CHAPTER 4

FIRE-FIGHTING FUNDAMENTALS

Learning Objective: Recall the components of the "fire triangle," the classifications of fires, the fundamentals of extinguishing fires, and the different extinguishing agents used.

Fire is a constant potential hazard aboard ship. You must take all possible measures to prevent fires from starting. If a fire does start, you must immediately report the fire to the officer of the deck and then extinguish it rapidly. Often a fire will start in conjunction with other damage caused by enemy action, storms, or an accident. A fire can cause more damage than the initial casualty if not immediately extinguished. In fact, a fire could cause the loss of a ship even after the original damage has been repaired or minimized. A Damage Controlman has to know how to identify the different classes of fires, how to extinguish them, and how to use and maintain fire fighting systems and equipment. The more you learn, the more you will be able to contribute to the safety of your ship effectively.

This chapter covers the fundamentals of fire fighting. These fundamentals include the components of fire, classification of fires, the effects of fire, the fundamentals of extinguishing fires, and the extinguishing agents used.

FIRE COMPONENTS

Learning Objective: Recall the components of the "fire triangle."

Three components are required for a fire. They are a combustible material, a sufficiently high temperature, and a supply of oxygen. Known as the "fire triangle" (fig. 4-1), these three components are simply referred to as follows:

- Heat
- Fuel
- Oxygen

Fires are generally controlled and extinguished by eliminating one side of the fire triangle; that is, if you remove either the fuel, heat, or oxygen, you can prevent or extinguish a fire. For more details on flaming combustion requirements, refer to *Naval Ships' Technical Manual* (*NSTM*), chapter 555, volume 1.

HEAT

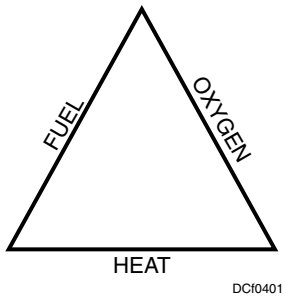

Figure 4-1. The fire triangle.

Fire is also called combustion. Combustion is a rapid chemical reaction that releases energy in the form of light and noticeable heat. Most combustion involves rapid OXIDATION, which is the chemical reaction by which oxygen combines chemically with the elements of the burning substance. Even when oxidation proceeds slowly, such as a piece of iron rusting, a small amount of heat is generated. However, this heat usually dissipates before there is any noticeable rise in the temperature of the material being oxidized.

With certain types of materials, slow oxidation can turn into fast oxidation if heat is not dissipated. This phenomenon is known as "spontaneous combustion" and results in a fire. Therefore, materials identified as subject to spontaneous combustion are normally stowed in a confined space where the heat can be dissipated rapidly. Materials, such as rags or papers that are soaked with animal fat, vegetable fats, paints, or solvents, are particularly subject to spontaneous combustion.

For a combustible fuel or substance to catch on fire, it must have an ignition source and be hot enough to burn. The lowest temperature at which a flammable substance gives off vapors that will burn when a flame or spark is applied is known as the FLASH POINT. The temperature at which a fuel will continue to burn after it has been ignited is known as the FIRE POINT. The fire point is usually a few degrees higher than the flash point. The AUTO-IGNITION or SELF-IGNITION POINT is the lowest temperature to which a substance must be heated to give off vapors that will burn without the application of a spark or flame. In other words, the

auto-ignition point is the temperature at which spontaneous combustion occurs. The auto-ignition point is usually at a much higher temperature than the fire point. The range between the smallest and the largest amounts of vapor in a given quantity of air that will burn or explode when ignited is called the FLAMMABLE RANGE or the EXPLOSIVE RANGE. For example, let's say that a substance has a flammable or explosive range of 1 to 12 percent. This means that either a fire or an explosion can occur if the atmosphere contains more than 1 percent but less than 12 percent of the vapor of this substance. In general, the percentages referred to in connection with flammable or explosive ranges are percentages by volume.

FUEL

Fuels take on a wide variety of characteristics. A fuel may be a solid, liquid, or even a vapor. Some of the fuels you will come into contact with are rags, paper, wood, oil, paint, solvents, and magnesium metals. This is by no means a complete list, but only examples.

OXYGEN

The oxygen side of the fire triangle refers to the oxygen content of the surrounding air. Ordinarily, a minimum concentration of 15 percent oxygen in the air is needed to support flaming combustion. However, smoldering combustion can take place in an atmosphere with as little as 3 percent oxygen. Air normally contains about 21 percent oxygen, 78 percent nitrogen, and 1 percent other gases, principally argon.

REVIEW QUESTIONS

Q1. A rapid chemical reaction that releases energy in the form of light and noticeable heat is known as combustion.

1. True
2. False

Q2. The lowest temperature at which a flammable substance gives off vapors that will burn when a flame or spark is applied is known by what term?

1. Combustion point
2. Fire point
3. Flame point
4. Flash point

Q3. The temperature at which a fuel will continue to burn after it has been ignited is known by what term?

1. Combustion point
2. Fire point
3. Flame point
4. Flash point

FIRE CLASSIFICATIONS

Learning Objective: Recall the different classifications of fires.

Fires are classified according to the nature of the combustibles (or fuels) involved, as shown in table 4-1. The classification of any particular fire is of great importance since it determines the manner in which the fire must be extinguished. Fires are classified as being either class ALPHA, class BRAVO, class CHARLIE, or class DELTA fires as follows:

- Class ALPHA (A) fires are those that occur in such ordinary combustible materials as wood, cloth, paper, upholstery, and similar materials. Class A fires are usually extinguished with water, using high or low velocity fog or solid streams. Class A fires leave embers or ashes and must always be overhauled.

- Class BRAVO (B) fires are those that occur in the vapor air mixture over the surface of flammable liquids, such as gasoline, jet fuels, diesel oil, fuel oil, paints, thinners, solvents, lubricating oils, and greases. Aqueous film-forming foam (AFFF), Halon 1211, Halon 1301, or dry chemical Purple-K-Powder (PKP) can be used to extinguish class B fires. The agent used will depend upon the circumstances of the fire.

- Class CHARLIE (C) fires are those which occur in electrical equipment. Nonconducting extinguishing agents, such as PKP, Carbon dioxide, and Halon 1211, are used to extinguish class C fires. CO_2 and Halon 1211 are preferred because they leave no residue.

- Class DELTA (D) fires occur in combustible metals, such as magnesium, titanium, and sodium. Special techniques have been developed to control this type of fire. If possible, you should jettison the burning material overboard. Most class D fires are fought by applying large amounts of water on the burning material to cool it down below its ignition temperature. However, a magnesium fire can be smothered by covering it with a large volume of dry sand.

Table 4-1. Fire Classifications

FIRE CLASSIFICATION	EXAMPLES OF TYPES OF MATERIAL	TYPE OF EXTINQUISHER
ALPHA	Wood, paper, cloth, upholstery	Water
BRAVO	Flammable liquids, such as gasoline, jet fuel, paint, oil, grease	AFFF, Halon 1301, PKP, CO_2, water fog
CHARLIE	Electrical equipment and wiring	CO_2 and Halon 1211 are preferred; PKP can be used
DELTA	Combustible metals, such as magnesium, titanium, and sodium	Jettison from ship, large volumes of water and sand

REVIEW QUESTIONS

Q4. What class of fire occurs in combustible metals, such as magnesium, titanium, and sodium?

1. ALPHA
2. BRAVO
3. CHARLIE
4. DELTA

Q5. Class ALPHA (A) fires leave embers or ashes and must always be overhauled.

1. True
2. False

Q6. What type of fire occurs in electrical equipment?

1. ALPHA
2. BRAVO
3. CHARLIE
4. DELTA

Q7. What type of fire occurs in the vapor-air mixture over the surface of flammable liquids?

1. ALPHA
2. BRAVO
3. CHARLIE
4. DELTA

THE EFFECTS OF FIRE

Learning Objective: Recall the effects of fire.

A burning substance produces a number of chemical reactions. These reactions produce flames, heat, smoke, and number of gases and other combustion products. The gases and combustion products will reduce the amount of oxygen available for breathing. All of these effects are vitally important to you as a fire fighter. You must be prepared to protect yourself against them.

FLAME, HEAT, AND SMOKE

Personnel must be protected from the flames, heat, and smoke to avoid injuries or loss of life. Before you enter a compartment or area where there is a fire, you need to be dressed out properly. You must tuck your pants into your socks, button the collar on your shirt, and put on a helmet. Wear any other protective clothing prescribed by current directives. If you are a nozzleman or hoseman, you will also need to wear protective gloves and an oxygen breathing apparatus (OBA). The flames and heat from a fire can be intense. However, if you are dressed out properly and maintain adequate distance, you can minimize your chances of getting burned. The smoke will make it hard to see and breathe. However, you can cope with these problems by wearing an OBA and a headlamp.

GASES

Some of the gases produced by a fire are toxic (poisonous). Other gases, although nontoxic, are dangerous in other ways. We will discuss briefly some of the more common gases that are associated with fires.

Carbon Monoxide

A fire produces carbon monoxide (CO) when there is not enough oxygen present for the complete combustion of all of the carbon in the burning material. CO is a colorless, odorless, tasteless, and nonirritating gas. However, it can cause death even in small concentrations. A person who is exposed to a concentration of 1.28 percent CO in air will become unconscious after two or three breaths. They will probably die in 1 to 3 minutes if left in the area. CO also has a wide explosive range. If CO is mixed with air in the amount of 12.5 to 74 percent by volume; an open flame or even a spark will set off a violent explosion.

Carbon Dioxide

Carbon dioxide (CO_2) is produced by a fire when there is complete combustion of all of the carbon in the burning material. CO_2 is a colorless and odorless gas. Although CO_2 is not poisonous, unconsciousness can result from prolonged exposure at 10 percent volume and higher. Above 11 percent volume, unconsciousness can occur in 1 minute or less. In a sufficient quantity, death could occur, since CO_2 does not provide any oxygen to breathe. The danger of asphyxiation should not be taken lightly; CO_2 does not give any warning of its presence, even when it is present in dangerous amounts. It does not support combustion and it does not form explosive mixtures with any substances. Because of these characteristics, CO_2 is very useful as a fire-extinguishing agent. It is also used for inerting fuel oil tanks, gasoline tanks, and similar spaces.

Hydrogen Sulfide

Hydrogen sulfide (H_2S) is generated in some fires. It is also produced by the rotting of foods, cloth, leather, sewage, and other organic materials. H_2S can be produced within 6 to 12 hours. Use caution when fighting fires around sewage systems and in spaces where there has been a sewage spill. H_2S is a colorless gas that smells like rotten eggs. Air that contains 4.3 to 46 percent H_2S is violently explosive in the presence of a flame. H_2S is extremely poisonous if breathed, even in concentrations as low as 20 parts per million (ppm). You may rapidly become unconscious, stop breathing, and possibly die after one breath in an atmosphere that contains 1,000 to 2,000 ppm of H_2S.

INSUFFICIENT OXYGEN

A fire in a closed compartment may cause an inadequate supply of oxygen for breathing. An enormous amount of oxygen is used by the fire itself, leaving relatively little oxygen to breathe. The amount of oxygen normally present in the air is 20.8 percent. You breathe and work best with this amount of oxygen. When a space is suspected of having an insufficient amount of oxygen, wear an OBA. Keep the OBA on until atmospheric tests show that oxygen content is at least 20 percent and no more than 22 percent by volume.

REVIEW QUESTIONS

Q8. A fire produces carbon monoxide (CO) when there is not enough oxygen present for the complete combustion of all of the carbon in the burning material.

1. True
2. False

Q9. A fire produces carbon dioxide (CO_2) when there is complete combustion of all of the carbon in the burning material.

1. True
2. False

Q10. Under normal conditions, oxygen accounts for what percentage of the chemical composition of air?

1. 10.5%
2. 20.8%
3. 30.2%
4. 40.1%

FIRE EXTINGUISHMENT

Learning Objective: Recall the fundamentals of fire extinguishing.

In general, fires may be extinguished by removing one side of the fire triangle (fuel, heat, or oxygen) or by slowing down the rate of combustion. The method or methods used in any specific instance will depend upon the classification of the fire (table 4-1) and the circumstances surrounding the fire.

REMOVING FUEL

Although it is not usually possible to remove the fuel to extinguish a fire, there may be circumstances in which it is possible. If part of the fuel that is near or actually on fire can safely be jettisoned over the side, do so as soon as possible. Damage control parties must

stand ready at all times to shift combustibles to safe areas. Take whatever measures possible to keep additional fuel away from the fire. In particular, immediately close supply valves in fuel oil, lube oil, and JP-5 lines.

REMOVING HEAT

The fire will go out if you can remove enough heat by cooling the fuel to below temperature at which it will support combustion. Heat may be transferred in three ways as follows:

1. By radiation
2. By conduction
3. By convection

In the process known as radiation, heat is radiated through the air in all directions. Radiated heat is what causes you to feel hot when you stand near an open fire. In conduction, heat is transferred through a substance or from one substance to another by direct contact from molecule to molecule. Therefore, a thick steel bulkhead with a fire on one side can conduct heat from the fire and transfer the heat to the adjoining compartments. In convection, the air and gases rising from a fire are heated. These gases can then transfer the heat to other combustible materials that are within reach. Heat transferred by convection is a particular danger in ventilation systems. These systems may carry the heated gases from the fire to another location several compartments away. If there are combustibles with a low flash point within a compartment served by the same ventilation system, a new fire may start.

To eliminate the heat side of the fire triangle, cool the fire by applying something that will absorb the heat. Although several agents serve this purpose, water is the most commonly used cooling agent. Water may be applied in the form of a solid stream, as a fog, or used together with aqueous film-forming foam (AFFF).

CONTROLLING OXYGEN

Oxygen is the third component of the fire triangle. Oxygen is difficult to control because you obviously cannot remove the oxygen from the atmosphere that normally surrounds a fire. However, oxygen can be diluted or displaced by other substances that are noncombustible. For example, if a fire occurs in a closed space, it can be extinguished by diluting the air with carbon dioxide ($C0_2$) gas. This dilution must proceed to a certain point before the flames are extinguished. The point at which the dilution is enough to extinguish the fire can be reached faster if you quickly secure all ventilation systems to the space. In general, a large enough volume of $C0_2$ must be used to reduce the oxygen content to 15 percent or less.

REDUCING THE RATE OF COMBUSTION

Dry chemical fire extinguishing agents and Halon 1301 do not extinguish fires by cooling or smothering. Instead, they are believed to interrupt the chemical reaction of the fuel and oxygen. This action reduces the rate of combustion, and the fire is extinguished quickly.

Speed is very important in fire fighting. If you allow a fire to burn without confining or extinguishing it, the fire can spread rapidly. A small fire in a trash can may spread to other combustibles and become a large fire that could affect several compartments or even the whole ship. The cost of damage that may have originally been a few dollars could end up costing millions of dollars. Therefore, the ship's fire party must get to the scene with their equipment and start fighting the fire as soon as possible. Any delay that allows the fire to spread will make it more difficult to extinguish the fire with the personnel and equipment available.

REVIEW QUESTIONS

Q11. Which of the following processes is NOT a method of transferring heat?

1. Radiation
2. Conduction
3. Convection
4. Glaciation

Q12. Heat, fuel, and oxygen are the three components of the fire triangle.

1. True
2. False

EXTINGUISHING AGENTS

Learning Objective: Recall the different extinguishing agents used to extinguish fires.

The extinguishing agents commonly used by Navy fire fighters include the following:

- Water
- Aqueous film-forming foam (AFFF)
- Purple-K-Powder (PKP)

- Carbon Dioxide (CO_2)
- Halon 1301

The agent or agents that are used in any particular case will depend upon the classification of the fire and the general circumstances.

WATER

Water is a cooling agent, and onboard ship the sea provides an inexhaustible supply. If the surface temperature of a fire can be lowered below the ignition temperature of the fuel, the fire will be extinguished. Water is most efficient when it absorbs enough heat to raise its temperature to 212°F (100°C). At this temperature, the seawater will absorb still more heat until it changes to steam. The steam carries away the heat and results in the lowering of the temperature of the surface.

AQUEOUS FILM-FORMING FOAM (AFFF)

Foam is a highly effective extinguishing agent for smothering large fires, particularly those in oil, gasoline, and jet fuels. AFFF, also known as "light water," is a synthetic, film-forming foam designed for use in shipboard fire-fighting systems. The foam proportioning/injection equipment generates a white foam blanket. AFFF proportioning equipment is discussed in chapter 6 of this nonresident training course (NRTC).

AFFF is equivalent to seawater when it is used to extinguish class A fires. The unique action of AFFF stems from its ability to make a light water film float on flammable fuels. As foam is applied over the flammable liquid surface, an aqueous solution drains from the foam bubbles and floats out over the surface to provide a vapor seal. This aqueous film-forming action enhances extinguishment and prevents reflash, even when the foam blanket is disturbed. Fuels which have not been ignited may also be protected with this same action. AFFF can be used alone or in combination with Purple-K-Powder (PKP).

PURPLE-K-POWDER (PKP)

Dry chemical powders extinguish a fire by a rather complicated chemical mechanism. They do not smother the fire and they do not cool it. Instead, they interrupt the chemical reaction of the fire by suspending fine particles in the fire. In effect, the dry chemicals put a temporary screen between the heat, oxygen, and fuel and maintain this screen just long enough for the fire to be extinguished. Several types of dry chemicals have been used as fire extinguishing agents. For Navy use, the most important agent of this kind at present is potassium bicarbonate, also known as Purple-K-Powder (PKP). PKP is used to extinguish class B and class C fires because it is very effective against these fires. However, it is both corrosive and abrasive and should be used on class C fires only in emergencies. PKP is available in 18-pound and 27-pound portable extinguishers. PKP can be used in conjunction with AFFF. Portable PKP extinguishers and the special equipment for using PKP and AFFF together are described in chapter 5 of this NRTC.

CARBON DIOXIDE

Carbon dioxide (CO_2) is an effective agent for extinguishing fires by smothering them; that is, CO_2 reduces the amount of oxygen available for combustion. This smothering action is temporary and you must remember that the fire can quickly rekindle if oxygen is again admitted to the hot embers.

CO_2 is a dry, noncorrosive gas that is inert when in contact with most substances. It is heavier than air and remains close to the surface. CO_2 does not damage machinery or other equipment. Since it is a nonconductor of electricity, CO_2can safely be used to fight fires that might present electric shock hazards. However, the frost that collects on the horn of a CO_2 extinguisher does conduct electricity. Therefore, you should be careful and never allow the horn to come into contact with electrical components. Aboard ship, CO_2 fire extinguishing equipment includes 15-pound CO_2 extinguishers, 50-pound CO_2 hose and reel installations, and 50-poundCO_2 installed flooding systems. Although CO_2 is nonpoisonous, it is dangerous because it does not provide a suitable atmosphere for breathing. Asphyxiation can result from breathing CO_2; therefore, an oxygen breathing apparatus (OBA) must be worn when CO_2 is used below decks or in confined spaces.

HALON 1301

Halon 1301 is a colorless, odorless gas with a density approximately five times that of air. It does not conduct electricity or leave a residue. Halon 1301 is stored in compressed gas cylinders for shipboard use. This extinguishing agent is effective against class A, class B, and class C fires. The fires are not extinguished by smothering or cooling; instead, the chemical

reaction of the fire is interrupted similar to the result of using PKP.

Halon 1301 decomposes upon contact with flames that are approximately 900°F (482°C). For Halon 1301 to function effectively as an extinguishing agent, it must decompose. However, as it decomposes, several other products, such as hydrogen fluoride (HF) and hydrogen bromide (HBr), are formed. Both gases are irritating to the eyes, skin, and upper respiratory tract. Chemical burns are also possible. You should not stay in a space where Halon 1301 has been released unless you are wearing an oxygen breathing apparatus (OBA).

REVIEW QUESTIONS

Q13. Water is a cooling agent and the sea provides a ship an inexhaustible supply.

1. True
2. False

Q14. AFFF can be used alone or in combination with PKP.

1. True
2. False

Q16. Halon 1301 is a dense colorless and odorless gas that does not conduct electricity or leave a residue.

1. True
2. False

Q15. Dry chemical powders interrupt the chemical reaction of the fire by suspending fine particles in the fire. These particles put a temporary screen between the heat, oxygen, and fuel and maintain this screen just long enough for the fire to be extinguished.

1. True
2. False

SUMMARY

In this chapter, you were introduced to the fundamentals of fire fighting. We identified the three elements required to have a fire along with the classifications of fires. You should now be aware of the effects of fire and the different types of gases you may encounter while fighting a fire. Remember, no two fires are identical; you will have to determine the best method or extinguishing agent to use when fighting a fire. Safety is to be observed always.

REVIEW ANSWERS

A1. A rapid chemical reaction that releases energy in the form of light and noticeable heat is known as combustion. **(1) True**

A2. The lowest temperature at which a flammable substance gives off vapors that will burn when a flame or spark is applied is known by what term? **(4) Flash point**

A3. The temperature at which a fuel will continue to burn after it has been ignited is known by what term? **(2) Fire point**

A4. What class of fire occurs in combustible metals, such as magnesium, titanium, and sodium? **(4) DELTA**

A5. Class A fires leave embers or ashes and must always be overhauled. **(1) True**

A6. What type of fire occurs in electrical equipment? **(3) CHARLIE**

A7. What type of fire occurs in the vapor-air mixture over the surface of flammable liquids? **(2) BRAVO**

A8. A fire produces carbon monoxide (CO) when there is not enough oxygen present for the complete combustion of all of the carbon in the burning material. **(1) True**

A9. A fire produces carbon dioxide (CO_2) when there is complete combustion of all of the carbon in the burning material? **(1) True**

A10. Under normal conditions, oxygen accounts for what percentage of the chemical composition of air? **(2) 20.8%**

A11. Which of the following processes is NOT a method of transferring heat? (4) Glaciation

A12. Heat, fuel, and oxygen are the three components of the fire triangle. **(1) True**

A13. Water is a cooling agent and the sea provides a ship an inexhaustible supply. **(1) True**

A14. AFFF can be used alone or in combination with PKP. **(1) True**

A15. Dry chemical powders interrupt the chemical reaction of the fire by suspending fine particles in the fire. These particles put a temporary screen between the heat, oxygen, and fuel and maintain this screen just long enough for the fire to be extinguished. **(1) True**

A16. Halon 1301 is a dense colorless and odorless gas that does not conduct electricity or leave a residue. **(1) True**