioxide and foam) extinguish a fire with smothering action by depriving the fire of oxygen.

This extinguishment method is difficult (but not impossible) to use in an open area. Gaseous smothering agents like carbon dioxide are blown away from an open deck area, especially if the vessel is underway. However, a fire in a galley trash container can be snuffed out by placing a cover tightly over the container, blocking the flow of air to the fire. As the fire consumes the oxygen in the container, it becomes starved for oxygen and is extinguished.

Tank vessels that carry petroleum products are protected by foam systems with monitor nozzles on deck. The discharged foam provides a barrier over the fuel, and when used quickly and efficiently, a foam system is capable of extinguishing a sizeable deck fire.

To extinguish a fire in an enclosed space such as a compartment, engine room or cargo hold, the space can be flooded with carbon dioxide. When the carbon dioxide enters the space and mixes with the atmosphere, the percentage of oxygen in the atmosphere is reduced and extinguishment results. This medium is used to combat fires in cargo holds. However, it is important to seal the enclosed space as reasonably gas-tight as possible to maintain the concentration of CO₂ and the reduction in oxygen.

It is also important to note that there are some cargoes known as *oxidizing substances* that release oxygen when they are heated or, in some instances, when they come in contact with water. Substances of this nature include the hypochlorites, chlorates, perchlorates, nitrates, chromates, oxides and peroxides. All contain oxygen atoms that are loosely bonded into their molecular structure, that is, they carry their own supply of oxygen, enough to support combustion. This oxygen is released when the substances break down, as in a fire. For this reason, burning oxidizers cannot be extinguished by removing their oxygen. Instead, for most oxidizers, large amounts of water, limited by vessel stability safety needs, are used to accomplish extinguishment. Oxidizers are hazardous materials, and as such, are regulated by the Flag Administration in association with the SOLAS Regulations.

5.3 Eliminating the Heat

The most commonly used method of extinguishing fire is to remove the heat. The base of the fire is attacked with water to cool the fuel surface, which reduces the amount of fuel vapor being generated. Water is a very effective heat absorber. When properly applied, it absorbs heat from the fuel and absorbs much of the radiation feedback. As a result, the chain reaction is indirectly attacked both on the fuel surface and at the flames. The production of vapor and radiant heat is reduced. Continued application will control and extinguish the fire.

Heat, which is a critical element in the fire tetrahedron, can be transferred from a fire by one or more of three methods: conduction, radiation and convection. Each of these methods of heat transfer must be considered when engaging a fire.

5.3.1 Conduction

Conduction is the transfer of heat through a solid body. For example, on a hot stove, heat is conducted through the pot to its contents. Wood is ordinarily a poor conductor of heat, but most metals are good conductors. Since most vessels are constructed of metal, heat transfer by conduction is a very real potential hazard. Fire can and will move from one hold to another, one deck to another and one compartment to another via heat conduction through the steel structure, unless structural fire protection arrangements are provided to prevent such propagation.

5.3.2 Radiation

Heat radiation is the transfer of heat from a source across an intervening space. No material substance is involved. The heat travels outward from the fire in the same manner as light, that is, in straight lines. When it contacts a body, it is absorbed, reflected or re-transmitted. Absorbed heat increases the temperature of the absorbing body. For example, radiant heat that is absorbed by an overhead will increase the temperature of that overhead, perhaps enough to ignite its paint. Radiant heat travels in all directions, unless it is blocked, and can extend a fire by heating combustible substances in its path, causing them to produce vapor and then igniting the vapor.

5.3.3 Convection

Convection is the transfer of heat through the motion of heated matter (e.g., through the motion of smoke, hot air, heated gases produced by the fire and flying embers). When it is confined as within a vessel, convective heat moves in predictable patterns. The fire produces lighter-than-air gases that rise toward high parts of the vessel. Heated air, which is lighter than cool air, also rises, as does the smoke produced by combustion. As these heated combustion products rise, cool air takes their place. The cool air is heated in turn and then rises to the highest point it can reach. As the hot air and gases rise from the fire, they begin to cool, and as they do, they drop down to be reheated and rise again. This is the convection cycle. It is important to recognize that heat originating from a fire on a lower deck will travel horizontally along passageways and then upward via ladder and hatch openings, and it can ignite flammable materials in its path.

5.4 Breaking the Chain Reaction

Another mechanism for destroying the fire tetrahedron, and therefore, extinguishing the fire, is by the interruption of the chain reaction. Once the chain reaction sequence is broken, the heat generation is reduced. This reduces the fuel vapor generation, as well as the heating of the vapor oxygen mixture, and as a result, the fire is extinguished. The extinguishing agents commonly used to attack the chain reaction and inhibit combustion are dry chemicals and Halon alternatives. These agents directly attack the molecular structure of compounds formed during the chain reaction sequence by scavenging the “O” and “OH” radicals. The breakdown of these compounds adversely affects the flame-producing capability of the fire.

It should be borne in mind that these agents do not cool a deep-seated fire or a liquid whose container has been heated above the liquid’s ignition temperature. In these cases, the extinguishing agent must be maintained on the fire until the fuel has cooled down naturally.

6 Hazardous/Combustible Materials

There are a number of hazards produced by a fire, including flames, heat, gases and smoke. Each of these combustion products can cause serious injuries or death and should be considered in the overall scope of fire-fighting arrangements onboard a vessel.

6.1 Flames

The flaming region of a fire is that portion of the combustion zone where the fuel and oxygen molecules are of an appropriate mixture and temperature to support the oxidation process. The direct contact with flames can result in totally or partially disabling skin burns and serious damage to the respiratory tract. To prevent skin burns during a fire attack, crewmen must maintain a safe distance from the fire unless they are properly protected and equipped for the attack. This is the reason that protective clothing, such as fireman’s outfits, is required by the Rules. Respiratory tract damage can be prevented by wearing breathing apparatus.

6.2 Heat

As a result of a fire, the temperature in an enclosed space can reach temperatures in excess of 93°C (200°F) very rapidly, and the temperature can build up to over 427°C (800°F) quickly. Temperatures above 50°C (122°F) are hazardous to humans, even if they are wearing protective clothing and breathing apparatus. The dangerous effects of heat range from minor injury to death. Direct exposure to heated air may cause dehydration, heat exhaustion, burns and blockage of the respiratory tract by fluids. Heat also causes an increased heart rate. A firefighter exposed to excessive heat over an extended period of time could develop hyperthermia, a dangerously high fever that can damage the nerve center.

6.3 Gases

The particular gases produced by a fire depend mainly on the fuel. The most common hazardous gases are carbon dioxide (CO₂), the product of complete combustion, and carbon monoxide (CO), the product of incomplete combustion.

Carbon monoxide is the more dangerous of the two. When air mixed with carbon monoxide is inhaled, the blood absorbs the CO before it will absorb oxygen. The result is an oxygen deficiency in the brain and body. Exposure to a 1.3% concentration of CO will cause unconsciousness in two or three breaths and death in a few minutes.

Carbon dioxide works on the respiratory system. Above normal CO₂ concentrations in the air reduce the amount of oxygen that is absorbed in the lungs. The body responds with rapid and deep breathing, which is a signal that the respiratory system is not receiving sufficient oxygen.

When the oxygen content of air drops from its normal level of 21% to about 15%, human muscular control is reduced. At 10% to 14% oxygen in air, judgment is impaired and fatigue sets in. Unconsciousness usually results from oxygen concentrations below 10%. During periods of exertion, such as fire-fighting operations, the body requires more oxygen, and these symptoms may then appear at higher oxygen percentages.

Depending upon the fuel source, there may be several other gases generated by a fire that are of equal concern to firefighters. Therefore, anyone entering a fire must wear an appropriate breathing apparatus.

6.4 Smoke

Smoke is a visible product of fire that adds to the problem of breathing. It is made up of carbon and other unburned substances in the form of suspended particles. It also carries the vapors of water, acids and other chemicals, which can be poisonous or irritating when inhaled.



SECTION 2 Classification of Fires

(2017) The characteristics of fires and the effectiveness of extinguishing agents differ with the fuels involved. While particular extinguishing agents are very effective on fires involving certain fuels, they may be much less effective or even hazardous for use on other types of fires. Take for example, the use of a portable water extinguisher. Water is a good extinguishing medium and is very effective on deep-seated fires, such as burning wood or rubbish. However, a firefighter would not want to use a portable water extinguisher on a fire involving a “live” electrical panel or switchboard due to the conductivity of the water and the possible shock that could result.

Considering the different types of fuels that may be involved in a fire, the different types of extinguishing agents available and the different mechanisms which the various agents use to extinguish a fire, it is important to be able to identify the type of fire on which a particular medium will be effective. The job of selecting the proper extinguishing agent has been made easier by the classification of fires into **five** types, or classes, lettered “A” through “D” and “F” or “K”, based upon the fuels involved. Within each class are fires involving those materials with similar burning properties and requiring similar extinguishing agents. Thus, knowledge of these classes is essential to efficient fire-fighting operations, as well as familiarity with the burning characteristics of materials that may be found aboard a vessel.

1 Overview (2017)

The International Maritime Organization (IMO) mentions two standards in IMO Resolution A.951(23) which define the various classes of fires. The first is the International Standards Organization (ISO) Standard 3941, and the second is the National Fire Protection Agency (NFPA) 10 Standard.

Section 2, Table 1 identifies these classes of fire as they are listed in IMO Resolution A.951(23). IMO Resolution A.951(23) is included in Annex of the International Code for Fire Safety System (IMO FSS Code).

While the types of combustibles covered by ISO and NFPA are very similar for Classes “A,” “B” and “D,” the combustibles covered by Class “C” designation differs substantially. Considering that the classification of the various types of combustibles used in the ABS Rules (e.g., Notes in 4-7-3/Table 4 of the *Rules for Building and Classing Steel Vessels*, 4-5-1/Table 1 of the *Rules for Building and Classing Steel Vessels Under 90 meters (295 feet) in Length*, etc.) more closely follows the NFPA designations, the Guidance Notes will use the NFPA classifications.

In the remainder of this Section, the fuels, their burning characteristics, by-products, etc., within each fire class are discussed in more detail.

TABLE 1
Fire Classifications (2017)

ISO Standard 3941	NFPA 10
Class A: Fires involving solid materials, usually of an organic nature, in which combustion normally takes place with the formation of glowing embers	Class A: Fires in ordinary combustible materials, such as wood, cloth, paper, rubber and many plastics.
Class B: Fires involving liquids or liquefiable solids.	Class B: Fires in flammable liquids, oils, greases, tars, oil base paints, lacquers and flammable gases.
Class C: Fires involving gases.	Class C: Fires, which involve energized electrical equipment where the electrical non-conductivity of the extinguishing medium is of importance. (When electrical equipment is de-energized, extinguishers for class A or B fires may be used safely.)
Class D: Fires involving metals.	Class D: Fires in combustible metals such as magnesium, titanium, zirconium, sodium, lithium and potassium.
Class F: Fires involving cooking oils.	Class K: Fires involving cooking grease, fats and oils.

2 Class “A” Fires

Class “A” fires involve three groups of materials commonly found onboard a vessel, including:

- Wood and wood-based materials
- Textiles and fibers
- Plastics and rubber

The following Paragraphs discuss Class “A” fires involving each of these materials:

2.1 Wood and Wood-based Materials

Wood products are often involved in fire, mainly because of their many uses. Marine uses include furniture, furnishings, dunnage and staging, as well as numerous other uses. Wood-based materials are those that contain processed wood or wood fibers and include some types of plywood and paneling, paper, cardboard and pressboard.

The burning characteristics of wood and wood-based materials depend on the particular type of wood involved. For example, seasoned, air-dried maple (a hard-wood) produces greater heat upon burning than does pine (a softwood) that has been seasoned and dried similarly. However, all these materials are combustible, and they will char, smolder, ignite and burn under certain conditions.

Wood is composed mainly of carbon, hydrogen and oxygen, with smaller amounts of nitrogen and other elements. In the dry state, most of its weight is in the cellulose. Some other ingredients found in dry wood are sugars, resins, gums, esters of alcohol and mineral matter.

2.1.1 Burning Characteristics (Wood)

The ignition temperature of wood depends on many factors, such as size, shape, moisture content and type. Generally, the ignition temperature of wood is taken to be about 204°C (400°F). However, it is believed that if wood is subjected to temperatures above 100°C (212°F) over a long period, under certain conditions ignition can take place. Similarly, the rate of combustion and heat release rate of wood and wood-based materials depends heavily on the physical form of the material, the amount of air available, the moisture content and other such factors.

For wood to become involved in a fire, the solid components of the surface of the wood must first be heated to the point where pyrolysis, the process whereby the solid components on the surface are converted to combustible vapors, is sufficient to support combustion.

The heat necessary to produce pyrolysis can come from a number of sources, including direct contact with a flame, contact with some other heated element or as a result of radiant heat from a separate fire. The combustible vapors resulting from the pyrolysis are released from the surface of the wood and mix with the surrounding air. When the mixture of combustible vapor and air is within the flammable range, any source of ignition may ignite the combustible vapor mass almost instantly. Even without an ignition source, if the surface temperatures rise sufficiently, auto-ignition can occur.

Flames move across the surface of combustible solids in a process called flame spread. Flame spread is the result of adjacent surfaces being heated by the existing flames to a point where the adjacent surface produces sufficient flammable vapors to support and fuel combustion. It is important to note that the orientation of the adjacent surface to the fire does play a role in the rate of flame spread. Flames will typically spread faster in an upward direction, since such locations are heated by radiant heat from the flame, as well as convective heat from the fire plume. The process of flame spread will continue until all fuel is consumed or there is not sufficient heat available to promote adequate pyrolysis of adjacent surfaces.

Bulky solids with a small surface area (for example, a heavy wood beam) burn more slowly than solids with a larger surface area (for example, a sheet of plywood), and solids in chip, shaving or dust form (wood, metal shavings, sawdust, grains and pulverized coal) burn even more rapidly, since they represent a much larger total area per mass of fuel. The larger surface area allows combustible vapor to be generated and released at a greater rate. (This is also true of flammable liquids. A shallow liquid spill with a large area will burn off more rapidly than the same volume of liquid in a deep tank with a small surface area.)

2.1.2 By-products of Combustion (Wood)

Burning wood and wood-based materials produce water vapor, heat, carbon dioxide and carbon monoxide. The reduced oxygen levels and the carbon monoxide present the primary hazard to crewmembers and firefighters. In addition, wood and wood-based materials produce a wide range of aldehydes, acids and other gases when they burn. By themselves or in combination with the water vapor, these substances can cause irritation at least, and in high enough concentrations, most produced gases are toxic.

2.2 Textiles and Fibers

Textiles, in the form of clothing, furniture, carpets, canvas, burlap, ropes and bedding are used extensively in the marine environment, and others are carried as cargo. In addition, almost all textile fibers are combustible. These two facts explain the frequency of textile-related fires and the many deaths and injuries that result.

2.2.1 Natural Textiles

2.2.1(a) Plant Fibers. Vegetable fibers consist largely of cellulose. They include cotton, jute, hemp, flax and sisal. Cotton and the other plant fibers are combustible [the ignition temperature of cotton fiber is around 400°C (752°F)]. Burning vegetable fibers produce heat and smoke, carbon dioxide, carbon monoxide and water. The ease of ignition, rate of flame spread and amount of heat produced depend on the construction and finish of the textile and on the design of the finished product.

2.2.1(b) Organic Fibers. Organic fibers, such as wool and silk, are solid and are chemically different from vegetable fibers. They do not burn as freely and they tend to smolder. For example, wool is a protein. It is more difficult to ignite wool than cotton [the ignition temperature of wool fiber is around 600°C (1112°F)], it burns more slowly and is easier to extinguish.

2.2.2 Synthetic Textiles

Synthetic textiles are fabrics woven wholly or mainly of synthetic fibers. Such fibers include rayon, acetate, nylon, polyester, acrylic and plastic wrap. The fire hazards involved with synthetic textiles are sometimes difficult to evaluate, owing to the tendency of some of them to shrink, melt or drip when heated. Rayon and acetate resemble plant fibers chemically, whereas most other synthetic fibers do not. Almost all are combustible in varying degrees, but differ in ignition temperature, burning rate and other combustion features.

2.2.3 Burning Characteristics (Textiles/Fibers)

Many variables affect the way in which a textile burns. The most important are the chemical composition of the textile fiber, the finish on the fabric, the fabric weight, the tightness of weave and any flame retardant treatment.

Vegetable fibers ignite easily and burn readily, giving off large amounts of heavy smoke. Partially burned vegetable fibers may present a fire risk, even after they have been extinguished. Half-burned fibers should always be removed from the fire area to a location where re-ignition of the material would not create an additional problem. Most baled vegetable fibers absorb water readily. The bales will swell and increase in weight when large quantities of water are used to extinguish fires in which they are involved.

Wool is difficult to ignite, and it tends to smolder and char rather than to burn freely, unless it is subjected to considerable external heat. However, it will contribute toward a fierce fire. Wool can absorb a large amount of water – a fact that must be considered during prolonged fire-fighting operations.

Silk is a less dangerous fiber. It is difficult to ignite and it burns sluggishly. Combustion usually must be supported by an external source of heat. Once set on fire, silk retains heat longer than any other fiber. In addition, it can absorb a great amount of water. Spontaneous ignition is possible with wet silk. There may be no external evidence that a bale of silk had ignited, until the fire burns through to the outside.

The burning characteristics of synthetic fibers vary according to the materials used, but the characteristics of some of the more common synthetics are given in the following table.

TABLE 2
Burning Characteristics of Synthetic Fibers

<i>Synthetic</i>	<i>Burning Characteristics</i>
Acetate	Burns and melts ahead of the flame. Ignition point is similar to cotton.
Acrylic	Burns and melts. Ignition temperature approx. 560°C (1040°F). Softens at 235-330°C (455-626°F).
Nylon	Supports combustion with difficulty. Melts and drips; melting point, 160-260°C (320-500°F). Ignition temperature approx. 425°C (797°F) and above.
Polyester	Burns readily. Ignition temperature 450-485°C (842-905°F). Softens at 256-292°C (493-558°F) and drips.
Plastic wrap	Melts.
Viscose	Burns about the same as cotton.

These characteristics are based on small-scale tests and may be misleading. Some synthetic fabrics appear to be flame-retardant when tested with a small flame source, such as a match. However, when the same fabrics are subjected to a larger flame or a full-scale test, they may burst into flames and burn completely while generating quantities of black smoke.

2.2.4 By-products of Combustion (Textiles/Fibers)

All burning materials produce hot gases (called fire gases), flame, heat and smoke, resulting in decreased oxygen levels. The predominant fire gases are carbon monoxide, carbon dioxide and water vapor. Burning vegetable fibers such as cotton, jute, flax, hemp and sisal give off large amounts of dense smoke. Jute smoke is particularly acrid.

Burning wool gives off dense, grayish-brown smoke. Another product of the combustion of wool is hydrogen cyanide, a highly toxic gas. Charring wool forms a sticky, black, tar-like substance.

Burning silk produces a large amount of spongy charcoal mixed with ash, which will continue to glow or burn only in a strong draft. It emits quantities of thin gray smoke, somewhat acrid in character. Silk may produce hydrogen cyanide gas under certain burning conditions.

2.3 Plastics and Rubber

A variety of organic substances are used in manufacturing plastics. These include phenol, cresol, benzene, methyl alcohol, ammonia, formaldehyde, urea and acetylene. The cellulose-based plastics are largely composed of cotton products. However, wood flour, wood pulp, paper and cloth also play a large part in the manufacturing of many types of plastic.

Natural rubber is obtained from rubber latex, which is the juice of the rubber tree. It is combined with such substances as carbon black, oils and sulfur to make commercial rubber. Synthetic rubbers are similar to natural rubber in certain characteristics. Acrylic, butadiene and neoprene rubbers are some of the synthetic types.

2.3.1 Burning Characteristics (Plastics/Rubber)

The burning characteristics of plastics vary widely and depend upon the specific material involved, as well as the form of the product (solid sections, films and sheets, foams, molded shapes, synthetic fibers, pellets or powders). Most major plastic materials are combustible at least to some extent, and in a major fire, all contribute fuel to the fire.

Plastics may be divided roughly into three groups with regard to burning rates:

- i) *Materials that either will not burn at all or will cease to burn if the source of ignition is removed.* This group includes asbestos-filled phenolics, some polyvinyl chlorides, nylon and the fluorocarbons.
- ii) *Materials that are combustible, burn relatively slowly, but may or may not cease to burn when the source of ignition is removed.* These plastics include the wood-filled formaldehydes (urea or phenol) and some vinyl derivatives.
- iii) *Materials that burn without difficulty and can continue to burn after the source of ignition is removed.* Included in this group are polystyrene, the acrylics, some cellulose acetates and polyethylene.

In a class of its own is the oldest well-known form of plastic, celluloid, or cellulose nitrate plastic. It is typically considered the most dangerous of the plastics. Celluloid decomposes at temperatures of 121°C (250°F) and above with great rapidity, and without the addition of oxygen from the air. Flammable vapor is produced by the decomposition. If this vapor is allowed to accumulate and is then ignited, it can explode violently. It will burn vigorously and is difficult to extinguish.

The caloric value of rubber is roughly twice that of other common combustible materials. For example, rubber has a heating value of 17.9×10^6 kilo-joules (17,000 BTU/lb), whereas pine wood has a value of 8.6×10^6 kilo-joules (8200 BTU/lb). Most types of natural rubber soften when burning and may thus contribute to rapid fire spread. Natural rubber decomposes slowly when first heated. At about 232°C (450°F), it begins to decompose rapidly, giving off gaseous products that may result in an explosion. The ignition temperature of these gases is approximately 260°C (500°F).

Synthetic rubbers behave similarly, though the temperature at which decomposition becomes rapid may be somewhat higher. This temperature ranges upward from 349°C (660°F) for most synthetics, depending on the ingredients. Latex is a water-based emulsion and so does not present fire hazard.

2.3.2 By-products of Combustion (Plastics/Rubber)

Burning plastic and rubber produce the fire gases, heat, flame and smoke. These materials may also contain chemicals that yield additional combustion products of a toxic or lethal nature. The type and amount of smoke generated by a burning plastic material depends on the nature of the plastic, the additives present, whether the fire is flaming or smoldering and what ventilation is available. Most plastics decompose when heated, yielding dense to very dense smoke. Ventilation tends to clear the smoke, but usually not enough for good visibility. Those plastics that burn cleanly yield less dense smoke under conditions of heat and flame. When exposed to flaming or non-flaming heat, urethane foams generally yield dense smoke, and in almost all cases, visibility is lost quickly.

Hydrogen chloride is a product of combustion of chlorine-containing plastics, such as polyvinyl chloride, a plastic used for insulating certain electrical wiring. Hydrogen chloride is a deadly gas that has a pungent and irritating odor.

Burning rubber produces dense, black, oily smoke that has some toxic qualities. Two of the noxious gases produced in the combustion of rubber are hydrogen sulfide and sulfur dioxide. Both are dangerous and can be lethal under certain conditions.

2.4 Locations of Class “A” Materials Onboard (2017)

Although vessels are constructed of metal and may appear incombustible, there are many flammable products aboard. Practically every type of material (Class “A” and otherwise) may be carried as cargo. It may be located in the cargo holds or on deck, stowed in containers or in bulk stowage. In addition, Class “A” materials are used for many purposes throughout the vessel.

In accordance with SOLAS (Consolidated Edition 2014) Reg. II-2/5.3.2, a certain amount of combustible materials may be used in the construction of facings, moldings, decorations and veneers in accommodation and service spaces. In addition, the furnishings found in passenger, crew and officer accommodations are usually made of Class “A” materials. Lounges and recreation rooms may contain couches, chairs, tables, bars, television sets, books and other items that may be constructed of Class “A” materials.

Other areas in which Class “A” materials may be located include the following:

- Bridge contains wooden desks, charts, almanacs and other such combustibles.
- Wood in many forms may be found in the carpenter shop.
- Various types of cordage are stowed in the boatswain’s locker.
- Emergency locker on the bridge wing contains rockets and/or explosives for the line-throwing gun.
- Undersides of metal cargo containers are usually constructed of wood or wood-based materials.
- Lumber for dunnage, staging and other uses may be stored below decks.
- Large numbers of filled laundry bags are sometimes left in passageways, awaiting movement to and from the laundry room.

2.5 Extinguishment of Class “A” Fires

It is a fortunate coincidence that the materials most often involved in fire, Class “A” materials, may best be extinguished by the most available extinguishing agent, water, provided by the required fire main system. In addition, other types of extinguishing mediums, such as foam and certain types of dry chemicals are also effective on Class “A” combustibles.

3 Class “B” Fires

Class “B” fires involve two groups of materials commonly found onboard a vessel:

- Flammable liquids
- Flammable gases

3.1 Flammable Liquids

SVR 4-6-1/3.23 indicates that for the purposes of SVR Sections 4-6-1 through 4-6-7, a flammable fluid or liquid is any fluid, regardless of its flash point, liable to support flame, and that “aviation fuel, diesel fuel, heavy fuel oil, lubricating oil and hydraulic oil are all to be considered flammable fluids.” Accordingly, all types of liquids that will burn are typically considered to be flammable fluids, including oil-based paints and solvents.

3.1.1 Burning Characteristics (Flammable Liquids)

As previously noted, it is the vapor of a flammable liquid, rather than the liquid itself, which burns or explodes when mixed with air and ignited. These liquids will vaporize when exposed to air and at an increased rate when heated.

Flammable vapor explosions most frequently occur within a confined space, such as a tank, room or structure. The violence of a flammable vapor explosion depends upon:

- i) Concentration and nature of the vapor,
- ii) Quantity of vapor-air mixture present, and
- iii) Type of enclosure in which the mixture is confined.

The flashpoint is commonly accepted as the most important factor in determining the relative hazard of a flammable liquid. However, it is not the only factor. The ignition temperature, flammable range, rate of evaporation, reactivity when contaminated or exposed to heat, density and rate of diffusion of the vapor also determine how dangerous the liquid is. However, once a flammable liquid has been burning for a short time, these factors have little effect on its burning characteristics.

The burning rates of flammable liquids vary somewhat, as do their rates of flame travel. The burning rate of gasoline is 15.2 to 30.5 cm (6 to 12 in.) of depth per hour, and for kerosene, the rate is 12.7 to 20.3 cm (5 to 8 in.) of depth per hour. For example, a pool of gasoline 1.27 cm ($\frac{1}{2}$ in.) deep could be expected to burn itself out in 2.5 to 5 minutes.

3.1.2 By-products of Combustion (Flammable Liquids)

In addition to the usual combustion products, there are some products that are peculiar to flammable liquids. Liquid hydrocarbons normally burn with an orange flame and give off dense clouds of black smoke. Alcohols normally burn with a clean blue flame and very little smoke. Certain terpenes and ethers burn with considerable boiling of the liquid surface and are difficult to extinguish. Acrolein (acrylic aldehyde) is a highly irritating and toxic gas produced during the combustion of petroleum products, fats, oils and many other common materials.

Liquid paint can also burn fiercely and gives off much heavy black smoke. Explosions are another hazard of liquid paint fires. Since paint is normally stored in tightly sealed cans or drums up to 150-190 liters (40-50 gallons) capacity, fire in any paint storage area may easily heat up the drums and cause them to burst due to excessive pressure. The contents are likely to ignite very quickly, possibly with explosive force with the exposure to air.

3.1.3 Locations of Flammable Liquids Onboard

Large quantities of flammable liquids, in the form of heavy fuel oil, diesel oil, lubricating oil and hydraulic oil are also stowed aboard a vessel, for use in propelling and generating electricity. In addition, heavy fuel oil and diesel oil are frequently heated during the purification process or in preparation for injection into a boiler or an engine, which introduces additional hazards due to the additional volume of vapors capable of being created and the existence of those vapors at elevated temperatures. Fires involving these particular Class “B” combustibles are usually associated with machinery spaces.

In addition, flammable liquids of all types are carried as cargo by tank vessels, and flammable liquids in smaller packages may be found in holds of vessels carrying dangerous goods, as well as in the tanks of vehicles being transported in ferries or ro-ro vessels.

Most paints, varnishes, lacquers and enamels, except those with a water base, present a high fire risk in storage or in use. Accordingly, ABS-classed vessels are required to carry such products in designated paint or flammable liquid lockers.

Other locations where combustible liquids may be found include the galley (hot cooking oils) and the various mechanics shops and spaces where lubricating oils are used. Fuel and diesel oil may also be found as residues and films on and under oil burners and equipment in the engine room.

3.1.4 Extinguishment of Flammable Liquids (2017)

In general, the Rules require a fixed fire-fighting system to be installed in spaces specifically subject to Class “B” fires. Various types of fixed systems are discussed in detail in following Sections and are in addition to the required fire main system, as well as the various required portable and semi-portable appliances.

A few examples are provided below:

- *Machinery Spaces.* Category “A” machinery spaces are required to be fitted with a fixed gas extinguishing system, fixed water spray system or high expansion foam system, in accordance with SVR 4-7-2/1.1.1.
- *Cargo Tanks.* In addition to an inert gas system intended to maintain the cargo tanks in an inerted condition, oil and chemical carriers with cargo tanks carrying flammable liquid cargoes are required to be fitted with a foam system for coverage on the deck, in accordance with SVR 5C-1-7/27 and 5C-9-11/3. The cargo pump rooms for such spaces are also required to be fitted with fixed fire extinguishing systems (SVR 5C-1-7/29 and 5C-9-11/2).
- *Ro-Ro Spaces.* Ro-ro spaces are required to be fitted either a fixed gas extinguishing system or a water spray system, in accordance with SVR 5C-10-4/3.3.
- *Paint and Flammable Liquid Lockers.* Paint and flammable liquid lockers must be fitted with a CO₂ system, a fixed water spray system or a dry powder system, in accordance with SVR 4-7-2/5.1. For paint lockers and flammable liquid lockers of floor area less than 4 m² (43 ft²) having no access to accommodation spaces, portable fire extinguisher(s) sized in accordance with SVR 4-7-2/5.1.1i) and which can be discharged through a port in the boundary of the lockers may be accepted.

3.2 Flammable Gases

While most solids and liquids can be vaporized when their temperature is increased sufficiently, the term “gas” is taken to mean a substance that is in the gaseous state at atmospheric temperatures and pressures. In the gaseous state, the molecules of a substance are not held together, but are free to move about and take the shape of its container.

Any gas that will burn in the normal concentrations of oxygen in air is considered a flammable gas. As with other gases or vapors, a flammable gas will burn only when its concentration in air is within its combustible range and the mixture is heated to its ignition temperature.

Flammable gases are usually stored and transported aboard vessels in one of three ways:

- *Compressed.* A compressed gas is one that, at normal temperatures, is entirely in the gaseous state under pressure in its container.
- *Liquefied.* A liquefied flammable gas is one that, at 37.8°C (100°F) has a Reid vapor pressure of at least 2.8 bar (40 psi). At normal temperatures, it is partly in the liquid state and partly in the gaseous state under pressure in its container.
- *Cryogenic.* A cryogenic gas is one that is liquefied in its container at a temperature far below normal temperatures and at low to moderate pressures.

3.2.1 Basic Hazards

The hazards presented by a gas that is confined in a container differ from those presented when a gas that has escaped from its container. They will be discussed separately, although these hazards may be present simultaneously in a single incident.

3.2.1(a) Hazards of Confinement. When the exterior of a tank or cylinder containing gas is exposed to a fire, the internal pressure of the container increases due to the heating of the gas. If the pressure increases sufficiently, a gas leak or a container failure could result. In addition to the increasing pressure, heating of the container surface (e.g., contact of flames with the container, radiant heat, etc.) can reduce the strength of the container material.

To prevent the failure of tanks or cylinders containing compressed flammable gases, pressure relief valves and fusible plugs are typically installed. When the pressure exceeds a set limit, the relief valve opens allowing gas to flow out of the container, normally through a relief piping system to some safe location, thereby reducing the internal pressure. Typically a spring loaded device closes the valve when the pressure is reduced to a safe level.

A fusible plug is another protective device. The fusible plug is constructed of a metal that will melt at a specific temperature. The plug seals an opening in the body of the container, usually near the top. Heat from a fire, threatening the tank or cylinder, causes the metal plug to melt allowing the gas to escape through the opening. Excessive pressure within the tank is prevented. However, the opening cannot be closed and the gas will continue to escape until the container is empty.

Failure of the containment can occur when these safety devices are not installed or fail to operate properly. Another cause of failure is the very rapid build-up of pressure in a container at a rate that the pressure cannot be relieved through the safety valve opening fast enough to prevent the excessive build-up of pressure.

3.2.1(b) Container Protection. Compressed or liquefied gas represents a great deal of energy being held within the container. If the container fails, this energy is released-often very rapidly and violently. The gas escapes and the container or container pieces are scattered.

Failure of a liquefied flammable gas container due to exposure to a fire is of great concern due to the concern with boiling liquid-expanding vapor explosion, or BLEVE (pronounced “blevey”). Because of these concerns, the Rules require relief valves to be of a capacity that is capable of handling the flow rate of vapors during a maximum fire exposure.

3.2.1(c) Hazards of Gases Released from Confinement. The hazards of a flammable gas that has been released from its container depend on the properties of the gas, as well as the location and conditions where it is released. Any released flammable gas can present a danger of a fire or explosion or both.

A volume of released gas will not burn or explode if either:

- i) The concentration of gas is not sufficient to result in a flammable air-gas mixture, or
- ii) Any resulting flammable air-gas mixture does not come into contact with an ignition source.

A volume of released gas will burn without exploding if:

- i) There is an insufficient concentration of gas anywhere but in the immediate vicinity of the point of release due to the dissipation of the gas into the atmosphere, or
- ii) Because the initial release of gas was ignited so quickly that sufficient volumes of the un-ignited air-gas mixture did not have time to accumulate. These types of fires are normally referred to as jet fires.

Where a sufficient volume of flammable gas is released in a manner that creates an un-ignited gas-air mixture within the flammable concentration range, an explosion can, and typically will, occur, if ignited. Such concentrations can be readily achieved if a flammable gas is released in an enclosed area. However, even on an open deck, if a massive release occurs, a gas cloud of sufficient concentration and volume can be created (unless ignition at the point of release occurs immediately). Explosions of such open area gas clouds are known as open-air explosions or space explosions. Liquefied gases, hydrogen and ethylene are subject to open-air explosions.

3.2.2 Properties of Some Common Gases

Properties of a number of flammable gases are presented in the following pages. These properties lead to varying degrees and combinations of hazards when the gases are confined or released.

3.2.2(a) Acetylene. Acetylene is composed of carbon and hydrogen. It is used primarily in chemical processing and as a fuel for oxy-acetylene cutting and welding equipment. It is non-toxic and has been used as an anesthetic. Pure acetylene is odorless, but the acetylene in general use has an odor due to minor impurities mixed in with the gas.

Acetylene is subject to explosion and fire when released from its container. It is easier to ignite than most flammable gases and it burns more rapidly. This increases the severity of explosions and the difficulty of venting to prevent explosion. Acetylene is only slightly lighter than air, which means it will mix well with air upon leaving its container.

3.2.2(b) Anhydrous Ammonia. Anhydrous ammonia is composed of nitrogen and hydrogen. It is used primarily as fertilizer, as a refrigerant and as a source of hydrogen for the special atmospheres needed to heat-treat metals. It is a relatively toxic gas, but its sharp odor and irritating properties serve as warnings. However, large clouds of anhydrous ammonia, produced by large liquid leaks, have trapped and killed people before they could evacuate the area.

Anhydrous ammonia is subject to explosion and fire (and presents a toxicity hazard) when released from its container. However, its high LEL and low heat of combustion tend to minimize these hazards. In unusually tight locations, such as refrigerated process of storage areas, the release of the liquid or a large quantity of gas can result in an explosion.

3.2.2(c) Ethylene. Ethylene is composed of carbon and hydrogen and is used in chemical processing, such as the manufacture of polyethylene plastic. Smaller amounts are used to ripen fruit. It has a wide flammable range and burns quickly.

While nontoxic, ethylene is an anesthetic and asphyxiant, and is subject to explosion and fire when released from its container. Ethylene has a wide flammable range and high burning rate. In a number of cases involving rather large outdoor releases, open-air explosions have occurred.

3.2.2(d) Liquefied Natural Gas (LNG). LNG is a mixture of materials, all composed of carbon and hydrogen. The principal component is methane, with smaller amounts of ethane, propane and butane. LNG is nontoxic but is an asphyxiant. It is used as a fuel.

Liquefied natural gas is shipped as a cryogenic gas in insulated tanks. LNG is subject to explosion and fire when released from its container.

3.2.2(e) *Liquefied Petroleum Gas (LPG)*. LPG is a mixture of materials, all composed of carbon and hydrogen. Commercial LPG is mostly either propane or normal butane, or a mixture of these with small amounts of other gases. It is nontoxic but is an asphyxiant. It is used principally as a fuel and, in domestic and recreational applications, sometimes known as “bottled gas”.

LPG is subject to explosion and fire when released from its container. As most LPG is used indoors, explosions are more frequent than fires. The explosion hazard is accentuated by the fact that 3.8 liters (1 gallon) of liquid propane or butane produces 75 to 84 m³ (245 to 275 ft³) of gas. Large releases of liquid-phase LPG outdoors have led to open-air explosions.

3.2.3 Usual Locations Onboard

Many of the liquefied flammable gases, such as LPG and LNG, are transported in bulk on gas carriers, and fire protection requirements for such vessels are found in SVR Section 5C-8-11. Additionally, acetylene is typically found stored in cylinders for use on board.

3.2.4 Extinguishment of Flammable Gases

Flammable gas fires can be extinguished with dry chemicals that interrupt the chain reaction of the combustion (oxidation) process. The installation of a fixed dry chemical system is required on gas carriers in accordance with SVR 5C-8-11/4. In addition, water spray systems are required to provide heat shields for certain portions of the structure from the radiant heat of gas fires in accordance with SVR 5C-8-11/3.

The procedure for fighting a flammable gas fire tends to be allowing the gas to burn until the flow can be shut off at the source. Extinguishment is normally not attempted unless such extinguishment leads to shutting off the fuel flow, since the release of un-ignited gas can result in a more dangerous explosion. Until the flow of gas supplying the fire has been stopped, fire-fighting efforts are normally directed toward protecting areas that may contain materials that may be ignited by flames or radiated heat from the fire. Water, in the form of straight streams and fog patterns, is usually used to protect such exposures. When the gas is no longer escaping from its container, the gas flames should go out. However, if the fire is extinguished before shutting off the gas flow, firefighters must be careful to prevent the ignition of gas that is being released.

4 Class “C” Fires

Electrical equipment involved in fire, or in the vicinity of a fire, may cause electric shock or burns to firefighters. This Subsection discusses some electrical installations found aboard a vessel, their hazards and the extinguishment of fires involving electrical equipment.

4.1 Types of Equipment

- *Generators*. Generators are machines that produce electrical power. These machines are usually driven by internal combustion engines, or in older vessels, steam produced in an oil-fired boiler. The electrical wiring in the generator may be insulated with a combustible material. Any fire involving the generator or its prime mover will involve a high risk of electrical shock to personnel.
- *Panel boards*. A panel board has fuses and automatic devices for the control and protection of lighting and power circuits. The switches, fuses, circuit breakers and terminals within a panel board all have electrical contacts. These contacts may develop considerable heat, causing dangerously high temperatures and unnecessary operation of overcurrent devices, unless they are maintained in good condition. Overcurrent devices are provided for the protection of conductors and electrical equipment and open the circuit if the current in that circuit produces an excessively high temperature.
- *Switches*. Switches are required for the control of lights and appliances and for disconnecting motors and their controllers. They are also used to isolate high voltage circuit breakers for maintenance operations. Switches may be of either the air-break or the oil-break type. In the oil-break type, the device that interrupts the circuit is immersed in oil.

The chief hazard is the arcing produced when the switch is opened. In this regard, oil-break switches are the more hazardous of the two types. The hazard increases when a switch is operated much beyond its rated capacity, when its oil is in poor condition or when the oil level is low. Then the arc may vaporize the remaining oil, rupture the case and cause a fire. However, if properly used and maintained, these switches present no hazard.

- *Electric Motors.* Many fires are caused by electric motors. Sparks or arc, from short circuiting motor windings or improperly operating brushes, may ignite the motor insulation or nearby combustible material. Other causes of fires in motors include overheating of bearings due to poor lubrication and grimy insulation on conductors preventing the normal dissipation of heat.

4.2 Electrical Faults that Cause Fires

- *Short Circuits.* If the insulation separating two electrical conductors breaks down, a short circuit occurs. Instead of following its normal path, the current flows from one conductor to the other. Because the electrical resistance is low, a heavy current flows and causes intense local heating. The conductors become overloaded electrically, and they may become dangerously overheated unless the circuit is broken. If the fuse or circuit breaker fails to operate, or is unduly delayed, fire can result and spread to nearby combustible material.
- *Overloading of Conductors.* When too large an electrical load is placed on a circuit, an excessive amount of current flows and the wiring overheats. The temperature may become high enough to ignite the insulation. The fuses and circuit breakers that are installed in electric circuits will prevent this condition. However, if these safety devices are not maintained properly, their failure may result in a fire.
- *Arcing.* An arc is pure electricity jumping across a gap in a circuit. The gap may be caused intentionally (as by opening a switch) or accidentally (as when a contact at a terminal becomes loose). In either case, there is intense heating at the arc. The electrical strength of the arc and amount of heat produced depend on the current and voltage carried by the circuit. The temperature may easily be high enough to ignite any combustible material near the arc, including insulation. The arc may also fuse the metal of the conductor. Then, hot sparks and hot metal may be thrown about and set fire to other combustibles.

4.3 Hazards of Electrical Fires

- *Electric Shock.* Electric shock may result from contact with live electrical circuits. It is not necessary to touch one of the conductors of a circuit to receive a shock. Any conducting material that is electrified through contact with a live circuit will suffice. Thus, firefighters are endangered in two ways: First, they may touch a live conductor or some other electrified object while groping about in the dark or in smoke. Second, a stream of water or foam can conduct electricity to firefighters from live electrical equipment. Moreover, when firefighters are standing in water, both the chances of electric shock and the severity of shocks are greatly increased.
- *Burns.* Many of the injuries suffered during electrical fires are due to burns alone. Burns may result from direct contact with hot conductors or equipment, or from sparks thrown off by these devices. Electric arcs can also cause burns. Even persons at a distance from the arc may receive eye burns.

4.4 Locations of Electrical Equipment Onboard

Electric power is essential to the operation of a vessel. The equipment that generates, controls and delivers this power is found throughout the vessel. Some of this equipment, such as lighting devices, switches and wiring, is common and easily recognized.

- *Engine Room.* The source of the vessel's electric power is its generators. At least two generators are located in the engine room and often three or four generators are fitted. While the others are operating, one is always held in reserve for backup duty. The generators supply power to the main electrical switchboard, which is typically in the same area as the generators in the engine room. The switchboard houses the generator control panels, as well as a distribution section. If a fire breaks out in the vicinity of the generator switches or the main switchboard, the vessel's engineer can stop the generator by mechanical means. This will de-energize the panel board and switches. Also nearby is the engine room console, which contains controls for the fire pumps, ventilating fans, engineer's signal alarm panel, temperature detection system and other engine room equipment.
- *Emergency Generator Room.* An emergency generator and switchboard are available for use on most vessels in case the main generator fails. It will provide power for emergency lighting and equipment only. They are located in the emergency generator room, which is outside the main engine room.

- *Passageways.* Electrical distribution and lighting panel boards are located along passageway bulkheads. Much of the vessel's electrical wiring is placed in the passageway overheads. Access panels are provided in these overheads to allow work on the wiring, and these panels can be removed to check the area for fire extension.
- *Other Locations.* The bridge contains much electrical equipment, including the radar apparatus, bridge console, smoke detector indicating panel and lighting panel boards. Below decks, in the bow and stern, are electrical control panels for the capstan and winch motors. A power panel board in the machine shop controls the electric-arc-welding machine, buffer and grinder, drill press and lathe. There is still much more electrical equipment located throughout every vessel. The important point is that the hazards of live electrical equipment must be considered whenever a shipboard fire is being fought.

4.5 Extinguishment of Class "C" Fires

When any type of electrical equipment is involved with fire, its circuit should be de-energized. However, recognizing that the circuit may not be de-energized, the fire must be extinguished using a non-conducting agent, such as CO₂ or dry chemical. In considering the application of a fire extinguishing agent, an electrical circuit or panel should always be considered energized.

5 Class "D" Fires

Metals are commonly considered to be non-flammable. However, they can contribute to fires and fire hazards in a number of ways. Sparks from the ferrous metals, iron and steel, can ignite nearby combustible materials. Finely divided metals are easily ignited at high temperatures. A number of metals, especially in finely divided form, are subject to self-heating under certain conditions; resulting in fires. Alkali metals such as sodium, potassium and lithium react violently with water, liberating hydrogen, and sufficient heat is generated in the process to ignite the hydrogen. Most metals in powder form can be ignited as a dust cloud, and violent explosions have resulted. In addition to all this, metals can injure firefighters through burning, structural collapse and toxic fumes.

Many metals, such as cadmium, give off noxious gases when subjected to the high temperatures of a fire. Some metallic vapors are more toxic than others. However, breathing apparatus should be used whenever fires involving metals are fought.

5.1 Hazards/Characteristics of Specific Metals

- *Aluminum.* Aluminum is a light metal with good electrical conductivity. In its usual forms it does not present a problem in most fires. However, its melting point of 660°C (1220°F) is low enough to cause the collapse of unprotected aluminum structural members. It is for this reason that aluminum is not permitted to be used in a fire main, even on an aluminum vessel. Aluminum chips and shavings have been involved in fire, and aluminum dust is a severe explosion hazard. Aluminum does not ignite spontaneously and is not considered to be toxic.

In addition, if aluminum is mixed with or smeared into iron oxide (rust) and then struck, a spark can be generated which can ignite an existing flammable vapor. This is the reason that the Rules prohibit the use of aluminum paint within hazardous areas, such as those on oil carriers.

- *Iron and Steel.* Iron and steel are not considered combustible. In the larger forms, such as structural steel, they do not burn in ordinary fires. However, fine steel wool or dust may be ignited, and iron dust is a fire and explosion hazard when exposed to heat or flame. Iron melts around 1535°C (2795°F) and ordinary structural steel around 1430°C (2606°F).
- *Magnesium.* Magnesium is a brilliant white metal that is soft, ductile and malleable. It is used as a base metal in light alloys for strength and toughness. Its melting point is 649°C (1200°F). Dust or flakes of magnesium are easily ignited, but in solid form it must be heated above its melting point before it will burn. It then burns fiercely with a brilliant white light. When heated, it reacts violently with water and all moisture.
- *Titanium.* Titanium is a strong white metal, lighter than steel, which melts at 2000°C (3632°F). It is mixed with steel in alloys to give high working temperatures. It is easily ignited in smaller forms (titanium dust is very explosive), though larger pieces offer little fire hazard. Titanium is not considered toxic.

5.2 Locations of Class “D” Materials Onboard

The metal principally used in the construction of vessels is steel. However, aluminum, its alloys and other lighter metals are used to build the superstructures of some vessels. The advantage of aluminum lies in the reduction of weight. A disadvantage, from the fire-fighting viewpoint, is the comparatively low melting point of aluminum as compared to that of steel.

In addition to the material used for the vessel itself, metals are carried in most forms as cargo. Generally, there are no stowage restrictions regarding metals in solid form. On the other hand, the metallic powders of titanium, aluminum and magnesium must be kept in dry, segregated areas. The same rules apply to the metals potassium and sodium.

It should be noted here that the large containers used for shipping cargo are usually made of aluminum. The metal shells of these containers have melted and split under fire conditions, exposing their contents to the fire.

5.3 Extinguishment of Class “D” Fires (2017)

Metals that form a fire risk are usually carried as cargoes and fall under the category of dangerous goods. Frequently there is a violent reaction with water, which may result in the spreading of the fire and/or explosion. No one method of extinguishment has proven effective for all fires involving metals. Sand, graphite, various other powder extinguishing agents and salts of different types have been applied to metallic fires with varying success.

Recognizing the unique fire risks that individual dangerous goods present, the International Maritime Organization has established emergency procedures for such products. These emergency procedures typically identify the particular type of extinguishing agent to be used in the case of a fire involving these products and are found in appendices to the IMDG Code (International Maritime Dangerous Goods Code), as well as the IMO IMSBC Code ([International Maritime Solid Bulk Cargoes Code and supplement](#)). In reviewing the fire-fighting arrangements for a vessel intended to carry particular cargoes considered to be a Class “D” fire hazards, the above emergency procedures should be consulted.

6 Class “K” or “F” Fires (2017)

Class “K” or “F” fires involve unsaturated cooking oils in well-insulated cooking appliances. Fires that involve cooking grease, fats and oils are designated as “Class K” under the American system, and “Class F” under the European/Australasian systems. Though such fires are technically a subclass of the flammable liquid/gas class, the special characteristics of these types of fires, namely the higher flash point, are considered important enough to recognize separately. Wet chemical can be used to extinguish such fires.

6.1 Hazards/Characteristics of Fires Caused by Cooking Grease, Fats and Oils

In order to meet the demand for faster cooking, a new generation of well insulated, high efficiency cooking appliances was introduced and is widely used in ship galleys nowadays. These appliances heat faster, cook hotter and cool slower. They are also more economical to operate since less energy is needed. To accommodate this new technology, higher temperature vegetable cooking oils were needed. Deep fat fryers in particular, need the high-temperature vegetable cooking oils. Health concerns have also contributed to reduced use of animal fats or lard as a cooking oil.

This has fire protection consequences. The fat/oil used in deep fat fryers is normally heated to about 182°C (360°F) and the auto-ignition temperature of most animal fat is in the range of 288-316°C (550-600°F) compared to 363°C (685°F) or higher for vegetable oils. After the fat/oil has been in use for several days the auto-ignition temperature is lowered by 28°C (50°F) or more. The older the grease, the greater the hazard. When a temperature controller malfunctions, the temperature of the fat/oil being heated can readily increase to the auto-ignition point and the vapors will catch fire from the excess temperature. All of the fat/oil in the fryer, not just the surface, will be at the auto-ignition point and then fire occurs. The fire may also ignite the grease in the range overhead hood, allowing the fire to spread into the grease coated ductwork leading up to the exhaust outlet. The heat emanating from the ductwork may ignite structure members composed of combustible materials in the galley and other spaces where the ductwork passes through. Burning continues until the temperature of the fat/oil is lowered below the flash point (or the fuel is exhausted). Insulated cooking appliances tend to retain heat and to slow cooling. This makes a fire more difficult to extinguish.

Extinguishing agents used in galley fire protection systems typically have an alkaline base. When the agent is discharged on a fire, a process called saponification occurs. The alkaline base of the extinguishing agent combines with the fatty acids in the cooking oil and forms a soap-like substance which blankets the surface. This helps smother the fire. However, saponification occurs less with vegetable oils because they have significantly lower levels of fatty acids than animal fats do. In addition, the higher temperatures associated with cooking with vegetable oils contributes to the faster breakdown of the soapy layer. Therefore, the extinguishing capability of the fire suppression system is reduced and the probability of re-ignition is increased.

6.2 Location of Cooking Grease, Fats and Oils Onboard

In general, cooking grease, fats and oils only exist in galley and pantry areas onboard. Containers for cooking grease, fats and oils, frying griddles, broilers, deep fat fryers, stoves and ovens are major equipment containing or accumulating such liquids. Grease also accumulates in and around the range, particularly in the hoods, filters, the area immediately behind the filter screens (called the “plenum”) and ductwork over galleys.

The filters remove grease and oils from the smoke generated by the cooking process. When these substances remain on the filters, they react chemically. The reactions produce flammable substances, which are a fire hazard. In addition, clogged filters restrict the flow of ventilating air, so that the temperature rises above the safe level. The result is usually a fire.

When the range is being used for cooking, grease-laden air from the cooking area enters the ventilator duct. The air is forced to curve back and forth around several baffles at high speed. This zigzag motion tends to throw the grease and any lint and dust out of the airstream and onto the ducting and baffles. From there, it flows to a grease-collecting gutter.

Fires in the cooking area can be serious. However, since they are out in the open, they usually can be extinguished completely. Fires in the plenum and the duct system are of most concern. Even after such fires are apparently extinguished, there may still be some fire hidden from view, or the fire may have extended out of the duct and into nearby compartments. For this reason, automatic fire extinguishing systems should be installed to protect all parts of the range, plenum and ducts.

6.3 Extinguishment of Class “K” or “F” Fires

To extinguish a fire created by auto ignition of the cooking grease, fats or oils, the flames must be extinguished and the temperature of the burning liquid reduced below the auto ignition temperature. The amount of heat involved with the liquid above 363°C (685°F) is high and the use of the incorrect extinguisher can be extremely dangerous. For example, a water jet extinguisher directed at the surface of a burning cooking oil will create an explosion as the water is quickly converted into steam resulting in the expulsion of burning oil possibly spreading the fire and harming the operator. Conventional foam extinguishers have been proven to extinguish the flame, but the heat involved quickly destroys the foam blanket, exposing the surface of the oil, allowing re-ignition. Carbon dioxide and powder extinguishers are effective in extinguishing the flame, but without sealing the surface of the liquid from oxygen the oil rapidly re-ignites.

Conventional powder, foam or CO₂ extinguishers are normally too powerful and direct and can easily splash the burning liquid and spread the fire. A fast high rate discharge may be ideal for a petrol fire, but is very dangerous for fires involving burning cooking oils or fats.

Considering the above-mentioned limitations of conventional powder, foam or CO₂ extinguishers, extinguishers designed for cooking oil fires use wet chemical agents. Fire extinguishers of wet chemical type are available in hand portable models of 6 liter (1.5 gallon) and 9.5 liter (2.5 gallon). The extinguishing agent can be comprised of, but is not limited to, solutions of water and potassium acetate, potassium carbonate, potassium citrate, or a combination of these chemicals (which are conductors of electricity). The liquid agent typically has a pH of 9.0 or less. On Class “K” or “F” fires (cooking oil fires), the agent forms a foam blanket to prevent re-ignition. The water content of the agent aids in cooling and reducing the temperature of the hot oils and fats below their auto-ignition point. The agent, when discharged as a fine spray directly at cooking appliances, reduces the possibility of splashing hot grease and does not present a shock hazard to the operator.

In recent years, the development of high-efficiency cooking equipment with high-energy input rates and the widespread use of vegetable oils with high auto-ignition temperatures has highlighted the need for a new Class “K” or “F” fire extinguisher. The wet chemical extinguisher was the first extinguisher to qualify to the new Class “K” or “F” requirements such as “NFPA 10 – Standard for Portable Fire Extinguishers”, “ANSI/UL711 – Rating and Fire Testing of Fire Extinguishers” and “BS EN 3-7:2004+A1:2007 – Portable fire extinguishers – Part 7: Characteristics, performance requirements and test methods”.

In addition to offering rapid fire extinguishment, a thick foam blanket is formed to prevent re-ignition while cooling both the appliance and the hot cooking oil. Wet chemical extinguishers also offer improved visibility during fire-fighting as well as minimizing cleanup afterward.

For ship galleys with deep fat fryers, fire extinguishing systems and equipment for Class “K” or “F” fires are required in SOLAS (Consolidated Edition 2014) Reg. II-2/10.3 and 10.6.4.1 referring to IMO MSC.1/Circ.1275 “Unified Interpretation of SOLAS Chapter II-2 on The Number and Arrangement of Portable Fire Extinguishers on Board Ships” and “ISO 15371:2009 – Ships and marine technology — Fire-extinguishing systems for protection of galley cooking equipment”.

Per IMO MSC.1/Circ. 1433 “For ships constructed before 1 July 2013, ISO 15371:2000, Fire-extinguishing systems for protection of galley deep-fat cooking equipment – fire tests, may be used”.

Moreover exhaust ducts from galley ranges are to be fitted with fixed means for extinguishing a fire within the duct, when the exhaust duct passes through accommodation spaces or spaces containing combustible materials (Refer to SOLAS Reg. II-2/9.7.5 as amended by Res. MSC.365(93)).



SECTION 3 Fire Main Systems

1 General Principles of the Fire Main System

The fire main is a system consisting of sea inlet(s), suction piping, fire pumps and a distributed piping system supplying fire hydrants, hoses and nozzles located throughout the vessel. Its purpose is to provide a readily available source of water to any point throughout the vessel which can be used to combat a fire and is considered the backbone of the fire-fighting systems onboard a vessel. Through the fire main system, the firefighter is provided with a reliable and versatile system capable of providing a number of different methods with which to engage a fire. Water can be supplied as a straight stream for combating deep seated fires, as a spray for combating combustible liquid fires where cooling and minimum agitation is desired or as a means to protect personnel where cooling is the primary effect desired.

2 Extinguishing Capabilities of Water

Water primarily extinguishes a fire by the removal of heat (see 1/5.3). It absorbs heat more effectively than any other commonly used extinguishing agent due to its good thermal conductivity and its high latent heat of vaporization. It is most effective when it absorbs enough heat to raise its temperature to 100°C (212°F). At that temperature, water absorbs additional heat as it goes through the transition from a liquid to a vapor (i.e., steam).

In the process of heating the water from normal temperatures, up through its conversion into steam, water absorbs approximately 2.6 kilo-joules of heat per gram (1117 BTU/lb) of water, which is a much higher heat absorption value than any other agent. This absorption of heat reduces the temperature of the burning vapors and also reduces the amount of vapor being generated by the cooling of the fuel surface. With adequate cooling, there is insufficient heat to maintain the self-supporting combustion process and the fire goes out.

Water also has an important secondary effect. When it turns to steam, it expands about 1600 times in volume at atmospheric pressure. As a result, one cubic meter (cubic foot) of water can generate up to 1600 cubic meters (cubic feet) of steam vapor. This great cloud of steam surrounds the fire, displacing the air that supplies oxygen for the combustion process. Thus, water provides a smothering action as well as cooling.

3 Moving Water to the Fire

The purpose of the fire main system is simply to move the water to the locations needed at sufficient capacity and pressure so that it can be used as an effective extinguishing medium. At sea, the supply of water is limitless. However, moving the water is another matter. The amount of water that can be moved to a shipboard fire depends on the number and capacity of the fire pumps installed and the design of the fire main piping system. Even when water is available in huge quantities, it still must be used economically and wisely. If it is not, its weight can affect the equilibrium of the vessel. This is especially true if large amounts of water are introduced into, and remain at, high points in the vessel. The weight of the water raises the center of gravity of the vessel and can impair the vessel's stability.

Even water that is not confined, but can run to lower portions of the vessel, may affect the buoyancy of the vessel. Vessels have capsized and sunk because excessive amounts of water were used during fire-fighting efforts. Each 1 m³ (35 ft³) of water weighs approximately one tonne (0.98 ton).

Aboard a vessel, water is moved to a fire in two ways:

- i) Via the fire main system, through hose lines that are manipulated by the vessel's personnel
- ii) Through piping systems that supply fixed manual or automatic sprinkler or spray systems

Both are reliable methods for bringing water to bear on a fire, provided the pumps, piping and all components of the system are properly designed and maintained. The first method of distribution, the fire main system, is discussed in this Section. Water sprinkler and water spray systems will be discussed in Section 5.

The fire main system is a vital part of the various fire-fighting systems installed onboard vessels. Since the hose and the nozzle complete the job of moving the water to the fire, it is equally important to understand the effects of the various operations of a hose line and the nozzles.

3.1 Straight Streams

The straight stream, sometimes called the solid stream, is a valuable form of water for fire-fighting. The straight stream is formed by a nozzle that is specially designed for that purpose. The nozzle from which the water is thrown is tapered to increase both the velocity of the water at the discharge and the reach.

3.1.1 Efficiency of Straight Streams

The distance that a straight stream travels before breaking up or dropping is called its reach. Reach is important when it is difficult to approach close to a fire. Actually, despite its name, a straight stream is not really straight. Like any projectile, it has two forces acting upon it. The velocity imparted by the nozzle gives it reach, either horizontally or at an upward angle, depending on how the nozzleman aims the nozzle. The other force, gravity, tends to pull the stream down where it encounters the deck. Accordingly, the stream is an arch. The maximum horizontal reach is then attained with the nozzle held at an upward angle of 35 to 40 degrees from the deck. Section 3, Tables 1 and 2 provide information about the throw capability of individual nozzle sizes at various pressures/directions.

Probably less than 10% of the water from a straight stream actually absorbs heat from the fire. This is because only a small portion of the water surface actually comes in contact with the fire, and only water that contacts the fire can absorb heat. The rest runs off, sometimes over the side; but more often the runoff becomes free-surface water and is a problem for the vessel.

3.1.2 Using Straight Streams

A straight stream should be directed into the seat of the fire. This is important since for maximum cooling, the water must contact the material that is actually burning. A solid stream that is aimed at the flames is ineffective. In fact, the main use of solid streams is to break up the burning material and penetrate to the seat of a Class “A” fire.

It is often difficult to hit the seat of a fire, even with the reach of a solid stream. Aboard a vessel, bulkheads with small openings can keep firefighters from getting into proper position to aim the stream into the fire. In some instances, there may be an obstruction between the fire and the nozzleman. In these cases, frequently the stream can be bounced off a bulkhead or the overhead to get around the obstacle. This method can also be used to break a solid stream into a spray-type stream, which will absorb more heat. It is useful in cooling an extremely hot passageway that is keeping firefighters from advancing toward the fire.

The following are the basic characteristics of a straight stream:

- Can be aimed accurately
- Has good reach
- Must hit seat of fire to cool effectively
- Run-off of water may be excessive
- Generates very little steam

TABLE 1
Water Discharge Rates

Note: Theoretical discharge may be taken using this table. Please note that 2½" hydrant/hose normally corresponds to a 7/8" smooth bore nozzle and a 1½" hydrant/hose normally corresponds to a 5/8" smooth bore nozzle.

Rate (psi)	Gallons of Water Flowing Per Minute at Various Nozzle Pressures and Sizes												
	Nozzle Sizes (inch)												
	5/8	3/4	7/8	1	1 1/8	1 1/4	1 3/8	1 1/2	1 5/8	1 3/4	1 7/8	2	2 1/8
30	63	91	124	162	205	253	307	365	429	498	572	651	826
32	65	94	129	167	212	261	317	377	443	514	591	673	854
34	67	97	133	172	218	269	327	389	457	530	610	693	880
36	69	100	137	177	224	277	336	400	470	546	627	713	905
38	71	103	140	182	231	285	345	411	483	561	645	733	930
40	73	106	144	187	237	292	354	422	496	575	661	752	954
42	75	108	147	192	243	299	363	432	508	589	678	770	978
44	77	111	151	196	248	306	372	442	520	603	694	788	1000
46	79	113	154	200	254	313	380	452	531	617	710	806	1021
48	80	116	158	205	259	320	388	462	543	630	725	824	1043
50	82	118	161	209	265	326	396	472	554	643	740	841	1065
52	84	121	164	213	270	333	404	481	565	656	754	857	1087
54	85	123	167	217	275	339	412	490	576	668	769	873	1108
56	87	125	170	221	280	345	419	499	586	680	782	889	1129
58	88	127	173	225	285	351	426	508	596	692	796	905	1149
60	90	130	176	229	290	357	434	517	607	704	810	920	1168
62	91	132	179	233	295	363	441	525	617	716	823	936	1187
64	93	134	182	237	299	369	448	533	627	727	836	951	1206
66	94	136	185	240	304	375	455	542	636	736	845	965	1224
68	96	138	188	244	308	381	462	550	646	750	862	980	1242
70	97	140	190	247	313	386	469	558	655	761	875	994	1260
72	98	142	193	251	318	391	475	566	665	771	887	1008	1278
74	100	144	196	254	322	397	482	574	674	782	900	1023	1296
76	101	146	198	258	326	402	488	582	683	792	911	1036	1313
78	102	148	201	261	330	407	494	589	692	803	924	1050	1330
80	104	150	204	264	335	413	500	596	700	813	935	1063	1347
82	105	151	206	268	339	418	507	604	709	823	946	1076	1364
84	106	153	208	271	343	423	513	611	718	833	959	1089	1380
86	108	155	211	274	347	428	519	618	726	843	970	1102	1396
88	109	157	213	277	351	433	525	626	735	853	981	1115	1412
90	110	159	216	280	355	438	531	633	743	862	992	1128	1429

For smaller and larger size nozzles (also, straight bore type), use the following table:

N.P.	1/4"	5/16"	3/8"	1/2"		N.P.	2 1/2"	3"
30	10	16	23	41		30	1017	1464
32	11	16	24	42		32	1050	1512
34	11	17	24	43		34	1082	1558
36	11	17	25	45		36	1114	1604
38	11	18	26	46		38	1144	1648
40	12	18	26	47		40	1174	1691
42	12	19	27	48		42	1203	1732
44	12	19	28	49		44	1231	1773
46	13	20	28	50		46	1259	1813
48	13	20	29	51		48	1286	1852
50	13	21	30	53		50	1313	1890
52	13	21	30	54		52	1339	1928
54	14	21	31	55		54	1364	1964
56	14	22	31	56		56	1389	2000
60	14	22	32	57		60	1438	
70	16	24	35	62		70	1553	
80	17	26	37	66		80	1660	
90	18	28	40	70		90	1761	
100	19	29	42	74		100	1856	

TABLE 2
Horizontal Reach of Water Streams

For smooth bore nozzles 5/8" with 1 1/2" hose and 7/8" with 2 1/2" hose in still air conditions, horizontal reach can be estimated about 0.3 meter (1 foot) per 0.07 bar (1 psi) Pitot pressure, being 14 and 15.9 meters (47 and 52 feet) correspondingly at 3.5 bar (50 psi).

For protection of Class "B" fires (flammable liquids), where spray pattern is used, the range to be estimated at about 6-7.5 m (20-25 feet) in still air at 3.5 bar (50 psi) pressure.

For smooth bore lines with 2 1/2" hose lines, the following table may be used for reference.

Hose Streams Throw (in fee.) for smooth bore lines with 2 1/2" Hose Lines												
Rate (psi)	Nozzle Sizes (inch)											
	5/8	3/4	7/8	1	1 1/8	1 1/4	1 3/8	1 1/2	1 5/8	1 3/4	1 7/8	2
30	18	25	35	45	57	70	85	101	118	138	158	180
32	19	27	37	48	61	75	91	108	126	147	168	192
34	20	29	39	51	65	80	97	115	134	156	180	204
36	21	31	41	54	68	85	102	121	142	165	190	216
38	22	32	44	57	72	90	108	128	150	174	200	228
40	23	34	46	60	76	94	113	135	158	184	210	240
42	25	36	48	63	80	99	119	142	166	192	221	252
44	26	37	50	66	84	103	124	148	174	202	232	264
46	27	39	53	69	88	108	130	155	182	211	242	276
48	28	41	55	72	91	112	136	162	190	220	253	288
50	29	42	58	75	95	117	141	168	198	229	263	300

TABLE 2 (continued)
Horizontal Reach of Water Streams

<i>Hose Streams Throw (in feet) for smooth bore lines with 2½" Hose Lines</i>												
Rate (psi)	Nozzle Sizes (inch)											
	5/8	¾	7/8	1	1 1/8	1 1/4	1 3/8	1 1/2	1 5/8	1 3/4	1 7/8	2
52	31	44	60	78	99	122	147	175	206	239	274	312
54	32	45	62	81	102	126	153	182	214	248	285	324
56	33	47	64	84	106	131	158	189	221	256	295	336
58	34	49	66	87	110	136	164	196	229	266	305	348
60	35	51	69	90	114	141	170	202	237	275	316	360
62	36	53	71	93	118	145	176	209	245	284	326	372
64	38	54	73	96	122	150	181	216	253	293	337	384
66	39	56	76	99	125	155	187	223	261	303	347	396
68	40	58	78	102	129	160	193	230	270	314	359	409
70	41	59	80	105	133	164	199	237	277	322	370	421
72	42	61	83	108	137	169	204	244	285	331	380	433
74	44	63	85	111	141	174	210	250	294	340	390	445
76	45	65	87	114	144	179	216	257	301	350	402	456
78	46	66	90	117	148	183	222	264	309	360	412	469
80	47	68	92	120	152	188	227	270	317	358	422	480
82	48	70	94	123	156	193	233	277	325	377	432	492
84	49	71	96	126	159	197	238	284	333	386	444	505
86	50	73	99	129	163	202	244	291	340	395	454	518
88	52	75	101	132	167	207	250	297	348	405	465	529
90	53	76	103	135	171	212	255	304	357	415	475	540
92	54	78	106	138	175	216	262	311	365	423	485	552
94	55	80	108	141	179	220	267	318	372	432	495	565
96	56	82	110	144	182	226	272	325	380	441	506	578
98	57	83	112	147	186	230	278	332	389	451	517	590
100	59	85	115	150	190	235	284	338	397	460	530	600

3.2 Fog Streams

The fog (or spray) nozzle breaks the water stream into small droplets. These droplets have a much larger total surface area than a solid stream. Thus, a given volume of water in fog form will absorb much more heat than the same volume of water in a straight stream due to the larger exposed surface area.

The greater heat absorption of fog streams is important. Less water needs to be applied to remove the same amount of heat from a fire. In addition, more of the fog stream turns into steam when it hits the fire. Consequently, there is less runoff, less free-surface water and less of a stability problem for the vessel. The cloud of steam surrounding the fire displaces the air that supplies oxygen for the combustion process. Thus, the fog stream helps to provide a smothering action as well as cooling.

The following are the basic characteristics of a fog stream:

- Difficult to aim
- Limited reach
- Excellent cooling abilities
- Generates steam
- Has small amount of run-off

- Pushes smoke and fire
- Does not have to hit seat of fire to be effective

There are basically two different types of fog streams that are used onboard a vessel: the high velocity fog stream and the low velocity fog stream. Both can be used very effectively in combating a fire but serve different functions, as discussed below.

3.2.1 High-velocity Fog Streams

High velocity fog streams are created by a specially designed hose nozzle. In addition to the direct cooling of the flame, the high velocity fog stream can be used effectively to reduce heat in compartments, cabins and cargo spaces. High velocity fog streams can also be used to move air in passageways and to drive heat and smoke away from advancing firefighters.

3.2.2 Low-velocity Fog Streams (2017)

Low velocity fog is obtained by using a special applicator along with a combination nozzle. Applicators are tubes or pipes that are angled at 60° or 90° at the water outlet end. They are stowed for use with the low velocity head already in place on the pipe. Some heads are shaped somewhat like a pineapple, with tiny holes angled to cause minute streams to bounce off one another and create a mist. Some heads resemble a cage with a fluted arrow inside. The point of the arrow faces the opening in the applicator tubing. Water strikes the fluted arrow and then bounces in all directions, creating a fine mist.

Low velocity fog is effective in combating Class “B” fires in spaces where entry is difficult or impossible. Applicators can be poked into areas that cannot be reached with other types of nozzles. They are also used to provide a heat shield for firefighters advancing with foam or high-velocity fog. Low-velocity fog can be used to extinguish small tank fires, especially where the mist from the applicator can cover the entire surface of the tank. However, other extinguishing agents, such as foam and carbon dioxide, are usually more effective.

SOLAS (Consolidated Edition 2014) – Footnote to II-2/10.5.5 concerning water fog applicators

A water fog applicator might consist of a metal L-shaped pipe, the long limb being about 2 m in length, capable of being fitted to a fire hose and the short limb being about 250 mm in length, fitted with a fixed water fog nozzle or capable of being fitted with a water spray nozzle.

3.2.3 Limitations of Fog Streams

Fog streams do not have the accuracy or reach of straight streams. While they can be effectively used on the surface of a deep-seated fire, they are not as effective as solid streams in breaking through and reaching the heart of the fire.

3.2.4 Combination Nozzle Operation

The combination or dual purpose nozzle typically has a handle which is perpendicular to the plane of the nozzle and will produce either a straight stream or high velocity fog, depending on the position of its handle. Combination nozzles are available for use with 3.8 cm (1½") and 6.4 cm (2½") hoses. Reducers can be used to attach a 3.8 cm (1½") nozzle to a 6.4 cm (2½") hose. A straight stream is obtained by pulling the handle all the way back to the operator. A fog stream is obtained by pulling the handle back half way. The nozzle is shut down, from any open position by pushing the handle forward as far as it will go.

In addition, combination nozzles typically have the means to attach a low velocity applicator.

3.2.5 Conclusion

Straight stream and fog streams can be very effective against Class “A” fires as they have the ability to penetrate the fire and cool the fuel surface. Fog streams can be used on Class “A” fires to cool the flame and surrounding environment, but can also be effectively against Class “B” fires.

4 ABS Requirements for Fire Main Systems

The following information is provided as general guidance on the ABS requirements for fire main systems as required by the *Rules for Building and Classing Steel Vessels* (SVR) and *Rules for Building and Classing Steel Vessels Under 90 meters (295 feet) in Length* [SVR(L<90m)]. However, reference should always be made to the Rules applicable to the specific vessel concerned for the complete set of requirements.

4.1 Main Fire Pumps

4.1.1 Number Required

In accordance with SVR 4-7-3/1.5.1, each vessel is to be provided with at least two main fire pumps. For vessels 1000 gross tons and above, each main fire pump is to be independently power-driven. The phrase “independently power driven” should be understood to require that the driving power for each pump is not supplied from the vessel’s propulsion unit and also that the driving mechanism for each pump is independent of the other pump(s) driving mechanisms.

4.1.2 Arrangements

Unless an emergency fire pump is provided, the locations, as well as the arrangements, for access, power supplies, fuel supplies, sea suction, suction and discharge piping and supporting environmental services (lighting, ventilation, etc.) for the two main fire pumps must be arranged so that a fire in a space containing any one of the main fire pumps will not render both pumps inoperable, as specified in SVR 4-7-3/1.5.4. The following identifies the minimum requirements for access arrangements; separation and services supplying the two main fire pumps, as specified in SVR 4-7-3/1.5.4.

4.1.2(a) General Arrangement and Common Boundaries. The pumps are to be in separate rooms, completely isolated and independent from one another. It is usually necessary to confirm the arrangements to identify common entrances, passages and structural isolation of common boundaries. Only one common boundary is permitted between the spaces containing the two main fire pumps and this single common boundary must be a class “A-0” boundary or higher, as specified in SVR 4-7-3/1.5.4. Multiple common boundaries are not permitted.

4.1.2(b) Access. No direct access should be permitted between the spaces unless this is determined to be “impracticable”. Where so determined to be “impracticable,” SVR 4-7-3/1.5.4 indicates that a direct access may be considered. However, arrangements must comply with one of the arrangements specified in SVR 4-7-3/1.5.3vii), which are outlined in the following:

- i) An arrangement where the access is by means of an airlock. One of the doors of the machinery spaces is to be of A-60 class standard and the other is to be of steel, both reasonably gastight, self-closing and without any hold-back arrangements, or
- ii) An access through a watertight door. This door is to be capable of being operated from a space remote from the machinery space of category “A” and the spaces containing the fire pumps. The remote control must also be located at a point that is unlikely to be cut off in the event of fire in those spaces and for unattended propulsion machinery space operation, the door is to be remotely operable from the fire-fighting station (see SVR 4-9-6/21.3). As the door is a watertight door, controls from either side of the bulkhead are also required, in accordance with SVR 3-2-9/9.1.
- iii) Where direct access is provided in accordance with the arrangements specified in i) or ii) above, a second means of access must be provided to the spaces containing the main fire pumps. The second means of access to each space must be totally independent of the space containing the other fire pump.

4.1.2(c) Power Supplies. Power supplies for the two main fire pumps must be totally independent. If electrical, the review needs to confirm that the power is supplied from different sources (typically, one must be from the emergency generator), with the feeder cables being separated in all ways as far as practicable. Routing of the electric supply cable through the space containing the other fire pump or through high fire risk areas (category “A” machinery spaces) would not be acceptable. If diesel-driven, then arrangements for starting, fuel supply, air and exhaust piping, etc., are to be completely independent. Similarly, hydraulically-driven pumps are to have independent power units and controls without interconnections.

4.1.2(d) *Water Supply (2017)*. The sea chest, suction piping and discharge piping arrangements to the fire main, as well as the pump and valve controls, must be arranged so as to be totally independent from the other pump and are not to be located in or enter into the space containing the other pump, in accordance with SVR 4-7-3/1.5.4.

The sea chest and suction pipe for one of the main fire pumps (or the emergency fire pump), which is located outside of the machinery space, may be located in the machinery space provided the conditions and interpretations outlined in SVR 4-7-3/1.5.3vi) are satisfied.

It should be noted that if the suction or discharge piping is permitted to be within a category “A” machinery space, the piping is to be all welded except for flange connections to the sea inlet valve. (For detailed requirements, refer to Interpretation (IACS) of SVR 4-7-3/1.5.3vi).)

4.1.2(e) *Environmental Systems*. The arrangements of environmental systems (e.g., lighting, ventilation, etc.) are to be completely independent for both pump locations. If the information available on hand is not sufficient to verify these arrangements, a comment should be made relative to the drawing and the installation verified by the attending Surveyor.

4.1.3 Pump Type, Relief, etc.

4.1.3(a) *Suitability*. It is important to know certain details regarding the pumps (NPSH requirements, discharge characteristics, type of pump, etc.) being proposed for installation in order to verify the pump’s suitability for fire main service. Part of determining the suitability of the pumps involves the recognition that fire pumps must operate over a wide range of flow rates, from minimal a flow rate while supplying a single nozzle to full flow. With this wide range of operating flow rates, the resulting pressures developed by the pump must stay within an appropriate and safe range. Some pumps may be capable of providing the high flow rate at the minimum required pressure, but may develop excessive pressures when delivering only the flow for a single nozzle. Such excessive pressures can make handling the hose very difficult, and can actually present a danger if the pressure is too high and the hose gets loose. This issue is specifically addressed in SVR 4-7-3/1.7.3, which indicates that the maximum pressure at any hydrant is not to exceed that at which effective control of a fire hose can be demonstrated. The pump characteristics play an important part in establishing compliance with this requirement.

Other pumps may be able to provide suitable pressures at minimum flow rates but be unable to maintain the required pressures specified in SVR 4-7-3/1.7.2 when delivering at the required full capacity flow rates. As a result of the need to supply a wide capacity range over a relatively narrow pressure band, centrifugal pumps with flat or very shallow head/capacity curves are usually proposed. Such pumps are capable of supplying minimal flow rates (i.e., approaching shut-off head) without creating excessive and dangerous pressures, yet are also capable of providing large flow rates while maintaining the required pressures at the most remote nozzles. Appropriate details verifying the suitability of the pumps should be requested and verified.

4.1.3(b) *Relief Valves*. In addition to the concern associated with the possibility of danger in having excessive pressure for hose handling, many pumps are also capable of exceeding the maximum working pressures of the piping system components at shut-off pressures. Accordingly, SVR 4-7-3/1.5.6 requires relief valves to be provided in conjunction with all fire pumps if the pumps are capable of developing a pressure exceeding the design pressure of the water service pipes, hydrants and hoses. These relief valves are to be so placed and adjusted as to prevent excessive pressure in any part of the fire main system.

4.1.3(c) *ABS Certification (2017)*. In accordance with SVR 4-7-3/1.5.1 and item 4 of SVR 4-1-1/Table 6, fire pumps are to be provided with ABS certificates. The certificates must be available for presentation to the attending Surveyor. Other firefighting service pumps, such as pumps for fixed water-based systems, or equivalent, local application fire-fighting systems (SVR 4-7-2/1.11.2), sprinkler systems (SVR 4-7-3/9.5.3), deck foam systems, etc., fall also in the ABS certification requirements (SVR 4-6-1/7.3.1i).

4.1.3(d) Multiple Service Applications. As noted in SVR 4-7-3/1.5.2, the pumps are not required to be dedicated for fire services only. They may be utilized for other purposes and designated accordingly (e.g., fire and ballast, fire and bilge, general service pump, etc.). However, at least one pump is to be available for fire use at all times. In addition, fire pumps should not be connected to systems normally used for transfer of oil. The Rules do permit occasional, short-term oil duties for the pump. However, if so designated, there must be suitable positive changeover arrangements (e.g., elbow and blank flange) and a notice to assure the pump's connection to fire main after such use. Because of pumps' designation and use for other than fire services and the need for ready capability of the fire water supply, the pumps should have simple and reliable means to switch them to fire services. The most common arrangement is to manifold valves at the pumps. In addition, there may be certain arrangements where the fire pumps also serve other fire-fighting services (e.g., sprinkler system, etc.) which must be immediately available. In such cases, isolation arrangements, such as swing elbows and blank flanges, would not be suitable.

4.1.4 Main Fire Pump Capacities

4.1.4(a) Total Pump Capacity. In accordance with SVR 4-7-3/1.3.1, the combined output of the main fire pumps is to be sufficient to deliver for fire-fighting purposes a quantity of water not less than four-thirds of the quantity required to be handled by each independent bilge pump as calculated in accordance with SVR 4-6-4/5.3.2. However, the total required capacity of the fire pumps need not exceed 180 m³/hr (792 gpm), insofar as classification requirements are concerned. In order to verify this requirement, the required independent bilge pump capacity must be established. Then the combined capacity of the fire pumps, while delivering at the pressure necessary to meet the requirements of SVR 4-7-3/1.7.2 at the most remote hydrants (i.e., pressure drops associated with flowing through the main must be considered), must not be less than four-thirds of that value.

4.1.4(b) Individual Pump Capacity (2017). In accordance with SVR 4-7-3/1.3.2, each of the main fire pumps is required to have a capacity of not less than the greater of:

- i) 80% of the total required capacity divided by the number of required fire pumps,
- ii) 25 m³/hr (110 gpm), or
- iii) The capacity required to deliver at least the two jets of water.

SVR 4-7-3/1.3.2 indicates that these fire pumps are to be capable of supplying the fire main system under the required conditions, which should be understood to be those pressures specified in SVR 4-7-3/1.7.2.

SVR 4-7-3/1.3.2 actually identifies two interrelated requirements: flow rate at a required pressure. Therefore, when evaluating the individual fire pump capacity, the review should establish that each fire pump is capable of delivering the largest of the above required flow rates through the most hydraulically remote hydrants while maintaining the pressures specified in SVR 4-7-3/1.7.2 at the nozzles. In the case of the third requirement, the largest size nozzles to be used should be taken into considered.

In a few instances more than two pumps might be designated for fire services. The Rules leave this situation to special consideration. For example, provision of two smaller capacity pumps arranged together to make up the capacity of one of the required pumps will satisfy the intent of the Rules, provided they are arranged with common suction/discharge valves, power supply, start/stop controls, etc., and are interconnected in such a way as to perform the functions of the required pump.

In accordance with SVR 4-7-3/1.3.2, each pump for fire extinguishing which is installed in addition to the required number of pumps should have a capacity of at least 25 m³/h (110 gpm) and should be capable of delivering at least the two jets of water required in SVR 4-7-3/1.9.

Per IACS UI SC270, on board cargo ships designed to carry five or more tiers of containers on or above the weather deck, the total capacity of the main fire pumps need not exceed 180 m³/h in cases where the mobile water monitors, required by SOLAS Reg. II-2/10.7.3.2 are supplied by separate pumps and piping system.

4.1.5 Ready Availability of Water Supply

It should be noted that SVR 4-7-3/1.5.5 requires that cargo vessels be provided with the means to **provide** the ready availability of water supply for spaces intended for centralized or unattended operation.

4.1.6 Connections to Fire Main from Another Engine Room Pump

The Rules also require that in addition to the main and emergency fire pumps, on a cargo vessel where other pumps (such as general service, bilge and ballast, etc.) are fitted in a machinery space, arrangements are to be made **so** that at least one of these pumps, having the capacity and pressure required by SVR 4-7-3/1.3.2 and 4-7-3/1.7.2, is capable of providing water to the fire main.

4.2 Emergency Fire Pump

If the arrangements for the two main fire pumps are such that a fire in one space can put both main fire pumps out of service, an emergency fire pump is required to be provided, as per SVR 4-7-3/1.5.3. The emergency fire pump is required to be a fixed independently-driven pump and the requirements for the pump and its location are identified in SVR 4-7-3/1.5.3. These requirements are summarized below:

4.2.1 Arrangement (Independent Systems)

As per SVR 4-7-3/1.5.3, the emergency fire pump system, including the power source, fuel oil supply, electric cables, etc., as well as the lighting and ventilation for the emergency fire pump space are to be independent of the main fire pumps, so that a fire in any one compartment will not render both the main and emergency fire pumps inoperable. These items are to be verified during plan review whenever possible.

If the fire pump is electrically-driven, the power is to be supplied from the emergency generator and the feeder cable routed outside of high fire risk areas (category “A” machinery spaces). In addition, the electrical power and control cables for the emergency fire pump and valves are to also be widely separated from any electrical and control cables associated with the main fire pumps.

4.2.2 Capacity (2017)

In association with the requirements specified in the initial paragraph of SVR 4-7-3/1.5.3, as well as SVR 4-7-3/1.5.3i), the capacity of the pump is not to be less than 40% of the total capacity of the fire pumps required per SVR 4-7-3/1.3.1, and in any case, not less than the following:

- i) For cargo vessels of 2000 gross tonnage and upward: 25 m³/h (110 gpm), and
- ii) For cargo vessels less than 2000 gross tonnage: 15 m³/h (66 gpm).

Where applicable, the emergency fire pump is also to be capable of simultaneously supplying the amount of water needed for any fixed fire-extinguishing system protecting the space containing the main fire pump.

The emergency fire pump must also be suitable for the service and be provided with adequate protection against overpressurization (see 3/4.1.3).

Per IACS UI SC270, on board cargo ships designed to carry five or more tiers of containers on or above the weather deck, the total capacity of the emergency fire pump need not exceed 72 m³/hr.

4.2.3 Pressure

Per SVR 4-7-3/1.5.3ii), when the pump is delivering the quantity of water discussed above, the pressure at any hydrant is to be not less than the minimum pressures given in SVR 4-7-3/1.7.2. Verification of compliance with this requirement must be based upon considering the worst-case situation. See 3/4.1.4(b) of these Guidance Notes for a discussion regarding verification of the combined pressure/capacity requirement.

4.2.4 Starting Arrangements

In accordance with SVR 4-7-3/1.5.3iii), any diesel-driven power source for the pump is to be capable of being readily started in its cold condition down to a temperature of 0°C (32°F) by hand (manual) cranking. If this is impracticable, or if lower temperatures are likely to be encountered, heating arrangements are to be provided so that ready starting will be assured. If hand (manual) starting is impracticable, other means of starting may be considered. These means are to be such as to enable the diesel-driven power source to be started at least six (6) times within a period of 30 minutes and at least twice within the first 10 minutes. Diesel engines exceeding 15 kW (20 hp) are to be equipped with an approved auxiliary starting device (e.g., starting battery, independent hydraulic starting system or independent starting air system).

Also, any internal-combustion engine driving an emergency fire pump is to be capable of being readily started in its cold condition down to a temperature of 0°C (32°F). If this is impracticable, or if lower temperatures are likely to be encountered, heating arrangements are to be provided for ready starting of generator sets.

4.2.5 Fuel Supply

In accordance with SVR 4-7-3/1.5.3iv), any service fuel tank is to contain sufficient fuel to enable the pump to run on full load for at least three hours and sufficient reserves of fuel are to be available outside the main machinery space to enable the pump to be run on full load for an additional 15 hours.

4.2.6 Suction (2017)

The total suction head and net positive suction head of the pump are to be such that the requirements of SVR 4-7-3/1.5.3i), 4-7-3/1.5.3ii) and 4-7-3/1.7.2 are obtained under all conditions of list, trim, roll and pitch likely to be encountered in service, as per SVR 4-7-3/1.5.3v). (This excludes the docking condition of the vessel.) **In selecting the emergency fire pump, the minimum available net positive suction head is to provide a safety margin of at least the 1 meter (3.3 feet) or 30% of required net positive suction head of the pump, whichever is less, in accordance with SVR 4-7-3/1.5.3v).** In addition, the sea valve is to be operable from a position near the pump.

4.2.7 Arrangement (Boundaries)

As per SVR 4-7-3/1.5.3vi), the space containing the emergency fire pump is not to be contiguous to the boundaries of category “A” machinery spaces or those spaces containing main fire pumps. Where this is not practicable, the common bulkhead between the two spaces is to be insulated to a standard of structural fire protection equivalent to that required for a control station. The common bulkhead is to be constructed to “A-60” class standard and the insulation is to extend at least 450 mm (18 in.) outside the area of the joint bulkheads and decks. The structural fire protection arrangements of the compartment containing the emergency fire pump should also be verified.

4.2.8 Supply and Delivery Piping

The emergency fire pump including seawater suction and delivery pipes is to be located outside the compartment containing the main fire pumps. The sea chest with valve and main part of the suction piping should be, in general, outside the machinery spaces containing the main fire pumps. If this arrangement is impractical, the sea chest may be fitted in the machinery spaces containing the main fire pump on the condition that the suction valve is remotely controlled from a position near the pump in the same compartment and that the suction pipe is as short as possible. Only short lengths of suction and discharge piping may penetrate the machinery spaces if enclosed in a steel casing, as discussed in 3/4.1.2(d) of these Guidance Notes and in SVR 4-7-3/1.5.3vi).

4.2.9 Access (2017)

Similar to the requirements discussed above for the access arrangements between the main fire pumps, no direct access is to be permitted between the machinery space of category “A” and the space containing the emergency fire pump and its source of power. This requirement assumes that the main fire pumps will be located in a category “A” machinery space. Accordingly, in the event that the main fire pumps are not located in a category “A” machinery space, it should be noted that direct access between the space containing the emergency fire pump and the main fire pump(s) also would be unacceptable. However, like the arrangements for main fire pumps, where this is unavoidable, the Rules do permit the following arrangements to be considered, in accordance with SVR 4-7-3/1.5.3vii):

- i) *Via Airlock.* An arrangement where access is provided by means of an airlock may be considered. For such an arrangement one of the doors of the machinery spaces is to be of A-60 class standard and the other is to be of steel, both reasonably gastight, self-closing and without any hold back arrangements.
- ii) *Via Watertight Door.* An access through a watertight door may also be considered. This door is to be capable of being operated from a space remote from the machinery space of category A and the space containing the emergency fire pump and is to be unlikely to be cut off in the event of fire in those spaces.
- iii) *Via Second Means of Access.* Where direct access is provided in accordance with the arrangements specified in i) or ii) above, a second means of access must be provided to the spaces containing the emergency fire pumps. The second means of access must be totally independent of the space containing the main fire pumps.

Related ABS Interpretation/Instruction

Note: Where an emergency fire pump room (EFPR) is accessible from the steering-gear room (SGR), and access to the SGR is from a machinery space of category A or a space containing the main fire pumps, the arrangement will be acceptable based on the following conditions.

- a) *An ABS Technical Office is to be satisfied with the shipyard's or designer's technical explanation that the EFPR arrangement described above is unavoidable (i.e., impracticable for the EFPR to be located elsewhere).*
- b) *The requirements of SVR 4-7-3/1.5.3vii) are to be satisfied.*
- c) *A-60 insulation with 450 mm overlap is to be provided to contiguous boundaries between EFPR and machinery spaces of category A or those spaces containing main fire pumps.*
- d) *Where the second protected means of access required per SVR 4-7-3/1.5.3vii) is provided from EFPR to directly outside of the SGR (i.e., via an escape trunk), then A-0 insulation is acceptable between SGR and machinery spaces of category A or those spaces containing main fire pumps. However, the protected escape trunk is to be at least A-60.*

Where the second means of escape is provided from the EFPR to SGR and then from SGR to outside of SGR, the above A-0 insulation is to be replaced by A-60 insulation.
- e) *EFPR ventilation may be common with SGR, provided SGR ventilation is completely separate and independent from the ventilation for the machinery spaces of category A or those spaces containing main fire pumps.*

Related IACS Unified Interpretation

UI SC 114 re. SOLAS (Consolidated Edition 2014) Chapter II-2, Regulation 10.2.2.3.2.1

When a single access to the emergency fire pump room is through another space adjoining a machinery space of category A or the spaces containing the main fire pumps, class A-60 boundary is required between that other space and the machinery space of category A or the spaces containing the main fire pumps.

4.2.10 Ventilation

Ventilation arrangements to the space containing the independent source of power for the emergency fire pump are to be such as to preclude, as far as practicable, the possibility of smoke from a machinery space fire entering or being drawn into that space. The space is to be well ventilated and power for mechanical ventilation is to be supplied from the emergency source of power, in accordance with SVR 4-7-3/1.5.3viii). This should be verified by plan review or the attending Surveyor requested to verify the compliance.

4.2.11 Priming

SVR 4-7-3/1.5.3i) requires that the emergency fire pump is to be of the self-priming type and the same should be confirmed at the plan review.

4.2.12 ABS Certification

The requirement for ABS certification of fire pumps, as discussed in 3/4.1.3(c) is also applicable to emergency fire pumps.

4.3 Fire Main Sizing and System Pressures

(2017) The ability of the fire main system to provide adequate quantities of water through a sufficient number of fire hoses at the necessary pressures is critical to the effectiveness and usefulness of system. Accordingly, SVR 4-7-3/1.7.1 and 4-7-3/1.7.2 specify the following:

Quote:

4-7-3/1.7.1 Fire main diameter

The diameter of the fire main and water service pipes is to be sufficient for the effective distribution of the maximum required discharge from two fire pumps operating simultaneously. However, the diameter need only be sufficient for the discharge of 140 m³/hour (616 gpm).

4-7-3/1.7.2 Fire main pressure

With the two pumps simultaneously delivering through nozzles specified in 4-7-3/1.15, the quantity of water specified in 4-7-3/1.7.1, through any adjacent hydrants, the following minimum pressures are to be maintained at all hydrants:

- i) **Vessels of 6,000 gross tonnage and upwards: 0.27 N/mm² (2.8 kgf/cm², 40 psi)**
- ii) **Vessels less than 6,000 gross tonnage: 0.25 N/mm² (2.6 kgf/cm², 37 psi)**

Unquote

In examining the requirements of SVR 4-7-3/1.7, there are a number of interrelated issues involved with these requirements, including:

- i) Total required flow rate for the fire main system
- ii) Pressure drops associated with the fire main distribution system
- iii) Particular hydrants being considered
- iv) Sizes of the hose nozzles used
- v) Performance characteristics of the pumps

Each of these issues impacts the ability of the system to perform as required, and the interrelationship of these items needs to be well understood when evaluating the system.

4.3.1 Required Quantity of Water Discharged

The first item is the total required amount of water that the system must be capable of discharging from the fire main. A certain amount of clarification is needed. First, the requirement in SVR 4-7-3/1.7.2 references the quantity of water identified in SVR 4-7-3/1.7.1. Next, the quantity of water identified in SVR 4-7-3/1.7.1 is the “maximum required discharge from two fire pumps operating simultaneously.”

Defining the term “maximum required discharge from two fire pumps operating simultaneously” should be considered as the greater of the following:

- i) The total required capacity of the combined fire main pumps calculated in accordance with SVR 4-7-3/1.3.1 [see 3/4.1.4(a) of these Guidance Notes to determine this amount]; or
- ii) The combined capacities of the individual fire pumps where each individual fire pump capacity is determined in accordance with SVR 4-7-3/1.3.2 [see 3/4.1.4(b) of these Guidance Notes to determine this amount].

However, SVR 4-7-3/1.7.1 does place a limit on the capacity required by indicating that the diameter of the fire main and distribution system need only be sufficient for the discharge of 140 m³/hour (616 gpm), similar to the provisions of SOLAS. Accordingly, the required amount of water that the system must be capable of continuously discharging is the lesser of the “maximum required discharge from two fire pumps operating simultaneously” or 140 m³/hour (616 gpm). However, it should be noted that there are certain Flag Administrations that do not recognize the upper limit specified in SOLAS.

4.3.2 Fire Main Diameter/Pressure Drop

In association with other items, the pressure drop within the fire main when discharging the quantity of water discussed above is dependent upon the diameter, length, etc., of the fire main distribution piping, size and length of the hoses, nozzle sizes and elevation of hydrants. The requirements for the sizing of the fire main distribution piping are provided in SVR 4-7-3/1.7.1, which specifies, “The diameter of the fire main and water service pipes is to be sufficient for the effective distribution of the maximum required discharge from two fire pumps operating simultaneously.” Accordingly, the fire main piping must be sized to effectively deliver the “maximum required discharge from two fire pumps operating simultaneously.” As noted above, SVR 4-7-3/1.7.1 does place a limit on the capacity requirement by indicating that the diameter of the fire main and distribution system need only be sufficient for a maximum discharge of 140 m³/hour (616 gpm).

4.3.3 Hydrants Involved

SVR 4-7-3/1.7.2 indicates that the pressures stated therein must be maintained at “all” hydrants when discharging the total quantity of water through adjacent hydrants. To **confirm** that the minimum pressure will be available at “all” hydrants, the review must consider the worst case scenario. This would be at that hydrant which is the most hydraulically remote from the pumps. The “most hydraulically remote” hydrant is that hydrant in the system which would result in the largest pressure drop for the system when discharging the total required flow rate through the adjacent nozzles. In considering this requirement, one needs to recognize that the most hydraulically remote hydrant may be the hydrant located the farthest distance from the pump. However, it could also be the hydrant located highest on the superstructure or it may be a hydrant located at the end of a poorly sized branch line. It is a function of the pressure drop (at the required flow rate) in the piping to that hydrant which of course is a function of the distance, height and sizing of the fire main system leading to that hydrant. During the review of the fire main system, one should verify that with the total required quantity of water flowing through the nozzles of hoses attached to adjacent hydrants, the minimum specified pressure is maintained at all hydrants, including the most hydraulically remote hydrant.

4.3.4 Hose Nozzles

As indicated in SVR 4-7-3/1.7.2, the quantity of water involved must be discharged through hose nozzles that are sized in accordance with SVR 4-7-3/1.15. This is important to note, since the size of the nozzles to be used will impact the pressure drop through the system. A larger nozzle orifice will have a smaller pressure drop than a small nozzle when trying to flow the same amount of water. This requirement is also important in establishing that the discharge of the water through the adjacent hydrants must be through hoses which are attached to the hydrants being used to discharge the required flow rate. Thus, any calculations must take into account resistance of fire hoses with attached nozzles.

4.3.5 Pump Performance

The heart of the system is clearly the fire pump. Accordingly, the performance characteristics of the fire pumps at the required flow rates will be one of the major factors in the ability of the fire main system to provide the required minimum pressures. At least basic details of the type of pump and copies of the pump curves are necessary to verify compliance with SVR 4-7-3/1.7.1 and 4-7-3/1.7.2.

4.3.6 Conclusion

Typically, calculations are required to verify compliance with SVR 4-7-3/1.7.1 and 4-7-3/1.7.2. The calculations should establish that the fire main system, which includes the pumps, fire main distribution piping, hoses and nozzles, are properly selected and sized in order to supply the required total flow rate to the most hydraulically remote hydrants while maintaining the required pressure at every hydrant. The review of the calculations should **confirm** that the designer truly understands the requirements and also allows the Engineer to identify any problem areas before the system is built. However, even if verified by calculations, the ability of the system to meet the requirements of SVR 4-7-3/1.7.2 should also be demonstrated to the satisfaction of the attending Surveyor.

4.4 Fire Hose Reaction

SVR 4-7-3/1.7.3 indicates that the maximum pressure at any hydrant is not to exceed that at which the effective control of a fire hose can be demonstrated. Accordingly, the maximum pressure at any hydrant is to be limited to a pressure for which effective control of the fire hose can be maintained. The following provides a method for estimating the reaction forces from a discharging hose. Typically, forces from the nozzle with pitot tube pressures up to 6.9 bar (100 psi) would not be considered to produce excessive reactions.

Acceleration of water discharged from the smooth bore nozzle creates a reaction force:

$$F = 1.57 D^2 p \quad \text{lbf}$$

$$F = 0.157 D^2 p \quad \text{N}$$

where

F = reaction force, N (lb)

D = orifice diameter, mm (in.)

p = Pitot pressure, bar (psig)

The maximum pressure at any hydrant and the associated reaction forces should be investigated during the review of the calculations under all operating scenarios. This may require additional calculations since during the calculations discussed in 3/4.3 of these Guidance Notes are based upon full flow calculations at the most remote hydrants. However, the maximum hydrant discharge pressure will typically exist with a single nozzle discharging at the hydrant hydraulically closest to the pumps.

4.5 Isolation Valves and Routing Arrangements

In accordance with SVR 4-7-3/1.11.3, isolating valves are to be fitted in the fire main risers leading from those fire pumps located within Category “A” machinery spaces, as well as in any fire main branch piping which is routed back into Category “A” machinery spaces. Because of the uncertain conditions/intensity of fire in such spaces, the presumption is that the space is inaccessible, equipment inoperable and the main is left open-ended (e.g., damage, maintenance, etc.). As a result, water supply from the fire pump or pumps will not be able to build up the required pressure at hydrants and, further, such conditions will result in uncontrolled flooding of the space unless accessible isolation arrangements are available. Therefore, the Rules require accessible (i.e., located outside of the category “A” machinery space) valves be fitted so that damaged or open sections of the fire main piping located within the category “A” machinery spaces can be isolated to eliminate the pressure loss in the system.

In considering the fire main system design, particular attention should be paid to the way the fire main branches are routed. SVR 4-7-3/1.11.3 requires that the fire main and branches are to be so arranged that when the isolating valves are shut, all the hydrants on the vessel, except those into any particular category “A” machinery space, can be supplied with water by a fire pump not located in this machinery space and through pipes which do not enter the isolated space. This allows isolation of the piping within the space and use of the hydrants nearby to fight the fire. Therefore, the isolation valves must be located:

- i) Where the fire main risers leave the category “A” machinery spaces containing the fire pumps
- ii) Upstream of the point where any fire main branch piping re-enters the space.

As a result, no branch downstream of the riser piping isolation valve(s) should re-enter the space without an isolation valve, and no branch from the isolated space should project outside or into an adjacent compartment without an isolation valve and second source of supply.

4.6 Fire Main Piping Components/Materials

All valves, fittings and piping are to comply with the applicable requirements of SVR Sections 4-6-1 and 4-6-2. Accordingly, all valves and fittings are to be designed and constructed in accordance with a recognized standard, be suitable for the intended pressures and comply with all other requirements in SVR Section 4-6-2. A submitted drawing should include a complete Bill of Materials that provides the material specifications, standards of construction, pressure ratings and types of all valves and fittings, as well as the material specification, sizes and wall thickness of the piping, in accordance with SVR 4-6-1/9.3. The drawing should also identify the maximum system pressure and provide adequate information to identify the layout and arrangement of the system(s).

In addition to the common requirements and limitations in SVR Sections 4-6-1 and 4-6-2, the materials used in the system are not to be rendered ineffective by heat, unless the components are adequately protected, in accordance with SVR 4-7-3/1.11.1. This requirement is important so that the fire main system will remain intact and functional even if one portion of the fire main piping is actually within the immediate vicinity of the fire. In order to be considered not “readily rendered ineffective by heat,” a component is to be certified as having passed an acceptable recognized fire test or the material is to have a melting temperature higher than the test temperature specified in an acceptable fire test. Insofar as classification requirements are concerned, the fire test requirement may be waived, provided that shipyards/ manufacturers/ designers (as appropriate) document that all components used in fire mains have a solidus melting temperature above the minimum temperature specified in an acceptable fire test. The requirement for the fire main material not to be rendered ineffective by heat extends from the pumps throughout the system to the fire station hydrant valves. The hoses and nozzles are not required to meet the above criteria as it is assumed that the integrity of the system will be maintained by the hydrant valve, but are required to be of approved non-perishable material, as discussed below.

The integrity of the valves to maintain closure is also critical to avoid losses of fire main pressure. For this reason, resiliently seated valves may be considered for use in fire main systems, provided they are capable of passing an appropriate fire test acceptable to ABS and can be effectively closed with the resilient seat damaged or destroyed such that leakage through the closed valve is insignificant.

No hose connections, non-metallic expansion joints and similar provisions are allowed. Frequently used rubber (cloth inserted) gaskets are also not permitted, as their destruction under the fire could lead to the loss of pressure in the system.

For Regulatory compliance, criteria stipulated by Flag Administration must be satisfied and may differ in criteria from that stated above.

4.7 Hydrant Locations and Fire Hoses/Nozzles

4.7.1 Hydrant Locations (2017)

SVR 4-7-3/1.9 requires that the number and position of the fire hydrants be such that at least two jets of water not emanating from the same hydrant (one of which is to be from a single length of hose) may reach any part of the vessel normally accessible to the passengers or crew while the vessel is being navigated and any part of any cargo space when empty, any ro-ro cargo space or any special category space (in which latter case the two jets are to reach any part of such space, each from a single length of hose). Furthermore, such hydrants are to be positioned near the accesses to the protected spaces.”

SVR 4-7-2/5.3.2(a) also requires that at least two combination solid stream and water spray nozzles and hoses sufficient in length to reach any part of the helicopter deck be provided at any helicopter facilities, which would include landing as well as winching facilities.

In addition to the spacing to facilitate hose access, SVR 4-7-3/1.11.1 specifies that the piping and hydrants are to be so placed that the fire hoses may be easily coupled to them. Also where deck cargo is carried, hydrants are to be located such as to avoid damage during cargo operations, but at the same time to remain easily accessible at all times.

Verification that the arrangements of the hydrants comply with the above requirements during plan review can be very difficult as the actual structural arrangements, location of equipment, etc., makes this approach much less reliable, and therefore, is typically included in those items to be verified by the Surveyor. However, the layout and arrangement of the fire stations, as provided in the drawing, in conjunction with the proposed hose lengths should be reviewed and any areas of concern identified. For those areas which are questionable or where the details provided on the drawings are insufficient to verify compliance, appropriate comments should be made in order to the issue to the Surveyor’s attention.

Related IMO MSC Circular 1120 Interpretation

SOLAS (Consolidated Edition 2014) Ch. II-2/10.2.1.5.1 “Location of hydrant in machinery spaces”

At least one hydrant with hose, nozzle, and coupling wrench should be provided in machinery spaces of category A.

4.7.2 Hydrant Valves

In accordance with SVR 4-7-3/1.11.2, a valve is required to be fitted at a fire station to serve each fire hose so that any fire hose may be removed while the fire pumps are at work. Normally, each hydrant is fitted with an individual valve, but the drawing should be reviewed to verify such compliance and the hose valve determined to be of a design and material which will not be rendered ineffective by heat.

4.7.3 Fire Hoses

4.7.3(a) Hose Approval (2017). Fire hoses are required by SVR 4-7-3/1.13.1 to be of approved non-perishable material. Documentation to verify the material as non-perishable must be via certified to recognized standard by competent independent testing laboratory. In addition, fire hoses are to be ABS **Type Approved or Type Approved by flag Administration**, in accordance with item 7 of SVR 4-1-1/Table 4.

4.7.3(b) Hose Length. Hoses are to be sufficient in length to project a jet of water to any of the spaces in which they may be used, but they are to have a length of at least 10 m (33 ft), as per SVR 4-7-3/1.13.1.

Fire hoses should not have a length greater than:

- 15 meters (49 feet) in machinery spaces
- 20 meters (66 feet) in other spaces and open decks
- 25 meters (82 feet) on open decks with a maximum breadth in excess of 30 meters (98 feet)

The limitation on the length of hose is due to difficulties in unfolding, kinking and handling of hoses.

4.7.3(c) Number of Hoses. The Rules do not specifically require a hose to be provided at each fire hydrant location. The minimum number of hoses to be provided on vessels of 1,000 gross tonnage and upwards is at least one for each 30 m (100 ft) length of the vessel and one spare, but in no case less than five in all. Also, this number does not include any hoses required in any engine or boiler room. The number of hoses in the machinery space(s) is not specified, but must be in compliance with the relevant governmental authorities.

However, while the Rules do not require a hose to be provided at each fire hydrant location, SVR 4-7-3/1.11.1 does indicate that unless one hose and nozzle is provided for each hydrant on the vessel, there is to be complete interchangeability of the hose couplings and nozzles.

Vessels carrying dangerous goods should be provided with three (3) additional hoses and three (3) additional nozzles, in accordance to SVR 4-7-3/1.13.2.

4.7.4 Nozzles (2017)

SVR 4-7-3/1.15.1 indicates that the standard nozzle sizes are to be 12 mm (0.5 in.), 16 mm (0.625 in.) and 19 mm (0.75 in.) or as near thereto as possible. Larger diameter nozzles may be permitted, provided the system can maintain the required pressures specified in SVR 4-7-3/1.7.2.

For nozzles for accommodation and service spaces, SVR 4-7-3/1.15.2 indicates that a nozzle size greater than 12 mm (0.5 in.) need not be used. For machinery spaces and exterior locations, SVR 4-7-3/1.15.3 indicates that the nozzle sizes are to be such as to obtain the maximum discharge possible from two jets at the pressure mentioned in SVR 4-7-3/1.7.2 from the smallest pump, provided that a nozzle size greater than 19 mm (0.75 in.) need not be used.

All nozzles are to be of a dual purpose type (i.e., combination spray/jet type) incorporating a shut-off in accordance with SVR 4-7-3/1.15.4. In addition, SVR 4-7-3/1.15.4 indicates that all nozzles are to be of an approved type (which implies approval by a competent authority) for the intended service. Also, nozzles made of plastic material such as polycarbonate may be accepted subject to review of their capability and serviceability as marine use fire hose nozzles.

Related IACS Unified Interpretation

UI SC146 - SOLAS (Consolidated Edition 2014) Reg. II-2/10.2.3

Aluminum alloys may be used for fire hose couplings and nozzles, except in open deck areas of oil tankers and chemical tankers.

4.7.5 Miscellaneous

SVR 4-7-3/1.13.1 also requires each hose to be provided with a nozzle and the necessary couplings, and that the fire hoses together with any necessary fittings and tools are to be kept ready for use in conspicuous positions near the water service hydrants or connections. Details of the fire stations normally provide sufficient details to verify compliance with this requirement.

4.8 International Shore Connection Arrangements

In accordance with SVR 4-7-3/1.19.1 and 4-7-3/1.19.2, each vessel is required to be provided with at least one international shore connection and arrangements are to be provided to enable the connection to be used on each side of the vessel. The purpose of the connection is to provide a uniform piping joint, which allows water supply to the vessel's fire main from another vessel or shore facility. For this purpose, at least one hydrant on either side of the vessel, suitable for such connection, should be designated an international shore connection station. Provision of dedicated port/starboard hydrants with shore connections permanently fixed to them is an acceptable arrangement.

SVR 4-7-3/1.19.3 and 4-7-3/1.19.4 addresses the dimensions and design of the international shore connection. The standard dimensions of flanges for the international shore connection are required to be in accordance with SVR 4-7-3/Table 1. A copy of this table is provided in Section 3, Table 3, below.

In addition, SVR 4-7-3/1.19.4 indicates that the connection is to be of steel or other suitable material and is to be designed for 10 bar (150 psi) services. The flange is to have a flat face on one side and on the other is to be permanently attached to a coupling that will fit the vessel's hydrant and hose. The connection is to be kept aboard the vessel together with a gasket of any material suitable for 10 bar (150 psi) services, together with four 16 mm ($\frac{5}{8}$ in) bolts, 50 mm (2 in.) in length and eight washers.

The connection is to be accompanied with a gasket, bolts, nuts and washers. The shore connection is to be located in a readily accessible location.

TABLE 3
Dimensions of International Shore Connection

	<i>SI and MKS units</i>	<i>U.S. units</i>
Outside diameter	178 mm	7 in.
Inside diameter	64 mm	2.5 in.
Bolt circle diameter	132 mm	5.2 in.
Slots in flange	4 holes – 19 mm in diameter spaced equidistantly on a bolt circle of the above diameter slotted to the flange periphery.	4 holes – 0.75 inches in diameter spaced equidistantly on a bolt circle of the above diameter slotted to the flange periphery.
Flange thickness	14.5 mm minimum	0.57 in. minimum
Bolts and nuts	4 each of 16 mm diameter, 50 mm in length	4 each of 0.63 in. diameter, 1.97 inches in length

4.9 Cold Weather Protection

SVR 4-7-3/1.11.1 indicates that the arrangements of the fire main piping and hydrants are to be such as to avoid the possibility of freezing. Accordingly, those sections of the fire main, which may be subject to freezing temperatures, are required to be provided with adequate protection. Examples of acceptable arrangements would be heat tracing, installation of isolation valves inside the superstructure, provision of drain valves (for non-pressurized system), etc.