

**NAVAL SHIPS' TECHNICAL MANUAL**  
**CHAPTER 555 - VOLUME 2**  
**SUBMARINE FIREFIGHTING**



**THIS CHAPTER SUPERSEDES CHAPTER 555 VOLUME 2,  
DATED 8 DECEMBER 1997**

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**28 JULY 1998**



NAVSEA TECHNICAL MANUAL CERTIFICATION SHEET

1 of 1

Certification Applies to: New Manual  Revision  Change

Applicable TMINS/Pub. No. S9086-S3-STM-020/CH-555V2R5

Publication Date (Mo, Da, Yr) July 28, 1998

Title: Chapter 555, Volume 2, Submarine Firefighting

TMCR/TMSR/Specification No: N/A

CHANGES AND REVISIONS:

Purpose: Side bars in the margin indicate changes since the last revision. This revision makes changes as listed in Appendix C.



Equipment Alteration Numbers Incorporated: N/A

TMDER/ACN Numbers Incorporated: ACN 1/A

*Continue on reverse side or add pages as needed.*

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Authority	Name	Signature	Organization	Code	Date
Acquisition	R. L. Darwin		Naval Sea Systems Command	03G2	7/28/98
Technical	R. L. Darwin		Naval Sea Systems Command	03G2	7/28/98
Printing Release	Digital Publishing Media				



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## SECTION 31. FIRE AND FIREFIGHTING AGENTS

### 555-31.1 INTRODUCTION

**555-31.1.1 GENERAL.** This volume provides general guidance for firefighting equipment and procedures on submarines. **NSTM Chapter 555, Volume 1, Surface Ship Firefighting** provides similar guidance for surface ships.

**555-31.1.2 GLOSSARY.** See the glossary for definition of terms as used in this manual.

**555-31.1.3 REFERENCE LIBRARY.** A reference library for firefighting equipment should be established and maintained on board ship. This library should contain publications and instructions issued by the naval establishment and equipment manufacturers.

**555-31.1.4 SUGGESTED PUBLICATIONS.** Information provided should cover firefighting equipment and systems specific to each ship. In addition to the Ship's Information Book, the Standard Submarine Damage Control Book, Ship Systems Manuals (SSM's), all chapters of the Naval Ships' Technical Manual (NSTM), Maintenance Index Pages (MIPs) and Maintenance Requirement Cards (MRC's), a partial list of suitable publications is contained in Table 555-31-1.

**555-31.1.5 ADDITIONAL RESOURCES.** The library should contain audiovisual firefighting and damage control training aids. The Naval Education and Training Support Centers are the distribution facilities for audiovisual equipment. The San Diego center supplies the West Coast and the Pacific Ocean; the Norfolk center supplies the Mediterranean and fleet requests east of the Mississippi.

### 555-31.2 FIRE PREVENTION

**555-31.2.1 GENERAL.** Fire prevention is essential to the submarine. Continued efforts shall be made to minimize fire hazards.

**555-31.2.2 UNAUTHORIZED MATERIALS.** The Commanding Officer shall ensure that the installation or application of unauthorized or unapproved wood, bedding materials, upholstery, plastics, fibrous materials, paints, coatings, tile and adhesives, paneling, false bulkheads or overheads are not installed or carried in the ship. A material certification program, described in NAVSEA Technical Manual, S9510-AB-ATM-010, **Nuclear Powered Submarine Atmosphere Control Manual**, exists to qualify materials for use during design, construction, or overhaul of the submarine as well as the materials which may be brought on board by the crew. Any nonregulation or unapproved materials which are or may be installed shall be reported or submitted to NAVSEA for approval. All habitability materials shall comply with the fire performance requirements of MIL-STD-1623, **Fire Performance Requirements and Approved Specifications for Interior Finish Materials and Furnishings (Naval Shipboard Use)**.

**555-31.2.3 FIRE PREVENTION PROGRAM.** Each submarine is required to institute and maintain a fire prevention program. Each ship department head shall be responsible for implementing the fire prevention program. That program should heighten awareness of ships personnel in the following areas.

a. Good housekeeping practices reduce the danger of fires by controlling the presence of unwanted fuels, obstructions, and sources of ignition.

b. Stowage, handling, classification and labeling of hazardous materials as described in OPNAVINST 5100.19, Navy Occupational Safety and Health Program Manual for Forces Afloat, and in **NSTM Chapter 670, Stowage, Handling and Disposal of Hazardous General Use Consumables**, including inventorying and removal of obsolete, outdated or excess materials.

**Table 555-31-1. LISTING OF FIREFIGHTING REFERENCES**

NFPA Fire Protection Handbook National Fire Protection Association (current edition)	NAVSEA 0900-068-8010 Torpedo MK 48 Safety Criteria and General Casualty Control Procedures for Otto Fuel II Spills and Hot Runs
Fire Protection Guide on Hazardous Materials Published by National Fire Protection Association	NAVSEA S955B-X9-WSI-01A/SWSSSM(C4) Strategic Weapon System Support Systems Manual
DOD 6050.5-CD Hazardous Material Control and Management	NAVSEA S6340-AA-MMA-010 Otto Fuel II Safety, Storage, and Handling Instructions
OPNAVINST 3440.15 Minimum Criteria and Standards for Navy and Marine Corps Nuclear Weapons Accident and Incident Response	NAVSEA S6470-AA-SAF-010 U.S. Navy Gas Free Engineering Program
OPNAVINST 5100.19 and OPNAVINST 3040 U.S. Navy Safety Precautions	NAVSEA S9510-AB-ATM-010 Nuclear Powered Submarine Atmosphere Control Manual
COMSUBLANT/COMSUBPACINST 5400.39 Standard Submarine Organization and Regulations Manual (SSN)	NAVSEA S9555-AR-MMO-010 Fire Extinguishing System, Deep Fat and Doughnut Fryer
Naval Warfare Publication FXP 4 Mobility (Mob), Logistics (Log), Fleet Support Operations (FSO), Non-Combat Operations (NCO), and Explosive Ordnance Disposal (EOD) Exercises	NAVSEA OD 44979, VOL 16 Acoustic Device Counter Measures, Submarine Loading and Handling Procedures, MK 1 Mod 0 and Mk 2 Mod 0
NAVEDTRA 43119-4A Personnel Qualification Standard for Damage Control	NAVSEA OD 46199 SSBN Officers Guide for TRIDENT I Strategic Weapon System
NAVSEA SW050-AB-MMA-010, Vol. 1 Pyrotechnic, Screening, Marking, and Countermeasure Devices	NAVSEA OP 4 Ammunition Afloat
NAVSEA SW060-AA-MMA-010, Rev 1 Demolition Materials	NAVSEA OP 4021 Descriptions and Procedures Aboard Submarines, Torpedo MK 48 Mod 1
NAVSEA S0300-A6-MAN-030 US Navy Ship Salvage Manual - Volume 3, Firefighting and Damage Control	NAVSEA OP 4476 Launcher Subsystem
NAVSEA SW570-AO-MMI-021, SW570-AO-MMI-022 Mobile Submarine Simulator (MOSS), MK 57 Mod 0	NAVY TRAINING VIDEO, PIN 805433, Improved Shipboard Firefighting Using the Naval Firefighter's Thermal Imager

c. Control of ignition sources by training personnel to be alert to hazards such as equipment temperature rising beyond prescribed levels, cutting and welding sparks, faulty wiring, friction due to inadequate lubrication, and smoking lamp violations.

d. Shipboard fuel fire prevention program as described in **NSTM Chapter 541, Ship Fuel and Fuel Systems.**

e. Hotwork precautions and firewatch training as described in **NSTM Chapter 074, Volume 1, Welding and Allied Processes.**



- f. Removal of trash, fuels and lubricants in drip pans and bilges; maintenance actions to reduce leakage from motors, couplings, gear boxes, flanges and valves.
- g. Maintenance and operation of portable fire extinguishers.
- h. Frequent and regular inspection of all spaces to identify and correct hazardous conditions.
- i. Procedures to follow for sounding and transmitting a fire alarm signal (pier side).
- j. Fire Prevention requirements for gas free engineering as described in **NSTM Chapter 074, Volume 3, Gas Free Engineering**.
- k. Maintenance of proper atmosphere specifications and prohibitions against carrying flammable material which could introduce atmosphere contaminants as described in the **Nuclear Powered Submarine Atmosphere Control Manual**.

### 555–31.3 CHEMISTRY OF FIRE

**555–31.3.1 OXIDATION.** Oxidation is a chemical process in which a substance combines with oxygen. During this process, energy is given off, usually in the form of heat. The rusting of iron and the rotting of wood are common examples of slow oxidation. Fire or combustion involves rapid oxidation with the evolution of heat and light. Typically, fire involves rapid oxidation at temperatures above 1,500°F accompanied by the evolution of highly heated products of combustion and the emission of visible and invisible radiation. The combustion process occurs in two modes, flaming and surface combustion (including deep-seated glowing embers).

**555–31.3.2 START OF A FIRE.** All matter exists in one of three states; solid, liquid, or gas (vapor). The atoms or molecules of a solid are packed closely together, and those of a liquid are packed loosely. The molecules of a vapor are not packed together at all. They are free to move about. In order for a substance to burn, its molecules must be well surrounded by oxygen molecules. The molecules of solids and liquids are too tightly packed to be surrounded; therefore, only vapors can burn. When a solid or liquid is heated, its molecules move about rapidly. If enough heat is applied, some molecules break away from the surface to form a vapor just above the surface. This vapor can now mix with oxygen. If there is enough heat to raise the vapor to its ignition temperature, and if there is enough oxygen present, the vapor will ignite.

**555–31.3.3 COMBUSTION.** Combustion involves the rapid oxidation of millions of vapor molecules. The molecules oxidize by breaking apart into individual atoms and recombining with oxygen into new molecules. It is during the breaking and recombining process that energy is released as heat and light.

**555–31.3.3.1 Radiant Heat.** The heat that is released is radiant heat—the same form of energy that is radiated by the sun. Heat radiates in all directions. Part of the heat radiates back to the seat of the fire, to the burning solid or liquid.

**555–31.3.3.2 Radiation Feedback.** The heat that radiates back to the fuel is called radiation feedback. See Figure 555–31–1. Part of this heat releases more vapor, and part of it raises the vapor to the ignition temperature. At the same time, air is drawn into the area where the flames and vapor meet. The result is the newly formed vapor begins to burn. The flames increase.

**555–31.3.4 SELF-SUSTAINING REACTION.** A self-sustaining reaction starts in which burning vapor produces heat which releases and ignites more vapor. The additional vapor burns, producing more heat, which releases and ignites still more vapor. This process continues until all available fuel or oxygen has been consumed or the fire has been extinguished. When the combustion process is confined so that a rapid pressure rise occurs, it is called an explosion.

**555–31.3.4.1** Flammable gases burn more intensely than solids or liquids, because they are already in the vapor state. All the radiation feedback goes into igniting the vapor, so it is more fully ignited. Gases burn without smoldering or leaving residues. The size and intensity of a gas fire depend on the amount of fuel available.

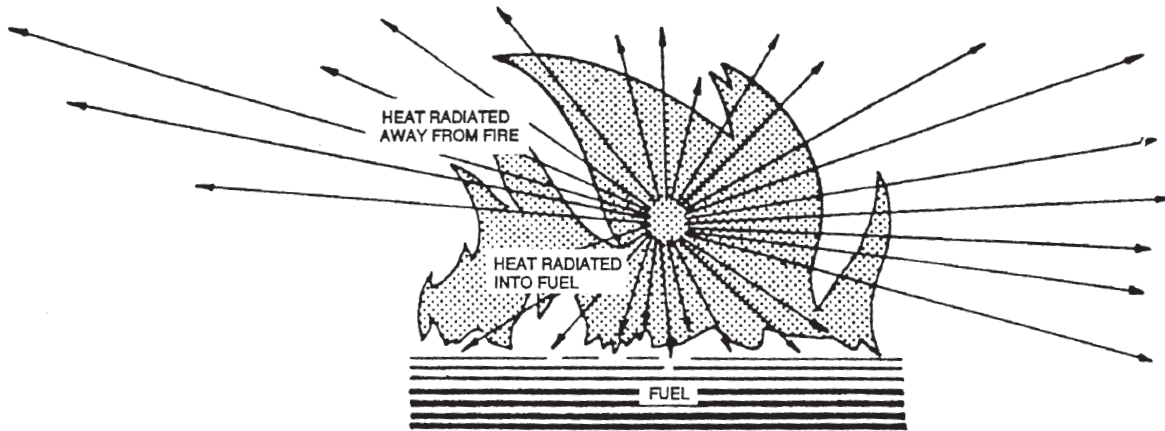


Figure 555-31-1. Radiant Feedback

#### 555-31.4 REQUIREMENTS FOR COMBUSTION

**555-31.4.1 FIRE TRIANGLE.** From the preceding section, three things are required for combustion: fuel (to vaporize and burn), oxygen (to combine with fuel vapor), and heat (to raise the temperature of the fuel vapor to its ignition temperature). The fire triangle illustrates these requirements. See Figure 555-31-2. It also illustrates two facts of importance in preventing and extinguishing fires:

- a. If any side of the fire triangle is missing, a fire cannot start.
- b. If any side of the fire triangle is removed, the fire will go out.

**555-31.4.2 FIRE TETRAHEDRON.** The fire triangle is acceptable for describing requirements for surface glowing or smoldering, but does not completely describe flaming combustion requirements. A fourth requirement,

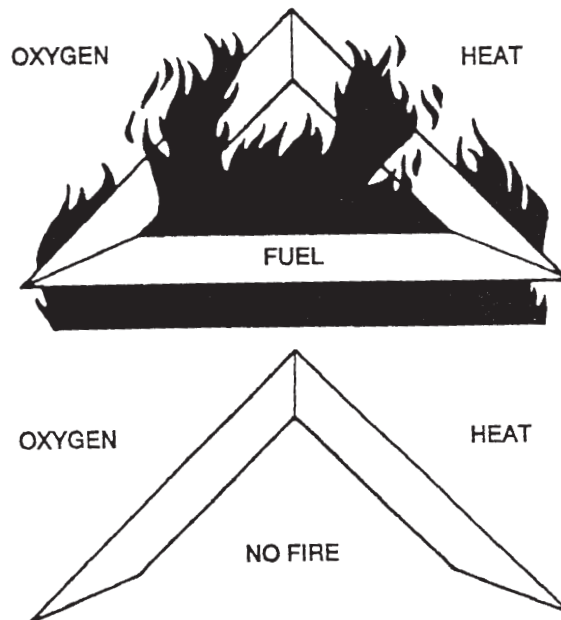
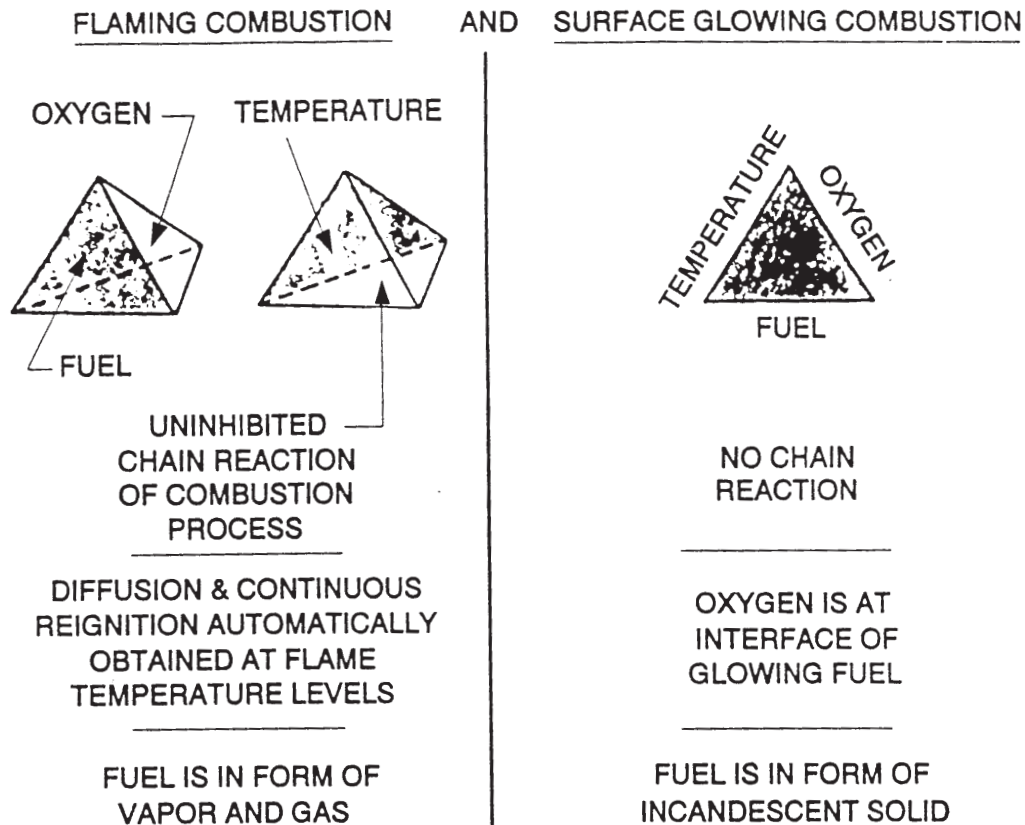


Figure 555-31-2. Requirements for Combustion

an uninhibited chemical chain reaction, is needed for flames to exist. This is illustrated by the fire tetrahedron, Figure 555-31-3. A tetrahedron is a solid figure with four triangular faces.



**Figure 555-31-3. Tetrahedron and Fire Triangle**

A tetrahedron is a solid figure with four triangular faces. It is useful for illustrating the flaming combustion process because it provides for the chemical chain reaction requirement and each face touches the other three sides. See Figure 555-31-4. As described for the fire triangle, flaming combustion stops when one of the four sides of the fire tetrahedron is removed. Dry chemical fire extinguishing agents work by interrupting the chemical chain reaction.

### 555-31.4.3 FUEL

**555-31.4.3.1 Solid Fuels.** The most obvious solid fuels are wood, rubber, plastics, paper and cloth. These are found aboard ship as insulation, canvas, packing, electrical cabling, wiping rags and mattresses.

**555-31.4.3.1.1 Pyrolysis.** Before 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. The decomposition causes a change from the solid state to the vapor state. See Figure 555-31-5. If the vapor mixes sufficiently with air and is heated to a high enough temperature, combustion results.

**555-31.4.3.1.2 Burning Rate.** The burning rate of a solid fuel depends on its configuration. Solid fuels in the form of dust or shavings will burn faster than bulky materials (that is, small wood chips will burn faster than a solid wood beam). Finely divided fuels have a much larger surface area exposed to the heat. Therefore, heat is absorbed much faster, and vaporization is more rapid. More vapor is available for ignition, so it burns with greater intensity and the fuel is quickly consumed. On the other hand, a bulky fuel will burn longer than a finely divided fuel. Burning rate is measured in kilowatts (kW). One kW is approximately 0.95 BTU/min. A small waste paper basket fire peaks around 10 kW.

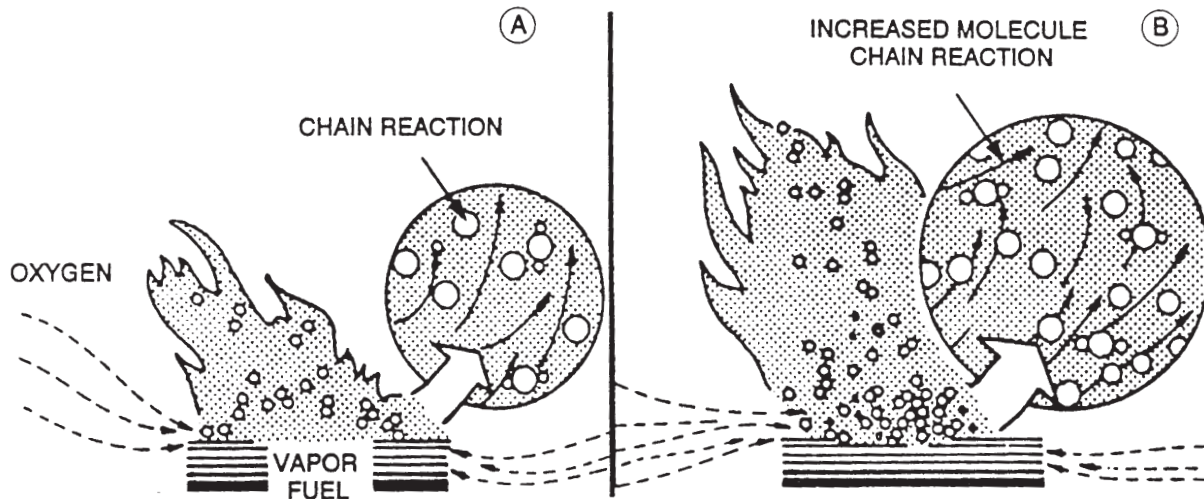


Figure 555-31-4. Chain Reaction

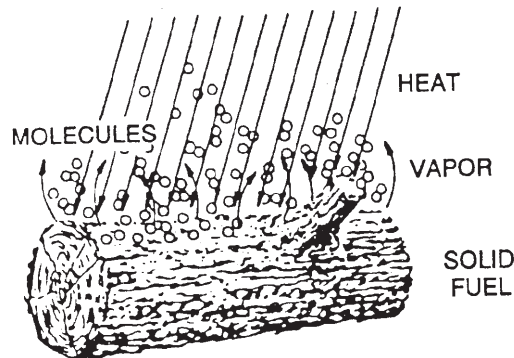


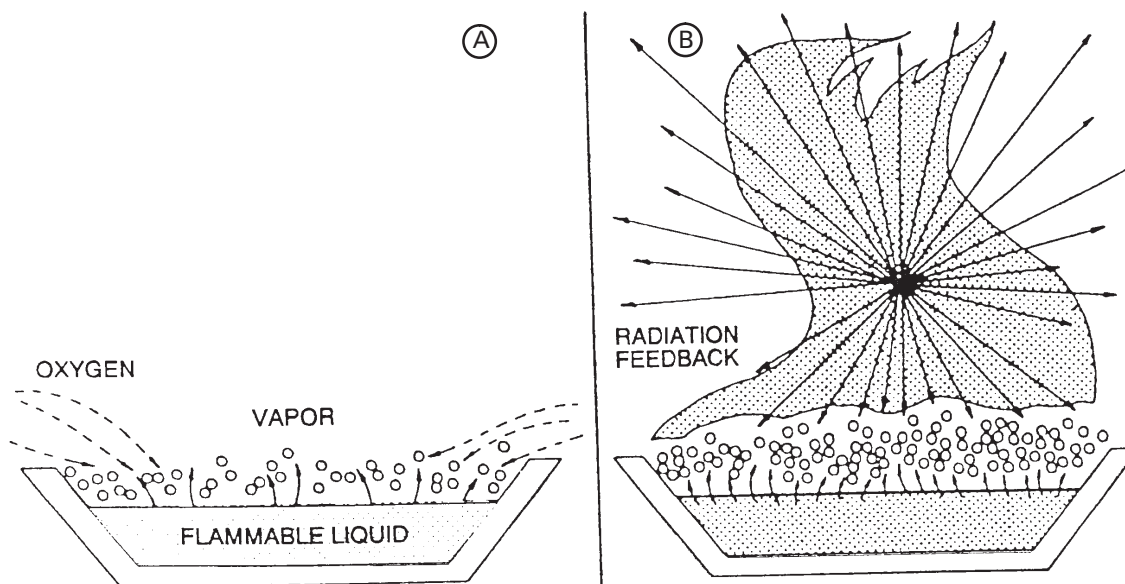
Figure 555-31-5. Pyrolysis

**555-31.4.3.2 Liquid Fuels.** The flammable liquids most commonly found aboard submarines are diesel fuel, lubricating oil, hydraulic fluid, torpedo Otto fuel, cooking oil and oil base paints and their solvents. See paragraph 555-36.5 for flammable liquid firefighting tactics.

**555-31.4.3.2.1 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 loosely packed molecules. In addition, liquids can release vapor over a wide temperature range. See Figure 555-31-6. Heating increases the rate of vapor release.

**555-31.4.3.2.2 Flashpoint.** The flashpoint is the lowest temperature at which a liquid gives off sufficient vapor to form an ignitable mixture. An ignitable mixture is a mixture composed of vapor and air that is capable of being ignited by an ignition source. Gasoline has a flashpoint of  $-45^{\circ}\text{F}$  ( $-43^{\circ}\text{C}$ ). This makes gasoline a continuous fire hazard; it produces flammable vapor at normal temperatures. The flashpoints (temperatures) of liquids are determined in controlled tests described in **NSTM Chapter 541**. For a discussion of the classification of flammable liquids see **NSTM Chapter 670**.

**555-31.4.3.2.3 Burning Characteristics.** Pound-for-pound, flammable liquids produce about 2.5 times more heat than wood. This heat is liberated 3 to 10 times faster from liquid than from wood. These ratios illustrate quite clearly why flammable liquid vapors burn with such intensity. When flammable liquids spill, they expose a very large surface area, release a great amount of vapor, and produce great amounts of heat when ignited. This is one reason why flammable liquid-spill fires burn so violently.



- NOTE: A – VAPOR FROM HEATED FUEL RISES, MIXES WITH AIR AND BURNS. IT PRODUCES ENOUGH HEAT TO RELEASE MORE VAPOR AND TO DRAW IN AIR TO BURN THAT VAPOR.
- B – AS MORE VAPOR BURNS, FLAME PRODUCTION INCREASES. MORE HEAT IS PRODUCED, MORE VAPOR RELEASED, MORE AIR DRAWN INTO THE FLAMES AND MORE VAPOR BURNS.

**Figure 555-31-6. Vaporization**

**555-31.4.3.2.4 Diesel Fuel.** Diesel fuel (F-76, navy distillate) at room temperature and pressure is not explosive. With a flash point of 140°F and an ignition temperature of 450°F, liquid diesel fuel is in fact difficult to ignite. However, atomized fuel oil exposed to hot surfaces (over 400°F) will burn readily, giving off dense black smoke. The fuel spray fire is of serious concern because the heat can be intense, and dense smoke will rapidly obscure the source of the fire. Immediate action is required before heat and smoke force personnel to abandon the compartment. Securing the source of the fuel is the most important step in combatting the fire.

**555-31.4.3.2.5 Hydraulic Fluid.** Hydraulic fluids (2190 TEP used in the ship service, stern diving, and missile tube hydraulic systems, and 2075T-H used in the external hydraulic system) are relatively safe when not under pressure because of their high flash points (400°F for 2190 TEP and 315°F for 2075T-H). However, under casualty conditions, pressurized fluid spraying from a hydraulic system (3000 psig for ship service, stern diving, and missile tube hydraulic systems, and 1500 psig for the external hydraulic system) may become atomized and susceptible to ignition from sparks, open flame, or hot surfaces. Prevention of hydraulic fluid fires is best accomplished by ensuring that all fluids are contained and that leaks and spills are controlled immediately to prevent the spread of the fluid and its vapor.

**555-31.4.3.2.6 Lubricating Oil.** Lubricating oils are relatively safe due to their high flashpoints, which range from 350°F minimum, and their ignition temperature of over 650°F. However, when sprayed on hot surfaces (over 650°F), lubricating oils will burn readily, giving off a very dense smoke. Lubricating oil has the same fire characteristics as hydraulic fluid.

**555-31.4.3.2.6.1 Prevention of lubricating oil fires** is best accomplished by ensuring that all oils are contained and that leaks and spills are controlled immediately to prevent the spread of the oil and its vapor. The main propulsion turbine and ship service turbine generator lube oil sump tanks are equipped with electrostatic precipitators which minimize oil vapor from entering the submarine atmosphere.



**555-31.4.3.3 Flammable Gases.** Flammable gases found on board a submarine include acetylene and hydrogen. See paragraph 555-36.6 for flammable gas firefighting tactics.

**555-31.4.3.3.1 Burning Characteristics.** Flammable gases are already in the vapor state. Only the proper ratio with oxygen and sufficient heat are needed for ignition. Most gases, like flammable liquids, produce a visible flame; they do not smolder. Hydrogen burns with a flame that is often invisible in normal light, unless there are other materials present in the flames.

**555-31.4.3.3.2 Radiation Feedback.** Radiation feedback is not necessary to vaporize the gas; however, some radiation feedback is still essential to the burning process, to provide continuous reignition of the gas.

**555-31.4.3.4 Explosive Range (Flammable Range).** A flammable gas or the flammable vapor of a liquid has to mix with air in the proper proportion to make an ignitable air-vapor mixture. The smallest percentage of gas (or vapor) that will make an ignitable mixture with air is called its lower explosive limit (LEL). If there is less gas (or vapor) than the LEL in the mixture, it is too lean to burn. The greatest percentage of a gas (or vapor) in an ignitable mixture is called its upper explosive limit (UEL). If a mixture contains more gas (or vapor) than the UEL, it is too rich to burn. The range between the lower and upper explosive limits is called the explosive range of the gas (or vapor).

**555-31.4.3.4.1 Explosive Limits.** Table 555-31-2 gives the LEL, UEL and flashpoint for a number of substances. It shows that a mixture of 1.4 percent to 7.6 percent gasoline vapor in air will ignite. A mixture of 9 percent gasoline vapor and 91 percent air will not ignite, because it is too rich (above the UEL). A large volume of air must intermix with a small amount of gasoline vapor to form an ignitable mixture. Certain devices can detect the presence of potentially hazardous concentrations of flammable gases. Such devices include the combustible gas indicator, see **NSTM Chapter 079, Volume 2**.

**555-31.4.3.4.2 Safety Guidelines.** It is important to realize that certain ranges of vapor-air mixtures can be ignited, and to use caution when working with flammable liquids. The explosive ranges of specific types of flammable liquids are published in **National Fire Protection Association (NFPA) Fire Protection Handbook**, and the **Fire Protection Guide for Hazardous Materials** published by the National Fire Protection Association and DOD 6050.5-CD, **Hazardous Material Control and Management**.

**555-31.4.4 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.

**555-31.4.4.1 Oxidizing Materials.** An oxidizing material is a material that releases oxygen when it is heated and may react readily with other materials. Such substances include the hypochlorites, chlorates, perchlorates, nitrates, chromates, oxides and peroxides. All carry their own supply of oxygen, enough to support combustion. Oxygen is released when the materials break down, as in a fire. For this reason, burning materials with their own oxidizers cannot be extinguished. Instead, large amounts of water are needed to cool surroundings while permitting a controlled burnout. Oxidizers are hazardous materials and must be stored in approved locations. For information on oxidizing materials including approved stowage see **NSTM Chapter 670**.

**555-31.4.5 HEAT.** Heat is the third side of the fire triangle. When sufficient heat, fuel and oxygen are available, the triangle is complete and fire can exist. Heat of ignition initiates the chemical reaction that is called combustion. Heat can come from the flame of a match, a hot surface (see Table 555-31-3), sparks caused by ferrous metals striking together, heat generated by friction, lightning, an oxyacetylene torch cutting or welding metal, an electrical short circuit, or an electrical arc between conductor and motor casing. See Appendix B, Glossary, for definition of hot surfaces for flammable liquid piping. Sufficient heat may also be produced internally, within the fuel, by a chemical reaction called spontaneous heating.

**Table 555-31-2. PROPERTIES OF SELECTED FLAMMABLE LIQUIDS AND GASES**

Material	Flashpoint	LEL	UEL	Ignition Temp	Ref. Source
Acetylene (C <sub>2</sub> H <sub>2</sub> )	gas <sup>1</sup>	2.5%	100%	581°F (305°C)	NFPA 325M
Carbon Monoxide (CO)	gas <sup>1</sup>	12.5%	74.0%	1128°F (609°C)	NFPA 325M
Cooking Oil	610°F <sup>6</sup>	— <sup>3</sup>	— <sup>3</sup>	740° – 830°F <sup>6</sup> (393° – 443°C)	NFPA 325M
Ethyl Alcohol (C <sub>2</sub> H <sub>5</sub> OH)	55°F (13°C)	3.3%	19.0%	685°F (363°C)	NFPA 325M
Fuel, Diesel, Navy Distillate (F-76) (MIL-F-16884)	140°F (60°C)	— <sup>2</sup>	— <sup>2</sup>	450°F (232°C)	NSTM 541
Gasoline (100 Oct)	-45°F (-43°C)	1.4%	7.6%	853°F (456°C)	NFPA 325M
Hydraulic Fluid MIL-H-17672 2075 T-H	315°F (157°C)	— <sup>3</sup>	— <sup>3</sup>	—	Mat. Safety Data Sheet
Hydrogen (H <sub>2</sub> )	gas <sup>1</sup>	4.0%	75.0%	932°F (500°C)	NFPA 325M
JP-5 (MIL-T-5624)	140°F (60°C) (NSTM 542)	0.6%	4.6%	475°F (246°C)	NFPA 325M
Lubricating Oil:					
2190 TEP (MIL-L-17331) <sup>7</sup>	400°F (204°C)	0.9%	7.0%	665°F (352°C) <sup>4</sup>	Mat. Safety Data Sheet
9250 (MIL-L-9000)	380°F-390°F (193°C-199°C)	— <sup>3</sup>	— <sup>3</sup>	—	Mat. Safety Data Sheet
Methane <sup>5</sup> (CH <sub>4</sub> )	gas <sup>1</sup>	5.0%	15.0%	999°F (537°C)	NFPA 325M
Methyl Ethyl Ketone (CH <sub>3</sub> COCH <sub>2</sub> CH(CH <sub>3</sub> ) <sub>2</sub> )	16°F (-9°C)	1.4%	11.4%	759°F (404°C)	NFPA 325M
Propane (C <sub>3</sub> H <sub>8</sub> )	gas <sup>1</sup>	2.1%	9.5%	842°F (450°C)	NFPA 325M
Torpedo OTTO Fuel II	265°F (129°C)	— <sup>3</sup>	— <sup>3</sup>	—	MIL-O-82672A

<sup>1</sup>Flammable gases do not list flashpoints since they can be ignited at any temperature.

<sup>2</sup>Explosive limits of fuel, navy distillate (F-76) are similar to those of JP-5.

<sup>3</sup>Data for LEL and UEL not available.

<sup>4</sup>Ignition temperature ref. source is "Flammability of Aircraft Hydraulic Fluids" prepared by Coordinating Research Council, Inc., dated September 1985.

<sup>5</sup>Methane exists in and around the sanitary tanks, vents and filters.

<sup>6</sup>Cooking oil flashpoint and ignition temperatures vary with origin of oil, brand, age, and contaminants.

<sup>7</sup>Lubricating oil 2190 TEP also serves as a hydraulic fluid.

**Table 555-31-3. TYPICAL UNLAGGED HOT SURFACE TEMPERATURES**

Diesel Engine	1000° F (540° C)
Diesel Exhaust	700° F (370° C)
Nuclear Steam Plant	<500° F (<260° C)

**555-31.4.5.1 Spontaneous Heating.** Spontaneous heating is the process whereby a material increases in temperature without drawing heat from its surroundings. Spontaneous heating of a material to its ignition temperature results in spontaneous ignition. Spontaneous heating to dangerous temperatures is governed by the rate of heat generation, material configuration, air supply and insulating properties of the surroundings. In order for spontaneous ignition to occur, sufficient air must be available to permit oxidation but not so much air that the heat is dissipated by convection as rapidly as it is formed. Spontaneous ignition occurs typically in materials that are tightly packed and saturated in greases, paints, animal and vegetable oil or fats. An oily rag which might spontaneously heat in the bottom of a waste paper basket will not if laid out in the open where air movement can remove the heat. Aboard ship, spontaneous ignition has occurred in materials immediately removed from clothes dryers and stored in laundry bags. Current dryers are fitted with a cool down cycle that minimizes the potential for fires occurring in laundry bags.

**555-31.4.5.2 Ignition Temperature.** The ignition temperature of a substance (solid, liquid or gas) is the lowest temperature at which sustained combustion will occur without the application of a spark or flame. Ignition temperatures vary among substances. For a given substance, the ignition temperature also varies with physical form, surface area and other factors. The ignition temperatures for common combustible materials lie between 300°F (150°C) and 1,000°F (540°C).

**555-31.4.5.3 Spark Ignition.** Finely atomized fuel vapors and gases can be ignited by a hot spark that provides the minimum ignition energy (MIE) for that fuel. The hot spark can come from many sources, such as grinding operations or operating an uncovered electrical switch. For hydrocarbon vapor in air, the minimum ignition energy is approximately 0.2 millijoules (mJ), which is much less than the spark energy from electric power systems. Low flashpoint flammable liquids, such as gasoline (MOGAS), vaporize from a standing pool at normal room temperatures and always present a spark ignition hazard. However, the high flashpoint flammable liquids normally found on U.S. Navy ships, such as diesel fuel, lube oil and hydraulic fluid, must be finely atomized by a spraying leak to be ignited by a spark. This is because the minimum ignition energy (MIE) increases rapidly with the vapor particle size. A coarse (large particle) spray of a high flashpoint fuel will not ignite with a small spark but will ignite with a steam pipe or diesel exhaust duct that is hotter than the fuel's ignition temperature because the fuel is first vaporized by the hot surface, see Table 555-31-2 and Table 555-31-3. Since most electric spark sources are enclosed, it is very unlikely that a high flashpoint fuel spray will be ignited by a spark.

## **555-31.5 HAZARDOUS PRODUCTS OF COMBUSTION**

**555-31.5.1 GENERAL.** Fire produces flames, heat, gases and smoke. Each of these combustion products can cause serious injuries or death.

**555-31.5.2 FLAMES.** Direct contact with flames can result in total or partial disabling skin burns and serious damage to respiratory tract. To prevent skin burns during a fire attack, crew members should maintain a safe distance from the fire unless they are properly protected and equipped for the attack. Protective clothing should be worn when combatting an advanced fire. Respiratory tract damage can be prevented by wearing breathing apparatus. Firefighting personnel must remember that breathing apparatus does not protect the body from the extreme heat of a fire.

**555-31.5.3 HEAT.** Fire can generate compartment temperatures in excess of 2000°F (1093°C) particularly when a compartment has flashed over. Temperatures above 150°F (66°C) are hazardous to humans. Studies have shown that a skin surface temperature as low as 160°F (71°C) will result in second degree burns if contact is maintained for 60 seconds. 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 track 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 nerve centers. See Table 555-31-7 for more information.

**555-31.5.4 GASES.** The particular gases produced by a fire depend mainly on the fuel. The most common hazardous gases are carbon monoxide (CO), the product of incomplete combustion, and carbon dioxide (CO<sub>2</sub>), the product of complete combustion. In a smoldering fire, the ratio of carbon monoxide to carbon dioxide is usually greater than in a well ventilated, free burning fire.



**555–31.5.4.1 Carbon Monoxide.** Carbon monoxide (CO) is the major threat in most fire atmospheres. Exposure to CO results in an oxygen deficiency in the brain and body (see Table 555–31–4). Exposure to a 1.3 percent concentration of CO will cause unconsciousness in two or three breaths, and death in a few minutes. Exposure limits for CO are listed in the technical manual NAVSEA S9510–AB–ATM–010, **Nuclear Powered Submarine Atmosphere Control Manual**. Carbon monoxide (CO) is classified as a flammable gas (see Table 555–31–2).

**Table 555–31–4. HUMAN TOLERANCE TO CARBON MONOXIDE (CO)**

PPM CO	%CO	Incapacitation	Death
1500 ppm	.15%	30 minutes	2 hours
4000 ppm	.4%	15 minutes	1 hour
6000 ppm	.6%	5 minutes	10 minutes
20,000 ppm	2%	15-30 seconds	2 minutes
60,000 ppm	6%	Immediate (One breath)	< 1 minute

**555–31.5.4.2 Carbon Dioxide.** Carbon dioxide (CO<sub>2</sub>) works on the respiratory system. Above normal CO<sub>2</sub> concentrations in the air reduces the amount of oxygen that is absorbed in the lungs. The body responds with rapid and deep breathing (a signal that the respiratory system is not receiving sufficient oxygen). Exposure limits for CO<sub>2</sub> are listed in the technical manual NAVSEA S9510–AB–ATM–010, **Nuclear Powered Submarine Atmosphere Control Manual**. See also Table 555–35–1.

**555–31.5.4.3 Oxygen Reduction.** When the oxygen content of air drops from its normal level of 21 percent to about 16 percent at an atmosphere pressure equal to that at sea level, human muscular control is impaired. At 10 percent to 14 percent oxygen in air, judgment is impaired and fatigue sets in. Unconsciousness usually results from oxygen concentrations below 10 percent. During periods of exertion, such as firefighting operations, the body requires more oxygen and increased demands may result in oxygen deficiency symptoms at normal oxygen levels.

**555–31.5.4.4 Other Fire Gases.** Several other gases generated by a fire are of equal concern to firefighters. Toxic hydrocarbon vapors are produced by fuels. Hydrogen chloride (HCL) is produced when polyvinyl chloride (PVC) electric cable jacketing is burned. Hydrogen cyanide (HCN) is produced when chilled water piping insulation is burned. Fluorocarbon refrigerants, such as R–12, R–114, and HFC 134a, are non–flammable and non–explosive, but exposure to flames or hot surfaces will cause these compounds to generate hydrogen chloride (acid gas), hydrogen fluoride (acid gas) and other poisonous gases. See paragraph 555–35.10.3 for more information.

**555–31.5.5 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.

**555–31.5.5.1** Smoke greatly reduces visibility in and above the fire area. It irritates the eyes, nose, throat and lungs. Either breathing a low concentration for an extended period of time or a heavy concentration for a short time can cause great discomfort to a firefighter.

**555–31.5.5.2** Firefighters who do not wear breathing apparatus in the fire area will eventually have to retreat to fresh air or be overcome by smoke and toxic gases.

## **555–31.6 CLASSIFICATION OF FIRES**

**555–31.6.1 GENERAL.** There are four classifications of fire: class A, class B, class C, and class D. The different classifications are briefly described in the following paragraphs.

**555–31.6.2 CLASS A FIRES.** Class A fires involve wood and wood products, cloth, textiles and fibrous materials, paper and paper products. Class A fires are extinguished with water, usually in a fog pattern. If the fire

is deep-seated, aqueous film forming foam (AFFF), when available, is more effective than sea water and can be used as a wetting agent to rapidly penetrate and extinguish the fire. The AFFF system installed in the SSN 21 class submarine provides an AFFF capability to all 1-1/2 inch seawater fireplugs.

**555-31.6.3 CLASS B FIRES.** Class B fires involve flammable liquids such as gasoline, diesel fuel, hydraulic fluid and lube oil. These fires are normally extinguished with AFFF, or Potassium Bicarbonate, or water. See paragraph 555-31.4.4 for flammable liquid burning characteristics. See paragraph 555-36.5 for flammable liquid firefighting tactics. Class B fires also involve flammable gases which should never be extinguished unless there is reasonable certainty that the flow of gas can be secured. See paragraph 555-31.4.3.3 for flammable gas burning characteristics. See paragraph 555-36.6 for flammable gas firefighting tactics.

**555-31.6.4 CLASS C FIRES.** Class C fires are energized electrical fires that are attacked at prescribed distances using nonconductive agents such as CO<sub>2</sub> or water fog. The most effective tactic is to deenergize and handle the fire as a class A fire. When fires are not deep seated, clean agents that pose no clean up problem such as CO<sub>2</sub> are preferred. Paragraph 555-36.2 provides information on combatting class C fires.

**555-31.6.5 CLASS D FIRES.** Class D fires involve combustible metals such as magnesium (pyrotechnics), lithium hydride (countermeasures), sodium, potassium, aluminum, zinc, titanium, zirconium, and iron. Heat from radiation, conduction, or convection can be sufficient to cause ignition; flame is not necessary. Probable causes of this class of fires include the exposure to high temperature (magnesium), or violent reaction to water (sodium, potassium). Firefighting methods vary with the type of metal involved. Paragraph 555-36.8 provides information on combatting class D fires.

## **555-31.7 BURNING CHARACTERISTICS OF PROPELLANTS AND EXPLOSIVES**

**555-31.7.1 COMPOSITION OF PROPELLANTS AND EXPLOSIVES.** Propellants and explosives typically are composed of energetic materials that combine both a fuel and an oxidizer. These materials once ignited, cannot be extinguished. Burning will continue until the material is consumed. Cooling streams of seawater (or AFFF in the SSN 21 class) should be used to control the burn and cool the surrounding area. From a damage control standpoint, efforts should be directed at tube loading and jettisoning the weapons. In the presence of flammable liquids, burning explosives or propellants will pose a continuous source of ignition. See OP-4, **Ammunition Afloat**, for further information on weapons fires. Firefighting procedures for nuclear weapons are addressed in OD 46199, **SSBN Officers Guide for TRIDENT I Strategic Weapon System**, and OPNAVINST 3440.15, **Minimum Criteria and Standards for Navy and Marine Corps Nuclear Weapons Accident and Incident Response**.

**555-31.7.2 FIGHTING FLAMMABLE LIQUID AND WEAPONS FIRES.** Firefighting procedures involving weapons and flammable liquid fires that occur in torpedo rooms or missile compartments are addressed in the ships casualty procedures. Flammable liquid fires should be fought with AFFF, PKP, and water in the form of fog. After the fire is extinguished, the area should continue to be cooled with AFFF, when available, or water, as required. Combined use of AFFF hoses and seawater hoses should be avoided because seawater will dilute and degrade the AFFF film.

**555-31.7.3 TORPEDO OTTO FUEL.** Otto Fuel II is a stable liquid monopropellant used in the propulsion of the Mk 46, Mk 48, Mk 55, Mk 56, and Mk 60 torpedoes. Otto Fuel II is composed of a nitrate ester in solution with a desensitizing agent and a stabilizer. It is a bright red, free flowing, oily liquid that is heavier than water. It is insoluble in water. Detailed safety, handling, and cleanup instructions for Otto Fuel are contained in references cited in Table 555-31-1. See paragraph 555-36.9 for guidance on extinguishing an Otto Fuel fire.

**555-31.7.3.1** Otto Fuel II liquid and vapor are extremely toxic. Otto fuel toxic effects may occur from inhalation of Otto Fuel II vapors, inhalation of combustion by-products, absorption from direct skin contact, or ingestion. The nitrate esters in the Otto fuel are known for their acute effects, including nausea, turgidity (swelling), blood pressure changes, headaches, and dyspnea (difficult breathing).

**WARNING**

Personnel shall not be exposed to Otto Fuel II vapor concentrations in excess of 0.2 ppm (1.3 mg/m<sup>3</sup>). Injury or death of personnel could result.

**WARNING**

The smoke from burning Otto fuel must be considered as hazardous and toxic as Otto fuel fumes.

**555-31.7.3.2** For Otto Fuel II fires, personnel without self-contained breathing protection or EAB masks should not enter smoky areas. Personnel without full protective clothing should not enter spaces containing spilled or burned Otto Fuel II.

**555-31.7.3.3** Fire team personnel should take extreme care not to expose skin surfaces. Fire party personnel, clothing, and equipment exposed to Otto Fuel II should be considered contaminated until tested. Once the fire is extinguished, Otto Fuel II spill cleanup and decontamination should be conducted in accordance with the applicable references in Table 555-31-1.

**555-31.8 HEAT TRANSFER**

**555-31.8.1 GENERAL.** Heat from a fire is transferred by one or more of three methods: conduction, radiation, and convection.

**555-31.8.2 CONDUCTION.** Conduction is the transfer of heat through a body or from one body to another body by direct physical contact. For example, on a hot stove, heat is conducted through the pot to its contents. Wood is ordinarily a poor conductor of heat, but metals are good conductors. Since submarines are constructed of metal, heat transfer by conduction is a potential hazard. Fire can move from one space to another, one deck to another, and one compartment to another by heat conduction.

**555-31.8.2.1** In many cases the skillful application of water, typically applied using fog patterns to rapidly coat and recoat surfaces with a film of water will retard or halt the transmission of heat by conduction. Fog patterns coat surfaces more efficiently than solid streams, reducing run off and the effect on ship trim.

**555-31.8.3 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 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.

**555-31.8.3.1** Heat radiates in all directions unless it is blocked. Radiant heat extends fire by heating combustible substances in its path, causing them to produce vapors, and then igniting the vapor. Radiant heat flux is the measure of radiant energy (heat) flow per unit area, and is normally expressed in kilowatts per square meter (kW/m<sup>2</sup>).

**555-31.8.3.2** Within a compartment, radiant heat will raise the temperature of combustible materials near the fire and, depending on the ship's design, at quite some distance from the fire. Ship fires can spread as a result of radiating bulkheads and decks. Intense radiated heat can make an approach to the fire extremely difficult. For this reason, protective clothing should be worn by firefighters.

**555-31.8.4 CONVECTION.** Convection is the transfer of heat through the motion of circulating gases or liquids. Heat is transferred by convection through the motion of smoke, hot air and heated gases produced by a fire.

**555-31.8.4.1** When heat is confined (as within a compartment), convected heat moves in predictable patterns. The fire produces lighter-than-air gases that rise toward high parts of the compartment. Heated air, which is lighter than cooler air, also rises. 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.

**555-31.8.4.2** Hot smoke originating at a fire on a low deck will travel horizontally along passageways, and then upward by way of frame bays, and ladder and hatch openings, heating flammable materials in its path. To prevent fire spread, and assist the fire party in combatting the fire, it may be necessary to vent the heat, smoke and gases overboard via a ship's hatch. The intense heat may cause secondary fires along the ventilation path if the ship's ventilation system is used. It is imperative that the fire be confined to the smallest possible area. Joiner doors should be kept closed when they are not in use. If a fire is discovered, attempts should be made to close off all openings to the fire area until firefighting personnel and equipment can be brought into position to fight the fire.

### 555-31.9 SPACE FIRE DYNAMICS

**555-31.9.1 FIRE GROWTH IN A SPACE.** During its life, a space fire normally experiences four different stages: growth, flashover, fully developed fire, and decay. See Figure 555-31-7.

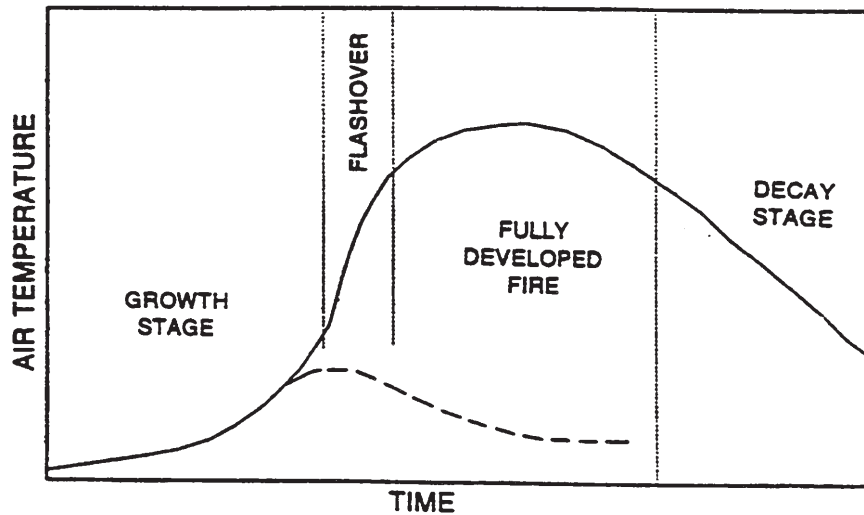


Figure 555-31-7. Stages of Space Fire Growth

**555-31.9.1.1 Growth Stage.** In the growth or pre-flashover stage the average space temperature is low and the fire is localized in the vicinity of its origin. High local temperatures exist in and around the burning material(s), and smoke from the fire forms a hot upper layer in the space. See Figure 555-31-8.

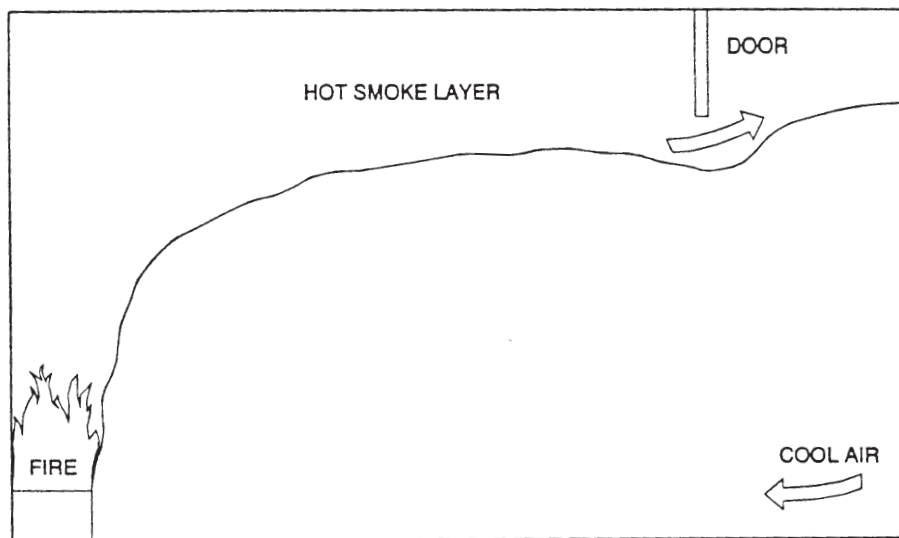


Figure 555-31-8. Growth Stage - Space Fire

**555–31.9.1.1.1 Rollover.** Rollover is the formation of a flame front of burning gases across the overhead of a space. Rollover takes place in the growth stage when unburned combustible gases from the fire mix with fresh air in the overhead and burn at some distance from the seat of the fire. Rollover differs from flashover in that only the gases are burning and not all the contents of the space.

**555–31.9.1.2 Flashover Stage.** Flashover is the period of transition from the growth stage to the fully developed fire stage. Flashover occurs in a short period of time and may be considered as an event, as ignition is an event. It normally occurs when the upper smoke layer temperature reaches 1100°F (600°C) and the radiant heat flux at the deck reaches 20 kW/m<sup>2</sup>. The most obvious characteristic of flashover is the sudden spread of flame to all remaining combustibles in the fire space. Survival of personnel who have not escaped from the space prior to flashover is unlikely.

**555–31.9.1.3 Fully Developed Fire Stage.** In the fully developed or post-flashover fire stage, all combustibles in the space have reached their ignition temperature and are burning. During this stage, the burning rate in the space is normally limited by the amount of oxygen available in the air for combustion. Flames may emerge from any opening. Unburnt fuel in the smoke may burn as it meets fresh air in adjacent spaces. Structural damage to exposed steel normally occurs as it is heated to extreme temperatures. A fully developed fire may be inaccessible by fire teams, prohibiting a direct attack. A space can reach the fully developed fire stage very quickly in flammable liquid fires.

**555–31.9.1.4 Decay Stage.** Eventually, the fire consumes all available fuel and/or oxygen, at which time combustion slows down (decays) and the fire goes out.

**555–31.9.2 SIGNIFICANT EXPOSURE THRESHOLDS.** Significant exposure thresholds are provided in Table 555–31–5, Table 555–31–6, Table 555–31–7, and Table 555–31–8.

**Table 555–31–5. IGNITION THRESHOLDS (PILOTLESS IGNITION WITHIN 30 SECONDS)**

Material	Hot Air (Oven Effect)	Hot Metal Contact (Frying Pan Effect)	Radiant Heat Flux
Paper	450°F (230°C)	480°F (250°C)	20 kW/m <sup>2</sup>
Cloth	480°F (250°C)	570°F (300°C)	35 kW/m <sup>2</sup>
Wood	570°F (300°C)	660°F (350°C)	40 kW/m <sup>2</sup>
Cables	700°F (370°C)	840°F (450°C)	60 kW/m <sup>2</sup>

**Table 555–31–6. IGNITION OF PAPER VIA RADIANT HEAT**

Radiant Heat Flux	Time to Ignition
20 kW/m <sup>2</sup>	25 sec
25 kW/m <sup>2</sup>	14 sec
35 kW/m <sup>2</sup>	8 sec
50 kW/m <sup>2</sup>	3.5 sec
75 kW/m <sup>2</sup>	2.5 sec

**555–31.9.3 BACKDRAFT.** If a fire self-extinguishes because of a lack of oxygen, as can occur in a sealed airtight compartment, fuel vapors may still be formed from a flammable liquid which is above its flashpoint, or from pyrolysis of a solid material. If fresh air is then introduced and the fuel-vapor-rich air is still above its ignition temperature, the three elements of the fire triangle are again present and the mixture can ignite explosively. This is known as backdraft. A backdraft is an unusual occurrence and has never been known to occur on a submarine.

**Table 555–31–7. HUMAN TOLERANCE TO HEAT**

<b>Hot Air Exposure</b>	
200°F (90°C)	Incapacitation 35 minutes, death 60 minutes.
300°F (150°C)	Incapacitation 5 minutes, death 30 minutes.
300°F (190°C)	Immediate incapacitation, death 15 minutes.
400°F (200°C)	Irreversible respiratory tract damage.
650°F (340°C)	Death
<b>Radiant Heat Exposure</b>	
1 kW/m <sup>2</sup>	Noon sun radiation at sea level on clear summer day.
5 kW/m <sup>2</sup>	Pain threshold for exposed skin.
10 kW/m <sup>2</sup>	Immediate blistering.

**Table 555–31–8. THERMAL EFFECTS ON ELECTRONICS**

120°F (50°C)	Computers develop faults.
300°F (150°C)	Permanent computer damage.
480°F (250°C)	Data transmission cables fail.

**555–31.9.4 SUBMARINE FIRE DYNAMICS.** Submarines have some unique characteristics that affect the growth of a fire and the spread of smoke and heat from a fire. These characteristics are discussed in the paragraphs that follow.

**555–31.9.4.1 Fire Growth and Intensity.** The primary characteristics unique to a submarine that affect fire growth are the closed environment of a submarine and the oxygen concentration.

**555–31.9.4.1.1** Fires tend to become intense quickly in the closed environment of a submarine. The insulated hull reduces the transfer of heat from the submarine to the environment. This increases the amount of heat from the fire contained inside the submarine. Also, the pressure increase caused by the fire may contribute to the rapid growth of the fire. In a submarine without any ventilation to the atmosphere, personnel without protective gear could be forced by heat from the immediate area of a moderately severe fire in less than a minute after the fire starts.

**555–31.9.4.1.2** In a closed environment, eventually the fire will be extinguished due to a lack of oxygen. But in the typical, large submarine compartment there is sufficient oxygen for a fire to generate severe, untenable conditions before the fire consumes the available oxygen in a compartment.

**555–31.9.4.1.3** Increasing the concentration of oxygen will increase the intensity and growth rate of a fire. Higher than normal concentrations of oxygen can occur locally at oxygen bleed points, the chlorate candle furnace or at a leak in the oxygen system. In addition, increased oxygen concentration tends to lower the ignition temperature of materials, causing materials to burn that otherwise might not be thought of as combustible. For example, a fire in an oxygen candle furnace caused the steel deck supporting the furnace to burn.

**555–31.9.4.1.4** Decreasing the concentration of oxygen will decrease the intensity and growth rate of a fire. The minimum oxygen volume concentration has been lowered to 17% O<sub>2</sub> in technical manual, NAVSEA S9510–AB–ATM–010/(U), **Nuclear Powered Submarine Atmosphere Control Manual**, to reduce the fire risk on submarines.

**555–31.9.4.2 Spread of Smoke and Heat.** The primary paths for the spread of smoke and heat in a submarine are openings to the frame bays and open ladder ways between platforms. Other openings, such as ventilation openings



in doors and bulkheads and open structure at the top of joiner bulkheads also provide paths for the spread of smoke and heat. Smoke and heat will spread very quickly to the upper level from a fire in lower level, particularly where there is a continuous path, such as a frame bay, for the smoke to follow.

**555–31.9.4.2.1** Heat from a fire in the lower level can force personnel from spaces in the upper level of the compartment quickly. Emergency air breathing masks will not protect personnel from heat exposure. The firefighter’s ensemble (FFE) will provide some protection from heat.

**555–31.9.4.2.2** Heat from a fire in the upper level will accumulate first in the upper level and then spread slowly to the lower levels. The lower levels will remain tenable longer than the upper level.

**555–31.9.4.2.3** Smoke from the fire will impair visibility, reducing the operating effectiveness of the crew, impairing firefighting efforts and impairing safe evacuation of the compartment. In the upper level, where smoke tends to accumulate the quickest, visibility can be lost in less than 30 seconds.

**555–31.9.4.2.4** Venting the fire compartment to weather may help reduce the heat and smoke in the compartment. Venting can be accomplished by opening hatches when surfaced or by operating the ventilation system when snorkeling. Venting by opening a hatch probably will not cause the fire to grow significantly. Operating the ventilation system increases the risk of additional fire growth and of spreading smoke and heat through the operating ventilation system. In any case, if venting initially improves tenability to allow a successful attack on the fire, the advantages of venting may outweigh the disadvantages.

**555–31.9.4.3 Typical Fire Growth Scenario.** A typical growth scenario for a moderately severe class A fire in the lower level of the forward compartment is provided below. See Figure 555–31–9.

0	–	The fire starts
30 seconds to 1 minute	–	Visibility in the upper level is lost due to smoke.
1 to 3 minutes	–	Unprotected personnel driven by heat from the scene.
2 to 6 minutes	–	Unprotected personnel driven by heat from the upper level.

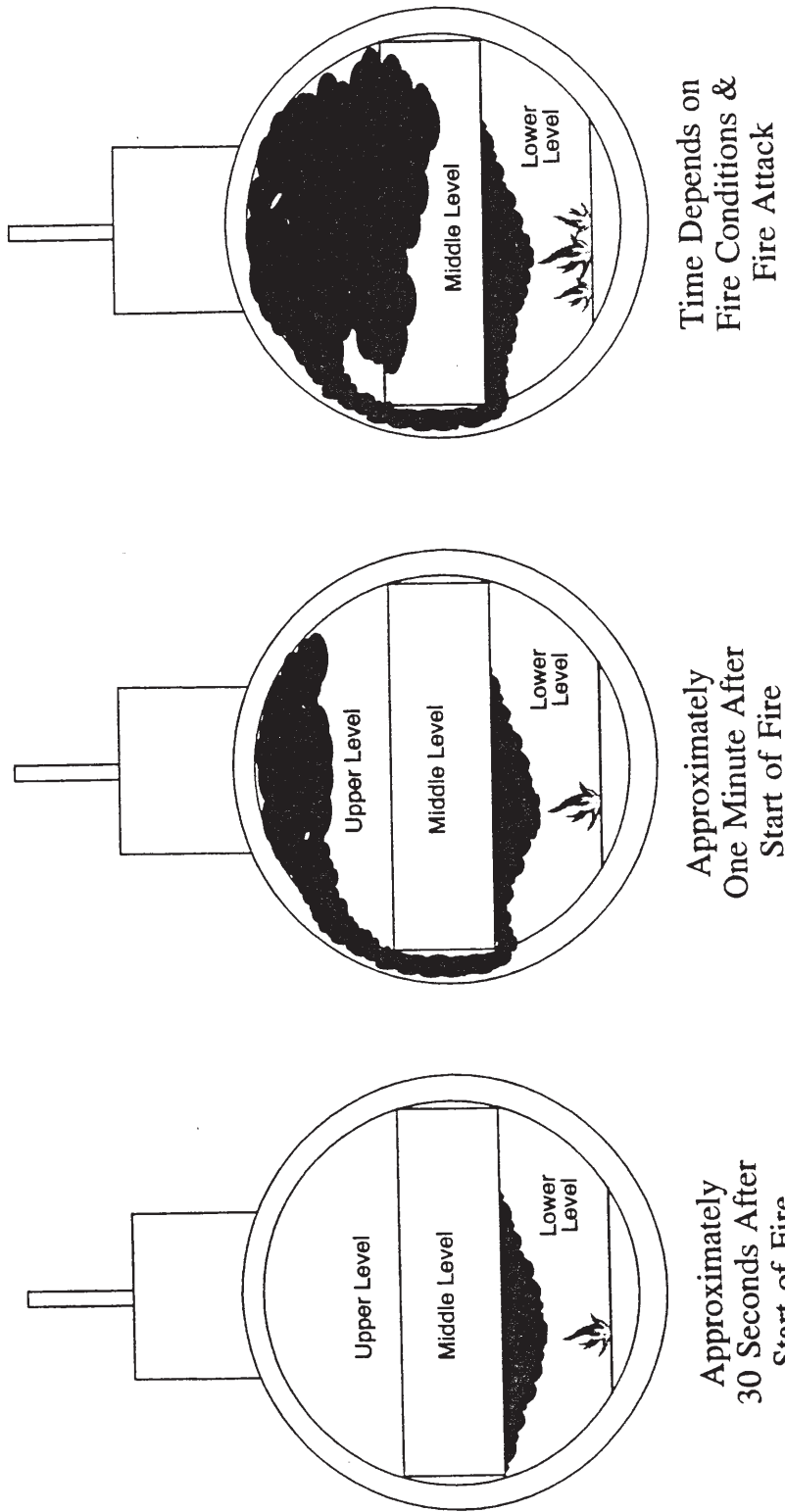
**555–31.10 FIRE SPREAD**

**555–31.10.1 GENERAL.** If a fire is attacked early and efficiently, it can be confined to the area in which it started. If it is allowed to burn unchecked, it can generate great amounts of heat that will travel away from the fire area, igniting additional fires wherever fuel and oxygen are available.

**555–31.10.1.1** Steel bulkheads and decks and other fire barriers can delay but not prevent transfer of heat.

**555–31.10.1.2** When a space, such as the radio or sonar control room, is fully involved in fire, e.g. post–flashover, fire is most quickly spread to other spaces within the compartment through openings such as doorways, vent ducts, and open pipeways and wireways. It will also spread to adjacent spaces by heat conduction through the bulkheads. Fires normally spread faster vertically to the space above than to adjacent horizontal spaces.

**555–31.10.2 FIRE SPREAD IN ELECTRICAL CABLE RUNS.** The spread of fire in electrical cable runs and the water from firefighting efforts can interrupt power, lighting and communications which serve vital spaces and functions. Even though cables in a cable run may be armored, fire experience has shown armor does not deter fire in a cable. The metal braid is not sufficiently heavy to act as a heat shield to reduce cable temperature, nor is it sufficiently gastight to prevent the burning of outgassing products emitted from the insulation. If fire is allowed to



Rate of smoke and heat spread will depend on the size of the fire and the success of the initial attack.

Figure 555-31-9. Spread of Smoke and Heat – Moderately Severe Class A Fire on Lower Level



extend to grouped cables, a deepseated fire that feeds on electrical insulation and generates toxic, dense black smoke can occur. New cables currently in use are in accordance with MIL-C-24643 and are designed to reduce the amount of smoke generated. A cable run fire will spread past penetrations through non-tight partitions, bulkheads, and decks. Cable fires will not spread past properly installed stuffing tubes in watertight bulkheads. A cable fire burning against a bulkhead can ignite combustibles on the other side by heat conduction.

**555-31.10.3 DIFFICULTIES ASSOCIATED WITH FIRES IN ELECTRICAL CABLE RUNS.** The tight grouping of cables limits the ability of firefighters to direct hose streams to the source of the fire. Because cable fires generate so much smoke, a significant delay can be expected in locating the seat of the fire.

### **555-31.11 THEORY OF EXTINGUISHMENT.**

**555-31.11.1 GENERAL.** A fire can be extinguished by removing the fuel, removing the oxygen or removing the heat (cooling). Another method is flame inhibition (breaking the combustion chain reaction).

**555-31.11.2 REMOVING THE FUEL.** One way to remove the fuel from the fire is to physically drag it away. 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.

**555-31.11.2.1** Sometimes the supply of liquid or gaseous fuel can be cut off from a fire. When a fire is being fed by a fuel 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 shutdown to remove the fuel source and extinguish the fire.

**555-31.11.2.2** Fire involving acetylene or hydrogen can often be extinguished by shutting the valve on the cylinder.

**555-31.11.3 REMOVING THE OXYGEN.** A fire can be extinguished by removing its oxygen or by reducing the oxygen level in the air to below 15 percent. Many extinguishing agents (for example, CO<sub>2</sub> and foam) extinguish fire with a smothering action that deprives the fire of oxygen.

**555-31.11.3.1** Extinguishment by oxygen removal is difficult, but not impossible, in an open area with gaseous smothering agents like CO<sub>2</sub>. CO<sub>2</sub> would be blown away topside. On the other hand, 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.

**555-31.11.3.2** Aqueous Film Forming Foam (AFFF) portable fire extinguishers are installed in all submarines. The SSN 21 class will also have a fixed AFFF fire extinguishing system. AFFF acts by establishing a film over flammable liquids to exclude oxygen and by preventing the formation of flammable vapors. AFFF also cools the liquid surface to reduce vapor formation.

**555-31.11.4 REMOVING HEAT.** Water, when applied in fog or straight stream, is the most effective means of removing heat from ordinary combustible materials such as wood, paper and cardboard. Cooling with water can ultimately stop the release of combustible vapors and gases associated with the burning of solid fuels.

**555-31.11.4.1** When fire is attacked with a hose line, one gallon per minute (gpm) of water could theoretically absorb heat at approximately 10,000 BTU per minute (180 kW) if fully vaporized. This water will vaporize to steam and expand approximately 1,700:1, greatly reducing the percentage of oxygen concentration in an enclosed space.

**555-31.11.5 BREAKING THE COMBUSTION CHAIN REACTION.** Flaming combustion occurs in a complex series of chemical chain reactions. Once the chain reaction sequence is broken, a fire can be extinguished rapidly. The extinguishing agents commonly used to attack the chain reaction and inhibit combustion are dry chemicals. These chemical agents directly attack the molecular structure of compounds formed during the chain reaction sequence. The breakdown of these compounds adversely affects the flame-producing capability of the fire. The attack is extremely rapid.

**555-31.11.5.1** It should be understood that these agents do not cool a smoldering fire or flammable 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. A cooling medium such as water or AFFF should be used to cool the smoldering embers or the sides of the container.

## **555-31.12 FIREFIGHTING AGENTS**

**555-31.12.1 PRIMARY AGENTS.** There are many materials that may be used as firefighting agents. The primary agents discussed in the following paragraphs are the most extensively used aboard submarines. The primary firefighting agents are:

- a. Water
- b. Aqueous Film Forming Foam (AFFF)
- c. Carbon Dioxide (CO<sub>2</sub>)
- d. Potassium Bicarbonate (PKP)
- e. Aqueous Potassium Carbonate (APC)

**555-31.12.2 WATER.** Water is a cooling agent and on board ship the sea provides an inexhaustible supply. If the surface temperature of a fire can be lowered below the fuel's ignition temperature, 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 which cools the surface temperature.

**555-31.12.3 STRAIGHT STREAM.** Water in the form of straight stream is used to reach into smoke-filled spaces or areas at a distance from the firefighter. When a straight stream is needed as an extinguishing agent, it should be directed into the seat of the fire. For maximum cooling, the water must come in direct contact with the burning material. A straight stream is best used to break up and penetrate materials.

**555-31.12.3.1 Water Volume.** Keeping in mind the constant problem of excess water disposal, high volume water discharge should be used as little as possible. The 1-1/2 inch vari-nozzle provides constant flow at all pattern settings.

### WARNING

To avoid shock hazards, do not use straight stream water pattern on an energized electric source. Maintain a minimum standoff distance of four feet when applying water fog to an energized electric source.

**555-31.12.3.2 Electrical Hazard.** Straight stream water is the greatest conductor of electricity as opposed to the spray pattern and straight stream should not be used on electrical fires. See paragraph 555-36.2 for additional discussion on the electrical hazard of a straight stream of water.

**555-31.12.3.3 Effect on Class B Fires.** A straight stream of water is ineffective for extinguishing class B fires and can cause a violent fire reaction if the water stream atomizes the fuel into the air causing a greatly increased surface area.

**555-31.12.3.4 Heat Transfer Characteristics.** Straight streams do not have good heat transfer characteristics and do not absorb nearly as much heat as fog patterns.

**555-31.12.4 WATER FOG.** Water in the form of fog is very effective for firefighting purposes. However, the fog must be applied directly to the area to be cooled if its benefits are to be realized.

### WARNING

Do not use a fog pattern to extinguish a charcoal bed fire. In a reaction with water fog, charcoal fires may produce "water gas", a mixture of hydrogen and carbon monoxide. A straight stream of water should be used to extinguish a charcoal bed fire.

Additionally, water fog can provide protection to firefighters from both convective and radiant heat.

**555-31.12.4.1 Electrical Hazard.** See paragraph 555-36.2 for guidance on the electrical hazards of water.

**555-31.12.4.2 Use on Class A Fires.** Water fog extinguishes by cooling. See Section 35 for class A firefighting tactics.

**555-31.12.4.3 Use on Flammable Liquids.** Because of the cooling qualities of the finely divided water particles, water fog can be used successfully on fires involving fuels with flashpoints above 140°F, such as diesel fuel and hydraulic fluid. Extinguishment occurs by cooling the flammable liquid below its flashpoint. Water fog should be used on flammable liquids only when AFFF is not available. Danger of reflash exists until all of the fuel is cooled down below its flashpoint. See paragraph 555-36.5 for flammable liquid firefighting tactics.

**555-31.12.5 AQUEOUS FILM FORMING FOAM.** AFFF is composed of synthetically produced materials similar to liquid detergents. These film forming agents are capable of forming water solution films on the surface of flammable liquids. For general shipboard use, the Navy typically uses a six percent AFFF solution (six parts AFFF concentrate mixed with 94 parts water) using Type 6 concentrate per military specification MIL-F-24385. The SSN 21 class uses a three percent AFFF solution using Type 3 concentrate. Non-military specification commercial AFFF should not be used.

**555-31.12.5.1 Description.** AFFF concentrate is a clear to slightly amber colored liquid. The AFFF solution of water and concentrate possesses a low viscosity and is capable of quickly spreading over a surface. AFFF concentrate is nontoxic and biodegradable in diluted form. AFFF concentrate may be stored indefinitely without degradation in characteristics. The concentrate will freeze if exposed to temperatures below 32°F. If the frozen concentrate is thawed out it can be reused, but storage in heated areas is recommended.

**555-31.12.5.2 Firefighting Advantages.** AFFF, when proportioned with water, provides three fire extinguishing advantages. First, an aqueous film is formed on the surface of the fuel which prevents the escape of the fuel vapors. Second, the layer of foam effectively excludes oxygen from the fuel surface. Third, the water content of the foam provides a cooling effect.

**555-31.12.5.3 Use of Aqueous Film Forming Foam.** The principle use of foam is to extinguish burning flammable or combustible liquid spill fires (class B). AFFF has excellent penetrating characteristics and is superior to water in extinguishing class A fires.

**555-31.12.5.4 Electrical Hazard.** The electrical hazard of AFFF is the same as that for water alone. See paragraph 555-36.2.

**555-31.12.5.5 Environmental Restrictions.** AFFF is designated as an environmental pollutant. Except when used during a fire, it shall be disposed of in accordance with OPNAVINST 5100.19, **Navy Occupational Safety and Health (NAVOSH) Program Manual for Forces Afloat, Appendix B3-C**. AFFF should not be discharged into any system which, when pierside, may feed into an ashore sewer treatment plant. AFFF may kill the bacteria that aids in sewer treatment and disrupt plant operation.

**555-31.12.6 CARBON DIOXIDE.** A method of extinguishing fires by smothering is the use of the inert gas carbon dioxide (CO<sub>2</sub>). CO<sub>2</sub> is about 1.5 times heavier than air. This makes CO<sub>2</sub> a suitable extinguishing agent because it tends to settle and blanket the fire.

**555-31.12.6.1 General Characteristics.** Carbon dioxide (CO<sub>2</sub>) is a dry, non-corrosive gas, which is inert when in contact with most substances and will not leave a residue and damage machinery or electrical equipment. In both the gaseous state and the finely divided solid (snow) state, it is a nonconductor of electricity regardless of voltage, and can be safely used in fighting fires that would present the hazard of electric shock.

**555-31.12.6.2 Method of Extinguishing.** Carbon dioxide extinguishes the fire by diluting and displacing its oxygen supply. If gaseous CO<sub>2</sub> is directed into a fire so that sufficient oxygen to support combustion is no longer

available, the flames will die out. Depending on the fuel, this action will take place when the 21 percent oxygen content normally present in air, is diluted with CO<sub>2</sub> to below 15 percent oxygen. Some ordinary combustible class A fires require that the oxygen content be reduced to less than 6 percent in order to extinguish glowing combustion (smoldering fire). CO<sub>2</sub> has limited cooling capabilities, and may not cool the fuel below its ignition temperature and is more likely than other extinguishing agents to allow reflash. Therefore, the firefighter must remember to stand by with additional backup extinguishers. The temperature of the burning substance and its surroundings must be lowered below its ignition temperature if the fire is to remain extinguished.

**555-31.12.6.3 Use on Materials Producing Oxygen.** Carbon dioxide is not an effective extinguishing agent for fires in materials that produce their own oxygen supply such as flares. Fires involving reactive metals, such as magnesium, sodium, potassium, lithium, or titanium cannot be extinguished with CO<sub>2</sub>. Because of the relatively high temperatures involved, these metal fuels decompose CO<sub>2</sub> and continue to burn.

**555-31.12.6.4 Health and Safety Hazards of Carbon Dioxide.** Carbon dioxide (CO<sub>2</sub>) is a colorless, odorless gas that is naturally present in the atmosphere at an average concentration of 0.03 percent. It is used for extinguishing fires since it reduces the concentration of oxygen in the air to the point where combustion stops. Typically, CO<sub>2</sub> concentrations of 30 to 70 percent are required to extinguish fires.

**555-31.12.6.4.1** Carbon dioxide for fire fighting is maintained as a liquid at high pressure. When discharged into the space, a large portion of the liquid CO<sub>2</sub> flashes to vapor, and the rest is converted to fine dry ice particles (snow) at a temperature of -109°F (-78°C). This dry ice gives the discharge a white or cloudy appearance. The low temperature condenses water in the entrained air creating fog that will persist after the dry ice is evaporated. CO<sub>2</sub> is 1.5 times heavier than air, and will collect at low points. Until forced ventilation is provided, the CO<sub>2</sub> will remain in the protected space and may migrate to adjacent spaces, especially adjacent spaces at lower elevations than the protected space.

**555-31.12.6.4.2** The primary hazard to personnel is death by asphyxiation. If carbon dioxide is breathed at extinguishing concentrations (over 30 percent), loss of consciousness will occur in less than 16-35 seconds. Cardiac arrest can occur within seconds of loss of consciousness depending on the individual. Serious and permanent injury to the brain can occur within 3-5 minutes after cardiac arrest unless cardiopulmonary resuscitation (CPR) is started.

**555-31.12.6.4.3** At low CO<sub>2</sub> concentrations (7-10 percent), an increased rate and depth of breathing will occur almost immediately. For example at three percent CO<sub>2</sub> concentration the volume of air breathed each minute is approximately doubled, at five percent it is tripled and at ten percent, it is ten times what it is at a resting condition. Even at these low concentrations loss of consciousness can occur. For example, at ten percent CO<sub>2</sub> concentration, loss of consciousness can occur in four minutes. At ten percent CO<sub>2</sub> headaches and vomiting in addition to the severe discomfort from hyperventilation will occur. Personnel who lose consciousness may be revived without permanent injury if they are immediately removed from the hazardous atmosphere and provided CPR, if necessary.

**555-31.12.7 DRY CHEMICAL EXTINGUISHING AGENT, POTASSIUM BICARBONATE.** Potassium bicarbonate (PKP) is a dry chemical principally used as a fire extinguishing agent for flammable liquid fires. It is the preferred agent for 3-dimensional, running fuel fires. It is used in portable extinguishers.

**555-31.12.7.1 Additives.** Various additives are mixed with the PKP base materials to improve their storage, flow, and water repellency characteristics. The most commonly used additives are silicones which coat the particles of PKP to make it free-flowing and resistant to the caking effects of moisture and vibration.

**555-31.12.7.2 Method of Extinguishing.** When PKP is applied to fire, the dry chemical extinguishes the flame by breaking the combustion chain. PKP does not have cooling capability.

**555-31.12.7.2.1** When PKP is applied, an opaque cloud is formed in the combustion areas. This cloud limits the amount of heat that can be radiated back to the heart of the fire. Less fuel vapors are produced due to the reduced radiant heat.

**555-31.12.7.2.2** When PKP is applied to the fire, it attacks the chain reaction required to sustain the fire. It is believed that PKP reduces the ability of the molecular fragments to recombine, therefore breaking the chain reaction.

**555-31.12.7.3 Use of Potassium Bicarbonate (PKP).** PKP is highly effective in extinguishing flammable liquid (class B) fires. Although PKP can be used on electrical (class C) fires, it will leave a residue that may be hard to clean. If AFFF is not available, PKP can also be used in the galley for such items as the hood, ducts and cooking ranges.

**555-31.12.7.3.1** The following is a list of limitations for PKP use.

- a. Like all other fire extinguishing agents, PKP is not effective on materials that contain their own oxygen.
- b. PKP should not be used in electrical controllers or cabinets where relays and delicate electrical contacts are present.
- c. PKP is not effective on combustible metals and may cause a violent reaction.
- d. Where moisture is present, PKP may combine with it to corrode or stain surfaces on which it settles; when possible it should be removed from the surfaces.
- e. PKP does not produce a lasting inert atmosphere above the surface of a flammable liquid; consequently, its use will not result in permanent extinguishment if ignition sources such as hot metal surfaces or persistent electrical arcing are present.
- f. PKP is not effective on fires involving ordinary combustibles (class A). However, it can be used to knock down a flaming fire, keeping it under control, until hose lines are advanced to the scene.

**555-31.12.7.3.2 Personnel Hazards.** The ingredients used in PKP are non-toxic. However, the discharge of large quantities may cause temporary breathing difficulty during and immediately after the discharge and may seriously interfere with visibility.

**555-31.12.8 AQUEOUS POTASSIUM CARBONATE.** Aqueous potassium carbonate (APC,  $K_2CO_3$ ) is used onboard submarines for extinguishing burning cooking oil and grease in deep fat fryers and galley ventilation exhaust ducts. Aqueous potassium carbonate (APC) solution consists of 42.2 percent potassium carbonate ( $K_2CO_3$ ) and 57.8 percent water. Application of APC, upon contact with the burning surface, generates a soaplike froth that excludes air from the surface of the grease or oil, and the fire is extinguished. See paragraph 555-32.4.



## SECTION 32. FIRE EXTINGUISHING AND RELATED SYSTEMS

### 555-32.1 FIRE AND SMOKE BOUNDARIES

**555-32.1.1** A fire boundary is a physical boundary to retard the passage of flame and smoke. The watertight transverse bulkheads are typically utilized as fire boundaries. Fire boundaries confine a fire within a space or compartment and provide staging areas for fire parties.

**555-32.1.2** A smoke boundary is a physical boundary which is set to prevent or reduce the spread of smoke. For example the bulkhead at the aft end of the forward compartment in the SSN 688 class is a smoke boundary. A smoke curtain is located at the side passageway door and should be rigged during a fire. It will reduce smoke spread between compartments when personnel or hoses pass through the door.

**555-32.1.3** Although watertight transverse bulkheads separating compartments serve as fire and smoke boundaries, fire and smoke boundaries generally cannot be set within compartments, such as the engine room and missile compartment, since complete bulkheads and decks do not exist.

**555-32.1.4** The boundary of certain spaces within a compartment such as auxiliary machinery room, radio and ECM room, and sonar control room, are generally of sufficient tightness to serve as a fire and smoke boundary. Doors and hatches serving such spaces should be kept closed during a fire to minimize fire and smoke spread.

**555-32.1.5** To retard the spread of smoke from a fire, smoke stops are installed in frame bays at deck edges in the forward compartment in the SSN 21 class. The smoke stop is a fume tight barrier of flexible sheet material installed between the deck edge and the hull. The flexible barrier material is installed on each of the 3 platform levels, along the length of the forward compartment. The smoke stops will help to control vertical fire spread from a fire in the lower levels.

### 555-32.2 VENTILATING SYSTEMS

**555-32.2.1 VENTILATING MODES.** The ventilation system, which includes vent ducts, fan coil units and fans, circulates a clean, conditioned atmosphere throughout the submarine. The recirculate mode is a closed loop operation which provides the conditioned atmosphere in the ship, while keeping the ship's atmosphere completely isolated from the outside. The recirculate mode is the normal submerged operating mode of the ventilation system. The emergency ventilate mode is the ventilation means used for evacuation of a specific compartment or compartments of atmospheric contaminants such as smoke, toxic gas, or other objectionable gases. In this open loop mode, a supply of fresh air is brought into the ship through the snorkel induction system while air from the contaminated space is exhausted overboard using either the diesel generator or LP blower. Surface ventilate is an open loop operating mode that is normally used when surfaced for an extended period in calm seas and when in port.

**555-32.2.2 FIRE EMERGENCY.** When a submarine is in a fire emergency immediate action must be taken to isolate the unaffected compartment(s) and secure the ventilation system in accordance with the Fire Bill. Smoke from a relatively small fire can completely fill the entire ship in a short time. Normally, a class B fire should be completely extinguished, a reflash watch stationed, and a search for hot spots with the NFTI completed before preparations for emergency ventilation of the affected compartment are commenced. For a class A or C fire, emergency ventilation may commence after the fire is reported out (as defined in the Glossary). See paragraph 555-35.10.2. However, the presence of heavy smoke and heat in the compartment may dictate venting the heat and smoke overboard to assist the fire party in combatting the fire. The ship's installed ventilation system should normally not be used in the burning compartment as the intense heat may cause secondary fires along the ventilation path in non-affected compartments.

**555-32.2.2.1** The decision to ventilate the burning compartment, using the ship's ventilation system, before the fire is out, will be made by the Commanding Officer. See paragraph 555-35.8 for key factors to consider in the decision to ventilate prior to fire extinguishment.



### 555-32.3 TRIM (FIREMAIN) SYSTEM

**555-32.3.1 AUXILIARY FUNCTION OF THE TRIM SYSTEM.** The trim system consists of pumps, piping, tanks and valves through which seawater is supplied to fire hose stations. It also supplies water for flooding the pyrotechnics, small arms ammunition, and chlorate candle stowage lockers.

**555-32.3.1.1** Details on the function, operation and maintenance of the trim system are found in the Ship Information Book (SIB) and Training Aid Booklet (TAB) for submarine classes preceding the SSN 688 class and in the Ship Systems Manuals (SSMs) for the SSN 688 and later submarine classes.

**555-32.3.2 FIREMAIN SYSTEM, SSN 21 CLASS.** One firemain is installed in the after compartment and another installed in the forward compartment. The firemain is supplied with sea water from the pressurized trim tanks and distributes sea water to services as required. The after firemain is installed between the aft trim tank and the trim discharge header near the after reactor compartment bulkhead. The forward firemain is installed between the forward trim tank and the trim discharge header near the forward reactor compartment bulkhead. Valves are installed in the trim discharge header to permit the forward trim tank to pressurize the aft firemain with the aft trim discharge header isolated, and vice versa. The size of the firemain is such that the system can simultaneously supply any two 1-1/2 inch hoses and the largest sprinkling system with a minimum pressure of 75 psi at the fire plug (valve). Fire hose stations are located such that all parts of the forward compartment and engine room can be reached from at least two stations with 50 feet of hose each. Additional hose lengths as necessary are stowed in the engine room on hose racks to allow two hose coverage to any part of the reactor compartment. Reactor compartment coverage is initiated by connecting any stowed hoses to existing 50-foot hoses and fireplugs located in the engine room. All fire hose stations are provided with AFFF capability.

### 555-32.4 OPERATION AND DESCRIPTION OF GALLEY FIRE PROTECTION SYSTEMS.

**555-32.4.1 GENERAL.** The aqueous potassium carbonate (APC) fire extinguishing system is installed in submarines to provide protection for galley deep fat and doughnut fryers and their exhaust systems. Aqueous potassium carbonate is specifically formulated to extinguish fire in the reservoirs by combining with the hot cooking oil surface to form a combustion resistant soap layer, thereby cutting off the grease from its source of oxygen. There is little or no cooling with APC. For more information on the APC fire extinguisher system, see technical manual NAVSEA S9555-AR-MMO-010, **Fire Extinguishing System, Deep Fat and Donut Fryer.**

**555-32.4.2 DESCRIPTION.** Each APC system includes one or two cylinders filled with a solution of potassium carbonate in water pressurized with compressed nitrogen (N<sub>2</sub>). Discharge piping from the cylinder leads to one or more nozzles which spray the solution into the cooking oil reservoirs, into the galley hood exhaust plenum and up into the galley hood exhaust duct. A spring tensioned cable keeps the system inactive. Releasing the tension in any of several ways, releases N<sub>2</sub> from a pressurized cartridge which opens the lever control head to discharge the aqueous potassium carbonate.

**555-32.4.3 SYSTEM TYPES.** One of two basic APC fire extinguishing systems is installed on submarines. The systems are designated as B and modified B. The B system, installed in the SSN 688, SSBN 726 and SSN 21 classes, uses a single 6 gallon cylinder assembly loaded with 4 gallons of extinguishing agent to supply appliance, plenum hood, and duct nozzles. The modified B system, in the SSN 637 class, uses a 6 gallon storage cylinder containing 4 quarts of extinguishing agent.

**555-32.4.4 SYSTEM COMPONENTS.** The basic system consists of a cylinder assembly, discharge piping and nozzles, detector assemblies, a cable release system, a pressure release control box and N<sub>2</sub> cartridge, and on the SSN 21 and SSBN 726 classes a remote manual control capability. See Figure 555-32-1.

**555-32.4.4.1 Cylinder Assembly.** The cylinder assembly is composed of a cylinder, cylinder valve, lever control head, and pressure switch.

**555-32.4.4.2 Cylinder.** The cylinder is used to store the system fire extinguishing agent, which is a solution of potassium carbonate and water. The cylinder is charged to 175 psi with nitrogen gas, installed in an upright position, and located near the deep fat fryer so that it is accessible to the operator. The modified B system is charged to 100 psi. The diameter of Types B and modified B cylinders provided by the vendor had a diameter



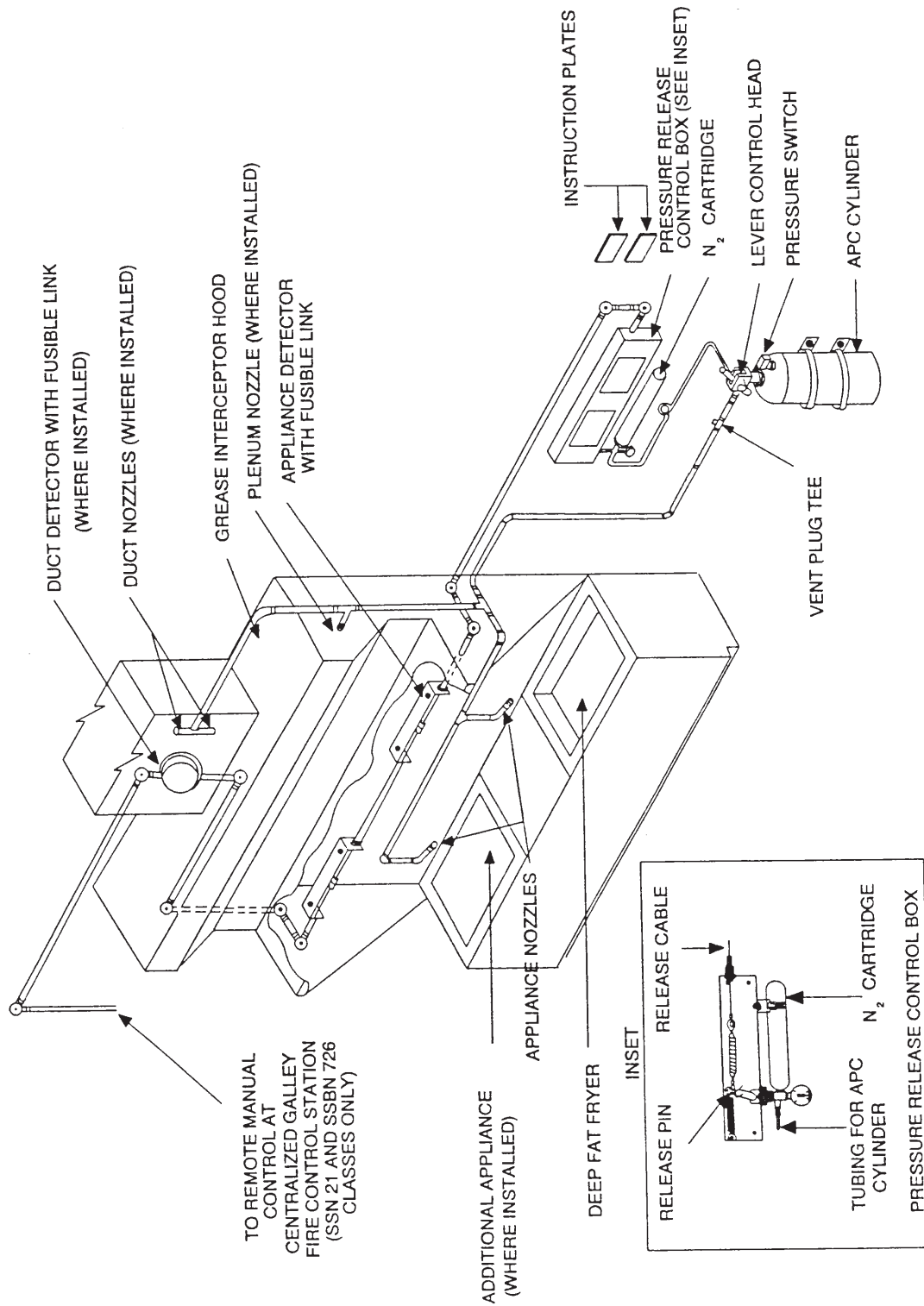


Figure 555-32-1. Typical Galley Fire Protection System

before 1989 of 8-1/4 inches. The diameter increased to 8-5/8 inches around 1989 and then to 8-7/8 inches around 1995. Ships may not be able to place a new cylinder in an existing bracket. The 8-1/4 inch and 8-5/8 inch diameter cylinders are not available from stock.

**555-32.4.4.3 Cylinder Valve.** The cylinder valve connects the cylinder assembly to the discharge system. The valve, when opened, allows the cylinder to discharge its extinguishing agent. A pressure gage, which is mounted to the cylinder valve and positioned so that the dial may be easily read, is used to monitor cylinder pressure.

**555-32.4.4.4 Lever Control Head.** The automatic or manual discharge of the cylinder assembly is controlled by the lever control head. One-fourth inch copper tubing from the N<sub>2</sub> cartridge in the pressure release control box is connected to the lever control head used for automatic operation. The lever control head's lever handle can also be used to manually discharge the cylinder assembly once the release pin is removed.

**555-32.4.4.5 Pressure Switch.** Each cylinder assembly is fitted with an appliance pressure switch to interrupt power to the deep fat fryer when the cylinder is discharged or the pressure charge leaks off.

**555-32.4.5 DISCHARGE SYSTEM.** The discharge system is designed to deliver the fire extinguishing agent to the nozzles. The basic design includes 5/8 or 3/8 inch OD CRES tubing and a vent plug. The vent plug is installed in a tee positioned in the discharge line and gets rid of any static pressure buildup.

**555-32.4.5.1 Nozzles.** The nozzles are used to distribute the extinguishing agent onto the fire. There are three nozzle types.

**555-32.4.5.1.1** The appliance nozzle discharges onto the protected appliance.

**555-32.4.5.1.2** The plenum exhaust hood nozzle is centrally located in the plenum with its discharge port directed along the axis of the plenum. Each nozzle can protect up to 10 feet along the length of the plenum.

**555-32.4.5.1.3** The duct nozzle is located inside of the exhaust duct with its discharge port directed along the axis of the duct.

**555-32.4.5.1.4** Each nozzle is fitted with a strainer to remove particles that could clog a discharge port. Each nozzle discharge port is also protected by a foil sealing disk to prevent clogging of the port by grease or particles from the fryers.

**555-32.4.5.2 Detector Assemblies.** The detector assemblies control the automatic operation of the system. Fusible links, designed to melt at 360°F, join sections of the release cable. When a link melts, it releases the tension of the cable and allows the pressure release control box to activate the system. The appliance detectors, if two or more are required, are arranged in a straight line. One appliance detector is provided for each fryer and is mounted to the hood directly over the protected fryer. Exhaust hood and duct detectors, if fitted, are located in the exhaust hood and duct, respectively. The duct detector is arranged in scissors fashion in order to locate the fusible link out into the exhaust system.

**555-32.4.5.3 Cable Release System.** For pre-SSBN 726 class submarines, this system consists of release cable sections, conduit, corner pulleys, and mounting hardware. The release cable sections are lengths of 1/16-inch cable threaded through sections of conduits. Any change in cable direction is accomplished through the use of corner pulleys. The SSBN 726 class submarines use a special type release cable which allows the cables to be routed without the use of conduit and pulleys.

**555-32.4.5.4 Pressure Release Control Box.** The pressure release control box activates the cylinder assembly during automatic operation. The system can also be discharged manually from the pressure release control box. It includes the pressure release cartridge and the control box.

**555-32.4.5.4.1** The pressure release cartridge consists of a cartridge, operating release lever, valve, and pressure gage. The cartridge is charged to 300 psi with nitrogen. The operating release lever is connected to the release cable turnbuckle and the extension spring. The lever operates the piston valve which is screwed into the cartridge and which controls the flow of nitrogen to the cylinder assembly through 1/4-inch copper tubing. A pressure gage attached to the cartridge provides a means to inspect the pressure.

**555-32.4.5.4.2** The control box is the mounting platform for the pressure release cartridge and consists of a box with a hinged front panel containing an extension spring, release pin, and turnbuckle. The extension spring is attached to the operating release lever and is anchored to the wall of the box. One end of the turnbuckle is pinned to the operating release lever by a release pin which is secured with a wire and lead seal. The other end of the turnbuckle is connected to the release cable by a large screw eye.

**555-32.4.5.5 Remote Manual Control Box.** Where provided, the remote manual control box houses the anchor for the cable release system. The release cable end is anchored to a U bracket by a release pin. A wire and lead seal secures the release pin.

**555-32.4.6 SYSTEM OPERATION.** Operation of the fire extinguishing system, is normally fully automatic. Manual backup modes of operation are provided at the cylinder valve assembly, pressure release control box, and where provided, at the remote manual control box. The system can also be operated remotely at the centralized galley fire control station on the SSBN 726 and SSN 21 classes.

**555-32.4.6.1 Automatic Operation.** Excessive heat (360°F) on one of the fusible links melts the link and releases the cable tension. The extension spring in the pressure control box pulls the lever which activates the pressure release cartridge. Nitrogen (N<sub>2</sub>) gas from the pressure release cartridge activates the lever control head, causing the cylinder to discharge.

**555-32.4.6.2 Manual Operation.** For pre-SSBN 726 class submarines, the system has two manual modes of operation. The SSBN 726 class has three manual modes of operation.

**555-32.4.6.2.1** At the cylinder valve assembly, remove the release pin in the lever control head completely, and operate the lever. This discharges the cylinder directly.

**555-32.4.6.2.2** At the pressure release control box, open the box and remove the release pin completely. This disconnects the release cable and allows the extension spring to activate the system as described under automatic operation.

**555-32.4.6.2.3** At the remote manual control box, where provided, remove the release pin completely. This disconnects the anchored end of the release cable, releases the tension, and allows the extension spring to activate the system as described under automatic operation.

**555-32.4.6.2.4** On the SSBN 726 and SSN 21 class the system can be activated remotely at the centralized galley fire control station by depressing the remote actuator detent button and pushing out the actuator.

## **555-32.5 MISSILE GAS SYSTEM, SSBN CLASSES**

**555-32.5.1 GENERAL.** Nitrogen is used as the tube pressurizing agent in missile launches because it will not support combustion of the launch gases and can act as an extinguishing or inerting agent to smother or prevent a fire in the missile tube. See **Strategic Weapon System Support Systems Manual**, S955B-X9-WSI-01A/SWSSSM(C4) and **Launcher Subsystem**, OP4476, for further details.

## **555-32.6 OPERATION AND DESCRIPTION OF AQUEOUS FILM FORMING FOAM SYSTEMS, SSN 21 CLASS**

**555-32.6.1 PURPOSE.** AFFF systems are installed in the SSN 21 class submarines to supply sprinklers to protect the diesel generator space, the lube oil bay bilge, the areas outboard of the fan room, and the area around hydraulic plants in the engine room, and to provide AFFF capability to all 1-1/2-inch seawater fireplugs.

**555-32.6.2 METHOD OF SUPPLY.** AFFF is generated by the following method. Two AFFF distribution systems are installed, one supplying the forward compartment fireplugs and sprinklers, and one supplying the engine room fireplugs and sprinklers. Each distribution system includes an AFFF concentrate tank, AFFF

concentrate supply piping, proportioning equipment, AFFF/seawater solution piping which supplies AFFF sprinklers, check valves, isolation valves, and controls. The concentrate tank is constantly pressurized from the service air system, at sufficient pressure to inject AFFF into seawater supplied from the firemain. The Type 3 AFFF concentrate is injected through constant flow control valves into the firemain branch lines supplying fireplugs and sprinklers to create a 3 percent AFFF/water solution.

**555-32.6.3 FOAM SERVICE OUTLETS.** AFFF capability is provided to all seawater fireplugs. AFFF concentrate is injected into the firemain branch line of each fireplug through a constant flow control valve. Each AFFF concentrate supply line has an isolation valve, a check valve, fireplug AFFF cutout valve, and constant flow control valve upstream of the AFFF injection point. Each firemain branch line has a check valve and a fireplug cutout valve upstream of the AFFF injection point to eliminate AFFF backflow into the firemain. Each AFFF-equipped fireplug is capable of supplying seawater or AFFF/seawater solution regardless of whether other AFFF stations have been activated. Each AFFF distribution system is sized to support simultaneous operation of the largest sprinkling load in the distribution system's respective compartment and two 1-1/2 inch fire hoses for 10 minutes. The AFFF/seawater produced through the constant flow control valves has an AFFF concentration level of at least 3 percent and no greater than 4 percent.

**555-32.6.3.1 Service Outlet Operation.** To operate the fireplug hose with seawater only requires manual operation of the fireplug cutout valve and hose nozzle. To operate the fireplug hose with AFFF/seawater requires manual operation of the fireplug AFFF cutout valve, fireplug cutout valve, and the hose nozzle.

#### **555-32.6.4 FOAM SPRINKLER SYSTEMS.**

**555-32.6.4.1 Location, Design, and Supply of Sprinkler Systems.** Sprinkling systems are installed in the following areas:

- a. Diesel generator space. Sprinklers are installed under the deck plates to protect the bilge region. Additionally, a minimum of two directional, fan spray pattern sprinklers are installed on each side of the diesel engine, angled so that AFFF covers the vertical surfaces of the engine but does not overspray onto the generator end of the diesel and adjacent equipment. The sprinklers protecting the diesel are supplied from the same sprinkler control valves protecting the bilge region. A manual shutoff valve is located outside the generator compartment to secure the directional sprinklers and allow operation of the bilge sprinklers only.
- b. Lube oil bay bilge. Sprinklers are installed under the deck plates to protect the bilge region.
- c. Area around the hydraulic plants. Sprinklers are installed around each hydraulic plant in the engine room to protect the tank top and any surrounding bilge region.
- d. Areas outboard the fan room. Due to access limitations, sprinklers are installed outboard the fan room and directed towards the frame bays to protect the area from fires coming from the machinery space below.

AFFF concentrate is injected into the firemain branch line of each sprinkling system through an isolation valve, a remotely operated control valve, and a constant flow control valve upstream of the AFFF injection point. Each firemain branch line supplying the sprinkler system has an isolation valve and a remotely operated control valve upstream of the AFFF injection point.

**555-32.6.4.2 Sprinkler System Operation.** The sprinkler control systems are manual seawater hydraulic with (non-automatic) manual control only. Each AFFF sprinkler control system operates the sea water control valve and the AFFF concentrate control valve for the AFFF sprinkler system. A local manual control valve is located outside and in close proximity to the protected area for systems in the engine room. A remote manual control valve is located at the AFFF system control panels. The fan room sprinklers are supplied from a 1-1/2 fireplug hose when connected by Ship Force. The hose connections are located inside the fan room.

**555-32.6.4.2.1** Each AFFF system control panel, located at the damage control station, consists of the following:

- a. Remote manual control valves for operating the respective sprinkler systems.
- b. Audible signals to indicate operation of the respective sprinkler system remotely operated control valves and the low level alarm.
- c. Visual signals to show “open” or “shut” position of the respective sprinkler system remotely operated control valves and the tank low level alarm.

**555-32.7 OPERATION AND DESCRIPTION OF THE FLOODING SYSTEM FOR PYROTECHNIC AND SMALL ARMS AMMUNITION LOCKERS**

**555-32.7.1** If a fire threatens the pyrotechnic and small arms ammunition lockers, both can be flooded by means of a single locked box flood valve which supplies water from the trim system on submarines other than the SSN 21 class. The valve and its operating wrench are located inside a break-glass box located within the compartment containing the lockers, remote from the lockers, and in such a position that the valve operator can see the lockers. On the SSN 21 class the seawater supply to the pyrotechnic and small arms ammunition lockers is via a normally shut firemain seawater valve.

**555-32.8 OPERATION AND DESCRIPTION OF THE SPRINKLING SYSTEM FOR OXYGEN CHLORATE CANDLE LOCKERS**

**555-32.8.1** An overhead sprinkling system is provided inside the oxygen chlorate candle stowage lockers on the SSBN 726 and SSN 21 class submarines. The lockers are sprinkled to cool the candles to prevent their ignition in event of a fire in or near the locker. The chlorate candle lockers are supplied water from the trim system through locked box flood valves similar to the system for flooding the pyrotechnic and small arms ammunition lockers on the SSBN 726 class. On the SSN 21 class, the seawater supply is controlled by a normally shut firemain seawater valve.

**555-32.8.2** For submarines without locker sprinkling, application of water fog will extinguish a candle fire. Water fog may be used to cool a locker when exposed to a nearby fire.



## SECTION 33. MANUAL FIREFIGHTING EQUIPMENT

### 555-33.1 DRY CHEMICAL POTASSIUM BICARBONATE EXTINGUISHERS

**555-33.1.1 GENERAL.** Potassium bicarbonate dry chemical (PKP) is provided in portable 18 pound fire extinguishers in accordance with MIL-E-24091. See Figure 555-33-1. The 27 pound extinguisher is not used on submarines.

**555-33.1.2 DESCRIPTION.** The extinguishers are cartridge-operated type with the expellant gas [carbon dioxide (CO<sub>2</sub>)] contained in a small gas pressure cartridge. All 18 pound extinguishers have the CO<sub>2</sub> gas pressure cartridge mounted on the outside of the extinguisher shell.

**555-33.1.3 OPERATION.** The extinguisher shell, containing the charge of dry chemical is not pressurized until the extinguisher is to be used. Before approaching a fire, pull out the pull pin. Actuate the extinguisher with a sharp downward push on the puncture lever which is marked PUSH. This action causes the CO<sub>2</sub> stored in the small cartridge to fill the extinguisher. The squeeze grip on the nozzle may then be operated to discharge dry chemical from the extinguisher.

**555-33.1.4 USE ON CLASS B FIRES.** The dry chemical extinguisher is intended for use primarily on class B fires (flammable liquids). The 18 pound portable PKP extinguisher has an effective range of 19 feet in still air and a minimum discharge time of 10 seconds. The chemical discharge should be aimed at the base of the flames and applied in a rapid side to side sweeping motion chasing the flames across the surface of the liquid. In confined spaces, it is important that the dry chemical be discharged in short bursts as necessary. Unnecessarily long discharges will reduce visibility, render breathing difficult and waste the agent.

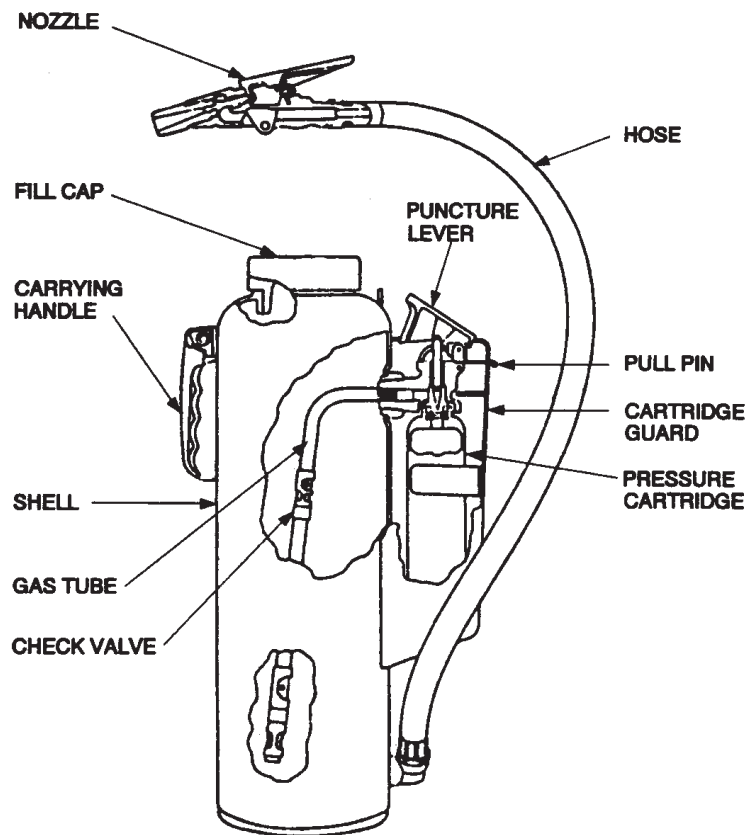


Figure 555-33-1. Typical Portable Dry Chemical Fire Extinguisher



**555-33.1.5 USE ON CLASS A AND CLASS C FIRES.** Dry chemical should not be used on class C fires (energized electrical equipment) in place of CO<sub>2</sub> unless necessary, so as to avoid fouling of electrical and electronic components. Dry chemical may be used as a first aid fire control measure to effect flame knockdown on a class A fire. However, seawater or AFFF will be required to complete extinguishment.

**555-33.1.6 GAS PRESSURE CARTRIDGE.** The CO<sub>2</sub> gas pressure cartridge supplies the propellant force to discharge dry chemical onto the fire. CO<sub>2</sub> is released through the gas tube when the puncture lever is depressed. The disk which is punctured by this operation is also a safety seal disk which will rupture at 4,050 to 4,500 psi internal pressure. This disk is held in position by a retaining nut which is hollow to accommodate the puncture pin. Consequently, discharge of CO<sub>2</sub> due to disk rupture or puncture of unattached cartridges will be directional and, unless precautionary measures are taken, will cause the cartridge to become a missile. For this reason an anti-recoil cap is installed for shipment and storage. This cap must remain in place until the cartridge is installed on the extinguisher.

**WARNING**

Do not exchange the safety disk of a CO<sub>2</sub> extinguisher and the CO<sub>2</sub> gas pressure cartridge used with the PKP extinguisher. The safety disk furnished for CO<sub>2</sub> extinguisher cylinder valves is smaller in diameter than the dry chemical extinguisher cartridge disk and will easily go into the disk recess. The CO<sub>2</sub> extinguisher disk, however, is thinner and the hole in the dry chemical extinguisher gas pressure cartridge retaining nut is larger. Consequently, the rupture pressure will be less than 2,650 psi. Use of CO<sub>2</sub> extinguisher disks as replacement for dry chemical CO<sub>2</sub> cartridge disks will result in an unsafe cartridge. The alteration of disks intended for use with dry chemical CO<sub>2</sub> gas pressure cartridges to fit CO<sub>2</sub> extinguisher valves will result in unsafe CO<sub>2</sub> extinguisher cylinders.

Used cartridges should normally be returned for recharge and replacement of safety disks. If cartridges are recharged in the field, the safety disk and retaining nut must be obtained from the extinguisher manufacturer.

## **555-33.2 CARBON DIOXIDE EXTINGUISHERS**

**555-33.2.1 GENERAL.** Portable CO<sub>2</sub> fire extinguishers and mounting brackets are installed in accordance with MIL-E-24269. See Figure 555-33-2. One extinguisher is normally located within 30 feet of equipment with a high potential for electrical fire.

**555-33.2.2 DESCRIPTION.** The standard Navy CO<sub>2</sub> fire extinguisher has a rated capacity (by weight) of 15 pounds of CO<sub>2</sub>. The CO<sub>2</sub> extinguisher is operated by removing the locking pin and squeezing the squeeze grip release valve. The squeeze grip release valve makes a tight seal when pressure on the grip is released; therefore, any unexpended CO<sub>2</sub> is held indefinitely without danger of leakage.

**555-33.2.3 OPERATION.** To operate the 15-pound CO<sub>2</sub> fire extinguisher, proceed as follows.

1. Carry the extinguisher in an upright position and get as close to the fire as possible.
2. Place the extinguisher on the deck, remove the tamper seal from the locking pin, and then remove the locking pin from the valve.
3. Grasp the horn handle. Rapidly expanding CO<sub>2</sub> being expelled from the extinguisher causes the extinguisher to become quite cold. The horn handle is insulated to protect the user.
4. Squeeze the operating lever to open the valve and release CO<sub>2</sub>. Direct the flow of CO<sub>2</sub> toward the base of the fire. The maximum effective range of a 15-pound CO<sub>2</sub> extinguisher is 4 to 6 feet from the outer end of the horn. In continuous operation, a 15-pound CO<sub>2</sub> extinguisher will be expended in approximately 40 seconds.
5. When conditions permit, close the valve. Continue to open and close the valve as the situation requires. When continuous operation is necessary, or when the valve is to remain open for recharging, slip the D-yoke ring, which is on the carrying handle, over the operating handle. The operating handle should be in the depressed position when the D-yoke ring is put on it. The D-yoke permits continuous operation of the extinguisher as long as any CO<sub>2</sub> remains.

- A. HOSE
- B. PIPE
- C. SWIVEL
- D. HORN
- E. PULL PIN
- F. TEST DATE
- G. LABEL BAND
- H. CYLINDER VALVE

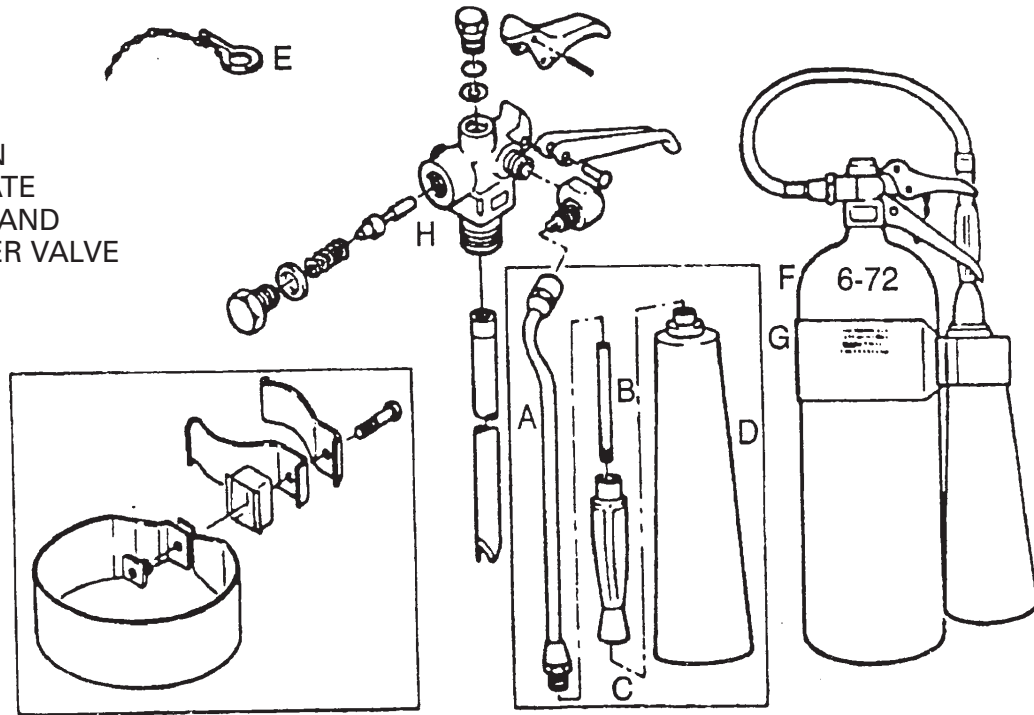


Figure 555-33-2. 15-Pound Carbon Dioxide Extinguisher

**WARNING**

To avoid shock from static electricity, ground the cylinder to the deck when discharging CO<sub>2</sub>.

**555-33.2.4 USE ON CLASS B AND C FIRES.** Carbon dioxide (CO<sub>2</sub>) portable fire extinguishers are used primarily for small electrical fires (class C) and have limited effectiveness on class B fires. Their use shall be confined to class B fires no greater than four square feet. Successful operations require close approach due to the extinguisher's characteristic short range (4 to 6 feet). See paragraph 555-36.2.2 for class C fire guidance.

**555-33.2.5 STATIC ELECTRICITY EXPLOSIVE HAZARDS.** High velocity CO<sub>2</sub> streams are prolific generators of static electricity because of solid particles (CO<sub>2</sub> snow) in the stream. A jet or stream that contains solid or liquid particles and issues from a nozzle, pipe, or hose at high velocity will probably accumulate static charge after leaving the transfer line. If the discharge occurs in the presence of a flammable vapor-air mixture there will be danger of fire or explosion. The introduction of high velocity streams into tanks containing flammable vapor-air mixtures produces a serious danger of fire or explosion if such mixtures are within their various flammable limits. Grounding of the tank and or discharge nozzle will not preclude the danger of fire or explosion.

**WARNING**

Use of CO<sub>2</sub> fire extinguishers for the purpose of inerting tanks or spaces that have contained hydrocarbon products is prohibited.

Inerting operations shall be in compliance with NAVSEA S6470-AA-SAF-010, **U.S. Navy Gas Free Engineering Program.**

**WARNING**

In a battery compartment, use CO<sub>2</sub> for class A and C fires only. Do not inject CO<sub>2</sub> into a non-burning battery compartment if the hydrogen concentration is above the alarm set point. The static electric discharge created during CO<sub>2</sub> discharge could ignite a hydrogen concentration within the explosive range.

**555-33.2.6 SUBMARINE BATTERY COMPARTMENT EXTINGUISHERS.** Submarines generally have two CO<sub>2</sub> extinguishers which have been coated with plastisol installed near the battery compartment for use by a fire watch. See **NSTM Chapter 223, Volume 1, Submarine Storage Batteries - Lead Acid Batteries**, for criteria on plastisol installation. See paragraph 555-36.11 for battery compartment firefighting guidance.

**555-33.2.7 RECHARGING CARBON DIOXIDE CYLINDERS.** Once a 15-pound cylinder has been used, it should be recharged before it is returned to stowage. The 15-pound cylinders are recharged from 50-pound commercial CO<sub>2</sub> cylinders that are carried aboard most naval surface ships for this purpose. The 50-pound CO<sub>2</sub> cylinders are not carried on submarines. The submarine should coordinate recharging or replacement of discharged CO<sub>2</sub> extinguishers in accordance with local tender, intermediate maintenance activity, or shore base directives.

**555-33.2.8 HYDROSTATIC TESTING OF CARBON DIOXIDE CYLINDERS.** Carbon dioxide fire extinguishers shall periodically undergo hydrostatic testing. Such testing must be done at a shore facility certified by the Department of Transportation. Forces afloat are not authorized to hydrostatic test portable fire extinguishers.

### **555-33.3 AQUEOUS FILM FORMING FOAM FIRE EXTINGUISHERS**

**555-33.3.1 GENERAL.** Aqueous film forming foam (AFFF) fire extinguishers are provided in accordance with MIL-E-24652 to vapor secure a small fuel spill to prevent a fire, to extinguish a small class B fire (including a deep fat fryer fire), to extinguish a small class A fire, and for use in standing fire watch during hotwork. AFFF extinguishers are typically located throughout the submarine.

**555-33.3.2 DESCRIPTION.** The portable AFFF fire extinguisher is a stainless steel cylinder that stores 2-1/2 gallons of a premixed solution of AFFF concentrate and fresh water. See Figure 555-33-3. It is pressurized with air to 100 psi at 70°F and weighs approximately 28 pounds when fully charged. AFFF is discharged from the bottom of the cylinder, through the siphon tube, extinguisher valve, and discharge hose to the nozzle. The solution undergoes an expansion of about 6.5 to 1 when passing through the nozzle, which produces around 16 gallons of expanded AFFF/water solution (foam) after discharge. The AFFF fire extinguisher has a 55 to 65 second continuous discharge time, and an initial range of 15 feet which decreases during discharge.

**555-33.3.3 OPERATION.** For use against a deep fat fryer fire, see paragraph 555-36.3. To vapor secure a small fuel spill and for use against a small class A or class B fire, the following guidance applies:

a. The AFFF fire extinguisher is intended for use on class A fires and class B pool fires. It is not recommended for use on class C fires. However, on a class C fire, AFFF extinguishers can be used if the nozzle is kept at least four feet from the energized electrical source.

b. Before approaching the fire, ensure that the pressure indicated on the pressure gage is within the indicated range and pull the pull pin on the extinguisher valve. Hold the extinguisher by the carrying handle with one hand and hold the discharge hose just above the nozzle with the other hand. To operate, squeeze the operating lever to the carrying handle. The extinguisher is capable of continuous operation or multiple bursts.

c. AFFF extinguishes class A fires by cooling. It is superior to water because AFFF has added wetting and penetrating ability. For small class A fires, apply the AFFF to the base (source) of the fire.

d. AFFF extinguishes a class B fire or protects an unignited fuel spill by floating on the flammable liquid and forming a vapor seal. One AFFF extinguisher will effectively extinguish 20 square feet (4-1/2 feet by 4-1/2 feet) of flammable liquid fire. To apply, start 15 feet away and sweep the AFFF from side to side at the base of the fire. One AFFF extinguisher can be used to vapor secure a fuel spill to prevent a fire up to 40 square feet (approximately 6 feet by 6 feet) in size. The fuel spill should be confined, within direct stream reach of the AFFF extinguisher and entirely visible. A fuel spill which is spread over an area larger than 40 square feet, is not accessible or entirely visible, warrants use of a 1-1/2 inch AFFF hose or AFFF bilge sprinkling system (For the SSN 21 class). See paragraph 555-36.5.2 for further discussion on using the fire extinguisher.

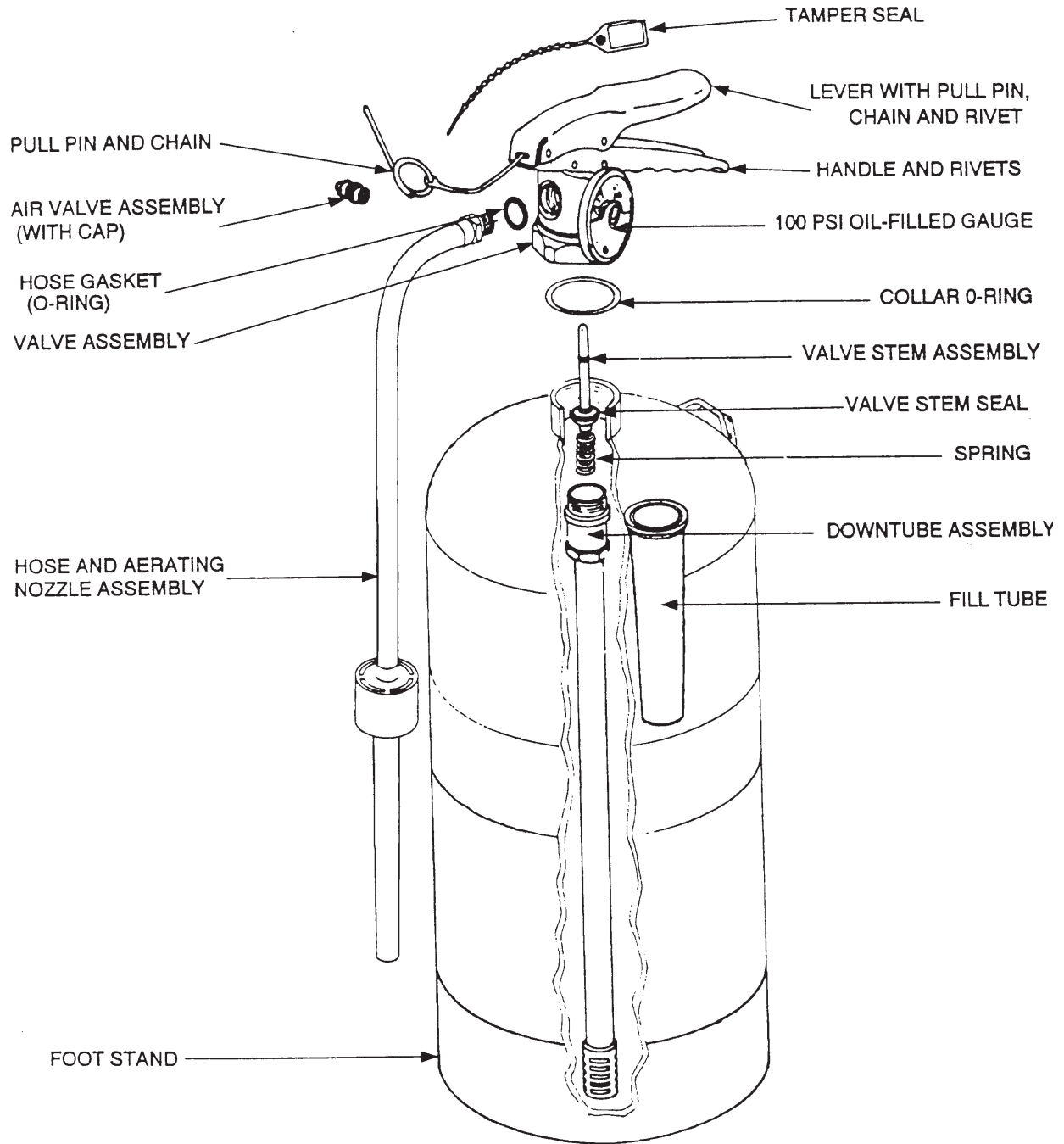


Figure 555-33-3. Typical Portable Aqueous Film Forming Foam Fire Extinguisher

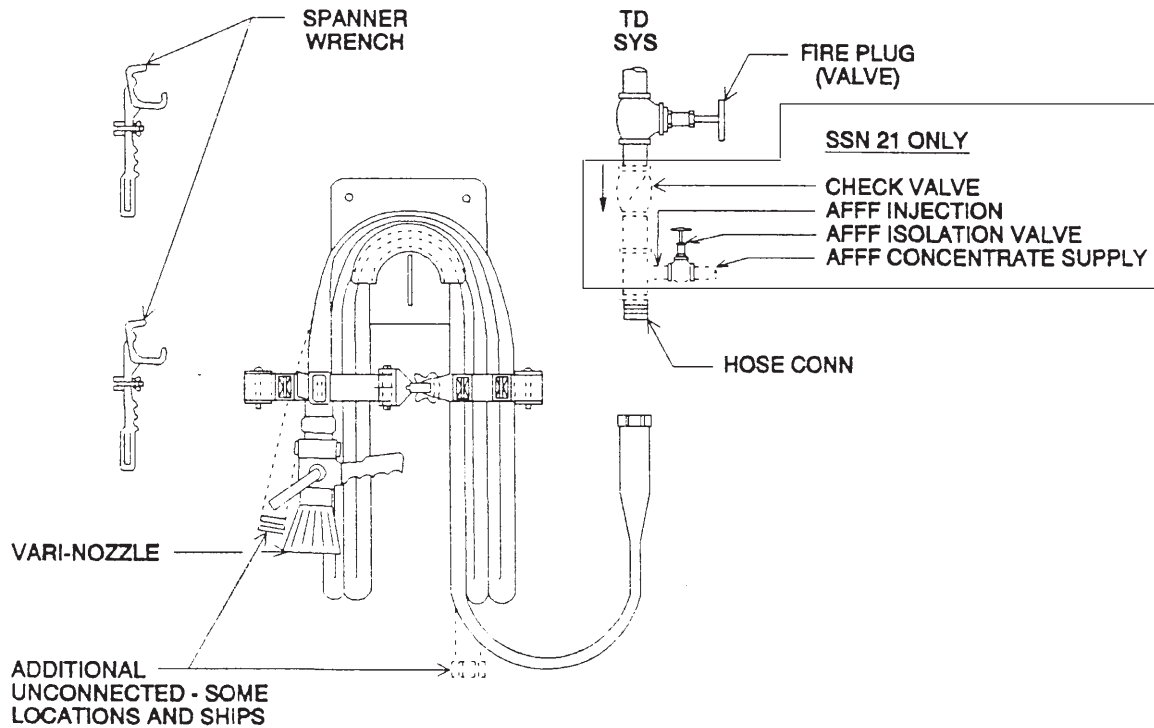


Figure 555-33-4. Typical Fire Hose Station

#### 555-33.4 FIRE HOSE STATIONS AND FIREPLUGS

**555-33.4.1 GENERAL.** A fire hose station is the location of a fireplug and associated equipment. A fireplug is the valve at a fire hose station. A fire hose station is commonly referred to as either a fire station or fireplug. The trim system (firemain for SSN 21 class) supplies water to fire hose stations throughout the submarine. See Figure 555-33-4. Fire hose stations have size 1-1/2 inch fireplugs. See Table 555-33-1, for typical fire hose station equipment.

**555-33.4.2 FIRE HOSE STATION COVERAGE.** Fire hose stations on pre-SSN 21 class submarines are installed in quantity and location such that all parts of the submarine, exclusive of the reactor compartment, can be reached from a fireplug with 50 feet of hose.

**555-33.4.2.1** On SSN 21, fire plugs are located such that all parts of the forward compartment and engine room can be reached from at least two fireplugs with 50 feet of hose each. Additional hose lengths as necessary are installed in the engine room to allow two fireplug coverage to any part of the reactor compartment.

#### 555-33.5 FIRE HOSE

**555-33.5.1 STANDARD NAVY HOSE.** The standard Navy fire hose is a double jacketed synthetic fiber with a rubber or similar elastomeric lining. The outer jacket is impregnated to increase wear resistance. The impregnating material contains an orange colored pigmentation for easy identification. The hose is manufactured to meet the requirements of Military Specification MIL-H-24606 and is available in sizes 1-1/2 through 4 inches diameter in 25 and 50 foot lengths. Navy fire hose has a maximum operating pressure of 270 psi with optimum hose handling characteristics occurring between 90 and 150 psi. Pressures above 150 psi are hazardous because excessive nozzle reaction force may result in loss of nozzle control.

**Table 555-33-1. TYPICAL EQUIPMENT FOR FIRE HOSE STATIONS**

Item	Quantity	NAVSEA Drawing No. or Spec No.
1-1/2-inch Hose	2 (note 1)	MIL-H-24606
1-1/2-inch Nozzle type I, 95 gal/min	1	MIL-N-24408
Hose Rack (note 2)	1	805-860089
Wrench, spanner	2	810-4444647
Notes:		
<p>1. SSN 688 class has two 25-foot hose lengths, except that valves TD-36 and TD-40 have three 25-foot hose lengths. SSBN 726 class has two 50-foot hose lengths. SSN 21 has one 50-foot hose length, with the two fire hose stations closest to the Reactor Compartment door having one additional 50 foot hose stowed but unconnected.</p> <p>2. Not installed on all submarines.</p>		

**555-33.5.1.1** Submarines use 1-1/2 inch diameter fire hose for firefighting. The 2-1/2 inch diameter fire hose is used for dewatering and pierside support.

**555-33.5.2 NON-COLLAPSIBLE RUBBER HOSE.** For the freshwater hose reel system on the SSN 21 class, two types of rubber covered, noncollapsible hoses are used. The 3/4-inch diameter noncollapsible hose is manufactured according to MIL-H-24580 and is available in 50-foot lengths. Two hose reels have a 100-foot long, 1-inch diameter noncollapsible hose per A-A-2160A, Class II, Size B.

**555-33.5.3 HOSE FITTING THREADS.** Hose fitting threads are according to FED-STD-H28/10 as shown in Table 555-33-2.

**Table 555-33-2. HOSE FITTING THREADS**

Size	Threads Per Inch	Designation
3/4	11-1/2	NH (Garden Hose)
1	11-1/2	NH
1-1/2	11-1/2	NPSH
2-1/2	7-1/2	NH

**555-33.5.4 HOSE STOCK NUMBERS.** National Stock Numbers for the various fire hoses are listed as follows:

- a. MIL-H-24606 (Synthetic Jacket Soft Hose)
  - 1. 1-1/2 inch by 50 feet, 4210-01-131-0249
  - 2. 2-1/2 inch by 50 feet, 4210-01-131-0247
  - 3. 1-1/2 inch by 25 feet, 4210-01-264-3871
- b. MIL-H-24580 (Rubber Covered Noncollapsible)
  - 1. 3/4 inch by 50 feet, 4210-01-076-8203

c. The 1 inch by 100 ft rubber hoses on SSN 21 do not have stock numbers; they are procured by Commercial Item Description (CID) A-A-2160A, Class II, Size B.

### 555-33.5.5 FAKING AND STOWING THE FIRE HOSE

**555-33.5.5.1 Fire Hose at the Fire Hose Station.** SSN 688 class has two 25-foot hose lengths connected together and stowed on the rack with one end connected to the fireplug and the other end connected to the nozzle. On the SSN 688 class, TD-36 and TD-40 have three 25-foot hose lengths connected together.

**555-33.5.5.1.1** The SSN 21 class has one 50-foot hose length per fire hose station. The two fire hose stations closest to the reactor compartment door have one additional 50-foot hose stowed but unconnected.

**555-33.5.5.1.2** On the SSBN 726 class each fire hose station has one ready service hose of 50-foot length and one unconnected 50-foot hose faked on the hose rack underneath the ready service hose. The ready service hose is made up to the fireplug, and a nozzle is attached to the other end. The hose is always faked in the rack with the ends hanging downward so that the couplings and nozzles are immediately at hand. The bottom of the folds should be at least 6 inches above the deck to prevent chafing the hose. See Figure 555-33-4.

**555-33.5.5.2 Stowing a Hose.** Hose to be stowed is rolled into a coil and sometimes tied with a small line. The coil is made by first laying the hose out on deck and doubling it so that the male end reaches 3 to 5 feet from the female end. The rolling is started at the fold, which is rolled inward on the part of the hose leading to the male end. The completed coil then has the female end of the hose on the outside, and covering the male end of the hose. The male coupling is therefore protected from damage to its thread. The double roll also allows the female couple to be connected and the hose run out without twisting. See Figure 555-33-5.

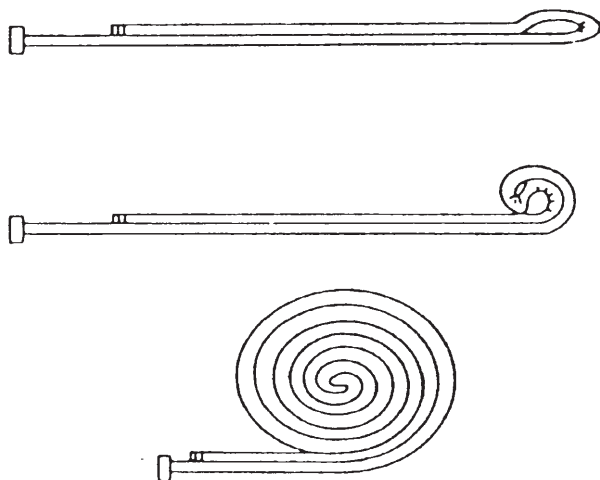


Figure 555-33-5. Preparing Fire Hose for Stowage

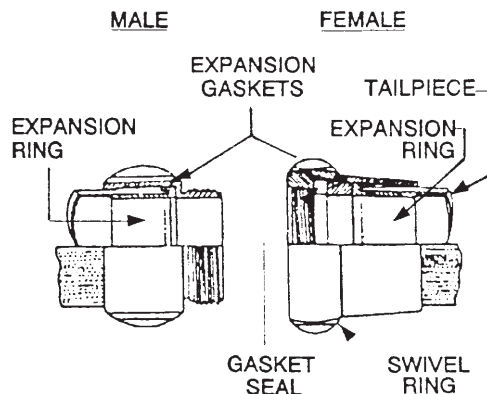
**555-33.5.6 HOSE MAINTENANCE.** The synthetic jacketed soft hose (MIL-H-24606) will not deteriorate due to prolonged exposure of the jacket to water. Continuous exposure to fuels and lubricants will soften the rubber components of fire hose. However, these effects can be negated by washing the exposed area as soon as practical after exposure. Hose couplings can be damaged by excessive abuse such as being dropped or being dragged around the deck. Also, hose fitting threads can be damaged by cross threading. Cotton jacket fire hose, per ZZ-H-451, is obsolete; if found, replace with synthetic jacketed fire hose. The cotton jacketed hose will suffer fungus rot if it remains wet.

### 555-33.6 FIRE HOSE FITTINGS

**555-33.6.1 INTRODUCTION.** Not all of the fittings discussed in this section are commonly used on submarines, however, the information is included to ensure familiarity with the equipment used on tenders, dry docks and other support activities.

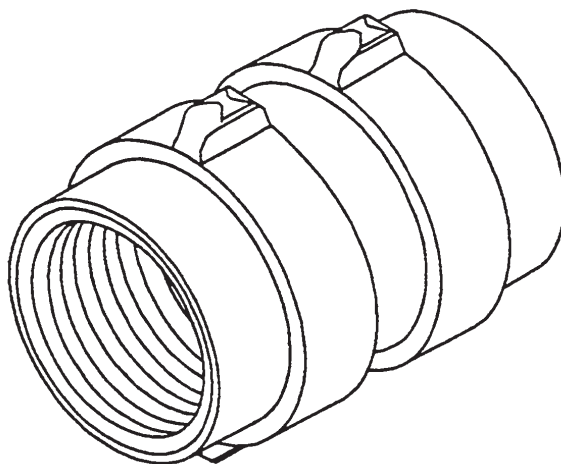


**555-33.6.2 GENERAL.** Fire hose fittings used for assembling fire hose aboard ship consist of the female coupling, the male coupling, the double female coupling, and the double male coupling. Two reducing couplings are used, the straight reducing coupling and the wye-gate for reducing to two small hoses. The straight increasing coupling is also used. All hose couplings for fire hoses on navy ships are made with uniform thread dimensions. They have an unobstructed waterway that is the full diameter of the hose. Rubber gaskets in female couplings should not protrude into the waterway. The couplings are made fast to the hose ends by means of expansion rings, which are set inside the hose and forced against the coupling. See Figure 555-33-6.



**Figure 555-33-6. Fire Hose Couplings**

**555-33.6.3 DOUBLE FEMALE COUPLING.** The double female coupling, either 2-1/2 or 1-1/2 inches in diameter, is furnished to connect two male couplings, to make jumper hose assemblies, and to connect a male coupling to a fireplug. Both ends are identical, with swivels and gaskets. See Figure 555-33-7.

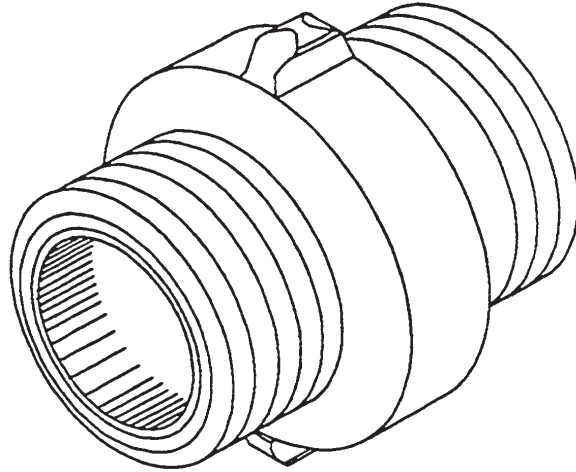


**Figure 555-33-7. Double Female Coupling**

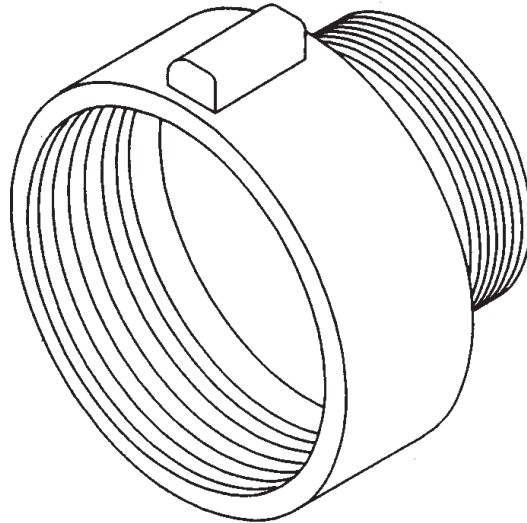
**555-33.6.4 DOUBLE MALE COUPLING.** The double male coupling, 2-1/2 or 1-1/2 inches in diameter, is furnished to connect two female couplings, and to make nozzle connections on female outlets. See Figure 555-33-8.

**555-33.6.5 STRAIGHT REDUCER COUPLING.** The straight reducer coupling serves to reduce a 2-1/2 inch size fireplug or fire hose to a 1-1/2 inch size. It has female threads at the large opening and male threads at the small opening. See Figure 555-33-9.

**555-33.6.6 STRAIGHT INCREASER COUPLING.** The straight increaser coupling serves to increase a 1-1/2 inch size to 2-1/2 inch size, either on a fireplug or fire hose. It has female threads at the small opening and male threads at the large opening. See Figure 555-33-10.



**Figure 555-33-8. Double Male Coupling**



**Figure 555-33-9. Straight Reducer Coupling**

**555-33.6.7 WYE-GATE.** The wye-gate is used to reduce a 2-1/2 inch hose to two 1-1/2 inch hoses. The standard wye-gate is equipped with two stop valves, so that either hose can be controlled independently of the other. See Figure 555-33-11. Where a wye-gate is installed on a fireplug with one hose connected, the outlet (gate) with no hose will normally be left open as a telltale for a leaking fireplug valve. Close the open outlet before opening the fireplug.

**555-33.6.8 SPANNER WRENCH.** To facilitate the tightening of leaking couplings and the disconnection of hoses, two adjustable (Figure 555-33-12), pin type lug, or multipurpose (Figure 555-33-13) spanner wrenches are provided at each fire hose station.

### **555-33.7 PRESSURE LOSS**

**555-33.7.1 CHECKING HOSE PRESSURE.** At rated pressure, the 1-1/2 inch hose, equipped with the proper nozzle will deliver a stream of water at the proper discharge rate. See paragraphs 555-33.8.2 and 555-33.8.4.1. If the discharge fails to conform to these criteria, the firefighter should:

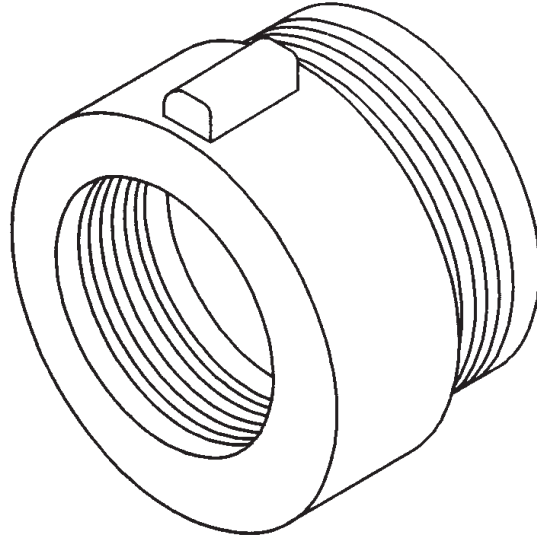


Figure 555-33-10. Straight Increaser Coupling

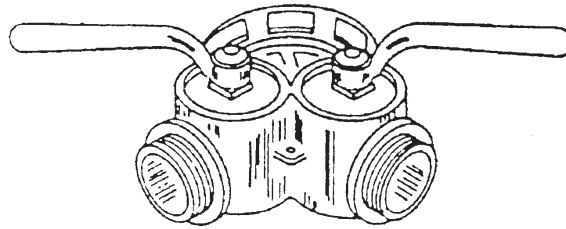


Figure 555-33-11. Wye-Gate

### SWIVEL HOOK SPANNER

MARKING TO INDICATE RANGE OF SIZES  
FOR WHICH SPANNER IS SUITABLE

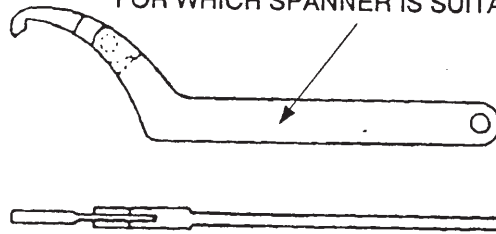
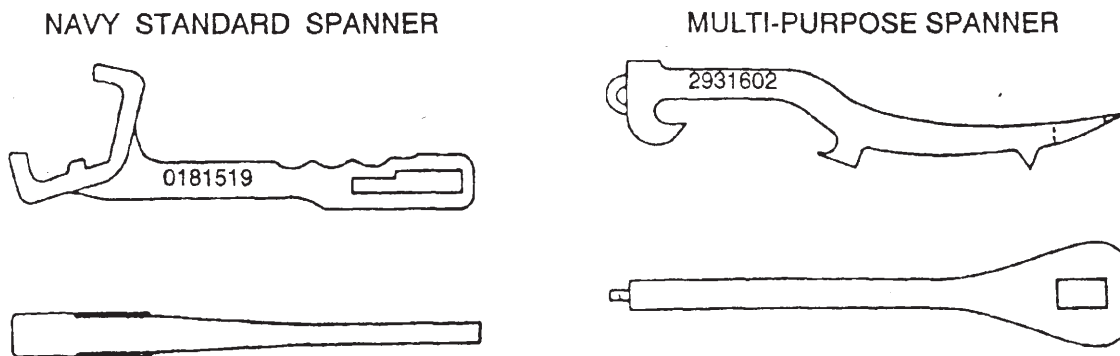


Figure 555-33-12. Adjustable Spanner Wrench

1. Check to ensure that all valves are fully opened.
2. Check the hose to see whether there is a double twist or kink.
3. Inspect the nozzle tip and barrel for a possible obstruction.



**Figure 555-33-13. Navy Standard and Multi-Purpose Spanner Wrenches**

**555-33.7.1.1** If none of the preceding steps corrects the discharge problem, it is probable that the trim system pressure is too low. If this is the case, the firefighter should immediately inform the man in charge at the scene. The man in charge at the scene should request the chief of the watch to verify that the trim system lineup and operation is in accordance with the approved procedures for supplying pressurized water for firefighting.

**555-33.7.2 FRICTION LOSS.** The firefighter does not have to calculate friction losses. It is only necessary for the firefighter to understand what happens when he connects additional hose, reduces a single hose to two smaller hoses, or makes other adjustments. Although friction loss through hose varies with the flow rate, it can be roughly estimated. For 1-1/2 inch hose, friction loss is roughly 25 psi per 100 feet at 100 gpm (one hose line).

**555-33.7.3 APPRAISING THE WATER STREAM.** In appraising the performance of a stream of water from the nozzle, the firefighter should take into consideration the loss of pressure in hoses resulting from the internal friction between the moving particles of water and the lining of the hose. Increasing the length of hoses by connecting additional hose, or reducing a single large hose line into smaller hose lines increases the overall friction losses. Friction loss, not only in the hose but in the trim system piping and fittings as well, accounts for much of the usual difference in pressure between the trim pump(s) or source tanks and the nozzles.

**555-33.7.4 CAUSES FOR PRESSURE LOSS.** Other causes for pressure loss include clogging, static head that results when pipes and hose are led upward (10 psi per 25 feet in height), ruptured hoses, and kinks in the hose.

### **555-33.8 NAVY VARI-NOZZLES**

**555-33.8.1 GENERAL.** The Navy nozzle used on seawater and AFFF (SSN 21) hoses and on the freshwater hose reels (SSN 21) is referred to as the vari-nozzle. See Figure 555-33-14. The spray pattern from this nozzle can be varied from straight stream through a range up to at least a 90° fog stream pattern. Some nozzles may adjust up to approximately 110° depending on the manufacturer. Stream patterns are changed by rotating the black shroud which surrounds the last 4 to 5 inches of the tip end of the nozzle. Markings are provided to indicate position settings for straight stream, narrow fog (30 degrees), and wide fog (90-110 degrees). The gallons per minute flow rate remains constant throughout the pattern range. The vari-nozzle flow rate can also be throttled from a trickle to full flow by operating the bail handle shut off. Table 555-33-3 provides vari-nozzle stream characteristics. The vari-nozzle produces an acceptable fog pattern down to 60 psi. Below 60 psi, the fog pattern is not full and radiant heat protection is degraded.

#### **NOTE**

Only the 1-1/2 inch, 95 gpm flow rate, NSN 9C-4210-00-465-1906, and the 3/4 inch, 30 gpm, NSN 4210-01-394-3951 (SSN 21) vari-nozzles are authorized for use on submarines. Occasionally a 1-1/2 inch nozzle with different flow rate or a 2-1/2 inch nozzle may be supplied from a tender or dry dock. These should be returned and not used.

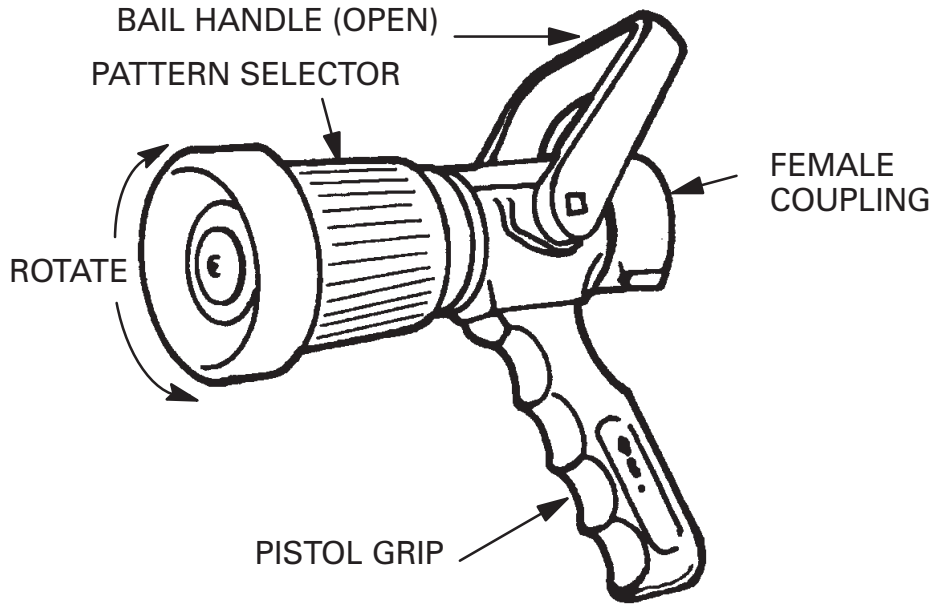


Figure 555-33-14. 1-1/2 Inch Navy Vari-Nozzle (pistol grip)

**555-33.8.2 FLUSH SETTING.** Vari-nozzles have a “flush” setting which increases the waterway clearances to pass typical firemain debris. This feature permits the nozzleman to flush out debris if the nozzle becomes partially or fully clogged. The flush setting allows a higher gpm flow in a distorted fog pattern. There are two styles of flush mechanisms depending on the manufacturer.

- a. On the Akron style, “flush” is reached by rotating the pattern adjustment shroud past the wide fog setting until it stops at the flush marking.
- b. The Elkhart style has a rotating ring about midway along the nozzle barrel with two indicated positions. The normal operating setting is indicated by a “95”, “125” or “250” (depending on nozzle size and rating) and the ring is held in this position by a spring loaded thumb latch. The flush position is reached by rotating the pattern adjustment shroud to wide fog and unlatching the flush ring and rotating it to the flush position.

**NOTE**

The pattern shroud must be in wide fog setting to achieve the maximum waterway clearance.

**Table 555-33-3. VARI-NOZZLE STREAM CHARACTERISTICS**

Navy Vari Nozzle	Size (in.)	1-1/2	1-1/2	1-1/2
	Pressure (psi)	50	60	70
Straight Stream	Discharge (gpm)	64	70	77
	Reach (ft)	58	68	70
Narrow Angle Fog	Discharge (gpm)	64	70	77
	Reach (ft)	25	25	28
	Diameter (ft), (at reach)	5	5	5
Wide Angle Fog	Discharge (gpm)	64	70	77
	Reach (ft)	11	11	11
	Diameter (ft), (at reach)	17	16	15

**555-33.8.3 VARI-NOZZLE DATA.** The 1-1/2 inch and 3/4 inch size nozzles have a pistol grip type handle. The sizes, flow rates, and applications of vari-nozzles appear in Table 555-33-4. Nozzle gpm rating is marked on the nozzle. When available, flow rates and stream characteristics of the 3/4 inch nozzle will be included in this section.

**Table 555-33-4. VARI-NOZZLE DATA**

Size	Rated Flow at 100 psi	Application	NSN
3/4	12-23-30	Fresh water hose reels, SSN-21 class	4210-01-394-3951
1-1/2	95	AFFF or Seawater hose lines	4210-00-465-1906

**555-33.8.4 STOWAGE.** Actions to Ensure Readiness:

1. During PMS, ensure that there is no apparent internal or external damage, all moving parts are free, the waterway is clear of foreign objects, and the pliable coupling gasket is in place.
2. For the Elkhart, the flush ring should be set and latched in the "95" setting.
3. The pattern shroud should be preset on narrow fog, the pattern most often used.

**WARNING**

To avoid shock hazards, do not use straight stream water pattern on an energized electric source. Maintain a minimum vari-nozzle standoff distance of four feet when applying water fog to an energized electric source.

**555-33.8.4.1** The Navy vari-nozzle should be stowed with the bail handle in the closed position and the nozzle set to the narrow angle (30 degree pattern) fog.

**555-33.8.5 GASKETS.** The Navy vari-nozzle is a disposable, not a repairable item. The only component part replacement authorized is the coupling gasket. The outside diameter of a 1-1/2 inch vari-nozzle gasket is slightly different for each manufacturer. NSN's for vari-nozzle gaskets are provided in Table 555-33-5.

**Table 555-33-5. VARI-NOZZLE GASKETS**

Manufacturer	Nozzle Size (in.)	Gasket Outside Diameter (in.)	NSN
Akron	1-1/2	2-1/16	9Z-5310-00-728-7702*
Elkhart	1-1/2	1-15/16	9Z-5330-01-041-7548**
Akron/Elkhart	2-1/2	3-3/16	9Z-5330-00-304-9265
* This gasket is also used on Akron's Navy All-Purpose (NAP) nozzles, line gages, and in-line eductors.			
** This gasket is also used on Elkhart's inline eductors.			

**555-33.9 PORTABLE PUMPS**

**555-33.9.1** Emergency portable electric submersible pumps are supplied to submarines as part of the ship's allowance. The primary purpose of the submersible pump is to ensure satisfactory drainage of isolated bilge pockets which cannot otherwise be drained under extreme angles of trim.

**555-33.9.2** The low discharge pressure from this pump will not operate the vari-nozzle in a fog position. However, the pump will produce a straight stream with a 30- to 40-foot reach for use in firefighting.

**555-33.9.3** A description and additional information on the use of the portable electric submersible pump is given in **NSTM Chapter 079, Volume 2**, the Ship's Information Booklet, and the Ship Systems Manual. Navy P-100 series portable pumps may be encountered during rescue and assistance operations involving surface ships. Submarine personnel should be aware of the equipment capability. For further information see **NSTM Chapter 555, Volume I, Surface Ship Firefighting**.

**555-33.10 FRESHWATER HOSE REEL SYSTEM, SSN 21 CLASS**

**555-33.10.1** Freshwater hose reels are installed in SSN 21 class submarines to provide a rapid response firefighting capability for class A fires. Hose reels are located such that all parts of the forward compartment and engine room can be reached with at least one hose with minimal travel up or down ladders. Two hose reels have a 100-foot long, 1-inch diameter, rubber covered, noncollapsible hose. All other hose reels have a 50-foot length of 3/4-inch diameter hose. All portions of the reactor compartment are reached with freshwater for fire fighting from a connection in the vicinity of the reactor compartment access door.

**555-33.10.2** The potable water system supplies freshwater with a minimum pressure of 50 psi at the hose reel. Each hose has a flow rate of 15 gpm at a nozzle pressure of 25 psi.





## **SECTION 34. FIREFIGHTING ORGANIZATION**

### **555-34.1 GENERAL**

**555-34.1.1** Submarines are designed to absorb and recover from all types of damage. A well structured and knowledgeable damage control organization will extract the maximum utility from the survivability features designed into the submarine. The control of damage on a submarine is always an all hands evolution. The ideal organization will provide for continuity of critical functions, while allowing a flexible attack against different types of fires under various circumstances. The submarine's general emergency procedure establishes a damage control (DC) central and damage control party organization for fire fighting and other casualties. A complete description of duties, responsibilities, and authority of each man in D.C. Central, the damage control party, and the fire team organization is found in the Battle Bill, the Submarine Force Commanders Ships Operating Procedures, and the Ship Systems Manual (SSM) for the SSN 688 and later class submarines.

### **555-34.2 CASUALTY COORDINATOR**

**555-34.2.1** During any emergency or casualty, such as a fire, a Casualty Coordinator is stationed at D.C. Central, normally in Control, to direct overall operation of ship's damage control equipment and personnel.

**555-34.2.2** The Navigator will normally be the Casualty Coordinator for emergencies in the engineering spaces. The Engineer will normally be the Casualty Coordinator for emergencies outside engineering spaces.

### **555-34.3 DAMAGE CONTROL ASSISTANT**

**555-34.3.1** The Damage Control Assistant (DCA), under the supervision of the Engineer is responsible for maintaining the ship's fire bill, maintenance of damage control equipment, and the training of the damage control party.

**555-34.3.2** During emergencies, the DCA will act as Assistant Casualty coordinator.

### **555-34.4 DAMAGE CONTROL PARTY**

**555-34.4.1 GENERAL.** The damage control party provides personnel to respond to shipboard emergencies. For a fire, the damage control party provides the Man In Charge at the Scene (scene leader), fire teams and rapid response fire team. The damage control party is typically located as follows:

- a. At battle stations or during the maneuvering watch:
  1. SSBN 726 class, the forward damage control party will muster in the crew's mess and the after damage control party will muster in AMR 2 upper level.
  2. Other submarine classes, the damage control party will muster in the crew's mess.
- b. When normal underway watches are stationed, i.e. not at battle stations nor during the maneuvering watch, and an emergency occurs, the damage control party of the OFFGOING watch section will provide and proceed to the scene of the casualty, if possible. The damage control party of the ONCOMING watch section will proceed to the crew's mess, muster, and await instructions from Control.
- c. In port, the duty section damage control party will proceed to the casualty scene.
- d. Selected and trained personnel shall be designated on the Watch, Quarter, and Station Bill within each watch section and duty section to comprise damage control parties.

**555-34.4.2 MAN IN CHARGE AT THE SCENE.** The Man In Charge at the Scene (hereafter referred to as the scene leader) is in charge of firefighting at the scene of a fire. He directs the attack against a particular fire. He directs deenergizing of electrical equipment as required. He communicates with the casualty coordinator and receives coordinating instructions from him. The senior man in the affected compartment acts as the scene leader until relieved. The designated scene leader is usually the Executive Officer when underway or the Ship's Duty Officer when in-port. In case of a multilevel fire, the scene leader coordinates firefighting efforts in the entire compartment.

**555-34.4.2.1** The scene leader decides what resources are needed for a fire team, including the need for a separate individual as fire team leader, a back-up hose and a NFTI.

**555-34.4.3 FIRE TEAMS.** Each ship should designate a minimum of four fire teams for underway and one for in port. The number of people in each fire team will vary, depending on fire conditions, the number of people available and the individual ship's organization.

**555-34.4.3.1** Fire team leader responsibilities shall be assigned by the scene leader for every fire to either the nozzleman or to an individual whose only function is that of fire team leader. A separate individual is necessary as fire team leader if a NFTI is used. A separate individual as fire team leader is desirable to direct the rotation of fire team personnel. The fire team leader directs the nozzleman in employment of the hose, directs the hosemen, asks that the hose be charged or secured, selects the spray pattern to be used, and directs the rotation of fire team personnel. A fire team leader should not be responsible for more than one fire team.

**555-34.4.3.2** The scene leader determines the number of hosemen necessary to man each hose. Typical hose manning, in addition to the fire team leader (when assigned separately), is a nozzleman and two hosemen for a 1-1/2 inch hose line. The last hoseman operates the fireplug as required.

**555-34.4.3.3** Generally, the nozzleman works the hardest and will need to be relieved before the hosemen. Rotating the nozzleman and the hosemen can extend the endurance of the fire team.

**555-34.4.3.4** The NFTI operator, when assigned, should be a senior, experienced individual. He should don an OBA (if available) and the maximum personnel protection available and proceed to the scene of the fire and report to the scene leader.

**555-34.4.4 RAPID RESPONSE FIRE TEAM.** As discussed in Section 35, submarine fire fighting depends on an immediate and escalating attack on the fire. The rapid response fire team fills the gap between the capabilities of the discovering crewman and the fire team, and is of the highest importance in maintaining an unrelenting attack on the fire. Each ship should designate a rapid response fire team for underway. As a minimum, the following functions will be performed:

- a. Immediately proceed to the fire and combat the fire with portable extinguishers or hosereel (when available).
- b. Establish communications with control.
- c. Rig fire hoses.
- d. See additional discussion in paragraph 555-35.3.2.2.

The rapid response fire team should be relieved as soon as possible by the fire team discussed above.

## **555-34.5 FIRE TEAM EQUIPMENT**

**555-34.5.1 PERSONNEL PROTECTION.** If a fire has been burning for any length of time, it can reach temperatures exceeding 2000°F (1093°C) and produce dangerous concentrations of smoke and toxic gases. Steam

created by water application to burning materials or hot surfaces will easily penetrate gloves and flashhoods and often poses the greatest hazard to the fighter. Firefighters who are not sufficiently protected against these hazards can not press their attack against the fire and may have to retreat, or may be burned or overcome by smoke. If they become casualties, then they reduce an already limited firefighting force. The scene leader makes the decision to request the firefighter's ensemble. Factors he considers are tenability of the area, stage of the fire, and success of the initial attack. The scene leader should also consider the time required for personnel to dress out in protective clothing and equipment. The greater time required to completely dress out allows time for the fire to grow. In certain situations, rapid response of less protected personnel may result in quick knockdown of a fire. For large, well established fires (e.g., machinery space fuel fire), adequate protection of personnel is generally required before a sustained attack is made. The optimum time to don the firefighter's ensemble is about 2 minutes, with another 1 to 2 minutes required to don an OBA. Under these conditions, the time to don full personnel protection will range from 2-1/2 minutes to 5 minutes. Under these conditions, standby personnel should assist fire team personnel in donning protective equipment. This reduces response time.

**555-34.5.1.1 Protective Equipment.** Members of the fire team not required to wear a firefighter's ensemble (FFE) should have official Navy issue dungarees and long-sleeved shirts buttoned to the highest possible point, or Navy issue coveralls, breathing apparatus (SCBA or OBA or EAB mask), antifeash hood(s), and protective gloves. If the firefighter's ensemble is not available, multilayered clothing will provide improved protection. The most important aspect is to protect all normally exposed areas of the body with some type of clothing. Areas particularly susceptible to steam burns include hands, wrists, neck, knees, ankles, and feet.

**555-34.5.1.2 Firefighter's Ensemble.** The firefighter's ensemble, shown in Figure 555-34-1, consists of firefighter's coveralls, firefighter's antifeash hood, and firefighter's gloves, all designed to protect the firefighter from the heat generated by a growing (pre-flashover) fire. For a flashover or fully developed fire, the FFE provides only a few seconds of protection for escape. On submarines, the firefighters helmet and boots are not provided with the FFE. Two layers of flashhoods are recommended with the FFE to increase neck protection. The firefighter's glove size should be selected for a loose hand and finger fit to reduce heat transfer from continuous material contact and allow glove adjustment at hot points. Additional hand protection can be gained by wearing a flash glove as an extra inner liner to an over-sized firefighter's glove. While waiting to enter the fire area, the FFE coveralls should only be donned to the waist, tying the coverall arms around the waist. Rubber coats, or unlined rubber or plastic gloves should not be worn next to bare skin as this commonly invites burns. Breathing apparatus should be activated before fire hoses are advanced into the fire area. OBA or SCBA operating times should be kept by a designated person(s) remote from the scene. In fighting major long term fires, which may occur in port, firefighters should leave the fire area after 30 minutes (in conjunction with the breathing apparatus alarm) and ensembles recycled to fresh personnel to minimize personnel heat stress. In a high heat environment, personnel endurance in an FFE may be 10 minutes or less. Personnel in an FFE may be forced to evacuate due to hot hands, hot feet or other local hot spots on the body. In training, common sense should be used to judge how long a firefighter should be kept in the suit.

**555-34.5.1.3 Adjusting Protection.** The scene leader may adjust personnel protection as the situation changes. For example, as progress is made during the attack, the fire is under control, and spaces are cooled, endurance of relief personnel will be improved by wearing only engineering coveralls rather than the FFE coveralls.

**555-34.5.1.4 Excessive Heat Exposure.** When clothing in contact with skin becomes wet, the water or water vapor formed may become heated enough to cause severe discomfort and burns. A firefighter reaching this condition should immediately retreat to a safe area and be treated in accordance with paragraph 555-35.6.10.g. If rapid escape from heat is not possible, he should be wetted down on site to prevent or reduce burns. Great care should be exercised in the decision of wetting down the firefighter to prevent or reduce burns. If the firefighter's clothing is dry and hot enough to burn the man, initial wetting could scald him. If clothing is already wet and burning the man, additional wetting probably will help. However, emphasis should be placed on remaining dry for as long as possible and switching to dry clothing after leaving the fire area for relief. When compartment fires have reached "flashover" the firefighter's ensemble will only offer sufficient protection to permit time to escape. Fortunately, fully developed (post-flashover) fires are not common on submarines at sea but have occurred in port. See paragraph 555-31.9.1.3. For a complete description of all Navy personal protection equipment, see **NSTM Chapter 077**.

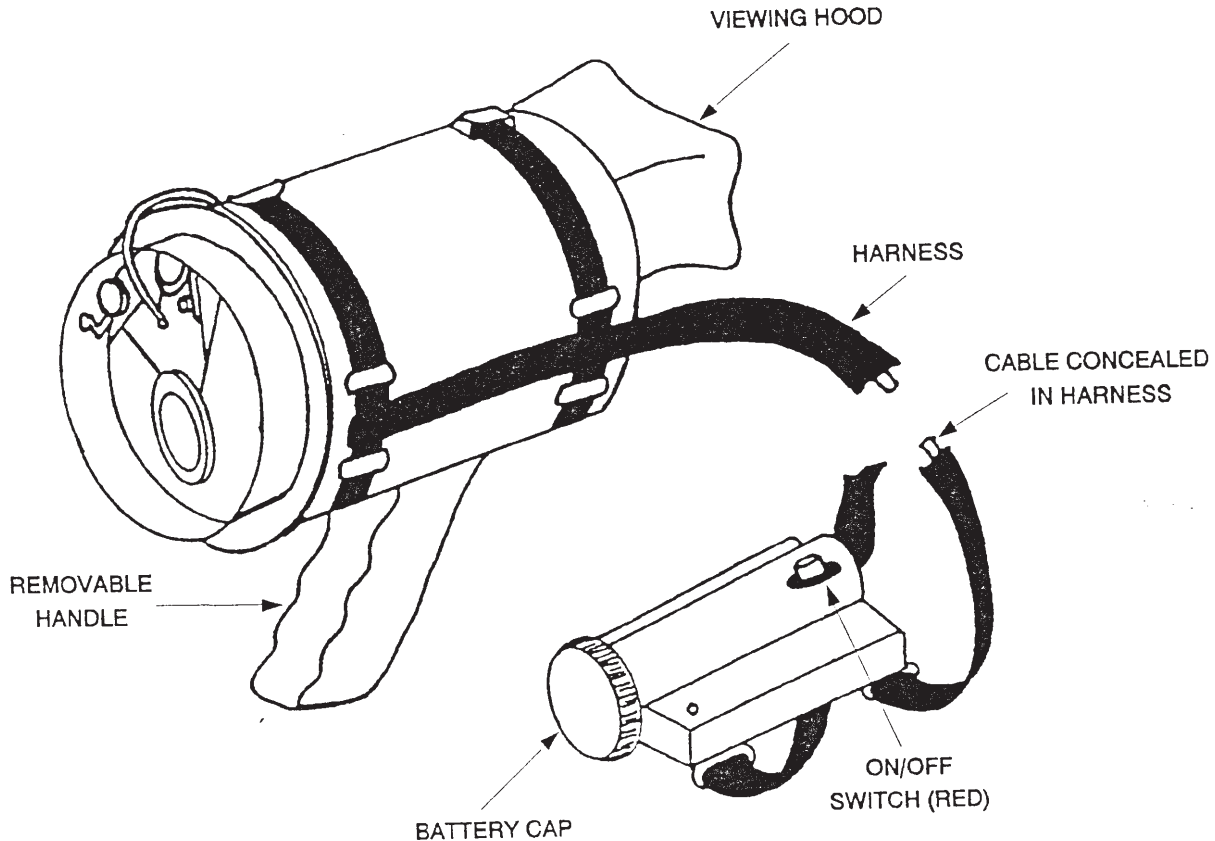


**Figure 555-34-1. Firefighter's Ensemble**

**555-34.5.2 NAVAL FIREFIGHTER'S THERMAL IMAGER (NFTI).** The Naval Firefighter's Thermal Imager (NFTI) is a device that allows the user to see through dense smoke and light steam by sensing the difference in infrared radiation given off by objects with a temperature difference of at least 4 degrees Fahrenheit. See Figure 555-34-2. A TV-like black and white image is displayed on the rear of the NFTI.

When looking through the NFTI the image presented looks like a negative picture, with hotter objects appearing lighter than cooler objects. It can be used to:

- a. Investigate reported fires.
- b. Locate the seat of the fire.



**Figure 555-34-2. Naval Firefighter's Thermal Imager**

- c. Locate and guide rescuers to injured personnel.
- d. Locate ignition sources during fire overhaul.

A training video is available, titled "Improved Shipboard Firefighting Using the Naval Firefighter's Thermal Imager," as PIN 805433.

**555-34.5.2.1 Stowage.** The NFTI should be stowed in its box in a cabinet or strapped down to the deck to protect it from shock. One NFTI should be stowed in the forward part of the ship and the second unit, if available, should be stowed in another convenient, far separated, secure space. It is important that the imager be stowed at moderate temperatures. Prolonged exposure to temperatures in excess of 140°F will severely damage the NFTI unit. Nevertheless, the NFTI can be used in high temperature spaces.

**555-34.5.2.2 Deployment.** The primary function of the NFTI is to help locate the fire when smoke or darkness restricts visibility. The NFTI also may be useful in assessing temperatures from outside a space and behind habitability bulkhead sheathing, and in searching a smoke filled compartment for injured personnel. Following knockdown of the fire, the NFTI can be useful to the reflash watch and to personnel overhauling the fire to locate any remaining hot spots. The NFTI should be brought to the scene whenever the fire is severe enough to require that firefighters wear ensembles and whenever requested by the scene leader. The NFTI is deployed as directed by the scene leader. The NFTI should be operated only by qualified personnel. If the fire team is directed to use the NFTI, it should be carried by the fire team leader.

**555-34.5.2.3 Operation.** The NFTI operator (as designated by the scene leader) should turn on the NFTI (red button) and check the battery status lights before entering a smoke-filled space. With fresh batteries, five L.E.D

lights should be illuminated in the lower left hand corner of the viewing screen. As batteries weaken, lights will go out. It is good practice to change the battery pack when more than one light is out. In addition, verify that the NFTI is operating in “chop” mode, not in “pan” mode, by checking the status of the blue button on the front of the NFTI. The “chop” mode is best for firefighting. The “chop” mode allows the user to focus on one area, while holding the unit still, but provides a less than sharp image. The “pan” mode provides greater sensitivity to small differences in temperature, but the NFTI must be kept in motion or the image will white out.

**555-34.5.2.3.1** When using the NFTI, it has been found that slow, steady advancement, along with periodic scanning of the scene during an approach, helps the operator to judge distances better. A side-to-side scan also provides important information on hazards in the area and the best direction in which to proceed. An occasional vertical scan will detect hazards above deck level, i.e. cable way or overhead fires.

**555-34.5.2.4 Limitations.** Water, dirt or soot will distort the NFTI’s image if deposited on the viewing lens. If this should happen, wipe the lens carefully with a soft, clean cloth. If the unit’s internal temperature gets too high the picture degrades and gets lighter. The screen will turn uniformly gray or white if the unit is exposed to excessive heat. The NFTI, if not otherwise damaged, will return to normal operation when removed to a cooler area.

**555-34.5.2.4.1** A battery pack requires 10 “AA” alkaline batteries. With fresh batteries, a battery pack has a life of approximately 60–90 minutes. To conserve power, turn the NFTI off when it is not in use. Allow one minute for warm-up when it is turned back on. Spare battery packs should be stored with the NFTI. The NFTI operator should carry at least one spare battery pack with him. If viewing images are distorted, gray or dark to the extent that the NFTI’s performance is not satisfactory, it is good practice to

- a. verify that the lens and viewing screen are clean and, if not, wipe them with a dry, clean, soft cloth
- b. check the battery pack to ensure adequate charge
- c. operate in a cooler place such as closer to the deck, or
- d. move out of the fire area to a cooler location.

The NFTI may not be fully operable topside due to electromagnetic interference. Consider this possibility when operating the NFTI topside. The NFTI should not be pointed at the sun. Doing this will temporarily saturate its sensor and the viewing screen will white out. The NFTI cannot be used to locate fires by viewing through glass windows. Glass is opaque to infrared radiation and thus the NFTI can not see through the window.

**555-34.5.2.4.2** The NFTI operator should stay low to avoid hot gases high in the space and to maintain a clear image with the NFTI. When pointed directly at a large fire, the unit’s sensor may become temporarily saturated. The picture will return if the camera is pointed toward a cooler scene. A better image is given if the fire is kept at the edge of the camera’s field of view. The spray from a fire hose nozzle may form an optical barrier which the thermal imager can not penetrate. This is sometimes a problem when fan patterns are used by the nozzle man. On the NFTI screen, this appears as an opaque, black curtain. If the nozzle man temporarily redirects the spray away from the fire, the NFTI’s field of view is improved. When approaching a large fire, hot gases flowing out of the fire space and along the passageway overhead will appear as white flashes through the camera. The operator must be aware of this and not mistake these flashes for flames.



## SECTION 35. FIREFIGHTING TACTICS

### 555-35.1 GENERAL

**555-35.1.1** Fires on submarines are unique because the ship is functionally a closed pressure vessel. A fire will heat the atmosphere, raising the internal pressure in accordance with gas expansion laws. Additionally, the fire compartment must normally be maintained in operation.

### 555-35.2 INITIAL ACTIONS

**555-35.2.1** The initial actions by the person who discovers a fire can make the difference between a controllable fire and one which threatens the very life of the ship. Even a small fire can create untenable conditions within a space in as little as two minutes. Any crew member discovering a fire or indication of fire must sound the alarm immediately. The report of fire and its location (compartment name, upper level, lower level, etc.) must reach the Officer of The Deck by whatever method available, such as 4 MC, messenger, sound powered phones or other announcing system. Following that, the discovering crewman or rapid response fire team will normally attack the fire using portable extinguishers or hosereels (when available), before advancing fire hoses.

<b>WARNING</b>
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Personnel not wearing OBA's or EAB masks should evacuate smoke-filled spaces. Toxic fire gases can cause unconsciousness and death. All non-essential personnel shall leave the fire area.

The initial attack can be made by personnel with limited or no protection. Incipient fires should be attacked by personnel in the immediate area using portable fire extinguishers. Portable AFFF extinguishers are provided for class A and class B fires. Potassium bicarbonate (PKP) and carbon dioxide (CO<sub>2</sub>) extinguishers are provided for class B and class C fires, respectively. However, the immediate use of PKP or CO<sub>2</sub> extinguishers on a incipient class A fire while hoses are being advanced may control a fire and prevent a major incident. The simultaneous discharge of two portable extinguishers onto a fire is more than double the effectiveness of discharging one after the other. If the fire is large, located in energized electrical equipment, fed by a pressurized fuel source or oxygen leak, or the fire origin is unknown, then initial actions should include isolation of affected systems.

### 555-35.3 FIRE ATTACK

**555-35.3.1 REPORTS FROM FIRE SCENE.** The fire characteristics, fire location, resources available, and fire growth all determine the overall plan of attack. Reports to be made from the scene are (1) location of fire, (2) class of fire, (3) identification of the man in charge at the scene, (4) action taken to isolate and combat the fire, (5) fire contained, (6) fire out, (7) reflash watch set, (8) fire overhauled, (9) ventilation recommendations, (10) compartment ventilated (smoke status), (11) compartment tested for oxygen, (12) compartment tested for flammable gases, and (13) compartment tested for toxic gases. Additional reports from the scene include number and extent of injured personnel, and damaged equipment. Refer to the glossary of terms for definitions of "Fire Contained" and "Fire Out."

**555-35.3.2 FIRE ATTACK STEPS.** Whether one manned hose or multiple manned hoses attack a fire, the steps are the same.

- a. Size up (evaluate) the fire.
- b. Attack the fire.
- c. Rig for fire and general emergency. Isolate affected equipment, systems and spaces in accordance with casualty procedures.

- d. Protect spaces exposed to the fire.

Attacking the fire should occur simultaneously with the other steps. The following paragraphs discuss each step, and some of the judgment factors that come into play when formulating a plan for attacking a fire.

**555–35.3.2.1 Size Up (Evaluate) the Fire.** Determine the location of the fire. For fires involving significant smoke spread, often only a general location can be determined initially. More precise definition will require men with OBA's or EAB's and thermal imagers to investigate further. Discolored or blistered paint, or smoke puffing from cracks or penetrations of nonstructural bulkheads are indications of fire on the other side of the bulkhead. Determine what is burning (the class of fire) and what other combustibles are at risk of igniting. Determine the preferred type of portable extinguisher (PKP, CO<sub>2</sub> or AFFF) to use on the fire. Simultaneously, hoses should be rigged and advanced to the scene. Determine what systems should be isolated.

**555–35.3.2.2 Attack the Fire.** The attack should be a multi-stage effort with a smooth, uninterrupted transition between stages.

**555–35.3.2.2.1** The first stage is an immediate attack by the person(s) discovering the fire: sound the alarm and, if conditions permit, grab the nearest portable fire extinguisher or hosereel (when available) and attempt to extinguish the fire or gain immediate control and prevent or minimize the fire spread. No consideration is given to donning an EAB or to determine if adequate protective clothing is worn. In this stage, come as you are, and attack the fire to the extent feasible.

**555–35.3.2.2.2** The next stage is a continuation of the initial attack, by the rapid response fire team. Upon hearing the word "Fire" the rapid response fire team members proceed immediately to the scene and continue the attack with portable extinguishers or hose reel (when available), rig fire hoses, and establish communication with the controlling station. These team members don EABs and take protective measures simultaneously with fighting the fire.

**555–35.3.2.2.3** The fire team relieving the rapid response fire team is the third stage of the attack. The fire team advances charged hoses into the immediate fire area, if not already being used, with the nozzleman in an EAB (if possible an OBA or SCBA) and all members with flashhoods and flashgloves. Nozzleman and hosemen wearing EABs should be replaced with OBA or SCBA personnel as they become available.

**555–35.3.2.2.4** The final stage, if needed, is the fire team aggressively continuing the attack with the appropriate fire team members in breathing apparatus and wearing the firefighter's ensemble (FFE). The NFTI operator is also at the scene, in breathing apparatus, to assist the fire team as directed by the scene leader.

**555–35.3.2.2.5** It is strongly emphasized that an aggressive hoseline attack should immediately follow an initial attack with portable extinguishers. The rigging of hoselines should not be delayed during the initial attack with portable extinguishers, nor should the use of the hoselines be delayed once the initial attack fails to extinguish the fire. In a direct attack firefighters advance into the immediate fire area and apply the extinguishing agent directly onto the seat of the fire. Access to the fire may be straight-forward in the early stages, but heat, gases, and smoke from an advanced fire make access increasingly difficult. If high temperature denies close access to the fire area from one direction but the burning material can be seen, aggressive attempts should be made to apply water from another access or direction.

**555–35.3.2.3 Rig for Fire and General Emergency.** Every effort should be made to secure and isolate those systems and equipment that are the root cause of a fire or have the potential to feed the intensity of a fire. Fires fed by a pressurized fuel source or oxygen leak normally can not be extinguished until the fuel source or oxygen is secured. In general, when a class A or class C fire occurs, affected equipment and systems are to be isolated except for firefighting equipment, lighting and IC circuits.

- a. Complete electrical isolation will be very difficult due to the number of cables terminating within and traversing a space. To the extent possible, all electrical equipment, except lighting and IC circuits, should be

secured from outside the affected space at a power distribution panel, load center, or even at the electric plant control panel if necessary. The purpose of securing power is to promote the safety of the firefighter, and to reduce ignition sources in the fire space. Effective firefighting should start before electrical power is secured.

b. The decision to secure lighting must be made on scene by the scene leader. Normally the fire team will benefit from improved visibility and therefore lighting should be left energized. Lighting should be secured if it is determined that an actual hazard to the firefighter, such as arcing or sparking, exists.

c. When a fire is discovered, immediate action should be taken to secure the ship’s ventilation system. Smoke from a relatively small fire may completely fill the entire ship in a short time; therefore the compartment must be isolated to keep the fire and smoke contained. As the fire attack progresses, it may be necessary to restart ventilation in the affected compartment before the fire is out. See paragraph 555–35.8 for guidance on ventilation.

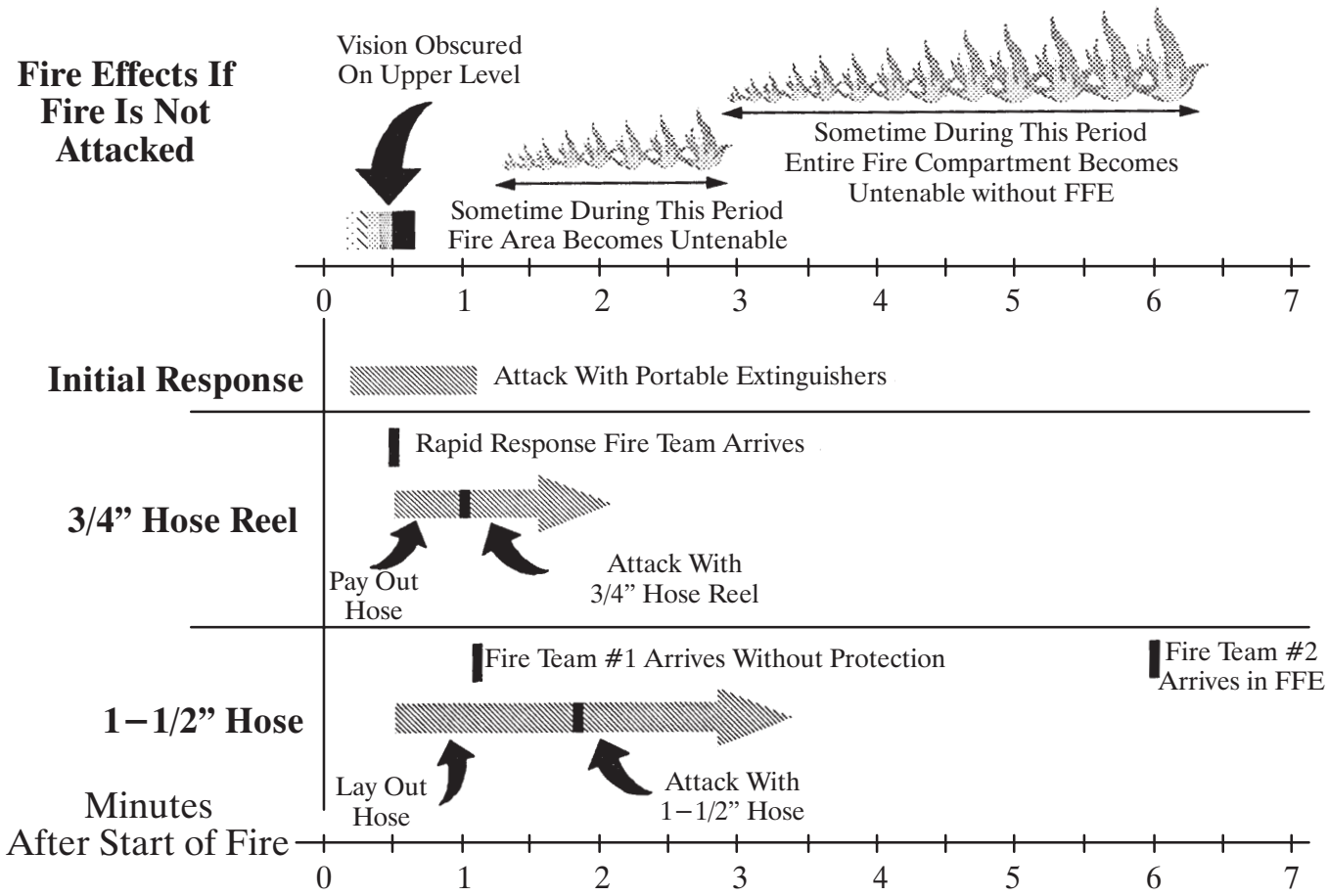
d. Set smoke boundaries. Smoke curtains are provided on submarines at watertight doors between compartments to reduce smoke spread. In the SSN 21 class forward compartment, smoke stops are provided in most frame bays at the deck edge to block vertical heat and smoke movement and retard flame spread up through frame bays.

After a fire has been discovered and a fire team sent to the scene, smoke curtains should be set at doors in these boundaries as directed by the man in charge based on his judgment of potential effectiveness. Curtains should be checked periodically to ensure they have a tight seal.

**555–35.3.2.4 Protect Spaces Exposed to the Fire.** The scene leader must be alert to the rapid vertical fire spread that can occur outboard in frame bays. He should direct a search for vertical fire spread. The person(s) conducting the search should recommend to the scene leader any further action such as manning hoselines on an upper level; deenergizing equipment or isolating systems; removing combustibles. A fire outboard on a lower level must be treated as a multi–level fire. Such a fire should be reported and acted upon on all levels of the compartment with the same urgency as the original fire. The scene leader may have to move to a different level to better assess the multi–level fire and direct the attack. Many fires can also spread by heat conduction through decks or nonstructural bulkheads without a mechanical breach. If fire spreads, cascading casualties occur and damage control parties are driven away from their tasks. In a casualty involving a flashed–over fire, ignition of combustibles located in the compartment directly above the fire may occur within as little as 3 minutes and within 5 minutes for other combustibles in the space. In adjacent compartments on the same deck, ignition of combustibles in direct contact with bulkheads may occur in as little as 7 minutes and within 20 minutes for other combustibles in the space. Fire spread through frame bay openings can be even faster. Exposure protection involves protecting uninvolved areas surrounding the affected space, including above and below. Typical exposure protection includes using hose streams to cool nonstructural bulkheads and decks, wetting combustibles, cooling flammable compressed gas cylinders, and moving or cooling ordnance. Cooling decks of spaces above the affected space is particularly important.

**555–35.3.3 TYPICAL RESPONSE TO A CLASS A FIRE.** This paragraph shows how the crew response relates to the submarine compartment fire dynamics for a moderately severe class A fire scenario. See Figure Figure 555–31–9. Some typical fire growth and crew response times are provided below for a fire in the lower level of the forward compartment. These times are also illustrated in Figure 555–35–1. The actual compartment fire dynamics will vary significantly for every fire. The times shown here cannot be expected to stay the same for all fires.

- 0 – The fire starts and is detected and located.
- 15 seconds – Initiate attack with portable extinguishers.
- 30 seconds  
to 1 minute – Visibility in the upper level is lost due to smoke.
- 1 to  
3 minutes – Unprotected personnel driven by heat from the scene. This time can be extended by a



Effective Initial Action Can Delay or Prevent Onset of Untenable Conditions

Figure 555-35-1. Fire Effects and Fire Attack - Class A Fire on Lower Level

rapid and effective initial attack with portable extinguishers, even if the attack does not extinguish the fire.

- 1 minute – Unprotected personnel ready to apply water with 3/4” hose reel (where available).
- 2 to 6 minutes – Unprotected personnel driven by heat from the upper level. This time can be extended by an effective attack with portable extinguishers and, where available, 3/4” hose reels, even if the attack does not extinguish the fire.
- 2 minutes – Unprotected personnel ready to apply water with 1-1/2” hoses.
- 6 minutes – Personnel in firefighter’s ensemble (FFE) arrive on the scene.

Clearly, rapidly detecting, locating, and attacking the fire can make the difference between a catastrophe and a controllable and contained incident. If the initial attack with portable extinguishers does not extinguish the fire by the time water can be brought to bear, water should be applied without hesitation. Even if these initial responses do not extinguish the fire, they may reduce the growth and intensity of the fire long enough to allow protected personnel to arrive and conduct an extended attack on the fire.

#### **555-35.4 HOSE HANDLING**

**555-35.4.1 GENERAL.** The objective of hose handling is to accomplish a rapid placement of hose at the desired location ready for use and to provide mobility during the fire as changing conditions necessitate. The following practices can more efficiently accomplish these objectives.

#### **555-35.4.2 ACTION TO ENSURE READINESS**

- a. Hose properly faked or rolled to avoid delays caused by sloppy stowage.
- b. Coupling hand tight to facilitate replacing a hose length or adding a hose length without wasting time finding and using spanner wrenches. A hand tight coupling having a gasket in good condition will not leak. Gaskets should be soft and pliable.
- c. Hose couplings in good condition; not out of round, no apparent hose slippage from the coupling, and no thread damage.
- d. Hose reel brakes set tight enough to avoid freewheeling, but loose enough to permit hose unreeling using reasonable effort. (For the SSN 21 class which has quick response hose reels.)

#### **555-35.4.3 CONTROLLING THE HOSE**

- a. A 1-1/2 inch hose can be controlled by one person in an initial quick attack. Sustained operation requires an additional hoseman near the nozzle (normally designated as “number one hoseman”).
- b. The function of the number one hoseman backing up the nozzleman is (a) push the hose forward to compensate for the nozzle reaction force pushing opposite the direction of flow; (b) hold the weight of the hose and (c) move the hose left, right, up, down to assist the nozzleman in directing the stream. The latter requires team work as in lifting the hose behind the nozzleman when he is directing the stream down or moving to the left when he is directing the stream to the right. The hoseman’s actions should not be fighting the nozzleman’s efforts. The hoseman’s position is as close to the nozzleman as possible without impeding his movements.

#### 555-35.4.4 ADVANCING THE HOSE

a. Hose is easiest to advance when the nozzleman carries the nozzle, assisted by his backup hosemen carrying each coupling. Additional personnel, if available, should be located at the midlength of each 50 foot section of hose. This procedure reduces friction due to dragging on the deck and prevents couplings from being snagged on door openings or other obstructions. A hoseman approximately every 25 feet along a hose is adequate. Additional persons can slow down the evolution, inhibit nozzleman mobility, and create higher accident potential.

b. Hose should be advanced to the nearest practical location of use prior to charging with water. A water filled hose is heavy and bulky and slows down the advancement evolution.

c. As soon as the nozzleman is in position and the dry hose completely off the rack, the nozzleman asks for water from the last hoseman. As the water fills the hose, hosemen straighten any kinks and check hose couplings for leaks. Opening the nozzle slightly will allow air to escape. In addition, once the decision is made to use hoselines, the scene leader must inform control so that the trim system operator can maintain the flow and pressure required for firefighting as well as compensate to maintain trim when submerged.

d. It is best to place hosemen on the same side of the hose. This principle allows easier maneuverability in narrow areas and makes space available for equipment and personnel to pass along the hose. Similarly, when passing two hoses through a door, hoses can be moved with minimum interference if the two hoses are passed side by side down the center of the access, with all the hosemen for each hose positioned so that the two hoses pass between them and the other hosemen.

e. When bringing a charged hose down an inclined ladder, one method is to carry the hose over one's shoulder with the nozzle in front in one hand. Proper hose tending by the hosemen will ensure that the nozzleman on the ladder maintains his balance.

#### 555-35.4.5 TENDING THE HOSE

a. Once the hose is deployed and charged, the hoseman nearest the nozzle works closely with the nozzleman, helping the nozzleman to position and direct the hose. The hoseman farthest from the nozzle feeds or retrieves hose as required by the nozzleman and operate the fire plug as required; they can move along the hose as needed, or they may be stationed at a critical location, such as the door or hatch into the fire space.

b. If hose tending will allow, the hosemen farthest from the nozzle can function as a communications link between the fire team leader and the scene leader.

c. To avoid unnecessary heat stress due to added time and hose handling in the hot environment and to minimize the delays between attacks on the fire, the attack hose may be left in the fire space with the nozzle closed, rather than moved in and out as fire teams are changed. However, if conditions permit, every attempt should be made to relieve fire team members on station so that the firefighting effort can continue without interruption. If the space is being abandoned, the hose should be withdrawn so that the accesses to the space can be secured.

**555-35.4.6 FRESHWATER HOSE REELS.** A hose reel (SSN 21 class) can be activated and effectively used by one man or by the rapid response fire team in an initial quick attack. The non-collapsible hose on the reel can be charged with all or some of the hose still on the reel. It is easier to handle than standard fire hose because of its smaller size, lighter weight, and lower nozzle reaction force when flowing water. The non-collapsible hose should be advanced to the scene by first ensuring the nozzle is closed, then opening the hose reel cutoff valve thereby charging the hose, and then advancing to the scene. The assistance of a hoseman may be advisable at ladders or other changes of direction.

#### 555-35.5 NOZZLE HANDLING

**555-35.5.1 NOZZLEMAN'S MISSION.** The mission of the nozzleman is threefold. He must direct the stream where desired, he must do so with the appropriate pattern, and at the appropriate flow rate. All three of these



actions are subject to continuous change as conditions dictate. The primary factors that affect how this mission is accomplished are: type of breathing apparatus worn (interference with hose) and the physical build, strength, and position (standing, crawling, lying, crouched) of the nozzleman. Because of physical differences between individuals and variations in fire scenarios, there is no specific nozzle handling method required to accomplish the nozzleman's mission. The correct way for a nozzleman to handle a nozzle is the method which permits him to accomplish his mission in the most physically comfortable manner. Figure 555–35–2 shows some acceptable hose and nozzle handling methods. See paragraph 555–33.8 for nozzle information.

**555–35.5.2 HAND PLACEMENT.** The nozzleman should devote one hand to holding the nozzle and directing the stream. The other hand should be available to alternate between the pattern shroud and the bail shut off handle to control pattern/flow variations as appropriate. This hand, knuckles up, on top of the nozzle is typically the most comfortable and provides for the least movement between pattern shroud and bail handle. When using a tactic of short bursts of water, this hand would typically be kept on the bail. For continuous flow tactics, keep the hand on the shroud for instant pattern variations and to assist in aiming the nozzle.

**555–35.5.3 HOSE PLACEMENT.** The nozzle may be held with the hose over the shoulder or under an arm, whichever works best to provide the necessary control.

**WARNING**

When holding the hose line under an arm, the OBA breathing bag on that side may be collapsed if the hose is pressed against it.

**555–35.5.4 PISTOL GRIP.** On the 1–1/2 inch vari-nozzle, the pistol grip handle may or may not be used, whichever method works best and is most comfortable for the nozzleman.

**WARNING**

Prior to reaching the fire or opening up a space, preset the nozzle pattern and crack open the shut off for a moment to bleed out air and ensure that the nozzle is not clogged.

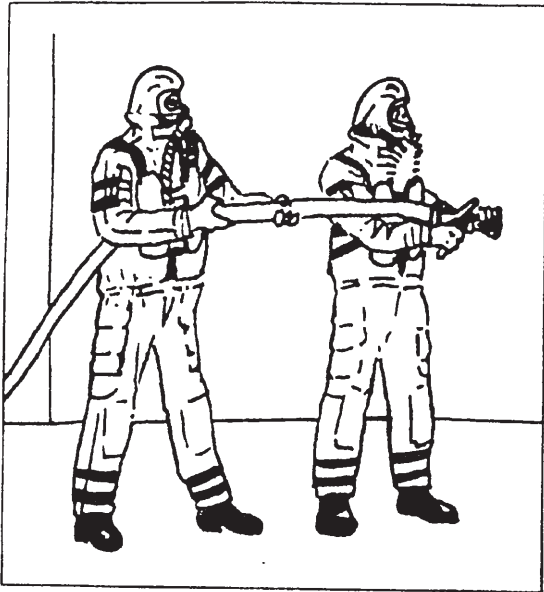
**555–35.5.5 NOZZLE CONTROL.** For the safety of personnel manning a hose in addition to those nearby, it is important to keep the nozzle end of a hose line under control. Loss of control can knock the hose crew down and direct the stream on others or critical electrical equipment. Loss of hose control can create a whip capable of causing severe injuries and equipment damage. Loss of control results from excessive nozzle reaction force (greater than 100 psi at the nozzle) or from losing the hand grip (slippery gloves, muscle cramps, fatigue, another crew member lets go). When a nozzleman senses that he is losing control, he may apply several techniques to reduce reaction force and regain control. The obvious technique is to shut down. When flow must continue, the nozzleman should throttle down the flow or go to wide angle fog. These actions are quickly performed when keeping one hand on the bail or the pattern shroud at all times. The operation of adjusting to wide angle fog or throttling back should also be used when personnel manning the hose are making significant changes in position, climbing over objects, or operating on ladders, when it is not feasible or safe to shut down. The same tactic should be applied when changing nozzle men while not shutting down.

**555–35.5.6 REGAINING NOZZLE CONTROL.** If a fire team loses their grip and a hose line becomes a thrashing whip, three methods of regaining control are:

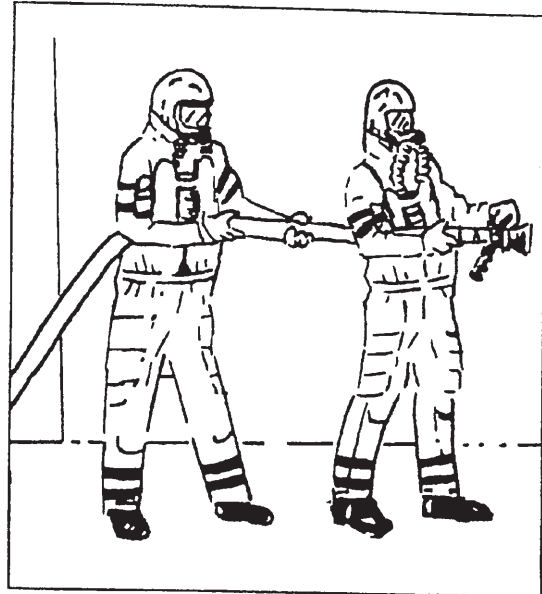
1. Shut off the flow at the fireplug to stop/reduce flow in order to safely approach and shut off the nozzle.
2. Take control of the hoseline at a non-moving point and fold hose twice in a “Z” or “Z-kink” to stop flow.
3. Take control of the hose line at a non-moving point and advance along the line toward the nozzle regaining control of the line while advancing.

**555–35.5.7 NOZZLE PATTERN SELECTION GUIDANCE.** The water fog patterns on the vari-nozzle can be varied through a range of settings from straight stream, narrow angle, and wide angle fog. Water pattern selection guidance:

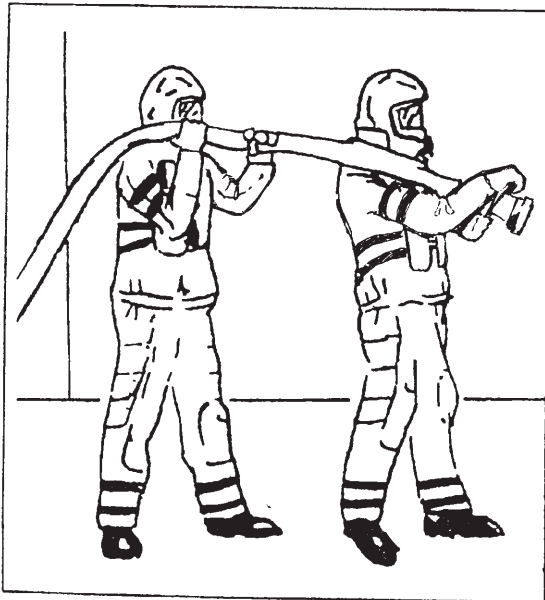




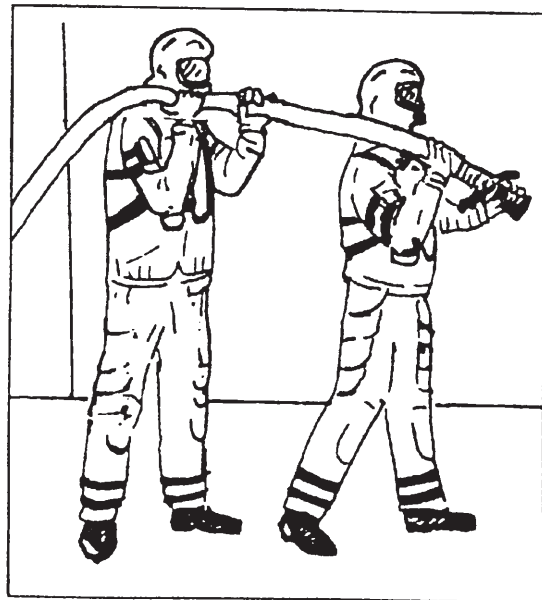
A. OVER THE ARM, USING PISTOL GRIP, GRASPING PATTERN SHROUD.



B. UNDER THE ARM, NOT USING PISTOL GRIP, GRASPING THE SHUT OFF BAIL HANDLE.



C. OVER THE SHOULDER, USING THE PISTOL GRIP, GRASPING SHUT OFF BAIL HANDLE.

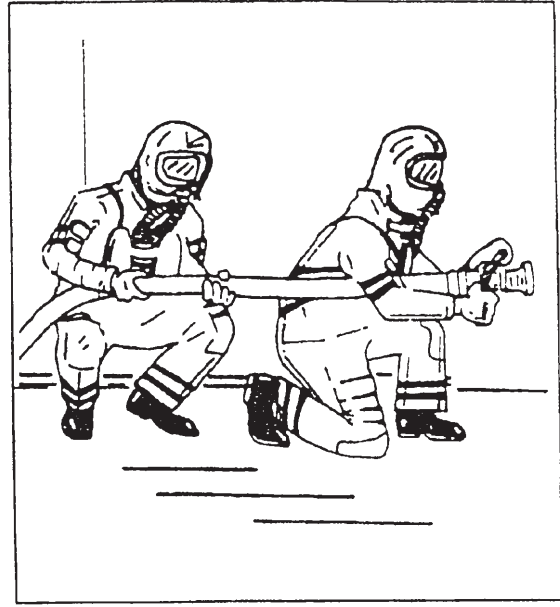


D. OVER THE SHOULDER, NOT USING PISTOL GRIP, GRASPING PATTERN SHROUD.

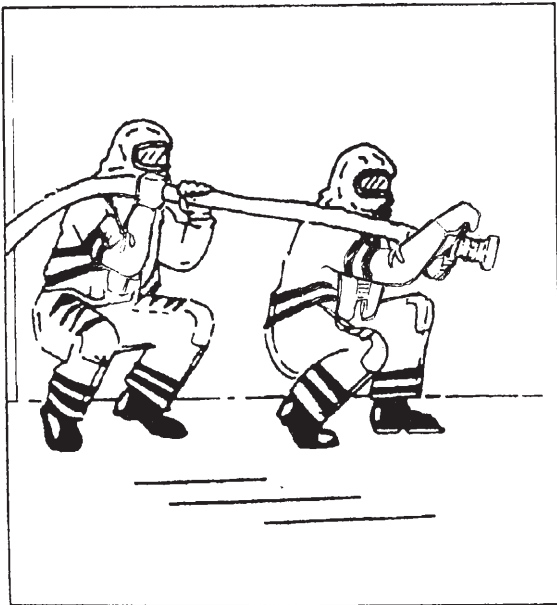
Figure 555-35-2. Hose Line and Nozzle Handling Methods (A-D)



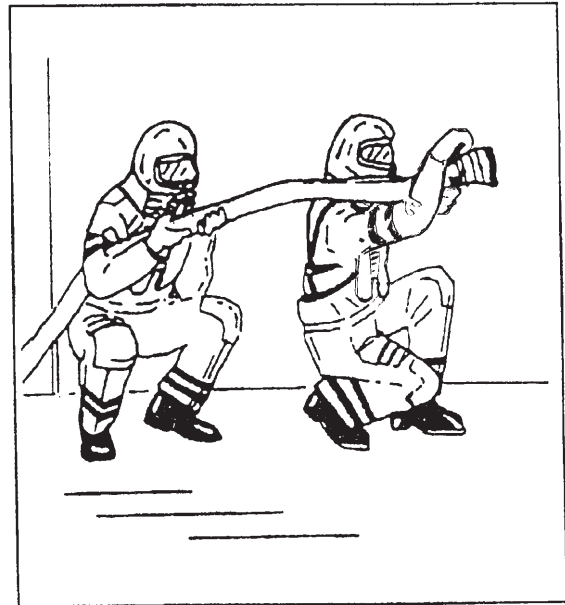
E. UNDER THE ARM, NOT USING PISTOL GRIP GRASPING THE PATTERN SHROUD.



F. UNDER THE ARM, USING PISTOL GRIP, GRASPING THE SHUT OFF BAIL HANDLE.



G. OVER THE SHOULDER, USING THE PISTOL GRIP, HAND ON PATTERN SHROUD, DIRECTING STREAM DOWN.



H. NOZZLEMAN OVER THE SHOULDER, HOSEMAN UNDER THE ARM, USING PISTOL GRIP, HAND ON PATTERN SHROUD, DIRECTING STREAM UPWARD.

Figure 555-35-2. Hose Line and Nozzle Handling Methods (E-H)

1. Straight Stream – reach for projecting water over a distance; penetration into or stirring up class A material; when deflecting streams off an overhead into a space.

**WARNING**

Do not use straight stream on a class C fire due to shock hazard. See paragraph 555-36.2 for safety precautions when using water on energized electrical equipment.

**WARNING**

Do not use water fog when attacking a charcoal bed fire; large quantities of toxic, flammable gases may be released.

2. Narrow Fog – The vari-nozzle narrow angle pattern (30 degrees) provides good reach but reduced heat absorption. The narrow angle pattern is also effective in providing a forceful push to flame fronts and allows the firefighter to work fires in given directions. It is also used for application of AFFF and as the general firefighting pattern.

3. Wide Fog – The medium and wide angle patterns do not provide as much reach, but do improve heat absorption in the fire area. It is used for hose line personnel protection as well as cooling bulkhead, decks, and overheads.

**555-35.5.8 STREAM REACH.** The reach of hose streams is controlled by position of the bail handle, nozzle pressure, and nozzle pattern. As a rule of thumb, a vari-nozzle in zero wind, fully open, and at 60 psi will reach approximately 68 feet in straight stream, 25 feet in narrow angle fog, and 11 feet in wide angle fog. Submarine nozzle pressures are typically 60 psi or less but can vary significantly with total demand.

**555-35.5.9 NOZZLE FLOW RATE.** Flow rate of the vari-nozzle can be controlled by throttling the bail handle to a partially open position. In a direct fire attack, this can reduce the formation of steam and help maintain tenable conditions for the attack team.

**555-35.6 DIRECT ATTACK**

**555-35.6.1 GENERAL.** This section addresses compartment fires that involve predominantly class A material. These compartments include living spaces, administrative and support spaces, shops, and storerooms. Other portions of this chapter deal with compartment fires where class B and class C fires are of major concern. Many spaces that contain a predominant amount of class A material may also contain limited quantities of flammable liquids. For fully involved compartment fires, the contribution of limited quantities of flammable liquids to a fully involved compartment fire will not change class A firefighting tactics. In spaces such as shops and cleaning gear rooms, class B materials may exist in aerosol spray cans. When exposed to fire, these containers may explode and be propelled into the air, spreading burning fluids and creating a safety hazard to the firefighters.

**555-35.6.2 SHOCK HAZARD.** Nearly all spaces contain electrical cables and fixtures. However, the shock hazard to the firefighter is low. This is due to frequent use of watertight or spraytight enclosures, cable insulation, electrical circuit protection devices and low voltage (120 volt) electrical service. Historically, the primary shock hazard is caused by direct contact between the firefighter or hose nozzle and an electrically energized object and not by electrical conduction via the hose stream. See paragraph 555-36.2.

**555-35.6.3 SPACE ENTRY**

a. When entering a space, the attack team leader typically should be the first man into the space (either the space adjoining the fire or the fire space) to look for fire and assess conditions. He should enter without a hose so that if conditions do not permit entry of the attack team, there will be fewer people and less equipment to back out.

b. Whether attacking from the doorway or entering the space, remain low at all times to take advantage of the cooler air and greater visibility near the deck.

c. Where mission requirements force quick entry under severe conditions, crawling into the fire space may be required. Before entry sweep the deck with the hose stream to clear debris, cool hot surfaces and burning materials, prevent burns to hands and feet, and prevent damage to the hose lines.

d. Heat expansion or warping may cause dogs on scuttles, hatches, and doors to jam. Joiner doors may also warp and jam in their frames. Hand tools such as a crow bar may be required to open jammed closures. Wearing flash gloves under firefighters gloves or use of hot mats may be required to protect hands when contacting hot surfaces.

**555–35.6.4 DETERMINE DIRECT ATTACK TECHNIQUE.** There are three distinct techniques available during a direct fire attack: direct attack on the seat of the fire, fog attack to control the fire, and direct attack from the access. After assessing the fire space condition, the team leader must determine the best technique to use.

a. **Direct Attack at the Seat of the Fire.** When direct access to the seat of the fire is available, the preferred method is to advance to the seat of the fire and apply water directly onto the seat of the fire for extinguishment (see Figure 555–35–3 and paragraph 555–35.6.5). Access to the fire may be straight forward in the early stage of the fire, but heat, gases, and smoke from an advanced fire make access increasingly difficult.

b. **Fog Attack (to Gain Control of Fire).** When entry can be made into the fire space, but direct access to the seat of the fire is not possible, firefighters may use a fog attack to gain control of the fire (see Figure 555–35–4 and paragraph 555–35.6.6). The following conditions indicate the use of fog attack to gain control:

1. Where overhead gases are burning (known as rollover),
2. Where the seat of the fire is obstructed and water streams cannot be applied directly to the seat.
3. Where multiple seats of the fire are growing within a compartment such that one seat of the fire would grow out of control while water is being applied to another seat of the fire.

c. **Direct Attack from Access.** If high temperature denies access to the fire space but the burning material can be reached by a hose stream from an access, water can be applied to the seat of the fire from the access. (See Figure 555–35–6 and paragraph 555–35.6.7.)

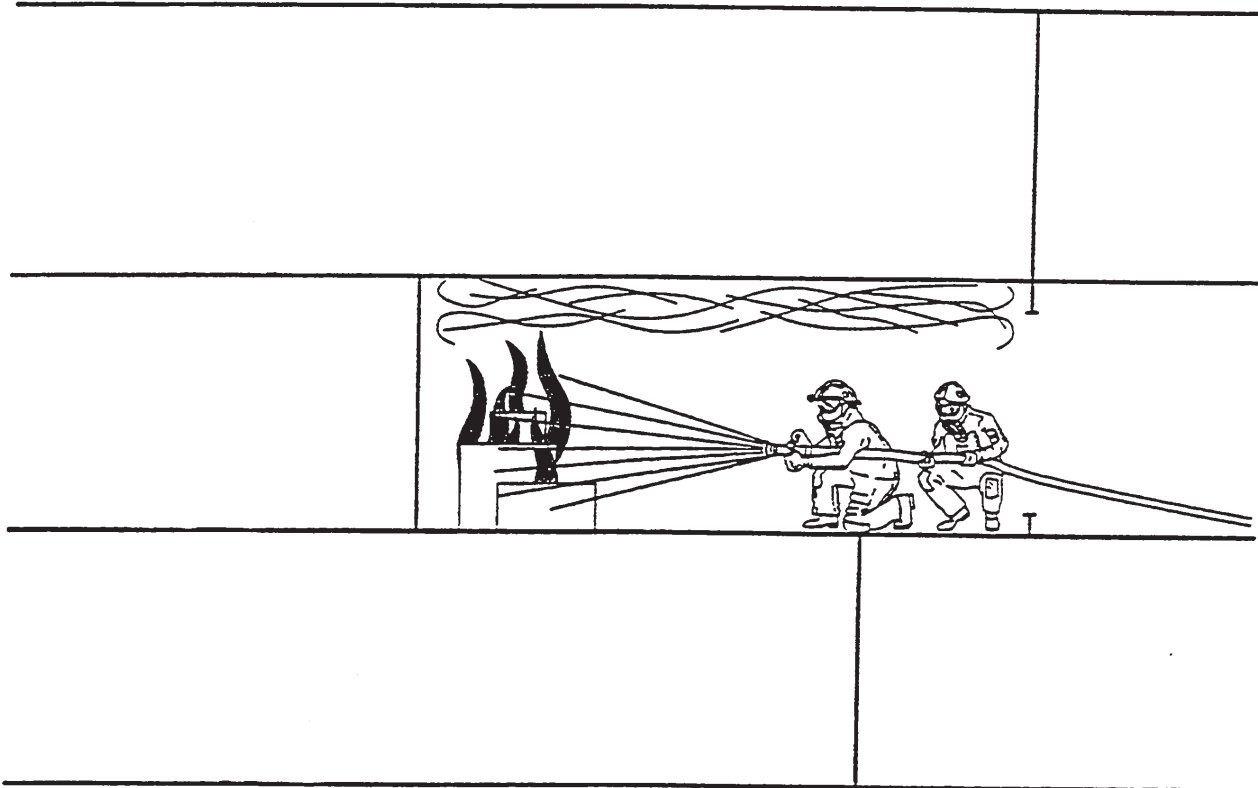
d. If conditions become too severe for these direct attack techniques, the attack team must withdraw and use other techniques, such as indirect attack or venting to improve conditions to allow a direct attack. (See Figure 555–35–5.)

**555–35.6.5 DIRECT ATTACK ON SEAT OF THE FIRE.** When direct access to the seat of the fire is available, firefighters advance into the immediate fire area and apply water directly onto the seat of the fire (see Figure 555–35–3).

a. The direct attack technique involves application of short bursts (several seconds) of water with a narrow angle fog or straight stream nozzle pattern onto the seat of the fire. The nozzleman pauses and lets the resultant steam pass over and subside. During this pause, the firefighter listens for noise to help locate fire. After the steam has subsided, water is again applied in a short burst. The duration of the short burst is a function of the amount of steam production. As steam production lessens, a greater duration water burst may be used as the firefighter moves forward and attempts to directly attack the fire or heat source. Water should only be used when the firefighter is faced with the fire or when the firefighter can not approach closer due to radiant heat. The practice of using continual water flow from all hoses when making interior entry should be discouraged. This does nothing more than disturb the thermal balance in the compartment, which causes large amounts of steam to be produced before the firefighter has a chance to advance on the fire, reduces visibility to the point where he can not see where he is going or where the source of the fire is, and creates potential flooding and stability problems.

## PREFERRED METHOD

### ENTER SPACE AND APPLY WATER TO THE SEAT OF THE FIRE

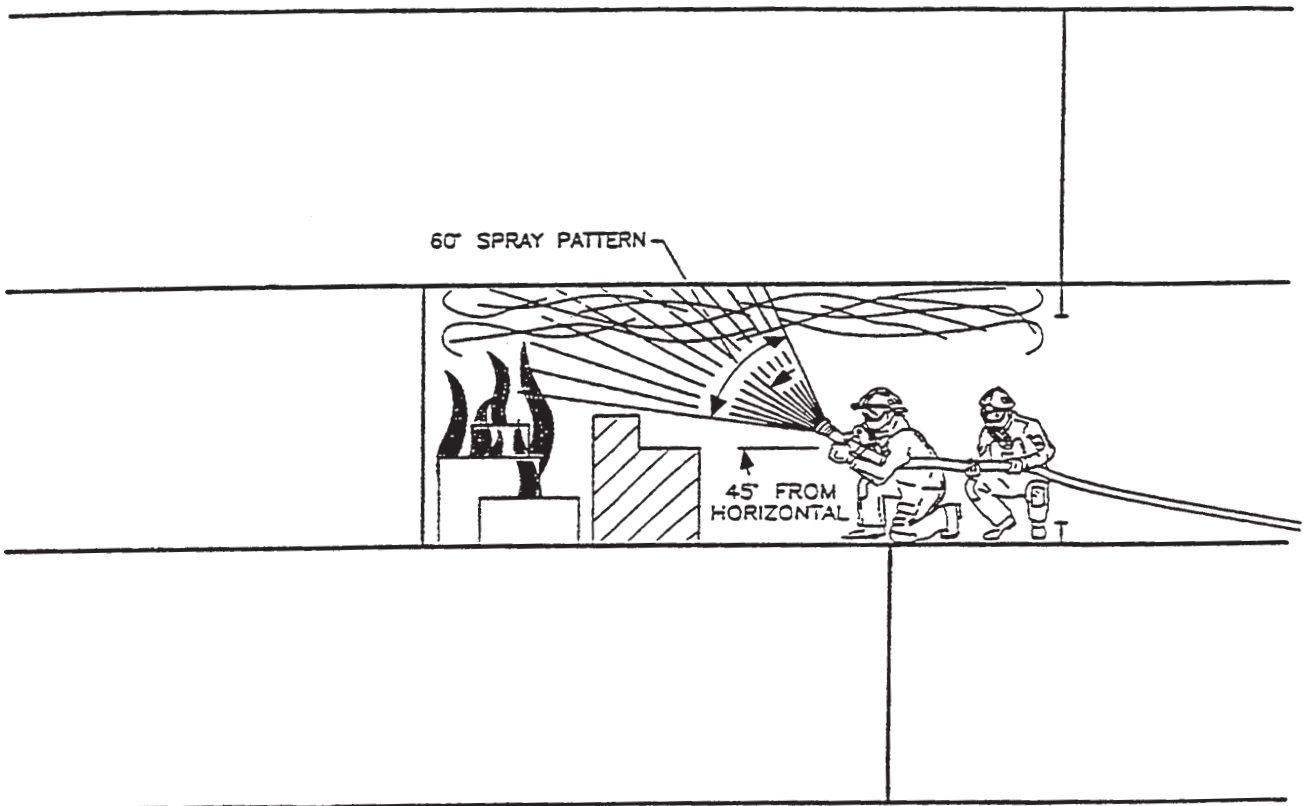


- Keep low and try to keep dry.
- Use short bursts of narrow fog/straight stream to minimize steam. Hit the seat of the fire.
- Don't hit overhead or bulkheads.

Figure 555-35-3. Fire Attack – Direct Attack on the Seat of the Fire

IF DIRECT APPLICATION OF WATER  
TO THE SEAT OF THE FIRE IS NOT POSSIBLE

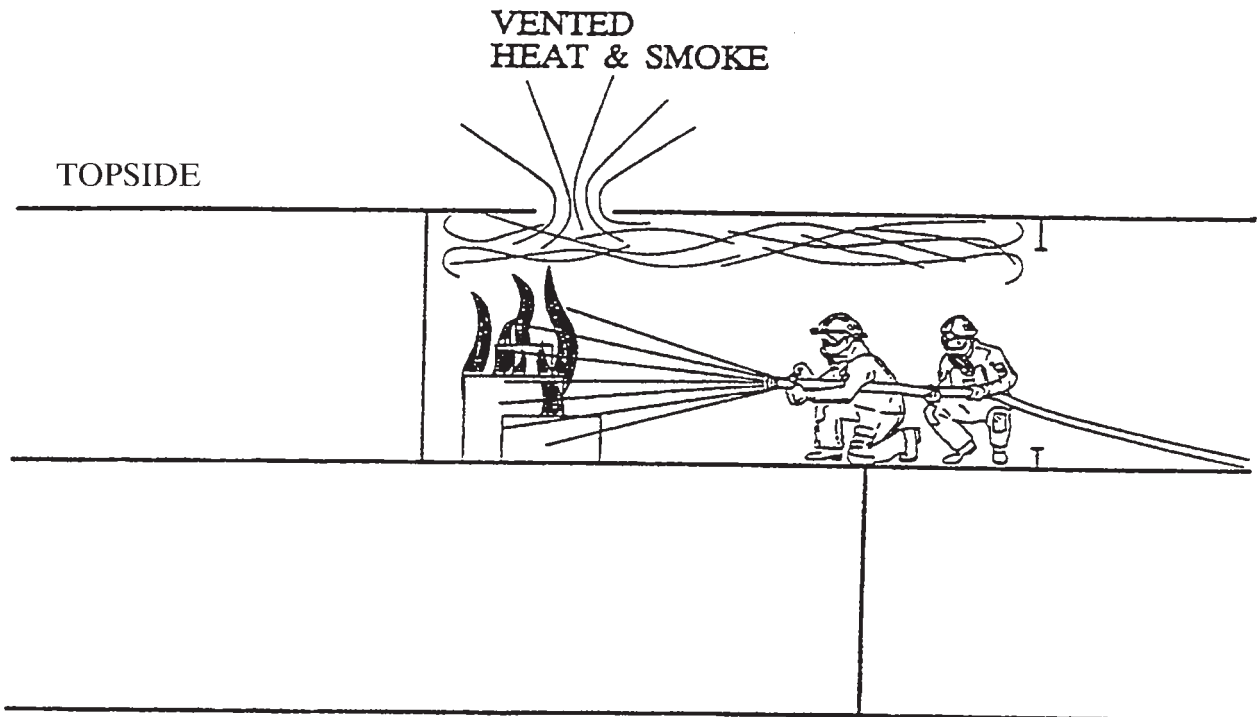
ENTER SPACE AND  
APPLY FOG BURSTS INTO UPPER GAS LAYER



- Keep low and try to keep dry.
- Use short fog bursts, directed at hot gas layer over the seat of the fire to control fire space conditions.
- Pause several seconds between short fog bursts to ensure steam generation is not excessive and to check for flames.
- Advance to the seat of the fire. Adjust nozzle to narrow fog/straight stream. Hit the seat of the fire.

Figure 555-35-4. Fire Attack – Fog Attack To Control Fire

IF HIGH TEMPERATURE  
DENIES ACCESS  
VENT HEAT TO WEATHER  
AND CONDUCT DIRECT ATTACK



- Open topside hatch over fire compartment
- As temperature drops, hose team enters and attacks fire.  
See Figure 555-35-3.

Figure 555-35-5. Fire Attack - Direct Attack with Vent to Weather In Port



b. Full water flow from nozzles during space entry has the additional drawback of wetting the firefighters outside and inside their fire suits. In general, firefighters should avoid getting wet inside their garments since any contact with hot fire gases when wet will result in a water vapor burn as the moisture inside the garment is heated.

c. Hose streams should be directed at the area of combustion, not blindly into smoke. The fire area may be visible, particularly once a space has been vented, if the thermal balance of rising smoke and gases has not been disrupted. Flames and smoldering areas may be located by the use of the Naval Firefighters Thermal Imager with the operator providing directions to the nozzle men. Burning areas may also be located by trials and error using short bursts of water into the suspected fire location and listening for the crackling, popping sound of water hitting the fire.

d. Overhead fires, such as in cables, fed from burning combustion gases generated from the fire below will be quickly extinguished as soon as fires at deck level are extinguished. A straight stream or fog stream less than 30 degrees is most effective if energized electrical equipment or cables are not involved. See paragraph 555-36.2. Where the hot upper gas layer is burning, a fog attack (see paragraph 555-35.6.3.b should be considered before extinguishing the fires below.

e. When the fire is knocked down, shut down the nozzle. Look and listen for flare ups and flame crackling, hitting these areas with sufficient bursts of water for knockdown. When the fire is out, perform overhaul and apply water only as necessary to complete extinguishment. Unnecessary and prolonged application of water adds to ship damage and to weight, stability, and dewatering problems.

f. Along with entry into the suspected or known fire space, check all adjacent spaces above and below for fire.

**555-35.6.6 FOG ATTACK (TO GAIN CONTROL OF FIRE).** When entry can still be made into the fire space, but direct access cannot be gained safely to apply water to the seat of the fire, firefighters may use a fog attack to gain control of the fire. Paragraph 555-35.6.4.b describes the conditions where use of fog attack is desirable.

a. Fog attack is the application of short bursts (several seconds) of water with a medium angle fog nozzle pattern into the overhead gas layer to control the fire. Fog bursts applied directly over the seat(s) of the fire will reduce fire space temperatures and radiant heat and will knock down flaming combustion.

b. In a fog attack, adjust the nozzle to medium angle (60 degree) pattern and point the nozzle upward approximately 45 degrees above horizontal (halfway between floor and ceiling), see Figure 555-35-4. Apply a short fog burst (2 to 3 seconds) with bail handle fully open into the upper gas layer followed by a 2 to 3 second pause. During the pause, the team leader checks for flames and directs additional fog bursts until the flames are knocked down.

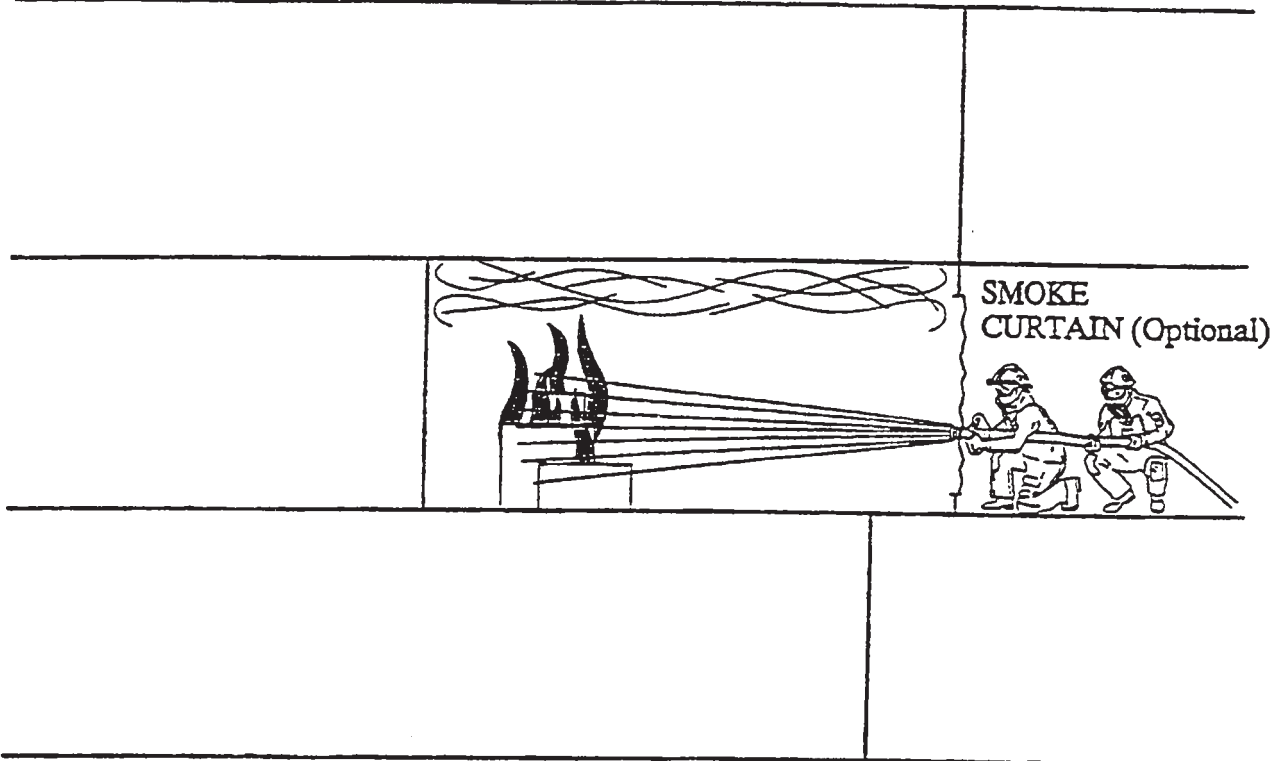
c. Use of short fog bursts followed by short pauses will maintain acceptable conditions in the space for firefighters. If the initial fog bursts are too long, the wrong fog pattern is selected, or the nozzle is not directed properly, then too much water may be applied onto the hot steel overhead or the hot upper portions of a bulkhead and excessive steam is generated. This excessive steam could force firefighters to withdraw.

d. The flame knock down allows the attack team to advance for direct water spray into the seat of the fire. See 555-35.6.5 for the technique of a direct attack on the seat of the fire.

**555-35.6.7 DIRECT ATTACK FROM ACCESS.** If high temperature denies access to the fire space, water may be applied to the seat of the fire from the access. See Figure 555-35-6.

a. The nozzleman may use the bulkhead at the access as a shield. If the seat of the fire can be reached by a hose stream, then the nozzle should be set to straight stream or narrow angle fog directed at the seat of the fire. A smoke curtain can also be hung at the door to shield the attack team.

IF HIGH TEMPERATURE  
DENIES ACCESS  
ATTACK FROM AN ACCESS WHEN FIRE CAN  
BE REACHED WITH HOSE STREAM



If able to reach fire with hose stream, attack from the access.

- Keep low and try to keep dry.
- Use narrow fog/straight stream. Hit the seat of the fire.
- Fog attack if needed.
- When conditions permit, advance into fire space.

**Optional: Use smoke curtain to protect nozzleman from heat and steam**

Figure 555-35-6. Fire Attack – Attack from an Access

b. If the seat of the fire cannot be extinguished by direct attack, a fog attack may be used to reduce the fire space temperatures and knock down flaming combustion. See paragraph 555-35.6.6.

c. When conditions permit, the attack team should advance into the immediate fire area and apply water directly onto the seat of the fire.

**555-35.6.8 BACKUP HOSE.** The decision to layout, charge, man, or bring the back-up hose to the immediate scene of the fire shall be made by the scene leader considering the following:

- a. The need for a coordinated second attack line working the fire.
- b. The need to control burning combustion gases in the overhead.
- c. The need to protect combustible materials exposed to heat from the fire.
- d. The need to provide protection for, or aid in the rescue of, the initial attack team in the event of a rapid spread of fire or explosion.
- e. The need for back-up in the event of a ruptured hose, or some other unexpected event.

If the back-up hose is laid out, position it so that it does not add unnecessarily to the congestion in the fire space or the adjoining space.

**555-35.6.9 MULTIPLE HOSE COORDINATION.** Special coordination is required when operating with multiple hose lines. Each hose should be operated as an attack hose, or alternatively as a back up hose if needed. It is the duty of the attack team leader to coordinate this effort in a safe and effective manner and to report status and progress to, and receive direction from, the scene leader. Each manned hose must strike a balance between greater mobility and greater risk brought on by separation. Firefighters must ensure they do not force flames and heat onto another manned hose. This is of particular concern when firefighters attack from different directions. When assigned by the scene leader, the attack team leader (NFTI Operator) should be in a position where he can best see the fire, observe the operation of the nozzle and urge the nozzleman forward at the proper time. He should ensure the nozzle is being operated properly. The repair party leader keeps track of OBA operating times, and requests reliefs for nozzlemen and hosemen. The repair party leader ensures that firefighters are available for relief. When at general quarters, the damage control party will form fresh fire teams and rotate personnel and equipment to reduce fatigue and heat stress.

**555-35.6.10 RELIEFS.** To compensate for fatigue and heat strain during a prolonged attack (which may occur in port) additional personnel should be provided to relieve hose teams. In a high heat stress environment, personnel endurance in a firefighter's ensemble may be limited to less than 10 minutes. The maximum time for personnel to function in a firefighter's ensemble is 30 minutes. If personnel are relieved before becoming completely exhausted, they may be able to return to firefighting duties after a brief rest.

- a. The primary objective of orderly reliefs is to maintain an uninterrupted attack on the fire. A secondary objective is to relieve personnel frequently enough to avoid losing personnel to heat strain for the duration of the firefighting effort. The casualty coordinator, scene leader, and attack team leader plan ahead and work together to provide for and rotate teams and individuals as dictated by the situation.
- b. In severe situations, the attack team leader probably will not give any advance notice before being forced to evacuate. The scene leader and casualty coordinator must anticipate the need for reliefs, without communication from the attack team leader, and have relief personnel don their FFE shortly before they are needed on scene.
- c. The attack team may be relieved as a unit, or individuals may be relieved one at a time. A procedure that works well in many situations is to relieve attack team personnel one at a time, keeping the attack hose functional

throughout the relieving process. This maintains an uninterrupted attack on the fire and eliminates the extra work and delay from backing a hose out of the space or bringing a hose into the space. It is often helpful for the attack team leader to assume temporary control of the nozzle to reduce confusion when the nozzleman is being relieved.

d. Using personnel being relieved to carry messages and status information from the team leader to the scene leader may help maintain good communications.

e. Reliefs shall be managed by a single point of contact identified by the casualty coordinator.

f. Standby or relief personnel should take measures to minimize heat strain experienced while waiting to enter the fire area.

1. Personnel standing by outside the firefighting area should don the firefighter's ensemble only to the waist until called to relieve personnel on scene.

2. When staged on weather decks in port, standby personnel should stay out of the sun and be kept cool.

3. Drinking water prior to donning the ensemble and breathing apparatus may increase endurance on the scene.

4. In the firefighting area, the scene leader should station standby personnel in areas as cool as practical.

g. Relieved crews should leave the scene for an adequate break to reduce their core (inner) body temperature before reassignment to duty. Personnel returning from the scene will need rehabilitation from heat strain. The rehabilitation area may be the same area in which standby personnel are staged. The following guidance applies to rehabilitating personnel returning from the fire area:

1. Be prepared to help them remove the firefighter's ensemble.

2. When staged on weather decks in port, keep personnel out of the sun.

3. Put them in a cool area exposed to a breeze, or provide a fan to move air.

4. Moisten them down with a wet, cool towel over their head, on their face, wrists, etc.

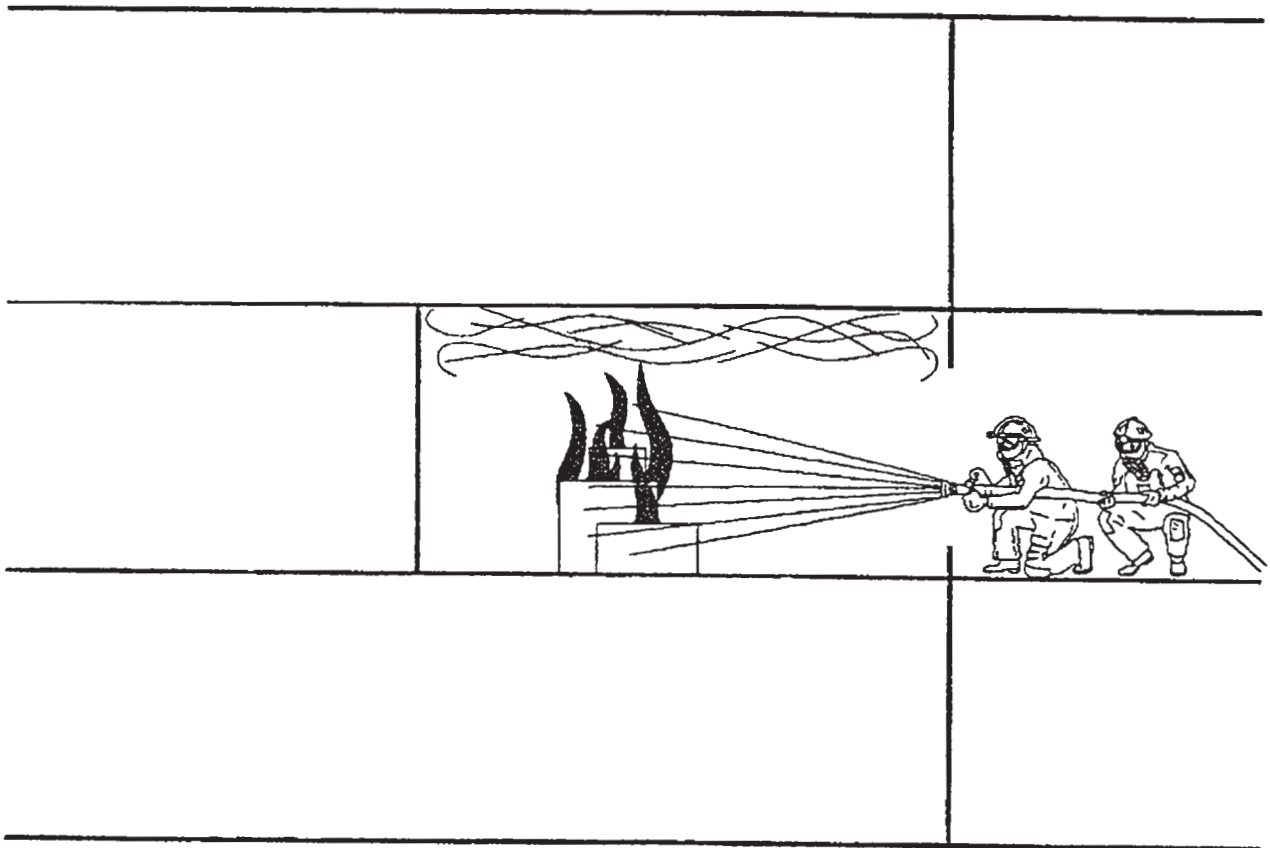
5. Ensure that each person drinks about 1/2 to 1 liter (about 1/2 to 1 quart) of cold water, such as melted ice water, or other fluid meant to replace bodily fluids.

6. Monitor personnel during the recovery period for signs of heat exhaustion or other problems.

**555-35.6.11 WITHDRAWAL.** Hose team withdrawal will normally consist of backing out the hose in the reverse order of entry. However, if the attack team leader determines that the hose must be abandoned in place due to an immediate threat to life and the exit is not visible, firefighters should follow the hose by feel back to the exit. It is very easy for even the most experienced personnel to become lost in smoke.

**555-35.6.12 CHEMLIGHTS.** Portable chemical light (chemlight) sticks can be useful under smoky or dark conditions for marking key damage control party members, EAB manifolds, stairs, ladders and equipment. The light from a chemlight penetrates smoke very well, which not only helps locate the marked item but also helps orient you to your surroundings. A chemlight should be pre-staged on each emergency air breathing (EAB) manifold. The pre-staged chemlight should be left in its package, torn open at the end for attachment, to allow inspection of expiration date and easy recognition of used lights. A chemlight should be attached to key personnel, such as the man in charge at the scene, the NFTI operator, nozzleman, and injured personnel to make them distinguishable in smoke. Chemlights may leak in an extremely hot environment, but are not toxic.

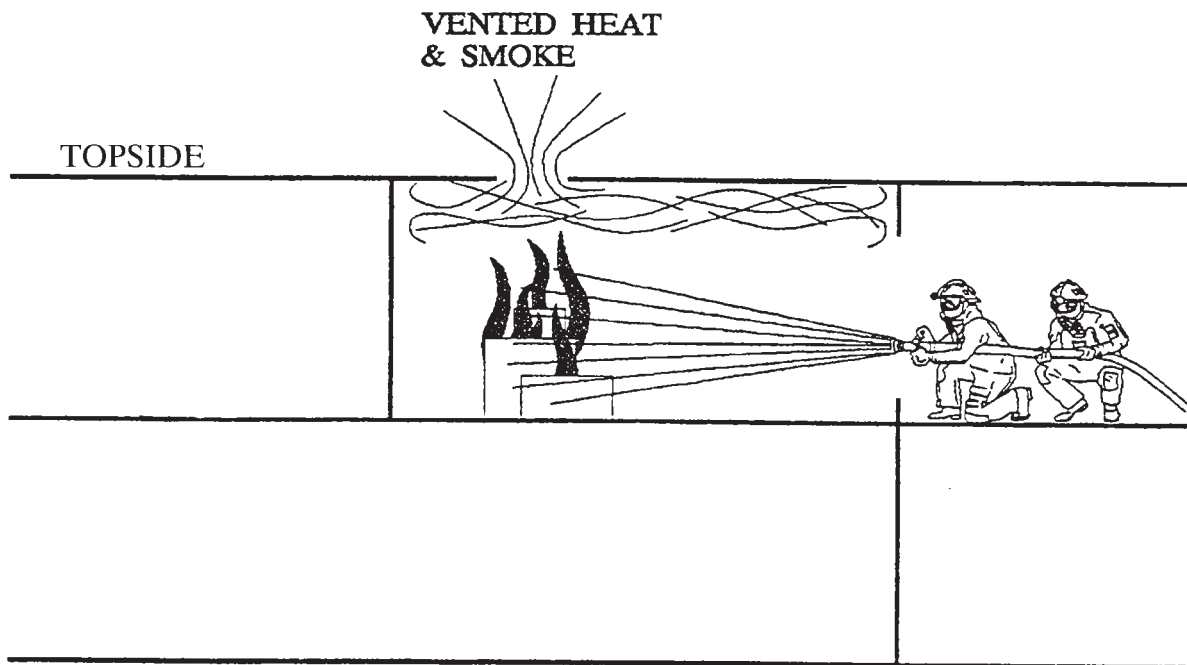
**IF HIGH TEMPERATURE  
DENIES ACCESS  
CONDUCT INDIRECT ATTACK**



- To cool fire space, apply water fog into the fire compartment from a cracked open access. See paragraph 555-35.7.
- Follow immediately with direct attack. See figure 555-35-3.

Figure 555-35-7. Indirect Attack - In Port

IF HIGH TEMPERATURE  
DENIES ACCESS  
VENT HEAT TO WEATHER  
AND CONDUCT INDIRECT ATTACK



- Open topside hatch over fire compartment
- To cool fire compartment, apply water fog into the fire space from a cracked open access. See paragraph 555-35.7.
- Follow immediately with direct attack. See figure 555-35-3.

Figure 555-35-8. Indirect Attack with Venting in Port

**555-35.7 INDIRECT ATTACK**

**555-35.7.1** An indirect attack is the application of water fog into the fire compartment through a topside hatch or watertight door (Figure 555-35-7 or Figure 555-35-8). When heat or other conditions deny access to the fire compartment, an indirect attack may improve conditions to permit reentry for a direct attack. The following guidance applies only to attacking a class A fire while in port or in an industrial availability.

a. The basic technique for an indirect attack is to apply water fog to the fire compartment for some time, then stop the water flow, and then assess conditions in the fire space through a cracked open access. Conditions in the fire space can be assessed by using a NFTI to monitor temperatures or by the severity of heat and steam that blow out of the access to the fire space. If it appears that the space can be reentered and the direct attack team is ready to enter the space, immediately reenter the space and conduct the direct attack. Otherwise, continue with the cycle of indirect attack and assessing conditions until the space can be reentered. The attack team leader should adjust water fog application times and indirect attack points based on his assessment of conditions.

b. Do not conduct an indirect attack when people are in the fire space or when a direct attack is underway.

c. Isolate the fire space during the indirect attack. Keep the fire space isolated between indirect attacks.

d. If the location of the fire is known, conduct the indirect attack from a point that allows application of water to the fire. Obstructions around the fire should be considered.

e. If the fire space is large, it may be desirable to conduct simultaneous indirect attacks from multiple points. If the fire is spread out or its location is uncertain, separate the attack points to maximize coverage of the fire space by water spray. Communications between attack teams is important.

f. Apply water fog continuously for approximately five to ten minutes for the initial attack.

g. Since the indirect attack may not extinguish the fire, temperatures in the fire compartment may begin to increase after the indirect attack is stopped. After the final indirect attack, enter the fire compartment as quickly as practical, within one or two minutes. If practical, use the final indirect attack to cool the access route inside the fire compartment.

h. When attacking through an existing access, crack open the door or scuttle just enough to admit the nozzle. It may be difficult to contain the steam blowing out of the access using a smoke curtain or smoke blanket. Once the nozzle is in place, the attack team should position themselves as far away from the access as they can to reduce their exposure to steam, while still maintaining control of the nozzle. When attacking through a scuttle, one method is to put the scuttle down to help hold the hose (and restrict the steam flow out of the fire space) while the nozzleman directs the nozzle by holding the hose about four to six feet back from the nozzle. Only a few inches of hose should extend beyond the scuttle into the fire space.

i. Maintain the water spray until steam blowing from the access forces the firefighters back, or until water has been applied for approximately five to ten minutes. If steam forces the firefighters back before the indirect attack is completed, close the access and retreat. After waiting one or two minutes, crack open the access to assess conditions in the fire space. Based on the conditions found, either reenter the fire space and conduct the direct attack or conduct another indirect attack.

**555-35.8 VENTILATION CONSIDERATIONS DURING THE FIRE**

**555-35.8.1** If the fire has gained headway, heat and smoke can quickly make the fire scene untenable, restricting access for firefighting, and preventing personnel from locating the burning material.

**555-35.8.2** Normally, the fire should be out and a reflash watch stationed before preparations for emergency ventilation of the affected compartment are commenced. In some cases, however, the presence of heavy smoke and heat in the compartment may dictate venting the heat and smoke overboard to assist the fire team in combatting the fire.



**555-35.8.3** The decision to ventilate the burning compartment, using the ship's ventilation system, before the fire is out and a reflash watch is set should be made by the Commanding Officer. Key factors to consider in the decision to ventilate prior to fire extinguishment include the following:

- a. Specific recommendations of the OOD, Casualty Coordinator, and the scene leader.
- b. The tactical situation with respect to ventilating, snorkeling and surfacing.
- c. The ability to maintain ship control functions, mission capability and reactor containment.
- d. The negative factor of providing fresh air to the fire.
- e. The nature of the existing fire with regard to size, location and fuel source(s).

When consideration of these factors has resulted in a decision by the Commanding Officer to ventilate, the choice must be made between the various options of normal or emergency ventilation by the blower, diesel or both.

**555-35.8.4** When surfaced in calm seas, or when in port the added option of opening a hatch may vent sufficient heat and smoke to facilitate the fire attack. The choice of how to ventilate is critical to the success of the effort.

**555-35.8.5** If smoke or heat in spaces outside the burning space is impeding the attack on the fire, then venting or ventilating of these spaces can improve the environment for firefighters.

### **555-35.9 SEARCH AND RESCUE**

**555-35.9.1** Successful rescue of trapped personnel requires a systematic approach. The task is difficult and dangerous. Factors to consider when organizing and directing a search are:

- a. Searchers should wear breathing apparatus. A hose line should be available in the immediate area to protect the searchers and their avenues of escape.
- b. Searchers should use some method of indicating where they have searched so that other teams will not repeat their efforts. Colored tags or chemlights fastened to doors are two possible methods.
- c. It should not be assumed all personnel have been located until the fire is out, the area has been ventilated, and the area has been searched a second time.
- d. The NFTI can be used to detect body heat against a cooler background, and is very useful in searches. Searchers should carry spare EAB's and be trained in their use and how to place an EAB on personnel overcome by smoke.

### **555-35.10 FIRE OVERHAUL**

**555-35.10.1 FINAL EXTINGUISHMENT.** Overhaul of a fire is an examination and cleanup operation. It includes finding and extinguishing hidden fire, and determining whether the fire has extended to other parts of the compartment. It is usually best to start at the perimeter of the fire and work toward the fire origin. Check for all possible areas of fire spread, including behind electrical cabinets and habitability bulkhead sheathing, in thermal or acoustic insulation, and in concealed spaces. Clues to concealed fires are smoke creeping out of openings, and bulkheads hot to the touch. Fire overhaul should commence after the fire is out and the reflash watch is set. A search for hot spots with the NFTI should be conducted after the fire is out, and before commencing preparations for compartment desmoking. These clues can be used to trace hidden fire. If necessary, pull down material, bulkhead sheathing, false overheads, etc. to discover and extinguish all remaining fire.

**555-35.10.2 POST-FIRE DESMOKING.** After a compartment fire is out, combustible gases may be present. For all classes of fire, carbon monoxide will be the predominant gas. Although combustible, substantial quantities of carbon monoxide must be generated to reach the flammable range (12.5 percent is the lower flammable limit). Heavy carbon monoxide production which does not ignite is typically associated with a confined fire that has smoldered for several hours.

**555–35.10.2.1** For a compartment which has experienced a class A or class C fire, after the fire is out (visible open flaming has been extinguished), desmoking to support fire overhaul can proceed with minimal risk. There are no recorded incidents where a post–fire atmosphere involving class A or class C compartment fires has ignited as a result of operating installed ship’s ventilation systems.

**555–35.10.2.2** If the fire involved class B material, the presence of flammable liquids can create a flammable atmosphere in a post–fire environment. Therefore desmoking of spaces cannot commence until the fire is totally extinguished (deep seated burning completely overhauled) and fuel surfaces cooled or made safe.

**555–35.10.2.3** The goal in desmoking is to replace 95 percent of the smoke–laden air with fresh air. This will require approximately 4 complete space volume changes in a compartment. This can be achieved with a fully operable ventilation system. Ship’s ventilation procedures must be consulted in order to calculate minimum ventilation times for all spaces.

### **555–35.10.3 POST–FIRE ATMOSPHERIC TESTING ON SUBMARINES**

**555–35.10.3.1 General.** The purpose of post–fire atmospheric testing is to certify the atmosphere as safe, which includes safe for breathing without respiratory protection. This guidance is applicable to all classes of fire.

#### **WARNING**

Atmospheric test personnel shall wear breathing apparatus until testing is completed and the atmosphere is certified as safe.

#### **WARNING**

If an unsatisfactory combustible gas reading (at or above 10 percent LEL) is obtained, there is a risk of an explosion. The space shall be immediately evacuated and additional desmoking conducted.

After the fire is out, the fire has been overhauled, and the compartment has been desmoked, a series of tests shall be conducted in the compartment for oxygen, combustible gases, and toxic gases concurrently or in that order. All spaces should be desmoked before atmospheric testing is started because oxygen analyzers do not operate reliably if the sensor is exposed to excessive moisture or is in contact with post–fire atmospheric particulates. Also, combustible gas analyzers will not operate reliably in oxygen deficient atmospheres; therefore an acceptable oxygen concentration is required before the combustible gas measurement can be considered for acceptance. If a particular location fails a test, only that location must be retested for the failed test. Additional ventilation and retesting is required only if initial test results are unsatisfactory. For a satisfactory test series:

a. Oxygen concentrations shall be between 17 percent and 21 percent by volume as specified in NAVSEA S9510–AB–ATM–010(U), **Nuclear Powered Submarine Atmosphere Control Manual**

b. Combustible gas concentrations shall be less than 10 percent of the lower explosive limit (LEL), and

c. Toxic gas concentrations shall be acceptable as specified in NAVSEA S9510–AB–ATM–010(U), **Nuclear Powered Submarine Atmosphere Control Manual**. For a class A or C fire, the toxic gas series shall include carbon monoxide (CO) and carbon dioxide (CO<sub>2</sub>). The toxic gas series shall include hydrogen chloride (HCl) and hydrogen cyanide (HCN) when material which produce these gases have been involved in the fire. Hydrogen chloride is produced when polyvinyl chloride electric cable jacketing is burned. Hydrogen cyanide is produced in Otto Fuel fires, and when vinyl nitrile rubber submarine hull insulation or chilled water piping insulation is burned. Other toxic gases should be tested for when their presence is suspected. For a class B fire, an additional toxic gas test for hydrocarbons is required. Toxic gas concentrations on submarines shall be below the exposure limit as specified in NAVSEA S9510–AB–ATM–010(U). See Table 555–35–1. Use of 90–day exposure limits is recommended.

#### **WARNING**

If the 1–hour (emergency) or 24 hour exposure limit is used to permit removal of emergency air breathing (EAB) masks, duration of crew exposure should not exceed the designated period of time.

**WARNING**

When more than one toxic gas is present, the cumulative effects of the gases may be hazardous even though the concentration of each gas is below the exposure limit. See **NSTM 074, Volume 3, Gas Free Engineering**, paragraph 074-20.8, for information on evaluating cumulative toxic gas effects.

**CAUTION**

Do not use the submarine central atmosphere monitoring system (CAMS) until it has been determined there are no acid gases, such as hydrogen chloride, present. Acid gases will damage the CAMS. The CAMS may be used for post-fire atmospheric testing when it is ensured that no acid gases are present.

**555-35.10.3.2 Locations for Atmospheric Testing.** Test locations are determined by the Gas Free Engineer, or other authorized personnel, based on conditions. The following guidance is provided to aid in determining the appropriate locations. However, additional test locations may be needed depending on specific conditions. This guidance does not replace the good judgement of the knowledgeable test personnel.

**555-35.10.3.2.1 General.** During a fire, combustible or toxic gases spread with smoke and heat. Fire gases initially rise due to their buoyancy from being hotter than surrounding air. However, as fire gases cool and mix with surrounding air, particularly outside the fire space, they spread through the ship with normal air currents. Generally, atmospheric testing should be conducted in the fire space and at locations high, center, and low in the affected water-tight compartment since some gases are lighter or heavier than air and may accumulate high or low. The rate of ventilation air-changes will vary for different ship locations. Extra ventilation and testing may be required for locations or spaces which have a low ventilation rate as they may maintain hazardous concentrations of flammable or toxic gases. Residual light smoke is a sign of a poorly ventilated location and indicates the need for additional ventilation and testing.

**Table 555-35-1. TOXIC GAS EXPOSURE LIMITS FROM THE NUCLEAR POWERED SUBMARINE  
ATMOSPHERE CONTROL MANUAL**

Chemical Name	90-Day Limit	24-Hour Limit	1-Hour Limit	Other Limits
Carbon monoxide (CO)	20 ppm	50 ppm	400 ppm	
Carbon dioxide (CO <sub>2</sub> )	0.5 percent	4 percent	4 percent	
Hydrocarbons,	10 mg/m <sup>3</sup>			
(a) total aromatics (less benzene)	60 mg/m <sup>3</sup>			
(b) total aliphatics (less methane)				
Hydrogen chloride (HCl) e.g. hydrochloric acid	0.5 ppm	20 ppm	20 ppm	4.7 ppm STEL (1)
Hydrogen cyanide (HCN) e.g. hydrocyanic acid				
Note:				
(1) HCN value is a 15-minute short term exposure limit (STEL) taken from <b>NSTM Chapter 074, Volume 3, Appendix B</b> . The Nuclear Powered Submarine Atmosphere Control Manual currently lists no exposure limit for HCN				

**555-35.10.3.2.2 Small fires.** When a small fire (such as a waste can or localized electrical fire) is extinguished quickly, there is little fire damage and light smoke which does not spread beyond the fire space. In this case, the spread of toxic gases is probably minimal. Therefore, a single test series at one location in the fire space may be

adequate and overboard desmoking may not be necessary. The need for testing will require judgement by the man-in-charge.

**555-35.10.3.2.3** Growing fires. In the event of a growing fire where smoke spreads beyond the original fire space, a single test location is not sufficient even when the ventilation system remains undamaged. After desmoking, an atmospheric test series should be conducted in at least one location in fire space (e.g. fire area) and at locations high, center, and low in the water-tight compartment. At least one test series should be conducted on each level. This would result in four test locations in a three-level compartment. Additional locations should be tested where poor ventilation and gas accumulation is suspected.

**555-35.10.3.2.4** Large fires. When a large fire damages the ventilation system or extensive partially-burnt material remains, including the result of a class B fire, extensive post-fire atmospheric testing will probably be required. A damaged ventilation system will result in poorer air replacement and a greater likelihood of local pockets of smoke and gases. Large surfaces of partially burnt material or unburnt flammable liquids will result in continued formation of hazardous gases and vapors after the fire. Locations for atmospheric testing should include the four corners and center of each level. In areas where low ventilation and gas accumulation are suspected, additional ventilation and testing should be conducted.

**555-35.10.4 DEWATER.** In determining the number of hose lines to be used, the firefighter should be guided by the extent and intensity of the fire. Every gallon of water released affects the submarine's trim. Dewatering may be required simultaneously with firefighting.

**555-35.10.5 POST-FIRE INVESTIGATION.** After fire overhaul, the fire should be investigated to determine the point of origin, combustibles involved, path of fire spread, ignition source, and significant events in the growth and eventual extinguishment of the fire. Starting from the point of farthest fire spread, burn patterns will usually extend back to the area of origin. Efforts should be directed toward recreating the conditions that caused the fire, and identifying any changes in design or procedures that could have prevented the fire or lessened its spread and intensity. These changes are very helpful to ship designers and operators. Photographs, material samples, metallurgical samples, and failed equipment assist in reconstructing a fire history. If there is a major fire which involves significant damage or loss of life, a NAVSEA technical expertise team is available to investigate fires to develop lessons learned from a ship design and a material standpoint.

## **555-35.11 ADDITIONAL CONSIDERATIONS FOR LARGE FIRES**

**555-35.11.1** Large fires require overall coordination which can not be developed from routine drills. Because multiple fire teams will be involved, central control is essential. Multiple hoses should normally work together on the same side of the fire. Attacking the fire from opposing directions can lead to situations where one manned hose forces heat and flames onto another. Therefore, where ship configuration only allows multiple hose attack from opposing directions each manned hose should be assigned clear responsibilities which avoid this danger. The scene leader must coordinate additional hoseline attacks from opposite directions, fore and aft, and above as fire spreads. In the event of a major fire, all fuel or lube oil pumping and hydraulic system operations that do not affect critical functions or ship safety, shall be secured. Large fires may require long hose lengths to reach the fire. However, firefighters should be aware that a 1-1/2 inch hose with a length longer than 200 feet has a severe pressure loss (25 psi per 100 ft, with a flow of 95 gpm).

**555-35.11.2** Smoke and heat from a severe fire can cause mission interruption, create a large demand for breathing apparatus, delay fire fighters in locating the fire and present a life threatening environment. As discussed in paragraph 555-35.8, consideration must be given to ventilate the burning compartment using the ship's ventilation system or by opening a topside hatch in the burning compartment for the purpose of releasing heat and smoke trapped inside the ship. When trapped smoke and heated gases have been removed, the resultant temperature reduction and smoke removal may permit fire teams to advance toward the fire.

**555-35.11.3** If smoke or heat in spaces outside the burning compartment is impeding the attack on the fire, then ventilating or venting of these spaces can improve the environment for fire fighters.

**555-35.11.4** Intense heat makes fire fighting efforts extremely difficult and may drive personnel away from the fire area. The following techniques are helpful in fighting larger fires:

- a. In the event of lower level fires, untenable conditions are first reached in upper levels. Casualty control efforts are more likely to succeed on lower levels because of the cooler temperatures and better visibility.
- b. Crouching and duck walking or crawling low when approaching a well developed fire may assist fire fighting personnel in maintaining visibility and reducing heat stress.
- c. The damage control party must be properly clothed. For any fire beyond the incipient stage, some personnel protection equipment will be required. For fully developed fires, the firefighter's ensemble (FFE) provides superior protection to that of work clothing. The FFE should be worn by the fire teams fighting a large fire.
- d. Have dressed out relief fire teams ready so that an aggressive attack can continue without pause.
- e. For a longer nozzle reach, use the narrow angle fog pattern setting, or a deflected solid stream to continue any feasible attack.
- f. Ensure Casualty Coordinator is aware of large water demands to assure an uninterrupted water supply as well as effects on ship's trim.

#### **555-35.12 TYPICAL DIFFICULTIES IN FIREFIGHTING**

**555-35.12.1 FIREFIGHTER FATIGUE.** Extended firefighting activity stresses a firefighter physically and mentally. Nozzlemen and others in the fire area may have to be relieved frequently. An exhausted firefighter is a danger to his shipmates as well as to himself. In training exercises, heat stress must be considered. Personnel should not be fully outfitted in firefighter's ensembles and breathing apparatus for periods longer than about 30 minutes before being relieved.

**555-35.12.2 LOSS OF TRIM SYSTEM (FIREMAIN) PRESSURE.** The crew must determine the cause of pressure loss and then quickly restore pressure to the system. In some cases, realignment of valves may be sufficient. In other cases, depending on the problem and pressurization method, more extensive system operations may be necessary. The BCP operator should coordinate the operations keeping the scene leader, the casualty coordinator and diving officer informed as applicable.

**555-35.12.3 SPACE ENTRY.** Whether attacking from the doorway or entering the space, remain low at all times to take advantage of the cooler air and greater visibility near the deck.

**555-35.12.4 COMMUNICATION.** Members of the fire party give information to each other by normal voice communications. Voice amplifiers, if available, are provided to personnel in the fire party. The scene leader uses the 4MC and soundpowered phones to pass information and requests to the Casualty Coordinator. The Casualty Coordinator, or the OOD passes key information over the 1MC to keep all hands informed of the status of the firefighting effort and the ship's atmosphere.

**555-35.12.4.1** Fire team leader will communicate as necessary with the scene leader using best available means.

**555-35.12.4.2** In a severe environment, fire team members will be able to focus only on breathing, survival and the immediate task before them. While attacking a severe fire or working under stress, the fire team leader cannot use the available means of communication effectively. Under severe conditions, the scene leader must initiate actions as necessary without depending on communication from the fire team. If the scene leader needs information about the attack, he should send a messenger to the fire team.

**555-35.12.4.3** Communication between Damage Control Central, the scene leader, and nozzlemen is often disrupted. Where installed communication is taken out of service due to fire, messengers should be used.

**555-35.12.4.4** A voice amplifier is a device which attaches to a firefighter's OBA mask and projects his voice, allowing him to communicate easier with other personnel. Without a voice amplifier, a firefighter wearing an OBA must shout loudly in order to be heard through his face mask.





## SECTION 36. SPECIAL FIRE SCENARIOS

### 555-36.1 INTRODUCTION

**555-36.1.1** This section discusses special fire situations and hazards for a variety of ship spaces and some useful techniques for firefighting.

### 555-36.2 ELECTRICAL FIRES

**555-36.2.1 GENERAL.** An energized electrical fire is a class C fire. See paragraph 555-31.6.4. The most effective tactic is to deenergize and handle the fire as a class A fire. A class C fire is attacked at prescribed distances using nonconductive agents such as CO<sub>2</sub>, or water fog. When the fire is not deep seated, clean agents that pose no clean up problems such as CO<sub>2</sub> are preferred. Initial attack should be with a portable CO<sub>2</sub> extinguisher. Although not as desirable, freshwater, seawater, or AFFF (if available) can be used to safely fight a class C fire, provided a fog pattern is maintained.

<b>WARNING</b>
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To avoid shock hazards, do not use straight stream water pattern on an energized electric source. Maintain a minimum vari-nozzle standoff distance of four feet when applying water fog to an energized electric source.

**555-36.2.1.1** Electrical current will follow a straight stream, but will not be conducted between the droplets in a narrow angle fog pattern. Narrow angle fog patterns may be safely directed against energized equipment or cables carrying up to 4160 volts, if the nozzle is kept at least four feet from the energized source. Preset the vari-nozzle to narrow angle fog pattern before attacking the fire. Do not use straight stream because it provides an electrical path back to the nozzle and is, therefore, a shock hazard.

**555-36.2.1.2** PKP should not be used in installations where relays and delicate electrical contacts are present. Where moisture is present, PKP may combine with it to corrode or stain surfaces on which it settles. It will leave a residue that may be hard to clean up.

**555-36.2.1.3** For class C fires which generate high heat through plasma arc or fireballs, and ignite nearby materials, isolate the source components electrically while conducting an initial attack with portable extinguishers. Simultaneously, rig hoselines and fight the fire with a narrow angle fog pattern as soon as possible.

**555-36.2.1.4** In the event of a class C electrical generator fire, extinguishing agent may be applied with hand held equipment as soon as the generator is isolated from the switchboard and the prime mover is secured. It is permissible to fight a class C generator fire as soon as the generator is isolated and before it stops turning.

**555-36.2.2 PROCEDURE FOR FIGHTING AN ELECTRICAL EQUIPMENT FIRE.** This procedure applies to all energized electrical equipment, including but not limited to switchboards, automatic bus transfers (ABT's), manual bus transfers (MBT's), panels, cabinets and motor controllers.

1. Secure electrical power to the affected equipment. In most cases, burning material in the equipment will self-extinguish after power is secured.

2. While power is being secured, extinguish any fire that spreads to materials beyond the equipment. Electrical equipment fires generally present a low risk of fire spread beyond the equipment. Use of CO<sub>2</sub> fire extinguishers is the preferred method for attacking an electrical equipment fire or a small class A (Alpha) fire in the vicinity of the electrical equipment. While attacking an electrical fire, keep the fire extinguisher outside the equipment. Do not make physical contact with any component on or within the equipment. If necessary to bring the fire under control, water fog may be used. Paragraph 555-36.2.1 allows the use of water fog, either seawater

or fresh water, while keeping the nozzle at least 4 feet away from the energized equipment. Preset a fog pattern on the vari-nozzle before attacking the fire. Do not use a Navy All Purpose Nozzle fog applicator or a straight stream pattern due to the electrical shock hazard.

3. After power is secured, stand by while the equipment cools. If residual burning appears to continue in the equipment, CO<sub>2</sub> may be applied through vent louvers, if applicable. Emergency access into the equipment is usually not warranted and puts personnel at risk of burn injury. However, such access may be necessary to extinguish a fire that is sustained and threatens to spread beyond the equipment.

4. When the area is cool enough to access without risk of burn injury, enter in accordance with requirements of **NSTM Chapter 300** for working on damaged equipment (tag out and verify all circuits are deenergized). Determine the fire is out, conduct overhaul to assure the fire is completely extinguished, and affect repair. The fire in the equipment cannot be deemed completely out until the equipment is accessed and visually inspected. However, the compartment may be desmoked prior to accessing the equipment if there are no visible flames involving material outside the cabinet.

**555-36.2.2.1 Emergency Access.** In unusual, emergency cases, the man in charge at the scene may determine that the equipment needs to be accessed while still energized in order to secure power via internal fuses or to extinguish a fire that is sustained and threatens to spread beyond the equipment. Typically, the small amount of damage reduction gained by entry to extinguish the fire does not warrant the risk to personnel when entering an energized equipment. The man in charge at the scene shall determine if it is necessary to remove the equipment access (cover). He shall then determine what appropriate action needs to be taken and inform the space supervisor or EOOW after the action is taken. Commanding Officers' permission is not required when the man in charge judges that emergency action is needed. The following procedure shall be followed:

1. Don rubber gloves and remove the equipment access (cover). Insulated tools are not required, but are recommended if readily available. The investigator should not reach into or break the "plane" of the electrical equipment enclosure. For equipment with possibly energized switches, meters, relays or other components mounted on the cover, the "plane" should be adjusted to preclude entry into the area created by the arc of the cover as it is swung open. After the fire is extinguished and verified out, the equipment should be promptly closed, and personnel should use the safety precautions in **NSTM Chapter 300** prior to commencing further investigation.

2. While extinguishing the fire, keep the fire extinguisher nozzle outside of the equipment enclosure. Do not make physical contact with any component on or inside the equipment.

### **555-36.3 DEEP FAT FRYER FIRE**

**555-36.3.1** Fires in deep fat fryers generally result from overheating of cooking oils and fats, and subsequent self-ignition of the fat. Fires involving cooking oils and fats are class B fires. Most fires have occurred while the fryers were operating unattended, either through failure of personnel to remain at the units when operating or through failure to properly secure the units after use. Factors contributing to the intensity and spread of the fires include delayed discovery of fire, grease laden ducts and hoods, and splashing and overflow of burning fat by straight stream nozzle pattern discharged directly onto the fat liquid surface.

**555-36.3.2** At the first sign of overheating (white smoke), shut off the fryer and place the cover securely on the fryer. Leave the cover on the fryer for at least five minutes. This will allow the hot cooking oil to cool down enough to prevent it from igniting.

**555-36.3.3** The galley is provided with an aqueous potassium carbonate (APC) system, Figure 555-32-1. In the event of fire in the fryer, sound the alarm, secure power to the fryer, and actuate the APC system. Concurrently, operate the range exhaust hood damper control to close the damper.

**555-36.3.4** Backup methods for extinguishing deep fat fryer fires are used only in the event the APC system fails to operate or extinguish the fire. Two methods are available and should be used in order of priority listed. Method #1 may be successfully used without personnel protection if the fire is detected early and if the space is tenable.

**WARNING**

Unprotected personnel should stay at least four feet from the deep fat fryer when discharging agent to avoid personnel burns from the splatter of hot cooking oil.

Method #2 requires personnel protection. It may be used when the fire is confined to the fryer. It is the preferred method where the fire has spread into the space. In all cases, for any of these methods to succeed, the power to the fryer must be secured.

**555–36.3.4.1** Method #1 – One person deploys AFFF portable 2–1/2 gallon extinguisher to the galley.

**WARNING**

Do not direct AFFF stream directly into the cooking oil. Plunging AFFF into the cooking oil can result in immediate boiling of the AFFF. Violent boiling may result in hot cooking oil being thrown out of the fryer.

- a. From a distance of at least four feet to avoid hot splatter, apply AFFF to the back wall of the fryer allowing AFFF to flow onto the burning cooking oil surface. This technique does not disrupt the cooking oil. Lobbing the AFFF stream gently onto the cooking oil can also be effective but has some risk of plunging the AFFF into the cooking oil. Apply AFFF until the fire is out and a foam layer is developed (approximately 10 seconds). The initial range of the AFFF extinguisher is 15 feet, which decreases during discharge.
- b. While applying AFFF, a second person rigs a 1–1/2 inch hose with vari–nozzle and brings to the scene as a backup.
- c. Look in and around the fryer to be sure the fire is out.
- d. If the cooking oil reignites, again apply AFFF until the fire is out (approximately 10 seconds).
- e. Check range exhaust hood and exhaust ductwork for signs of fire and initiate firefighting in these areas if necessary.

**555–36.3.4.2** Method #2 (Called Method #3 in **NSTM Chapter 555, Volume 1** for surface ships) – If a portable AFFF extinguisher is not available, or the fire has spread beyond the fryer and into the space, the fire can be extinguished by personnel wearing protective clothing and breathing apparatus and using water from a vari–nozzle set on a narrow angle fog pattern. Apply narrow angle water fog on the burning cooking oil surface for approximately one minute, sweeping gently from side to side, to extinguish the fire, cool the cooking oil and prevent reflash.

**WARNING**

The cooking oil fire may have a large flare–up on the initial application of water fog. This flare–up lasts approximately three seconds followed by fire extinguishment.

An uncontrolled deep fat fryer fire can spread rapidly from the fryer into the range exhaust hood and exhaust ventilation ductwork as well as into the space. An attack with only water fog should not be delayed in order to bring portable fire extinguishers to the scene.

**555–36.3.5** A deep fat fryer fire produces large volumes of hot irritating smoke. Although the initial response can be made by unprotected personnel, they may be forced to withdraw due to untenable conditions. Breathing protection such as OBA's or EAB's should be used when available, to replace initial response by unprotected personnel.

**555–36.4 HULL INSULATION FIRE**

**555–36.4.1 GENERAL.** Fires involving hull insulation are dangerous because:

- a. The flammability of the material permits rapid flame spread up frame bays.
- b. Large volumes of choking black smoke are generated.
- c. Firefighting access is difficult to achieve because of concealed spaces next to the hull and outboard areas behind habitability bulkhead sheathing.

#### 555-36.4.2 INSULATING MATERIALS

- a. **Vinyl nitrile Rubber.** Vinyl nitrile rubber, Mil-P-15280, is used throughout submarine interiors as thermal insulation on the hull and as an anti-sweat barrier on pipes, ducts, and other cold surfaces. This insulation will burn vigorously and flame spread across the surface is rapid. Any oil film on the insulation or oil soaked into the insulation makes the fire problem worse. Insulation smoke is extremely dense and black, is highly acidic, and will interfere with vision and breathing by irritating the eyes, mouth, nose, and throat. The acidic residue will continue to damage electronic components after the fire is out.
- b. **Transmission Loss Treatment.** Transmission Loss Treatment (TLT) is a composite material consisting of fibrous glass felt, vapor barrier compound, and fibrous glass cloth. It is used as hull insulation in the forward compartment(s) of some submarines. The glass fibers will not burn. The phenolic resin binder will burn when it is exposed to a heat source. It will initially self-extinguish when the heat source is removed. A fire in a confined space, either burning the phenolic resin or some other material, can cause the local temperature to rise and cause the TLT to continue burning even if the original heat source has been removed. While it is burning or exposed to a heat source, the resin will give off toxic gases which will interfere with vision and breathing by irritating the eyes, mouth, nose and throat.
- c. **Polyimide and Polyphosphazene.** Polyimide and polyphosphazene foams have replaced vinyl nitrile rubber and TLT insulation on later submarines of the SSBN 726 class and on the SSN 21 class. They will burn, but compared to vinyl nitrile rubber and TLT their fire is less vigorous, and they produce less smoke.

#### 555-36.4.3 FIRE PREVENTION

- a. Historically, hot work has been the leading cause of ignition for hull insulation fires.
- b. **NSTM 074, Volume 1, Welding and Allied Processes** describes safety precautions for hot work.
- c. Good housekeeping will prevent the accumulation of trash and oil films, which can potentially become ignition sources for an insulation fire. Industrial periods, when good housekeeping is most difficult, are precisely the times when the need is greatest.

#### 555-36.4.4 FIRE FIGHTING

- a. **Initial Response.** AFFF extinguishers or hosereels (when available) are used for initial attack because of their cooling capability and ability to penetrate, spread, and cover. Water fog may also be used for initial attack, and is required if the fire is beyond the capacity of AFFF extinguishers. CO<sub>2</sub> and PKP extinguishers will not extinguish a hull insulation fire once it is well established.
- b. **Fire Attack.** Immediate checks should be made for fire spread in concealed areas next to the hull and behind habitability bulkhead sheathing. When the fire has first begun, the fire may often be extinguished by removal of the ignition source, particularly for insulation materials other than vinyl nitrile rubber insulation. Once the hull insulation fire has become self-sustaining, actions should be devoted to extinguishment. Water fog is the preferred extinguishing agent. The fire will spread upward helped by a chimney effect. As additional personnel become available, the scene leader must continue to investigate for multi-level fire. Fire teams with charged hoses must be dispatched to check for fire spread in concealed spaces. The scene leader may also direct additional personnel to use damage control tools to remove surrounding insulation. If sufficient fire teams are not

immediately available, a senior petty officer(s) in an SCBA, OBA or EAB may investigate. If smoke and heat interfere with firefighting or ship control, a decision to ventilate before the fire is out may be appropriate.

### **555-36.5 FLAMMABLE LIQUID FIRES**

**555-36.5.1 GENERAL.** A flammable liquid fire is a class B fire. For burning characteristics of flammable liquids, see paragraph 555-31.4.4. Because of the cooling qualities of finely divided water particles, water fog has a limited ability to extinguish a class B fire, involving fuels with a flashpoint above 140°F, such as diesel fuel, hydraulic fluid, or lube oil. Water fog will not extinguish a fire involving fluids with a flashpoint below 140°F. Extinguishment occurs by cooling the flammable liquid below its flashpoint. However, water will wash away any AFFF film on the fuel surface and could increase the fire intensity.

#### **555-36.5.2 INITIAL RESPONSE**

a. For class B (flammable liquid) pool fires, the initial response should be with one or more AFFF extinguishers. A single 2-1/2 gallon aqueous film forming foam (AFFF) fire extinguisher can extinguish up to 20 sq. ft. of fire, but bilge obstructions and hull frames reduce its effectiveness. Bouncing AFFF off bulkheads and equipment is an effective method for spreading AFFF as a layer over burning fuel. Avoid plunging the AFFF stream into the pool fire. Simultaneous application of AFFF from multiple extinguishers is more effective than series application.

b. For class B running fuel (3-dimensional) fires or fires greater than 20 square feet, the initial response should be with potassium bicarbonate (PKP) and AFFF extinguishers. PKP knocks down the flames and AFFF seals horizontal fuel surfaces.

#### **555-36.5.3 FIRE ATTACK**

a. The decision whether to switch from AFFF/PKP extinguishers to water should be based on the current conditions and understanding of the limitations of each method. For the SSN 21 class submarine, AFFF is preferred over water for class B fires.

b. When fighting a class B pool fire with water, apply a continuous narrow angle fog pattern to the leading edge of the flames and sweep the water from side to side in a continuous motion, pushing the flames back across the fuel surface. Narrow angle fog increases the local water density at the fuel surface which increases its effectiveness. Wide angle fog does not provide sufficient water density to extinguish the class B fire. If the water application is interrupted or not dense enough, the fire will burn back across the fuel surface. Obstructions in the fuel, such as hull frames or machinery, will make extinguishment more difficult. Danger of reflash exists until all of the fuel is cooled below its flashpoint. At a nozzle pressure of at least 35 psig, a single hose should extinguish a class B pool fire. A nozzle pressure less than 35 psig may require multiple hose lines to extinguish the fire.

c. Multiple water hoses, working together, will increase the total water density and extinguishing effectiveness. However, hoses should be advanced singly, vice together, as advancing hose lines together results in mutual interference. A second hose, if employed, should be brought up separately. Multiple hoses should normally work together on the same side of the fire. Attacking the fire from opposing directions is not recommended as this could result in water spray pushing burning fuel and hot gases onto the opposing hose team. Where ship configuration only allows multiple hose attack from opposing directions, the scene leader should employ hoses at his discretion.

### **555-36.6 FLAMMABLE GAS FIRES**

**555-36.6.1 GENERAL.** A gas fire is a class B fire. A gas fire can immediately grow out of control and require evacuation. Common submarine flammable gases include acetylene, and hydrogen. See **NSTM Chapters 550 and 670** for specific information on gases, and paragraph 555-31.4.3.3 for characteristics of flammable gases.

- a. Securing the fuel source is the single most important step in controlling a gas fire. **DO NOT EXTINGUISH A GAS FIRE** with fire extinguishing agents, unless the leak is small and the source may be quickly secured. If a gas fire is extinguished without securing the source, the accumulated unburned gases may reignite and explode, causing greater damage than the unextinguished fire. A gas fire can be extinguished with potassium bicarbonate (PKP) dry chemical.
- b. After securing the fuel source, extinguish residual fire (non-gas fire) involving surrounding material with the appropriate agent.
- c. If the fuel source cannot be secured, control adjoining fires with the appropriate agent. Exposed compressed gas cylinders, or other hazardous materials/systems, should be cooled with a continuous film of water to prevent container or system rupture and fire involvement. Exposed weapons, flammable gas cylinders, flammable liquid containers, oxygen cylinders or oxidizing agent containers should receive priority in cooling.
- d. If the compressed gas cylinder safety disk ruptures, flame may shoot out 10–12 feet. If the cylinder wall ruptures, the flame may become a large fire ball. In both cases, if there is no way to secure the source, cool exposed materials or systems subject to ignition or failure with water fog until the fuel is consumed.
- e. If a flammable gas fire is in the weather (pier side), approach from upwind if possible.
- f. Leaks may occur around a cylinder valve. If a cylinder valve leak occurs and the flame is small, the flame may be wiped-off with a rag or glove. Dispose of the leaking cylinder immediately in accordance with **NSTM Chapter 550**.

**555-36.6.2 HYDROGEN.** Free hydrogen is a byproduct produced by the chemical action in either the lead-acid main storage battery or the electrolytic oxygen generator. A limited amount of bottled hydrogen gas is maintained on board submarines and could become a fire hazard if released or a fire occurs where the bottles are stowed.

**555-36.6.2.1** Hydrogen has a very wide explosive range in air, from 4.0 percent (LEL) to 75 percent (UEL). It has a high ignition temperature, 932°F (500°C). But its very low ignition energy, 0.01 mJ, can result in ignition from nominally small heat-producing sources, such as friction and static electricity. See paragraph 555-36.11.5.

**555-36.6.2.2** A hydrogen explosion could result in casualties to personnel, flooding, fire, toxic gas generation, forced abandonment of compartment and loss of ship.

## **555-36.7 COMPRESSED GASES**

**555-36.7.1 HEAT EFFECT ON COMPRESSED GAS CYLINDERS AND AIR FLASKS.** Most compressed gas cylinders are provided with safety devices to relieve excess pressure. However, safety devices are generally ineffective when direct flame from a fire impinges onto the cylinder. Direct flame impingement often results in local super-heating of the cylinder surface resulting in a point failure and cylinder rupture before the cylinder pressure raises sufficiently to cause safety device operation. Apply a continuous film of water to the exposed cylinder area until the fire is extinguished and the cylinder temperature returns to normal. If water does not flash into steam on contact with the surface, the cylinder temperature is most likely below 220°F and cooling is effective.

**555-36.7.1.1** Since metals lose their strength at temperatures below flame temperatures, metal exposed to direct flame impingement may fail at pressures far below the system design pressure and safety device relief pressure. Therefore, cylinders connected to a system which are being exposed to direct flame impingement should have all internal pressure relieved safely if possible. However, relief of combustible or toxic gases in a safe manner may not be possible during a fire.

**555-36.7.1.2** Acetylene, argon, carbon dioxide, compressed air, nitrogen, oxygen, propane, hydrogen, and refrigerant gases are stowed onboard in cylinders which are protected by these safety devices.



**555-36.7.1.3** Escaping acetylene and hydrogen gases add fuel to a fire and can cause explosions. Hydrogen has a low auto-ignition temperature and can ignite from low energy sparks. It burns with a nearly invisible flame and is hazardous even if explosive mixtures do not form. Escaping oxygen gases increase the intensity of a fire. Refrigerant R-12 or R-114 gases coming in contact with flames or hot metal form hydrogen fluoride and hydrogen chloride, both of which are highly corrosive.

**555-36.7.1.4** In the event of a fire in the area of compressed gas cylinders, flames and sparks should be kept away from cylinders, and the cylinders should be kept cool with a water fog.

**555-36.7.1.5** Carbon dioxide, argon, and nitrogen gases can asphyxiate personnel. In all instances, a compressed gas cylinder, whose safety device requires relieving a high-pressure gas, is a potential danger to personnel.

**555-36.7.1.6** For additional information on general safety precautions for compressed gases, see Naval Ship's Technical Manual Chapter 550.

**555-36.7.2 COMPRESSED GAS CYLINDERS WITHOUT SAFETY DEVICES.** The accumulator air flasks for the ship service, stern diving, external, and emergency flood control hydraulic systems, and the reactor plant valve operating air flasks are not provided with safety devices for overpressure. The flasks are normally connected to system relief valves. However, reduction of wall strength from localized, elevated temperatures can result in wall rupture.

**555-36.7.2.1** Aside from other effects, a fire in the vicinity of these air flasks can increase the pressure in the flasks due to heat. For example, at an initial pressure of 3000 psig, if air temperature in the flask reaches 472°F, the pressure will rise to above 4500 psig (system test pressure).

**555-36.7.2.2** To reduce the possibility of overpressurization of the flasks and therefore the loss of the user systems, steps should be taken to cool down the flasks. Direct application of water fog to the flasks and piping aids in maintaining the temperature and pressure within limits. If water does not flash into steam on contact with the flask the temperature is most likely below 220°F.

**555-36.7.2.3** If the possibility exists that the flasks will be subjected to a temperature that could raise the pressure high enough to rupture the flask or associated piping, and the flasks cannot be cooled down, steps can be taken to relieve the pressure. For example, the ship service hydraulic plant air flasks can be aligned to a relief valve on the air pressure reducing manifold.

**555-36.7.3 COMPRESSED GAS DISTRIBUTION PIPING.** Extended high temperatures can cause joint failures in compressed air piping system silver brazed joints, or failures in air and oxygen pipe walls. An air line failure allows air to feed the fire and can be a significant factor in the fire gaining intensity. In some cases an air line failure can cause loss of control air for vital pneumatic services. Casualty drills should incorporate isolation of ruptured air lines and use of jumper hoses for feeding critical pneumatic demands.

## **555-36.8 EXPLOSIVES, PYROTECHNICS AND COUNTERMEASURES**

**555-36.8.1 PYROTECHNIC AND SMALL ARMS AMMUNITION LOCKERS.** Pyrotechnic devices and small arms ammunition are stored in separate lockers.

**555-36.8.1.1** All pyrotechnics devices are required to function normally after exposure to a cycle of temperatures between 65°F and 160°F. The effect of temperatures above 160°F is uncertain; however, it must be assumed that any pyrotechnic devices subjected to high temperature or direct flame may ignite. Pyrotechnic devices that are at high temperature can be more sensitive to shock and may, or may not, have an abnormal shock sensitivity after cooling to ambient temperature.

**555-36.8.1.2** The pyrotechnic locker is equipped with thermometers which show the internal temperature of the locker. These are mounted on the outside of the locker and provide warning of any dangerous temperature rise. In the event of a fire in or near the locker, the locker can be flooded as described in paragraph 555-32.7.



**555-36.8.1.3** Signals or markers, which may have been heated to abnormal temperatures and subsequently immersed in water, are in an indeterminate condition and must be handled with care. A pyrotechnic locker subjected to these conditions should remain sealed and flooded, if feasible, until the ship is surfaced. The pyrotechnic devices should then be handled and disposed of in accordance with NAVSEA OP4, **Ammunition Afloat**.

**555-36.8.2 COUNTERMEASURES LOCKER.** The countermeasure locker is isolated from the pyrotechnic locker and is not floodable. Some countermeasure devices, such as false target cans (FTC's) and NAE beacons, contain lithium hydride, LiH, a class D (metal) combustible. If exposed, LiH may spontaneously ignite in air. It is violently reactive with strong oxidizers. On heating or in contact with water, moisture or acids, hydrogen gas and heat are evolved. Heating is often sufficient for ignition. Exposed LiH can form airborne dust clouds which may explode on contact with flame, heat, oxidizing materials, humid air, or static electricity.

**WARNING**

Do not use water, carbon dioxide, PKP dry chemical, or aqueous film forming foam to fight lithium hydride (LiH) fires. These agents will react violently with LiH and may produce toxic gases.

For an exposure fire outside the locker, apply water fog to cool the locker surface.

**555-36.8.2.1** Burning countermeasure devices containing LiH should be disposed of overboard. An open metal container may be useful in moving the device, wearing full protective clothing. In some cases, lithium hydride fires may be smothered by inverting a metal can over them. For fires near, but not involving, an exposed FTC or NAE beacon, the device should be removed from the area if possible. If the device can not be removed, use dry chemical to combat fires near, but not involving, exposed FTC's and NAE beacons.

**555-36.8.2.2** LiH is highly toxic. Exposure to even a minute amount of dust will irritate mucous membranes of the eyes and upper respiratory tract. Lithium hydroxide formed from lithium hydride and water is very caustic, chemically similar to lye.

**555-36.8.2.3** If personnel exposure is suspected as a result of a fire or accident involving countermeasures, prompt medical attention is indicated.

## **555-36.9 TORPEDO WEAPONS SYSTEM**

**555-36.9.1** A fire in or near the torpedo Mk 48 Mod 1 can seriously endanger the ship due to the presence of warhead explosives and torpedo propellants. The mobile submarine simulator (MOSS) is also stowed in the torpedo room, but is not considered a fire hazard.

**555-36.9.2** The torpedo Mk 48 Mod 1 contains a solid explosive material. If completely enveloped in flame for 1-1/2 to 2 minutes, the warhead will ignite and burn. Prolonged exposure to a temperature in excess of 300°F will result in a violent explosion. If the explosive warhead is replaced by the instrument exercise head, it becomes nonexplosive.

**555-36.9.3** A Mk 48 torpedo fuel tank contains 700 lbs of Otto Fuel II (a volatile liquid monopropellant). When the weapon is in dry stowage, the tank pressure is essentially atmospheric but the tank is not vented to the atmosphere. The fuel tank will rupture when exposed to a temperature in excess of 300°F. Otto Fuel II is composed of a nitrate ester in solution with a desensitizing agent and a stabilizer. It is a bright red, free flowing, oily liquid that is heavier than water. It is insoluble in water. Detailed safety, handling and cleanup instructions for Otto fuel are contained in NAVSEA S6340-AA-MMA-010, **Otto II Fuel Safety, Storage, and Handling Instructions**.

**555-36.9.4** Because Otto fuel is a monopropellant which contains its own oxidizer, combustion cannot be smothered. The most efficient method of extinguishing an Otto Fuel II fire is to cool the propellant below its

flashpoint of 265°F (129°C). This is best accomplished by the use of water fog or AFFF. Water and AFFF are both lighter than Otto Fuel II and will form a layer on the fuel surface and absorb the heat given off by the fire. For very small Otto fuel fires, flames may be swept off the surface and extinguished with carbon dioxide fire extinguishers.

**555-36.9.5** Otto Fuel II liquid and vapor are extremely toxic. Vapors should not be ventilated through the ventilation system. Otto Fuel toxic effects may occur from inhalation of Otto Fuel II vapors, inhalation of combustion byproducts, absorption from direct contact, or ingestion. The nitrate esters in the Otto Fuel are known for their acute effects, including nausea, turgidity (swelling), blood pressure changes, headaches, and dyspnea (difficult breathing).

**WARNING**

Personnel shall not be exposed to Otto Fuel II vapor concentration greater than 0.2 ppm (1.3 mg/m<sup>3</sup>). Injury or death could result.

**WARNING**

The smoke from burning Otto Fuel must be considered as hazardous and toxic as Otto Fuel fumes.

**555-36.9.6** For Otto Fuel II fires, personnel without self contained breathing protection or EAB masks should not enter smoky areas. Personnel without full protective clothing should not enter spaces containing spilled or burned Otto Fuel II. Oxygen breathing apparatus and demand type EAB's are used to fight Otto Fuel II fires. For non-burning Otto Fuel II spills, NAVSEA S6340-AA-MMA-010, **Otto Fuel II Safety, Storage, and Handling Instructions**, requires use of positive pressure type breathing equipment for spill clean up.

**555-36.9.7** Fire team personnel should take extreme care not to expose skin surfaces. Fire team personnel, clothing, and equipment exposed to Otto Fuel II should be considered contaminated until tested. Once the fire is extinguished, the space should be emergency ventilated and decontamination should be conducted in accordance with the applicable reference manuals listed in Table 555-31-1.

**555-36.9.8** Depending on the class of fire, CO<sub>2</sub>, dry chemical, aqueous film forming foam fire extinguishers or water should be used to combat a fire in the torpedo room. The fire is extinguished with the extinguishing agent at hand, but the fire hose is rigged as soon as possible for torpedo room fires. The prime consideration is to put out the fire while cooling the weapons. If a fire cannot be put out, it is unlikely that the weapons or the ship will be saved. The fuel source must be secured as soon as possible. Except for the weapons themselves, the only other significant fuel source in the torpedo room is hydraulic fluid. If hydraulic fluid is secured, the capability to open the torpedo tube muzzle door is lost. In other words, a torpedo cannot be jettisoned if hydraulic fluid to the torpedo room is secured. However, a torpedo can still be tube-loaded manually. The ventilation system should be secured immediately, and the inlet damper to the battery compartment should be closed to prevent the spread of smoke to the fan room. While battery ventilation is secured, the hydrogen detector should be carefully monitored for indication of hydrogen buildup in the battery compartment. Battery compartment ventilation should be restored after the fire has been extinguished.

**555-36.9.9** A fire near or in the weapon stowage bays requires immediate action. In conjunction with extinguishing the fire, the warhead and tankage sections of the Mk 48 torpedoes should be cooled down as quickly as possible with a water fog or AFFF and maintained below 250°F. The water fog should be sprayed over the complete length of the weapon(s) and over both sides in a sweeping motion. The approximate temperature of the weapon can be determined by observing the effect of the water fog. If the water does not flash into steam upon contact with the weapon, the exterior temperature is below 220°F.

**555-36.9.10** If a fire should break out near or in a torpedo tube that contains a torpedo, the tube should be immediately flooded and equalized and the muzzle door opened to maintain a safe weapon condition. If there appears to be no chance of controlling the fire within a few minutes and there is no way of determining the temperature within the tube, the weapon should be jettisoned.

**555-36.10 STRATEGIC WEAPONS SYSTEM**

**555-36.10.1** The SSBN Officers Guide and the Strategic Weapon System Support System's Manual for the applicable weapons type discuss strategic weapons system fires and action required to combat them, including casualties that may require missile jettison.

**555-36.11 BATTERY COMPARTMENT CASUALTIES**

**555-36.11.1 GENERAL.** Battery compartment (well) casualties include a short-term electrical short in the battery, a class A fire involving materials in the battery compartment, an uncontrolled battery discharge, and a hydrogen explosion. See **NSTM Chapter 223, Volume 1, Submarine Storage Batteries** for more guidance. For any battery casualty, the steps listed below should be accomplished immediately:

- a. If a battery charge is in progress, secure the charge.
- b. Any personnel in the battery compartment should evacuate.
- c. Isolate the battery compartment from the ventilation system and battery air agitation system.
- d. Electrically isolate the battery.

**WARNING**

To protect the operator from shock and to avoid battery short circuiting, an insulated fire extinguisher should always be used in the battery compartment

**555-36.11.2 ELECTRICAL SHORT.** A short-term electrical short can occur when a tool is dropped on the battery circuit. This results in local flaming caused by the short. The flaming will usually self-extinguish when the metal tool vaporizes. An insulated CO<sub>2</sub> extinguisher should be used to extinguish residual burning.

**WARNING**

Never attempt to extinguish a battery cable fire by pouring water onto the battery. Electrolytic currents will generate hydrogen and oxygen which may produce a violent explosion. Salt water or impure fresh water introduced into the battery compartment may cause toxic gases to be generated.

**555-36.11.3 CLASS A FIRE IN THE BATTERY COMPARTMENT.** Combustible material in the battery compartment consists primarily of bulkhead insulation and small amounts of other material such as wood cribbing or plastic tubing. There is very low risk of a class A fire in the battery compartment.

a. The safest and most effective method available for fighting a battery compartment fire is through oxygen starvation. Securing the battery compartment and stopping all ventilation within (including the battery air agitation system) will deprive the flames of oxygen. No attempts should be made to enter into the battery compartment to insert any activated fire extinguishers as this may result in spread of the fire and release of toxic gases into the forward compartment. Additionally, opening the battery compartment hatch will allow oxygen to enter the compartment and sustain the fire. The SSN 21 class has CO<sub>2</sub> portable extinguisher connections installed in the battery compartment bulkhead for injecting CO<sub>2</sub> into the battery compartment without opening the compartment door.

**WARNING**

Use CO<sub>2</sub> for class A or C fires only. Do not inject CO<sub>2</sub> into a non-burning battery compartment if the hydrogen concentration is above the alarm set point. The static electric discharge created during CO<sub>2</sub> discharge could ignite a hydrogen concentration within the explosive range.

b. Entry into the battery compartment should be attempted only after the fire has been put out, the compartment has cooled, and has been thoroughly ventilated to remove toxic and explosive gases. If battery compartment boundaries are tight, there may be a pressure buildup in the compartment. This pressure buildup will require that ventilation exhaust be established prior to removing the cover on the battery inlet filter; this will also minimize the spread of toxic and explosive gases in the ship. The pressure buildup against a dogged battery compartment access hatch will make entry into the compartment dangerous. The SSN 21 class has a battery compartment relief valve which discharges into the battery exhaust ventilation duct to prevent excessive pressure buildup. Emergency ventilation of the battery compartment with the blower will most rapidly and effectively remove toxic and explosive gases from the ship.

c. During overhaul and certain other maintenance conditions, it is not always possible to isolate the battery compartment. Fire protection for a minor fire under those conditions must be provided by insulated CO<sub>2</sub> fire extinguishers in order to avoid battery short circuiting and electrical shock to personnel. Two insulated (plastisol-covered) carbon dioxide extinguishers are required for use by fire watch personnel when hot work is performed on the boundary of the battery compartment or to protect against a minor fire when conditions prohibit isolation of the compartment. The plastisol covered extinguishers are to be used to attack a small fire, and should not be dropped into or left in the battery compartment unattended.

**555-36.11.4 UNCONTROLLED BATTERY DISCHARGE.** An uncontrolled battery discharge presents a significant hazard to the ship. Uncontrolled battery discharges have been caused by flooding of the battery compartment and by a large short between busses before the battery breaker. They could also occur from battery derangement following collision or shock.

a. An uncontrolled current discharge is a hazardous battery condition which threatens the safety of the submarine and crew.

b. The symptoms likely to be observed in such an emergency include smoke and odor of burning rubber, paint and plastic in the space(s) above and adjacent to the battery compartment. A high battery discharge current, and zero battery ground may be observed depending on the source and location of the short circuit.

c. The intense heat from the grounded cells will start fires in the space(s) above and adjacent to the battery compartment. Therefore, immediate action must be taken to monitor temperatures on the deck above and bulkheads around the battery compartment, and cool with water fog when required.

d. Once the discharge is recognized, and opening the battery breaker does not secure the discharge, it is unlikely that attempts to enter the battery compartment and open manual disconnects and disconnect bus bars will be possible.

e. Specific damage control actions including ventilation considerations for an uncontrolled current discharge must be based on a careful evaluation of the operating or in port situation.

**555-36.11.5 HYDROGEN EXPLOSION.** For prevention of a hydrogen explosion, see **NSTM Chapter 223 Volume 1, Submarine Storage Batteries**. Ignition of a hydrogen enriched atmosphere results in an explosion which can cause structural deformation, damage to ship systems, and secondary fires in combustible material. If the cause of hydrogen formation is not corrected, a hydrogen enriched atmosphere may reform and follow-on explosions can occur. Therefore, efforts should be focused on preventing reformation of a hydrogen enriched atmosphere. For additional information and procedures concerning the battery see **NSTM Chapter 223 Volume 1, Submarine Storage Batteries**.

#### **555-36.12 SPECIAL HULL TREATMENT (SHT) FIRES IN DRYDOCK**

**555-36.12.1 GENERAL.** Special Hull Treatment (SHT) and Advanced Special Hull Treatment (ASHT) materials are installed on the outside surfaces of submarines and may be a fire hazard when the ship is in dry dock and the material is exposed. The limited quantity of SHT exposed topside when a submarine is in the water is not

considered a significant fire hazard because of the lack of ignition sources, the limited surface area and the horizontal orientation which reduces flame spread.

**555-36.12.1.1 Special Hull Treatment (SHT).** SHT, designated AA-18 and AD-79M, is applied to SSN 637 and SSN 688 Class submarines and consists of a 5/16 inch to 7/8 inch thick flat tile made of a neoprene coverply on a nitrile or natural rubber base. AA-18 and AD-79M tiles are attached to the submarine hull by an epoxy adhesive. For additional information on SHT tiles see technical handbook NAVSEA S6360-AD-HBK-010 **Technical Handbook for Special Hull Treatment Maintenance and Repair for Submarines.**

**555-36.12.1.2 Advanced Special Hull Treatment (ASHT).** ASHT is applied to SSN-21 Class submarines. It is a polyurethane based material with no coverply, designated DURA-1. DURA-1 material is 2 inches thick, is poured in place, and is molded to the submarine hull.

**555-36.12.2 FLAMMABILITY AND FIRE SPREAD.** Testing has shown that these materials can be ignited by hot welding splatter. Other ignition sources in a dry dock include exposure to flames or heat such as from a small trash can fire. See technical handbook NAVSEA S6360-AD-HBK-010 for hot work precautions near SHT.

**555-36.12.2.1 SHT Flammability.** The neoprene coverply on the outside of AA-18 and AD-79M tiles offers limited fire resistance and initially protects the nitrile rubber base beneath it from ignition. The coverply burns with low intensity and may extinguish itself if the source of the fire can be removed. A larger fire source would subject the coverply to more intense heat and would significantly reduce the fire resistance of this outer layer. Once exposed, the rubber base material will readily ignite. Combustion of AA-18 and AD-79M SHT base material is characterized as self sustaining, vigorous, deep seated, burning at high surface temperature, producing very heavy smoke and intense heat. Figure 555-36-1 shows deep seated burning of a small panel of AD-79M SHT around seven minutes after ignition. The 6 foot wide 14 foot high panel in Figure 555-36-1 was ignited by a small fuel pan (shown after removal in the lower right hand corner of the photo). Flame spreading to the side edges and far beyond the top of the SHT panel show that the fire would continue to spread vertically and horizontally across a completely covered ship hull. The flaming AA-18 and AD-79M materials will flake off to expose unburned material deeper in the tile for further burning. Flaming pieces of the base material will fall into the dry dock and support continued combustion of SHT and fire spread to other materials.

**555-36.12.2.2 ASHT Flammability.** As with the nitrile or natural rubber base material of SHT tiles, the DURA-1 ASHT material will readily ignite if exposed to the sources of ignition described above. DURA-1, however, does not have a protective coverply layer to delay ignition of the base material. A fire involving DURA-1 will rapidly grow and become self sustaining. A DURA-1 fire is characterized as high intensity with medium density smoke. The material drips when it burns and will form a pool of burning material in the dry dock. This burning pool will make the fire larger by supporting continued combustion of the ASHT above it and spreading the fire to other materials.

**555-36.12.2.3 Fire Spread.** Fires involving SHT and ASHT quickly spread vertically up the submarine hull as hot smoke rises with the fire plume to heat and support fire spread. Horizontal spread of the fire occurs when the flames meet an obstruction such as scaffolding. The fire will spread to adjacent materials, such as wood scaffolding or staging, temporary enclosures, scrap, etc. due to direct contact with flames, exposure to intense heat, or windy conditions.

**555-36.12.3 EXTINGUISHING METHODS.** Water or AFFF will easily extinguish SHT/ASHT fires and is the recommended method. PKP may also be effective for flame knock down on the surface of the burning material, however, the potential for reflash is high, especially with AA-18 and AD-79M SHT materials. The burning material should be cooled sufficiently to prevent reflash. Application of water or AFFF will remove heat and extinguishes the fire.

**555-36.12.4 SHIPYARD ALARM AND EXTINGUISHING SYSTEMS.** Dry dock fire hose stations typically consist of 2-1/2 inch hose valves with 2-1/2 inch supply outlets and 1-1/2 inch hose outlets. Fire hose stations are required in dry docks so that any area can be reached with a 20-foot fog stream with 100 feet of hose. Fire hose stations serving the bottom of the dry dock should be hard piped from water supply sources, however, portable



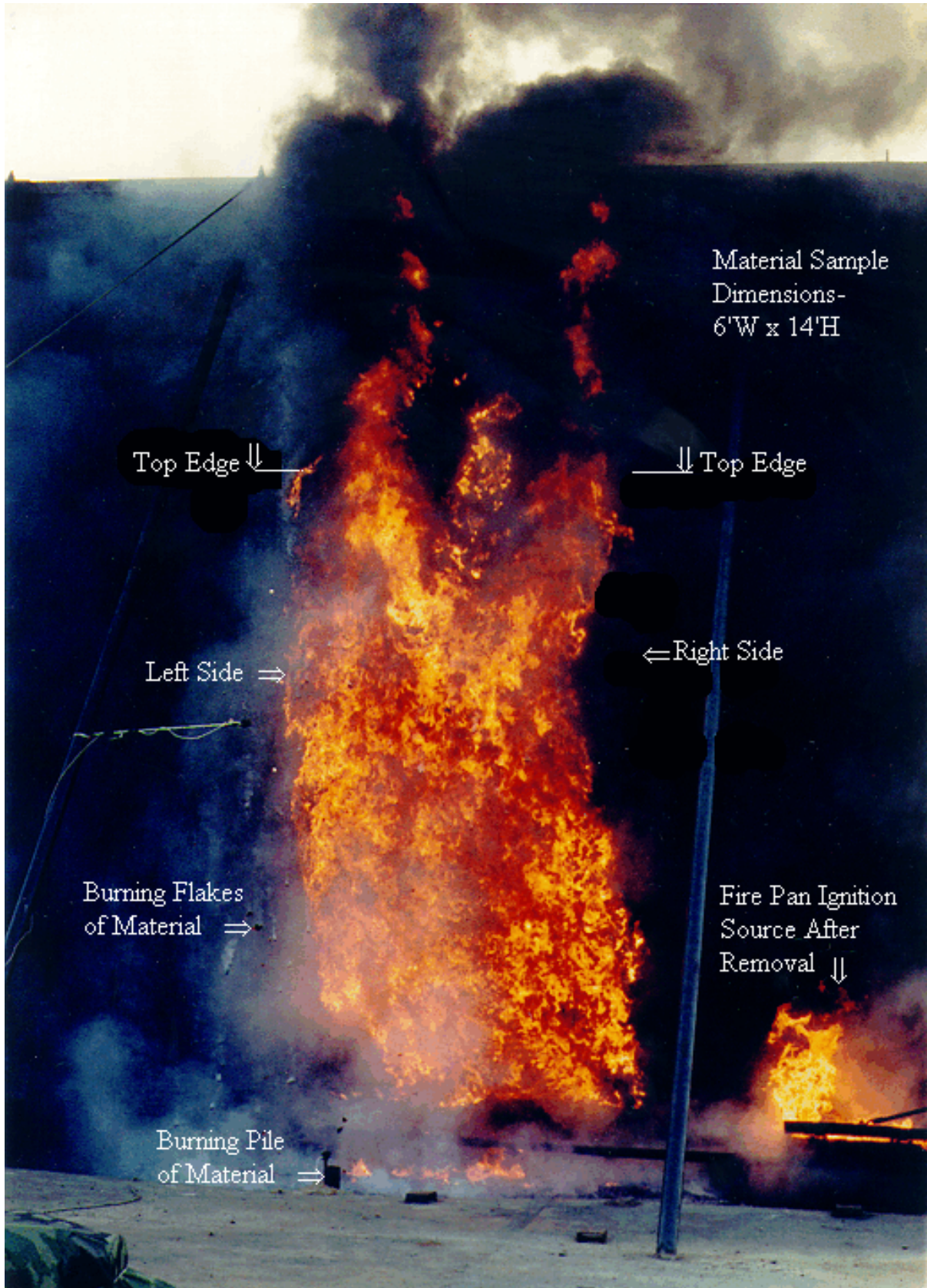


Figure 555-36-1. Special Hull Treatment (SHT) Fire

stations that are securely lashed down and supplied from jumper hoses may also exist. An adequate water supply for the dock should provide at least 1,000 gpm total flow at 60 psi to the most remote and highest elevation hose connection.

A casualty control (CASCON) station is provided to directly notify the shipyard fire department in the event of a reported fire in the ship, and in or around the dry dock. A fire involving SHT/ASHT materials that cannot be promptly extinguished must be reported immediately to the CASCON station.

#### **555-36.12.5 FIRE ATTACK.**

**555-36.12.5.1 Initial Response.** The fire watch assigned to monitor conditions outside of the ship's hull during hot work that could affect SHT/ASHT material should have available, as a minimum, a 2-1/2 gallon AFFF fire extinguisher, a UL-rated 3A-40B fire extinguisher, or (preferably) a 3/4 inch hose charged with water.

**555-36.12.5.2 Fire Attack.** Rig fire hoses from the nearest 1-1/2 inch dry dock fire hose station to the location of the fire and attack the fire. Be aware of intense heat and thick smoke produced by the fire. Directing hose streams onto unburned areas of the hull next to and above the burning area may be effective to prevent fire spread. Fire attack from the dry dock floor, if possible, may provide easier access to the fire with less exposure to heat and smoke. Application of water from dry dock wing walls may be effective if hose streams will reach the fire. Wind will affect stream reach and could prevent extinguishment.

- a. When fighting the fire, be aware of the following issues:
  1. the fire may spread beneath the submarine and up the opposite side of the hull
  2. heat transfer through the hull, or in the presence of hull cuts, may spread the fire to areas inside the submarine
  3. until the area involved in the fire has been completely cooled, reflash is likely
  4. smoke and heat may impede safe egress of personnel in the submarine.



## **SECTION 37. FIRE DRILLS AND TRAINING**

### **555-37.1 IMPORTANCE**

**555-37.1.1** The best organization and equipment is useless without trained personnel. A properly trained and drilled crew will minimize confusion during fires, increase the probability of proper initial actions taken against a fire, and enhance the predictability of firefighting responses and tactics. Vital to the effort, however, is continuity of personnel. That is, people assigned to a fire team should retain that position even if other shipboard duties change. All members of a fire team should be cross trained for at least one other position on the fire team in order to provide frequent rotation.

### **555-37.2 REQUIRED FEATURES**

**555-37.2.1** Effective fire drills do not happen automatically. A careless effort will result in useless drills which do not improve the crew's capability, or even bad drills which train poor habits. Each fire drill should include training elements which touch on the phases of firefighting outlined in Section 35. These drills will ensure that personnel know how and when to secure the fryer and extinguish the fire. As a firefighting party improves, realism can be incorporated. Time compression is the most important feature to incorporate. A fire can grow from a tiny flicker to a life threatening blaze in a few minutes. Drills must be practiced at real time speed. This creates two important conditions; the urgency of the situation, and the inevitable problems with donning personnel protection. The effects of smoke must also be included, including the use of blindfolds to simulate loss of visibility, the loss of staging areas, loss of equipment in lockers which can not be reached, and the extra confusion caused by all the above. Cascading casualties are also common in fires, as a fire spreads or damages vital services. Realistic, effective drills shall include these effects. Machinery space fires can grow out of control in seconds.

**555-37.2.2** During each drill it is important to observe and thoroughly evaluate the effectiveness of communications in accordance with the ship's bills.



**APPENDIX A.**  
**LIST OF ABBREVIATIONS**

**AFFF** – Aqueous Film Forming Foam

**APC** – Aqueous Potassium Carbonate

**CO<sub>2</sub>** – Carbon Dioxide

**FFE** – Firefighter’s Ensemble

**LEL** – Lower Explosive Limit

**NFTI** – Naval Firefighter’s Thermal Imager

**OBA** – Oxygen Breathing Apparatus

**PKP** – Potassium Bicarbonate Dry Chemical (formerly Purple-K-Powder)

**SCBA** – Self-Contained Breathing Apparatus

**UEL** – Upper Explosive Limit



## APPENDIX B

### GLOSSARY

**Affected Space** – The space that is burning.

**Breathing Apparatus** – “Breathing apparatus” and “self-contained breathing devices” refer to oxygen breathing apparatus (OBA’s) and SCBA’s. “Breathing apparatus” also refers to emergency air breathing (EAB) masks.

**Backdraft** – An explosion that results from combining fresh air with hot flammable fire gases that have reached their autoignition temperatures. Large volumes of carbon monoxide and other fire gases can be generated by incomplete combustion in closed spaces.

**Compartment** – A major water-tight subdivision of the submarine. This term differs from a surface ship, in which any major room is called a compartment.

**Direct Fire Attack** – A method of attacking a fire in which firefighters advance into the immediate fire area and apply the extinguishing agent directly onto the seat of the fire to extinguish the fire or spray a water fog (fog attack) into the hot gas layer over the seat of the fire to gain control. See paragraph 555–35.6.

**Fire Contained** – When one or more hose teams are making progress advancing on a fire and the fire is contained in a single area within a compartment. This term means the same as “Fire Under Control” and is used when reporting from the scene to avoid confusion with the term “Fire Out of Control.”

**Fire Hose Station** – Location where fire plug and associated equipment are stored; commonly referred to as either a fire station or a fireplug.

**Fire Plug** – The valve at the fire hose station.

**Fire Out** – All visible flames have been extinguished. Smoldering fires may still be present.

**Fire Team** – Designated personnel who advance a fire hose. As a minimum, the following functions will be performed by the fire team:

- Operate nozzle (Nozzleman)
- Tend hose and operate fire plug (Hoseman)
- Carry messages, fake out hoses, assist nozzleman, supply OBA canisters and clear passageways as required.

**Fire Totally Extinguished** – All hidden fires and hot embers have been found and extinguished.

**Fire Under Control** – When one or more fire teams are making progress advancing on a fire and the fire is contained in a single area within a compartment.

**Flashover** – The transition from a growing fire to a fully developed fire in which all combustible items in the compartment are involved in fire.

**Heat Strain** – The body’s reaction to heat stress. The reaction may be local, such as a burn, or generalized, such as an increase in core body temperature.

**Heat Stress** – Subjecting the body to higher than normal temperatures. Heat stress may be caused by a high temperature environment or by wearing clothing, such as a firefighter’s ensemble, that impedes the body’s normal cooling.

**Hot Surface** – For fire hazard precautions for piping systems containing flammable liquids, **NSTM Chapter 505** defines a hot surface as 650° F (343° C) for lubricating oil and hydraulic oil systems and 400° F (205° C) for all other flammable liquids.

**Indirect Fire Attack** – A method of attacking a fire in which firefighters outside the fire area discharge water fog into the fire area through a cracked open door or a bulkhead or overhead penetration. See paragraph 555–35.7.

**Out-of-Control Fire** – A fire that creates untenable conditions due to heat and smoke forcing personnel to abandon the space.

**Overhaul** – An examination and cleanup operation. It includes finding and extinguishing hidden fire and hot embers and determining whether the fire has extended to other parts of the ship.

**Radiant Heat Flux** – The measure of radiant energy (heat) flow per unit area, normally expressed in kilowatts per square meter ( $\text{kW/m}^2$ ).

**Rollover** – Sudden spread of flame through the unburnt gases and vapors in the upper layer across the overhead of a space.

**Rapid Response Fire Team** – Designated personnel (may include on-watch personnel) who proceed immediately to the fire and combat the fire with fire extinguishers, rig fire hoses, and establish communications with the controlling station.

**Shall** – When application of a procedure is mandatory.

**Should** – When application of procedure is recommended.

**Space** – A room or mostly-enclosed local area within a compartment.

**Surfactant** – A large group of surface acting compounds that include detergents, wetting agents and liquid soaps.

**Unaffected Space** – Any space other than the burning space.

**Vapor Secure** – Establishing a film or foam blanket over flammable liquid to prevent vaporization. When vapors cannot reach the flames, flame production ceases and the surface is vapor secured.

## APPENDIX C

### SUMMARY OF CHANGES

Rev 4 Paragraph	Change
<b>SECTION 32. FIRE EXTINGUISHING AND RELATED SYSTEMS</b>	
555-32.4.2	Impact of APC cylinder diameter variation added.
<b>SECTION 33. MANUAL FIREFIGHTING EQUIPMENT</b>	
555-33.2.4	New paragraph added to section 555-33.2 for the CO <sub>2</sub> fire extinguisher which cross references existing guidance on its use on C fires and provides guidance found in 555-10.3.2.2 on its use on class B fires.
<b>SECTION 36. SPECIAL FIRE SCENARIOS</b>	
555-36.12 through 555-36.12.5.2	Guidance added on special hull treatment (SHT) fires on external hull while in drydock.
Figure 555-36-1	Photo of SHT fire added.





## APPENDIX D

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