NFPA® 1405

Guide for Land-Based Fire Departments That Respond to Marine Vessel Fires

2016 Edition

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NFPA® 1405

Guide for

Land-Based Fire Departments That Respond to Marine Vessel Fires

2016 Edition

This edition of NFPA 1405, *Guide for Land-Based Fire Departments That Respond to Marine Vessel Fires*, was prepared by the Technical Committee on Fire Service Training. It was issued by the Standards Council on January 28, 2015, with an effective date of February 17, 2015, and supersedes all previous editions.

This edition of NFPA 1405 was approved as an American National Standard on February 17, 2015.

Origin and Development of NFPA 1405

This guide was developed in response to a recognized need in the area of fire fighter training. Marine vessel fires constitute one of the greatest challenges that structural fire fighters can face. The Technical Committee on Fire Service Training helped to establish a subcommittee of experts on the subject of shipboard fire fighting. The results of the subcommittee's efforts were contained in the first edition of NFPA 1405 in 1990.

The 1996 edition contained some minor updates to the original edition.

The 2001 edition contained additional updates to the original edition, including material about responder safety, vessel familiarity, vessel detection systems, incident command considerations, and a reminder that every vessel response should be treated initially as a hazardous materials incident. Some material from Appendix A was moved into a new Appendix B, Pre-Fire Survey Guide, to provide more visibility for this important sample survey.

The 2006 edition contained editorial changes and included the addition of the new International Maritime Organization (IMO) Graphical Symbols for Shipboard Fire Control Plans. This edition also featured technical changes related to definitions, vessel stability, and draft marks.

The title of the 2011 edition was changed from *Guide for Land-Based Fire Fighters Who Respond to Marine Vessel Fires* to *Guide for Land-Based Fire Departments That Respond to Marine Vessel Fires* to eliminate confusion with NFPA 1005, *Standard for Professional Qualifications for Marine Fire Fighting for Land-Based Fire Fighters.*

The 2016 edition was revised to internationalize the terminology within the document. A chapter on legal issues (Chapter 17) was deleted.

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Committee Scope: This Committee shall have primary responsibility for all fire service training techniques, operations, and procedures to develop maximum efficiency and proper utilization of available personnel. Such activities can include training guides for fire prevention, fire suppression, and other missions for which the fire service has responsibility.

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NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates that explanatory material on the paragraph can be found in Annex A.

Information on referenced publications can be found in Chapter 2 and Annex E.

Chapter 1 Administration

1.1 Scope.

1.1.1 This guide identifies the elements of a comprehensive marine fire-fighting response program including, but not limited to, vessel familiarization, training considerations, pre-fire planning, and special hazards that enable land-based fire fighters to extinguish vessel fires safely and efficiently. In general, the practices recommended in this publication apply to vessels that are covered by the Safety of Life at Sea (SOLAS) agreement or that call at United States ports.

1.1.2 This document does not consider offshore terminals or vessels on the high sea.

1.2 Purpose. (Reserved)

1.3 General Information.

1.3.1 The tactics and strategies utilized to attack a fire aboard a vessel are in many ways similar to those used routinely in structural fire fighting. However, there are many aspects of marine fire fighting that warrant special attention because of the unique environment encountered aboard a vessel. Ships often are compared to high-rise buildings. This is not an altogether inappropriate comparison. However, the ventilation of a vessel fire can be more difficult to achieve and the spread of a fire more difficult to check. The fire fighter's natural response when confronted with a structure fire is to act immediately. This is because most structure fires exhibit similar characteristics that have been encountered before and thus there is a source of knowledge and experience from which to draw. However, a major fire aboard a ship seldom occurs, and very few fire fighters have experienced such a fire. Therefore, fires aboard ship should be approached in a quick but safe and prudent manner. Fire fighters have come to realize that when they approach hazardous material incidents, it is preferable to proceed slowly rather than to react too quickly, thus increasing risks and jeopardizing success. The same is also true when fighting vessel fires.

1.3.2 Unlike structure fires, hazardous material incidents, and many other fireground operations for which there is extensive written material available for fire service personnel to study, there is relatively little information available to land-based fire fighters concerning the management of a fire aboard a vessel. The absence of this type of information often leads fire fighters to apply strategies and tactics associated with structure fires to fires aboard vessels. Although these strategies and tactics are similar, it is important to recognize that there are distinct differences in the two types of fires. Incidents in the marine environment are usually larger in scale than those encountered on land. For example, some fire departments are prepared to deal with an incident involving an 8000-gallon (30,283 L) tank truck fire. A bulk liquid barge can easily hold several million gallons of product. Tank vessels may hold as much as 84 million gallons (317,974,590 L) and be almost a quarter mile in length. These types of incidents require planning and resources that far exceed a routine fire department response.

1.3.3 NFPA, at the request of and in cooperation with the USCG, and with the assistance of the fire service and maritime communities, has undertaken the task of developing this guide for use by local fire-fighting organizations that could be confronted with a fire aboard a vessel.

1.3.4 Because there is extensive written material available concerning structure fires, hazardous material incidents, and other fireground operations, this guide provides only limited discussion of those aspects of vessel fire-fighting procedures that are similar. Those aspects that are different are emphasized and highlighted throughout this document.

Chapter 2 Referenced Publications

2.1 General. The documents or portions thereof listed in this chapter are referenced within this guide and should be considered part of the recommendations of this document.

2.2 NFPA Publications. National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02169-7471.

NFPA 11, *Standard for Low-, Medium-, and High-Expansion Foam,* 2011 edition.

NFPA 12A, *Standard on Halon 1301 Fire Extinguishing Systems,* 2015 edition.

NFPA 14, *Standard for the Installation of Standpipe and Hose Systems,* 2013 edition.

NFPA 1500, *Standard on Fire Department Occupational Safety and Health Program,* 2013 edition.

2.3 Other Publications.

2.3.1 IMO Publications. International Maritime Organization, Publishing Service, 4 Albert Embankment, London, SE1 7SR, UK.

International Conference on Marine Pollution, (1973) 1983.

International Convention on the Safety of Life at Sea (SOLAS), 2008.

International Maritime Dangerous Goods (IMDG) Code, 2008.

2.3.2 U.S. Government Publications. U.S. Government Printing Office, Washington DC 20402.

Title 33, Code of Federal Regulations, Parts 2.05–2.25, "Jurisdiction."

Title 40, Code of Federal Regulations, Part 300.43, "National Oil and Hazardous Substances Pollution Contingency Plan (NCP)."

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Title 46, Code of Federal Regulations, Part 72.05–72.10, "Construction and Arrangement."

Title 46, Code of Federal Regulations, Part 78.45-1 (a), "Operations."

Title 49, Code of Federal Regulations, Parts 100–177, "Pipeline and Hazardous Materials Safety Administration, Department of Transportation."

Title 14, U.S. Code, Part 88(b), "Saving Life and Property."

Title 14, U.S. Code, Part 634(a), "Officers Holding Certain Offices."

Title 33, U.S. Code, Part 1221, "Ports and Waterways Safety Act," 1972.

Title 33, U.S. Code, Part 2702-2761, "Oil Pollution Act (OPA)," 1990.

Title 42, U.S. Code, Part 1856-1856d, "Public Health and Welfare."

U.S. Coast Guard Marine Safety Manual, Vol. 6, Chapter 8, 2005.

2.3.3 Other Publications. *Merriam-Webster's Collegiate Dictionary,* 11th edition, Merriam-Webster, Inc., Springfield, MA, 2003.

2.4 References for Extracts in Advisory Sections. (Reserved)

Chapter 3 Definitions

3.1 General. The definitions contained in this chapter apply to the terms used in this guide. Where terms are not defined in this chapter or within another chapter, they should be defined using their ordinarily accepted meanings within the context in which they are used. *Merriam-Webster's Collegiate Dictionary,* 11th edition, is the source for the ordinarily accepted meaning.

3.2 NFPA Official Definitions.

3.2.1 Guide. A document that is advisory or informative in nature and that contains only nonmandatory provisions. A guide may contain mandatory statements such as when a guide can be used, but the document as a whole is not suitable for adoption into law.

3.2.2 Should. Indicates a recommendation or that which is advised but not required.

3.3 General Definitions.

3.3.1 Accommodation Spaces. Spaces designed for human occupancy as living spaces for persons aboard a vessel.

3.3.2 AFFF. Aqueous film forming foam.

3.3.3 After (Aft). The direction toward the stern of the vessel.

3.3.4* Anchorage. An area identified for safe anchoring.

3.3.5 Athwartship. Side to side, at right angles to the fore and aft centerline of a ship.

3.3.6 Ballast. Weight, liquid or solid, added to a ship to ensure stability.

3.3.7 Ballast Tank. A watertight compartment to hold liquid ballast.

3.3.8 Barge. A long, large vessel, usually flat-bottomed, self-propelled, towed, or pushed by another vessel, used for transporting materials.

3.3.9 Beam. The breadth (i.e., width) of a ship at its widest point.

3.3.10 Berth. (1) The mooring of a boat alongside a bulkhead, pier, or between piles. (2) A sleeping space.

3.3.11 Berthing Area. (1) A space at a wharf for docking a ship. (2) A bed or bunk space on a ship.

3.3.12 Bilge. The lowest inner part of a ship's hull.

3.3.13 Bitts. A pair of heavy metal posts fastened on a deck to which mooring lines are secured.

3.3.14 Boom. (1) A long pole extending upward at an angle from the mast of a derrick to support or guide objects lifted or suspended. (2) A floating barrier used to confine materials upon the surface of the water (e.g., oil).

3.3.15 Bow. The front end of a boat or vessel.

3.3.16 Bulkhead. (1) One of the upright, vertical partitions dividing a ship into compartments and serving to retard the spread of leakage or fire. (2) A fixed pier or wall back-filled to be continuous with the land.

3.3.16.1 ***Watertight Bulkhead.*** A bulkhead (wall) strengthened and sealed to form a barrier against flooding in the event that the area on one side fills with liquid.

3.3.16.2 ***Watertight Transverse Bulkhead.*** A bulkhead through which there are no openings and that extends from the tank top up to the main deck, built to control flooding.

3.3.17 Buoyancy. (1) The tendency or capacity to remain afloat in a liquid. (2) The upward force of a fluid upon a floating object.

3.3.18 Centerline. A line that runs from the bow to the stern of the vessel and is equidistant from the port and starboard sides of the vessel.

3.3.19 CFR. U.S. Code of Federal Register.

3.3.20 CO_2. Carbon dioxide.

3.3.21 Coaming. The raised framework around deck or bulkhead openings to prevent entry of water.

3.3.22 Cofferdam. A void between the compartments or tanks of a ship for purposes of isolation.

3.3.23 Companionway. An interior stair-ladder used to travel from deck to deck, usually enclosed.

3.3.24* COTP. United States Coast Guard Captain of the Port or national/regional equivalent.

3.3.25 CP. Command post.

3.3.26 Damage Control Locker/Emergency Gear Locker. A locker used for the storage of emergency equipment.

3.3.27 Deck. A platform (floor) extending horizontally from one side of a ship to the other.

3.3.27.1 ***Main Deck.*** The uppermost continuous deck of a ship that runs from bow to stern.

3.3.27.2 ***Tween Decks.*** Cargo decks between the main deck and the lower hold.

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3.3.28 Dewatering. The process of removing water from a vessel.

3.3.29 Double Bottom. A void or tank space between the outer hull of the vessel and the floor of the vessel.

3.3.30 Draft. The depth of a vessel's keel below the waterline.

3.3.31 Drafting. The act of acquiring water for fire pumps from a static water supply by creating a negative pressure on the vacuum side of the fire pump.

3.3.32 Dunnage. Loose packing material (usually wood) protecting a ship's cargo from damage or movement during transport.

3.3.33 EMS. Emergency medical services.

3.3.34 Escape Trunk. A vertical trunk fitted with a ladder to allow personnel to escape if trapped.

3.3.35 FAA. U.S. Federal Aviation Administration or national/regional equivalent.

3.3.36 Fantail. The stern overhang of a ship.

3.3.37 FCC. U.S. Federal Communication Commission or national/regional equivalent.

3.3.38* Fire Control Plan. A set of general arrangement plans that illustrate, for each deck, the fire control stations, fire-resisting bulkheads, and fire-retarding bulkheads, together with particulars of the fire-detecting, manual alarm, and fire-extinguishing systems, fire doors, means of access to different compartments, and ventilating systems, including locations of dampers and fan controls.

3.3.39 Fire Station. A location for the fire-fighting water supply outlet, hose, and equipment on board ship.

3.3.40* Fire Warp. Wire rope or other fireproof materials of sufficient strength to tow the vessel in the event of fire.

3.3.41 Forecastle (fo'c'sle). (1) The section of the upper deck of a ship located at the bow, forward of the foremast. (2) A superstructure at the bow of a ship where maintenance shops, rope lockers, and paint lockers are located.

3.3.42 Forward (Fore). The direction toward the bow of the vessel.

3.3.43 Frame. The structural members of a vessel that attach perpendicularly to the keel to form the ribs of the vessel.

3.3.44 Freeboard. The vertical distance between the waterline and the main deck.

3.3.45 Gangway. The opening through the bulwarks (sides) of a ship or a ship's rail to which an accommodation ladder used for normal boarding of the ship is attached.

3.3.46 GM. Metacentric height.

3.3.47 Gunwale. The upper edge of a side of a vessel or boat designed to prevent items from being washed overboard.

3.3.48 HazMat. Hazardous material.

3.3.49 Heeling. (1) Tipping to one side. (2) Causing a ship to list.

3.3.50 Hogging. Straining of the ship that tends to make the bow and stern lower than the middle portion.

3.3.51 House. A superstructure above the main deck.

3.3.52 HVAC. Heating ventilation and air conditioning.

3.3.53 IC. Incident commander.

3.3.54 IMO. International maritime organization.

3.3.55* International Shore Connection. A universal connection to the vessel's fire main to which a shoreside fire-fighting water supply can be connected.

3.3.56 Keel. The principal structural member of a ship, running fore and aft on the centerline, extending from bow to stern, forming the backbone of the vessel to which the frames are attached.

3.3.57 Ladder. All staircases, often nearly vertical, on board vessels.

3.3.57.1 ***Jacob's Ladder.*** A rope or chain ladder with rigid rungs.

3.3.58 List. An inclination to one side; a tilt.

3.3.59 LNG. Liquefied natural gas.

3.3.60 LP Gas. Liquefied petroleum gas.

3.3.61 Master. The captain of a merchant ship.

3.3.62 Mate. A deck officer on a merchant ship ranking below the master.

3.3.62.1 ***Chief Mate.*** The deck officer immediately responsible to the vessel's master.

3.3.63 MCC. Motor control center.

3.3.64* Mooring. (1) Equipment, such as anchors, chains, or lines, for holding fast a vessel. (2) The act of securing a vessel. (3) A location at which a vessel can be moored. (4) Any location where a boat is wet-stored or berthed.

3.3.65 MSO. Marine safety officer.

3.3.66 NIMS. U.S. National Incident Management System or national/regional equivalent.

3.3.67 NOAA. U.S. National Oceanic and Atmospheric Administration or national/regional equivalent.

3.3.68 NWS. U.S. National Weather Service or national/regional equivalent.

3.3.69 OCMI. Officer in charge of maritime inspection.

3.3.70 Overhaul. The process of final extinguishment after the main body of a fire has been controlled and all traces of fire have been extinguished.

3.3.71 Overhead. The vessel equivalent of a ceiling.

3.3.72 Passageway. A corridor or hallway.

3.3.73 PFD. Personal flotation device.

3.3.74 Platform. (1) Any flat-topped vessel, such as a barge, capable of providing a working area for personnel or vehicles. (2) A partial deck in the machinery space.

3.3.75 Port Side. The left-hand side of a ship when facing forward.

3.3.76 RIC. Rapid intervention crew.

3.3.77 Riser. A pipe leading from the fire main to the fire station (hydrants) on upper deck levels.

3.3.78 Roll-On/Roll-Off (Ro/Ro). A form of cargo handling utilizing a vessel designed to load or unload cargo that rolls, such as automobiles or tractor trailer units.

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3.3.79 Sagging. Straining of the ship that tends to make the middle portion lower than the bow and stern.

3.3.80 Sail Area. The area of the ship that is above the waterline and that is subject to the effects of wind, particularly a crosswind on the broad side of a ship.

3.3.81 SCBA. Self-contained breathing apparatus.

3.3.82 Scupper. An opening in the side of a vessel through which rain, sea, or fire-fighting water is discharged.

3.3.83 SDS. Safety data sheet.

3.3.84 Shaft Alley. A narrow, watertight compartment through which the propeller shaft passes from the aft engine room bulkhead to the propeller.

3.3.85 Shaftway. A tunnel or alleyway through which the drive shaft or rudder shaft passes.

3.3.86 SOLAS. The International Convention for the Safety of Life at Sea.

3.3.87 Starboard Side. The right-hand side of a ship as one faces forward.

3.3.88 Stern. The after end of a boat or vessel.

3.3.89 Stevedore. A person employed for the loading and unloading of ships, sometimes called a longshoreman.

3.3.90 Superstructure. An enclosed structure above the main deck that extends from one side of the vessel to the other.

3.3.91 Tank Top. The lowest deck, top plate of the bottom tanks.

3.3.92 Terminal. Either end of a carrier line having facilities for the handling of freight and passengers.

3.3.92.1 ***Break Bulk Terminal.*** A terminal where commodities packaged in bags, drums, cartons, and crates are commonly, but not always, palletized and loaded and unloaded.

3.3.92.2 ***Bulk Terminal.*** A terminal where unpackaged commodities carried in the holds and tanks of cargo vessels and tankers and generally transferred by such means as conveyors, clamshells, and pipelines are handled.

3.3.92.3 ***Car Terminal.*** A terminal where automobiles are the commodity handled.

3.3.92.4 ***Container Terminal.*** A terminal that is designed to handle containers that are carried by truck or rail car where transported over land.

3.3.92.5 ***Dry Bulk Terminal.*** A terminal equipped to handle dry goods that are stored in tanks and holds on the vessel.

3.3.93 Tides. The periodic variation in the surface depth of the oceans, and of bays, gulfs, inlets, and tidal regions of rivers, caused by the gravitational pull of the sun and moon.

3.3.94 Towboat. A powerful, small vessel designed for pushing larger vessels.

3.3.95 Tug. A powerful, small vessel designed for towing larger vessels.

3.3.96 ULCC. Ultra-large crude carrier.

3.3.97 Ullage Hole. An opening in a tank hatch that allows measuring of liquid cargo.

3.3.98 USCG. United States Coast Guard or national/regional equivalent.

3.3.99 Vertical Zone. The area of a vessel between adjacent bulkheads.

3.3.100 Watertight Door. A door that is designed to keep water out.

3.3.101 Winch. A stationary, motor-driven hoisting machine having a drum around which a rope or chain winds as the load is lifted.

3.3.102 Zone Boundary. A structural component designed to contain flooding or fire to a specified space within a vessel.

Chapter 4 Marine Environment

4.1 Introduction. The marine environment presents many unique challenges. It is very important that these challenges are identified and preplanned in order to have a successful outcome. This chapter describes the elements of the physical marine environment that can be encountered by those involved in managing a fire aboard a vessel. An understanding of these elements is necessary to plan for the changing conditions that occur during a vessel fire. Local sources of expertise that are available to provide specific information on the marine environment should be identified during the planning stages.

4.2 Tides and Currents. Tides and currents are critical to the fire officer, since they produce vertical and horizontal movement of the vessel. Equipment, such as hoses and ladders, that is attached to the vessel, as well as "drafting" operations from docks and piers, can be adversely affected.

4.2.1 Tides are the daily changes in the depth of the water. Depending upon location, this change can vary from unnoticeable to more than 30 ft (9.2 m). Currents can range from as little as ½ knot (0.5 mph) to more than 10 knots (11.5 mph).

4.2.2 Changes in the tide should be considered when mooring or anchoring a vessel and during fire suppression activity. The following concerns should be addressed:

(1) The vessel can become grounded, which, in turn, can cause listing or capsizing.
(2) Tides may put additional strain on the mooring system of a vessel and can even compromise a weakened system.
(3) Tides should be monitored to ensure that drafting operations are not affected.
(4) Ground ladders placed against a vessel must be monitored at all times.
(5) Operators of aerial apparatus must stay with equipment at all times to prevent damage or injury. Aerial apparatus should never be placed directly against the side of a vessel.
(6) Tide levels will also affect clearance under bridges and may prevent fire and rescue vessels from accessing the scene.

4.2.3 Currents can result from tide changes and river flow. Tidal currents change direction at predictable intervals. River flow increases or decreases the tidal current. The river flow rate usually increases during spring runoff and decreases during summer and fall droughts.

4.2.4 Currents affect the movements of vessels and boats. They put additional strain on the mooring system of a vessel

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and can even compromise a weakened system. When currents hit obstructions in the water, such as piers, they often change direction and form whirlpools and eddies. Fireboats and rescue boats maneuvering around piers can find it very difficult to maintain their position in these swirling waters. People who fall overboard into strong currents can be pulled by these currents under piers, barges, or vessels and can become trapped underneath them.

4.2.5 The Coast Guard, the vessel crew, and others who work in the port can estimate tides and tidal currents from tide tables and current tables produced by the NOAA. For local conditions around piers and in channels, docking pilots and channel pilots should be consulted.

4.3 Weather. Observing and reporting the actual weather conditions at the site of an incident is of critical importance to planning and executing an effective response. Observations of the on-scene weather conditions should be reported to the command post at regular intervals. Changes in on-scene weather conditions also are to be reported as soon as they are recognized.

4.3.1 A variety of weather forecasting information sources might be available to the IC for planning and modifying fire-fighting strategies.NWS offices might be able to provide weather forecasts that are specific to the location and nature of the incident. Continuous weather forecasts are broadcast by the NOAA on VHF-FM channels. The USCG has maritime weather observations and forecasts available for use by the IC. The command post (CP) should monitor appropriate VHF-FM channels (usually marine CH-16 and CH-22A) for Coast Guard urgent marine information broadcasts that warn of severe weather. Local airport FAA offices might make aviation weather observations and forecasts available.

4.3.2 Weather conditions over water are often different from the weather experienced over land. Rapid changes of the weather occur frequently in coastal areas and can take incident responders by surprise. Weather observations and forecasts for offshore conditions can become less accurate as the distance from shore increases.

4.3.3 The wind speed and temperature over water can be expected to be different from conditions observed over land. Temperatures over water can be a few degrees warmer during the winter but cooler during the summer. A breeze can be blowing along the coast even when it is calm inland because of this temperature difference. Winds can be stronger along the coast or in harbors where there are few obstructions. Weather can stop or hinder fire-fighting operations on boats under way. Winter weather can also have significant impacts on fire-fighting operations. Ice formed on vessels by fire-fighting water during freezing temperatures can cause loss of vessel stability as well as make deck surfaces unsafe for fire fighters and vessel personnel.

4.4 Vessel Traffic. The amount and type of vessel traffic vary from port to port, within a port, and along waterways. Vessels, such as fishing vessels, sailboats, pleasure boats, naval vessels, and deep-draft vessels, all present varying traffic problems. Vessel traffic may also create wakes and other hazards that could result in damage to response vessels or injury to responders. The COTP has the authority and resources to control vessel traffic in the harbor. *(See Chapter 14 for further information.)*

4.5 Channels and Navigation. Nautical charts are maps of a harbor, river, or bay that indicate the channels used by vessels to enter and leave a port. They also provide the projected depth of the channels and the buoys and beacons that mark the channel. These channels are similar to highways and have their own set of rules of the road that apply to all vessels. Operators of response vessels should be fully trained in safe navigation techniques.

4.5.1 Many larger vessels are under the guidance of a local professional pilot(s) who has extensive knowledge of local conditions.

4.6 Designated Fire-Fighting Anchorage and Piers. The USCG determines the locations of fire-fighting anchorages in the port and along waterways. The USCG also enforces the anchorage regulations. Moving a burning vessel to an anchorage often reduces exposure problems but could increase access and pollution problems. Even if a sufficient number of vessels or platforms can be obtained to gain access to the vessel, fighting a fire from a platform while exposed to the weather and currents is much more difficult than fighting a fire from a pier. An anchorage can be an excellent temporary location for the vessel while fire-fighting resources are being coordinated and a more advantageous location is sought.

4.6.1 Designated piers and anchorages should be, and usually are, provided in the U.S. Coast Guard Firefighting Contingency Plan for the area. *(See Chapter 14.)*

4.7 Bottom Conditions. Bottom conditions should be evaluated when a vessel is anchored or moored. An anchor might fail to hold on a rocky bottom, while it could hold too well on a muddy bottom, making the anchor difficult to pull up. The nautical chart of the area identifies the bottom conditions (e.g., mud, sand, rock, wrecks). When a vessel is moored to a pier and in danger of settling to the bottom due to an excess of fire-fighting water, the slope of the bottom determines how the vessel comes to rest. At some piers, the bottom is sloped steeply toward a deeper channel. A vessel settling on this bottom can slide out toward the channel or capsize. Preplans of berthing facilities should contain information about the bottom conditions.

4.8 Marine Terminal Types. Marine terminals vary in characteristics such as type, size, age, construction, and cargo-handling and fire-fighting equipment. The different types of marine terminals are as follows.

(1) Liquid bulk terminal, which transfers liquids such as oils, chemicals, and liquefied gases from tank vessels, through a fixed pipeline, and to large onshore storage tanks.
(2) Dry bulk terminal, which transfers items such as cement, grain, coal, salt, and fertilizer in bulk quantities, usually using bucket cranes and conveyor belts. Storage is in piles on the ground or in large warehouses.
(3) Container terminal, which transfers containers [8.5–9.5 ft high × 8 ft wide × 20–40 ft long (2.6–2.9 m high × 2.4 m wide × 6.1–12.2 m long)] from vessels to ground storage, chassis, or rail cars using specialized movable cranes.
(4) Break bulk terminal, which transfers nonbulk cargo, such as raw rubber, lumber, bags of cocoa and coffee beans, steel coils, and heavy machinery, to large transit sheds and warehouses using the ship's equipment or cranes. This method is very labor-intensive.
(5) Motor vehicle terminal, which transfers vehicles that are driven from large car carriers to large storage parking lots on the terminal.
(6) Roll-on/roll-off terminal, which transfers freight containers on transportation means such as chassis, trailers, and

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motor vehicles that are driven on or off the vessel using special piers or vessel ramps, or both.

(7) Rail terminal, which transfers railcars that are driven on or off the vessel on tracks located on the vessel and terminal and connecting the vessel and terminal.

(8) Ferry/passenger terminal, which transfers passengers, their vehicles, their baggage, and other belongings. The operations at a large cruise ship terminal are similar to those at an airport. Access to and from ferry/passenger vessels is normally through one point at the terminal. This creates difficulties if responders are attempting to gain access to a vessel when passengers are exiting. A secondary access point is sometimes available where crew and supplies access the vessel. Pre-fire plans should identify all access points for emergency response personnel.

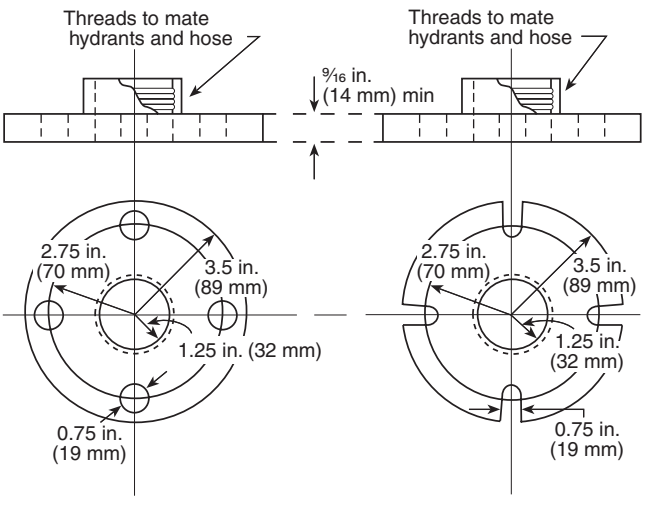
4.9* Piers and Wharves. Piers and wharves are constructed from materials that vary from concrete pilings and surfacing to wooden pilings with wooden or concrete decking. Ideally, vessel fires should be fought from concrete piers or wharves. The construction of buildings on piers and wharves also varies considerably.

4.10* Shipyards and Dry Docks. Because of the nature of the work [e.g., welding, burning (cutting), grinding], many vessel fires have occurred in shipyards and dry docks. These areas are typically crowded with people and machinery. Ship systems, including fire-fighting systems, can be inoperable due to repairs in progress. Access to the pier or dry dock is difficult. A vessel in a dry dock might stand 100 ft (30.5 m) out of the water with only one gangway leading into the ship from the top of the dry dock. Openings might be cut in the vessel, which contribute to the spread of smoke and fire.

4.11 Moorings. Vessels are moored to piers and wharves using wire or rope lines. Efforts should be made to protect mooring lines so that they do not burn through or break, setting the vessel adrift. On deck, mooring lines usually are handled on large power winches. Without power to these winches, mooring a vessel becomes very difficult. During vessel incidents, operations should be kept clear of all mooring lines and these lines should be frequently monitored for excessive strain. If the vessel stability changes, mooring lines can be strained to the point of parting or separation, causing a hazard for emergency personnel. Mooring lines can break with such force that they can kill or seriously injure personnel or damage equipment. Some winches are automatic and self-tensioning and can move without warning, creating hazards to personnel.

4.12 Cranes. Vessels often have their own cargo-handling gear (cranes and booms), which could be useful during a fire. At terminals, cargo-handling cranes come in various shapes, sizes, and capacities. They range from large container and derrick cranes to small mobile cranes. Marine construction companies usually operate cranes on barges that can be towed throughout the port. They can be useful if ship or terminal cranes have been damaged or cannot be used.

4.13* Shoreside Fixed Fire-Fighting Equipment. Some piers and wharves are equipped with fixed fire-main and potable water systems. The connections to these systems need to be examined to ensure that fire-fighting equipment can be connected to them. There is a way to connect a shore fire-main system to a vessel fire-main system by connecting two "international shore connections" *(see Figure 4.13)*. The ship's international shore connection connects to the ship's fire main and provides a standard international flange, while the shore international shore connection connects to the shore fire main and provides another standard international flange. These flanges can be bolted together to connect the two systems. The ship's international shore connection is required on all commercial vessels; however, there is no requirement to have a shore international shore connection. Therefore, each responding fire department should have its own international shore connection to adapt to the fire department thread. The international shore connection is tested only to 150 psi (1034 kPa). Care should be taken to avoid overpressurizing this device or the ship's fire-main system. Therefore, it is strongly recommended that the ship's flange be connected directly to the vessel's fire main, if possible, and not to the vessel's fire hose. This procedure can provide for cooling water for boundary protection. The maximum pressure to be applied to the international shore connection should be obtained to avoid actuating the pressure relief valve and pumping fire fighting water into the vessel's engine room or bilge.



Material: Any suitable for 150 psi (1034 kPa) service
Flange surface: Flat face
Gasket material: Any suitable for 150 psi (1034 kPa) service
Bolts: Four ⅝ in. (16 mm) minimum diameter, 2 in. (51 mm) long, threaded to within 1 in. (25.4 mm) of bolt head
Nuts: Four, to fit bolts
Washers: Four, to fit bolts

Material: Brass or bronze suitable for 150 psi (1034 kPa) service

FIGURE 4.13 International Shore Connection.

4.14 Shore Connections. Vessels sometimes take on potable water and fuel and sometimes are connected to shoreside electricity, sanitary water and sewer, bilge water, telephone, and other services while at a pier. These connections might need to be disconnected during fire-fighting efforts.

Chapter 5 Vessel Familiarization

5.1 Ship Construction. Modern ships are constructed mainly of steel plates that are welded together, including the decks and vertical framing. The interior bulkheads can be made of steel or other materials, provided that they meet the fire-resistive requirements of the bulkhead.

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5.1.1 Aluminum and other alloys sometimes are used in noncritical areas. Structural aluminum normally is found only above the main deck. The heat of a shipboard fire causes aluminum structures to sag or melt much more quickly than steel structures.

5.1.2 Composite materials, metal, or cored laminated panels are often used for bulkheads in accommodation and berthing areas.

5.1.3 Bulkheads can be fire and smoke rated in a manner similar to partitions in buildings, as detailed in Table 5.1.3.

Table 5.1.3 Example Bulkhead Rating

Class	Material	Containment	Time Period
A	Steel or equivalent	Smoke and flame	Up to 60 minutes
B	Noncombustible	Flame but not smoke	Up to 30 minutes
C	Noncombustible	Neither smoke nor flame	None

Note: See U.S. Code of Federal Regulations 46 CFR 72.05–72.10 for additional information.

5.1.4 Response personnel must familiarize themselves with terminology commonly used in the marine environment, such as *bow* for front and *stern* for the back of a vessel as well as *port* and *starboard* for left and right, respectively. These terms will be essential in size-up as well as in directing operations.

5.1.4.1 Ships are framed in a manner similar to buildings. The outer shell or plating and the decks provide the main frame of the ship. The main girder of the vessel is called the keel.

5.1.4.2 Vessel diagrams provide information on the vessel's layout of compartments. They are similar to building diagrams, and they may assist in determining the location of fire, potential extension, and exposures. Response personnel should consult with marine experts when reading and interpreting vessel diagrams. Vessel diagrams posted for the orientation of passengers may be incomplete and not show hidden passageways and accesses for crew use. The vessel fire control plan will assist in developing fire-fighting strategy and is critical to the IC and planning section chief.

5.1.4.3 Frames, similar to human ribs, provide the internal structure to support the decks and outer shell. Frames are numbered sequentially but vary as to point of reference. Numbering begins from the bow, stern, or amidships. The compartments also are numbered. The starboard side compartments are odd-numbered, and the port side compartments are even-numbered.

5.1.4.4 Decks on military ships usually are numbered. Decks on merchant vessels are named or numbered.

5.1.4.5 Military ship decks above the main deck are numbered as "01," "02," "03," and so on. The higher the number, the higher the deck in the superstructure. Decks below the main deck are numbered as "lst deck," "2nd deck," "3rd deck," and so on. The larger the number, the lower the deck within the hull.

5.1.4.6 Merchant vessel decks are named or numbered, or both. Names vary from vessel to vessel and even within the same vessel. It is important for fire fighters to refer to the vessel's general arrangement plan to determine the correct deck name or number for a specific vessel. *[See Figure 5.1.4.6(a) and Figure 5.1.4.6(b).]*

5.1.4.7 Ships are divided into zones by fire-resistive bulkheads and decks. The location of bulkheads and decks can be determined by referring to the ship's fire control plan.

5.1.4.8 The doors separating the vertical zones should have the same fire and smoke rating as the bulkhead.

5.1.4.9 Below the main deck, the doors can be remote controlled or manually operated watertight doors, or they can be standard fire doors.

5.1.5 During construction, U.S. flag vessels are inspected strictly by the Coast Guard. Penetrations are sealed or protected by dampers at zone boundaries.

5.1.5.1 Between the vertical zones, penetrations in bulkheads, framing, and decking may be permitted. These penetrations can cause hidden spaces to be created.

5.1.5.2 Other concealed spaces can be created due to cofferdams, shaftways, double bottoms and intakes, or discharges.

5.1.5.3 As ships age, the integrity of the vertical zones tends to diminish.

5.2 Interior Arrangements.

5.2.1 The sizes of a ship's interior spaces, ladders, companionways, and passageways are much smaller than those found in a building. It is difficult for two people to walk abreast in some passageways.

5.2.1.1 The cabins or berths usually are smaller than those found in a hotel.

5.2.1.2 Stairs are called "companionways" or "ladders." They often are steep and narrow, as well as open at the back.

5.2.2 The machinery spaces on a ship can be very large, since they commonly contain the equipment used to produce the ship's electrical and propulsive power.

5.2.2.1 Each self-propelled vessel is required to have at least two electric-generating sources, which can consist of battery or generator or both.

5.2.2.2 On most U.S. flag vessels, lighting for engine rooms, boiler rooms, and auxiliary machinery spaces is supplied by two or more electrical feeders.

5.2.2.3 Because of the oils and fuels used in the machinery spaces, everything in the space should be considered to have a coating of oil upon it and, therefore, it could be slippery, especially when wet.

5.2.2.4 Much of the decking in the machinery spaces is open-webbed grating to reduce the chance of slipping. If the fire is underneath the open-webbed or expanded metal decking (grating), the flames and heat pass through and can cause injury and early structural failure.

5.2.2.5 Because of the critical nature of machinery spaces, they usually are protected by manually activated extinguishing systems.

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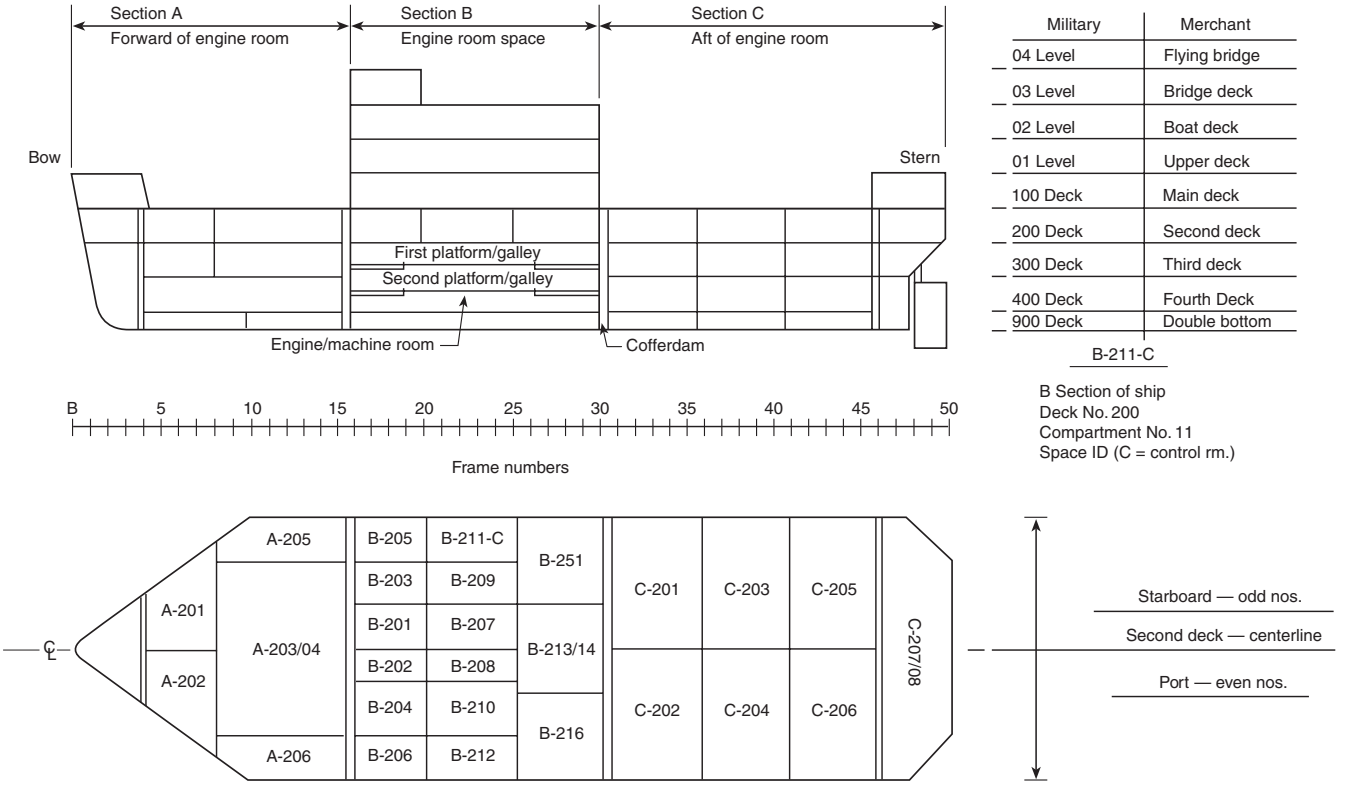

FIGURE 5.1.4.6(a) Pre-1949 Convention Compartment Identification System.

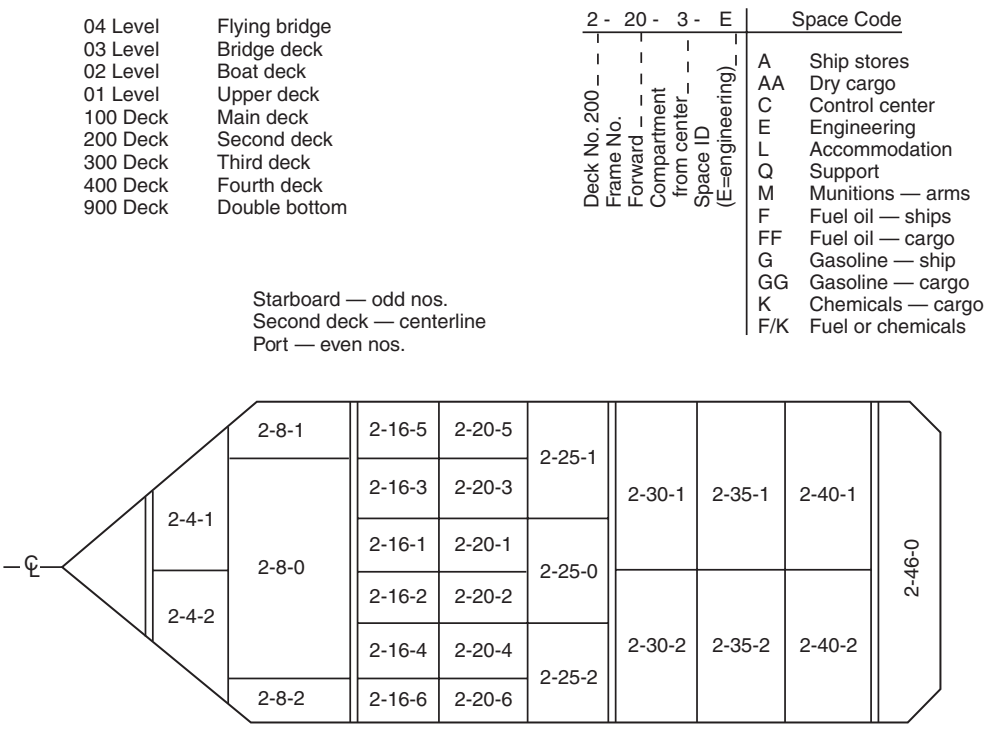

FIGURE 5.1.4.6(b) Post-1949 Convention Compartment Identification System.

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5.2.2.6 All the separate compartments in the main machinery spaces require at least two exits. One of these exits is usually an escape scuttle to the deck above.

5.2.3 Cargo storage areas (holds) are large spaces in which cargo is carried. These spaces usually have hatch covers at the main deck level through which cargo is handled. There also might be covers on the decks below. If the ship is in port, these covers could be open, posing considerable risk to people on deck, particularly in a smoke-filled environment. Generally, these spaces are required to be equipped with manually operated suppression systems. Holds can have mezzanines called *tween decks* to increase storage capacity.

5.2.3.1 Tanks are holds designed to contain liquids. The tanks are emptied by the use of pumps that are aboard ship.

5.2.4 Ships are equipped with fire pumps that supply fire mains, which are similar to standpipes in buildings. At least one of these pumps is required to have an alternate or emergency source of power.

5.2.4.1 Self-propelled vessels and some barges are equipped with fire pumps that supply fire mains that are similar to standpipes in buildings. Where two or more fire pumps are required, the pumps should be arranged with separate sea connections and sources of power so that a fire in any one space cannot put all of the fire pumps out of operation.

5.3 Types of Ships. Ships can be classified into several main types. The vessels that are flagged/registered as United States vessels comply with a slightly different set of rules than do vessels that are flagged by foreign countries. Those countries other than the U.S. participating in the SOLAS convention should comply with the SOLAS standards. Some vessel categories to which SOLAS does not apply include cargo vessels under 500 gross tons (454 m tons) (most offshore supply vessels) and vessels not propelled by mechanical means (barges and sail training ships). The major types of vessels are as follows:

(1) Dry bulk carriers, which typically carry goods such as grain, coal, iron ore, and scrap steel in large cargo holds *[see Figure 5.3(a)]*. The hazards associated with fires on these types of vessels can be compared to the hazards of grain silos, such as spontaneous combustion, dust explosions, and expansion of product due to the addition of water, with the added problem of instability. Additional care is to be taken because of the large deck openings into the holds.

(2) Break bulk carriers, which are ships that carry dry cargo in smaller parcels such as crates, bags, or barrels *[see Figure 5.3(b)]*. Break bulk carriers also can contain dunnage (usually wood) used to support and separate cargo. Break bulk carriers can carry hazardous materials in their holds.

(3) Ro/ro (roll-on/roll-off) ships, which are ships that carry automobiles and other vehicles. They are designed specially to carry as many vehicles as possible. These vessels can have low overheads, many decks, and sometimes straight, flat sides. They may carry a variety of trucks, tractor trailers, trailers, and vehicles. They may carry any products that can be carried by road vehicles, including hazardous materials. Ro/ro ships often carry containers on deck in addition to vehicles.

(4) Container ships, which are specialized carriers that carry break bulk goods in steel, fiberglass, or aluminum containers *[see Figure 5.3(c)]*. Containers typically have floors made of wood. Large container ships carry as many as 8000 20 ft (6.1 m) containers in holds and above deck. Container ship capacity is measured in TEUs (twenty-foot equivalency units), the number of 20 ft (6.1 m) containers a ship can carry. Containers can hold hazardous material or general cargo and may be refrigerated.

(5) Liquid bulk carriers, which are called *tankers* and are capable of carrying tremendous quantities of liquids in specially designed holds called *tanks [see Figure 5.3(d)]*. Tankers are sized according to volume, the smallest being called a *handy-size tanker* and the largest being called an *ultra-large crude carrier* (ULCC). The fire officer should become familiar with the sizes and types of tankers that call at the port. Some tankers carry different liquids in different tanks. Some carry 40 or more different liquids and are known as *drugstores*. A tanker also has the ability to pump off its own cargo during the off-loading process. Because of the pumps, there often is a great deal of piping on the main deck of the tanker. Care should be taken to preserve the integrity of the piping.

(6) Passenger vessels, which can carry several thousand people. Although the passenger spaces are similar to those in a hotel, there are several differences that should be noted. The corridors (passageways) are considerably more narrow than those in a hotel. The rooms also are smaller. The areas to which people can be evacuated on a ship are limited.

(7) Ferries, which usually are a combination of automobile carriers and passenger vessels that traverse smaller bodies of water, such as harbors, lakes, and rivers; however, some are quite large ocean-going vessels. Ferries usually resemble floating parking garages with large, undivided spaces. Passenger spaces are located within the superstructure. Larger ferries may have accommodation spaces similar to passenger vessels. Some ferries are capable of speeds in excess of 50 knots.

(8) Barges, which can carry any material that is carried by a larger ship. Barges often are used where deep-draft vessels cannot travel. Many barges can be tied together to form a "tow," which resembles a raft floating on the water.

(9) Multipurpose ships, which are designed to carry a variety of cargoes at the same time. Special systems are available to transport break bulk, refrigerated (frozen), and liquid cargoes *[see Figure 5.3(e)]*.

(10) Lighter-on-board ships, which carry smaller, barge-like craft called *lighters*, which ferry cargo from a ship anchored in deep water to shallow water ports. The lighters usually are loaded aboard the ship through openings in the stern or are lifted aboard by large ship-mounted cranes. Lighters may carry break bulk and occasionally solid bulk cargo, including hazardous materials.

5.4 Ship Personnel.

5.4.1 Captain. The IC should utilize a ship's personnel in developing plans to respond to a marine incident. The IC should not attempt to remove such personnel from the ship upon arrival. Removing them may endanger the vessel or even create an international incident as well as exceed the authority of the fire service if the vessel flies a foreign flag. Ship personnel will be required to maintain important systems such as power and fire-fighting systems. Key crew members should be identified, and their responsibilities can be integrated into preplans. Commercial vessels normally will have watch bills that identify the responsibilities of each of the crew members during emergencies. This information can be valuable to responders when developing incident action plans.

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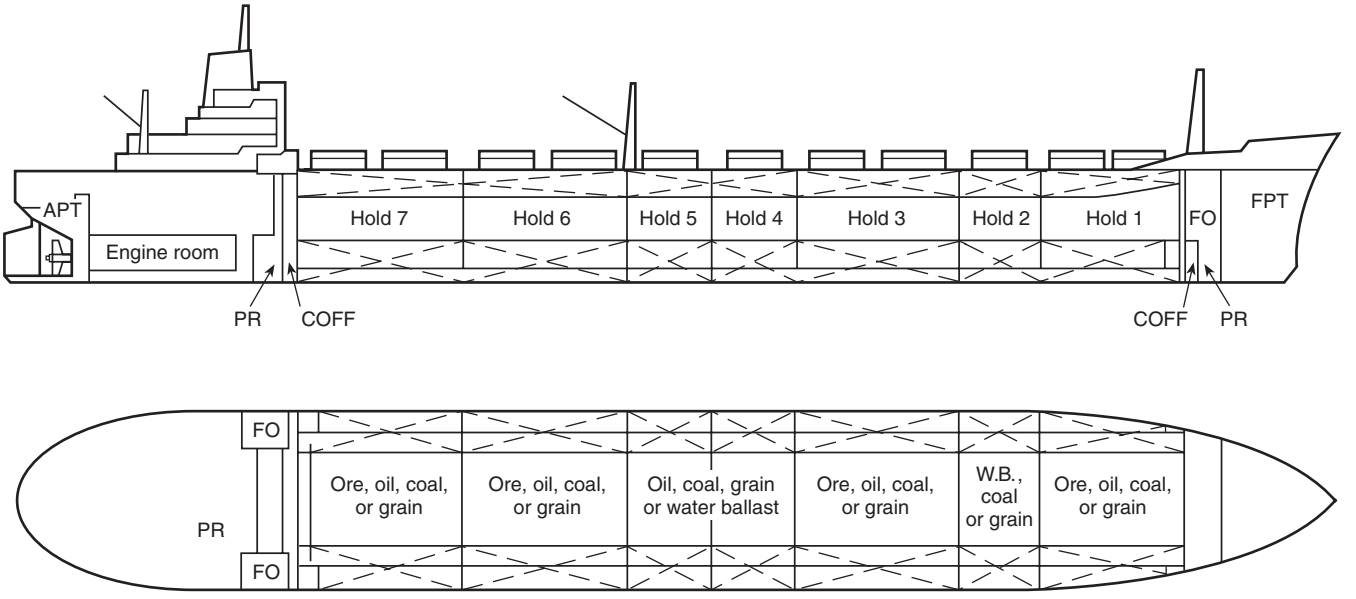

FIGURE 5.3(a) Dry Bulk Carrier.

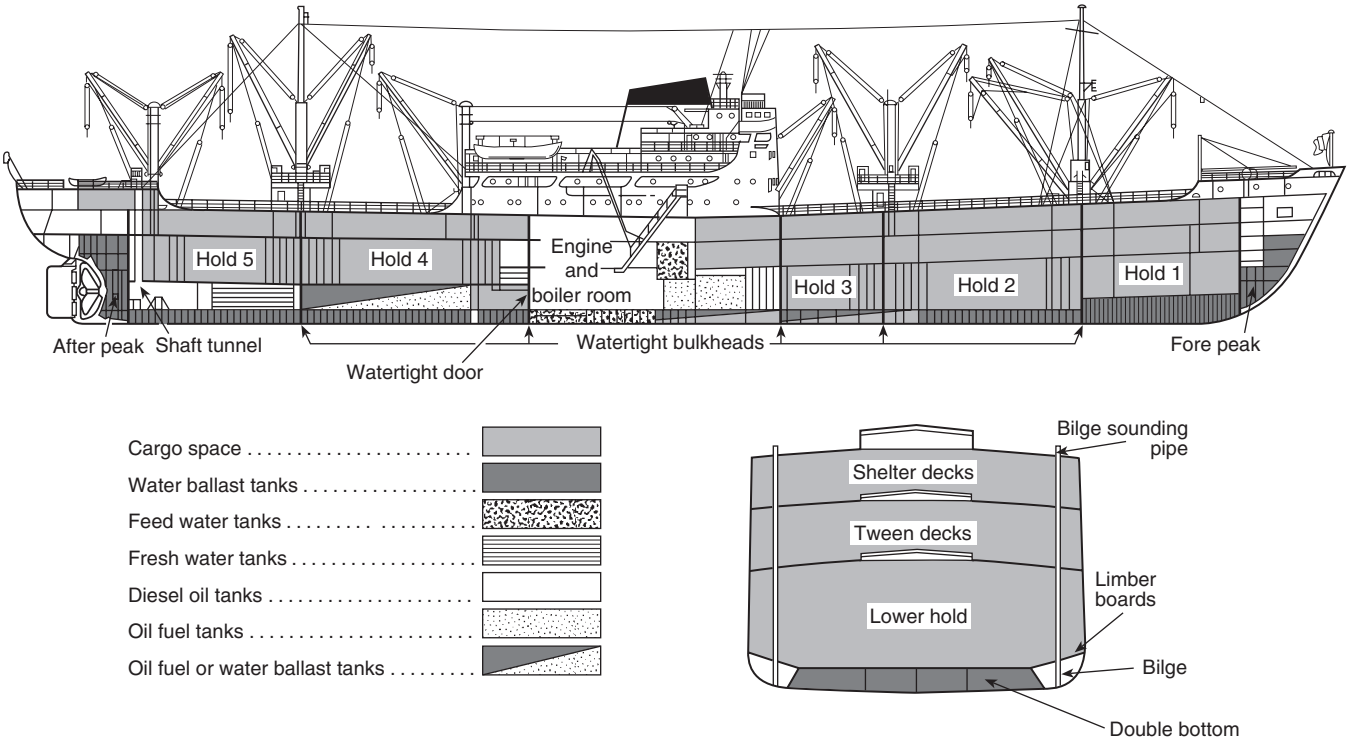

FIGURE 5.3(b) Break Bulk Carrier.

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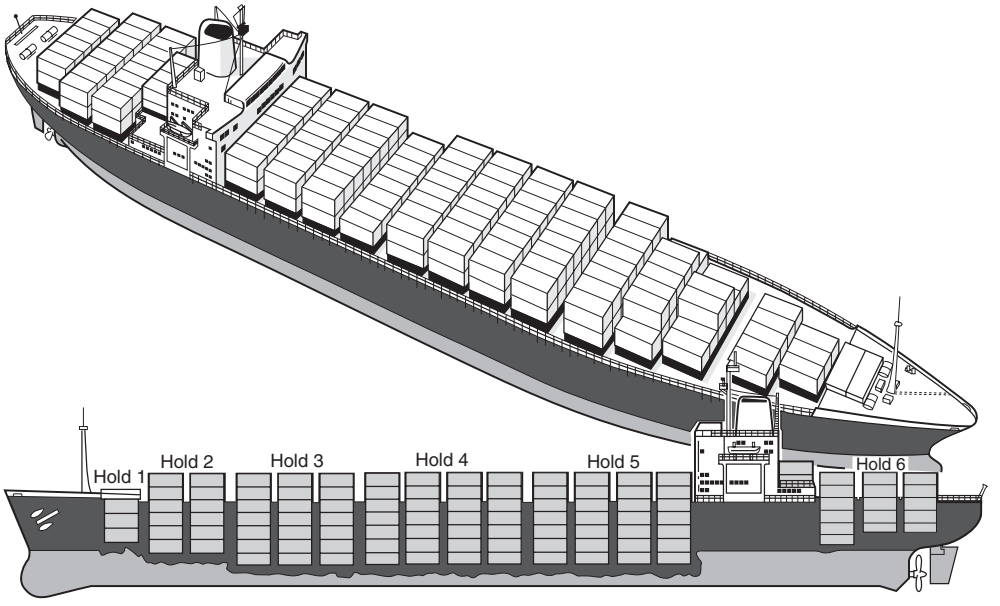

FIGURE 5.3(c) Container Carrier.

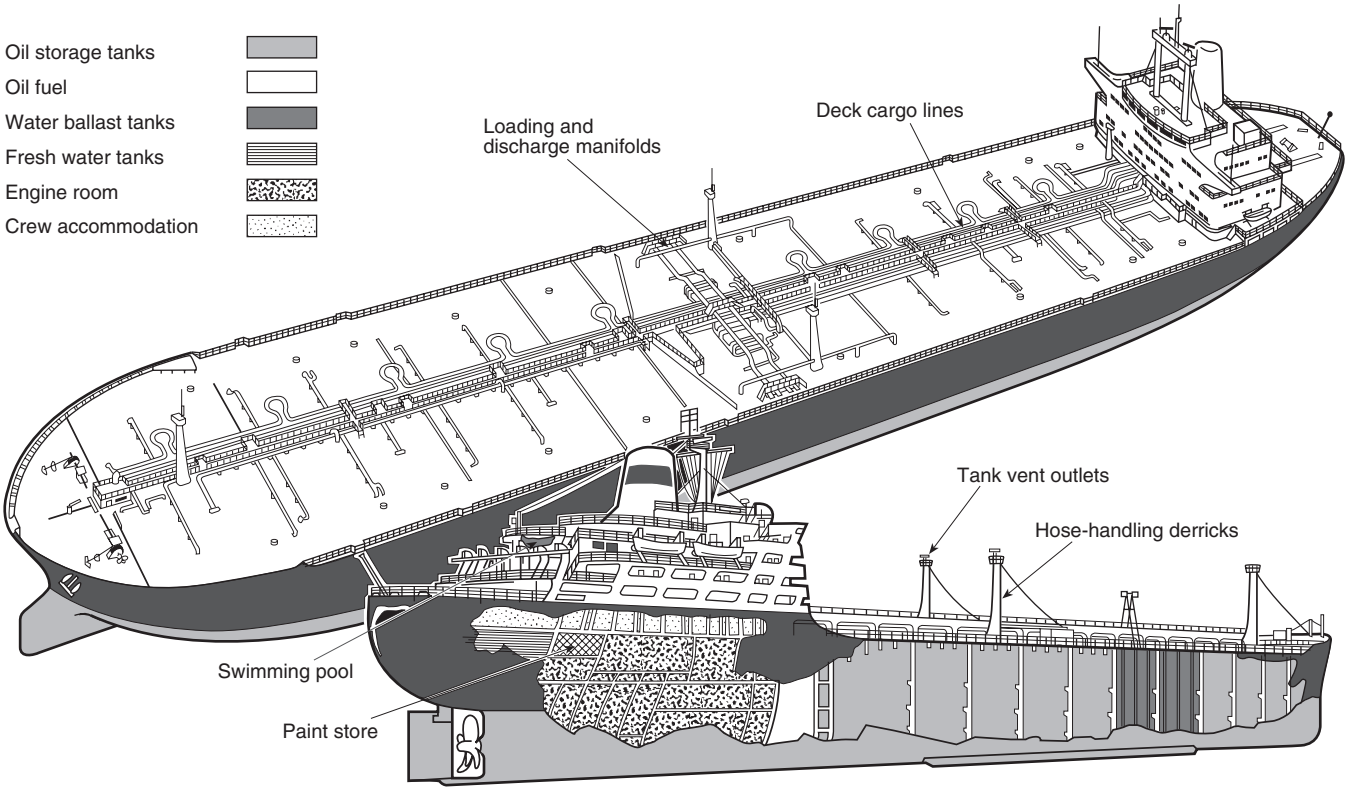

FIGURE 5.3(d) Liquid Bulk Carrier.

5.4.1.1 The captain, or master, of the ship is responsible for all that happens to and upon the ship. The captain has ultimate control over the safety of the vessel. However, the safety of the port is the responsibility of the United States Coast Guard COTP.

5.4.1.2 Liaison with the ship's captain is to be established as a priority item at the outset of any incident. Courtesy and cooperation with the captain greatly enhance any operations aboard the ship. The captain will provide information on the sequence of events and the actions taken prior to the

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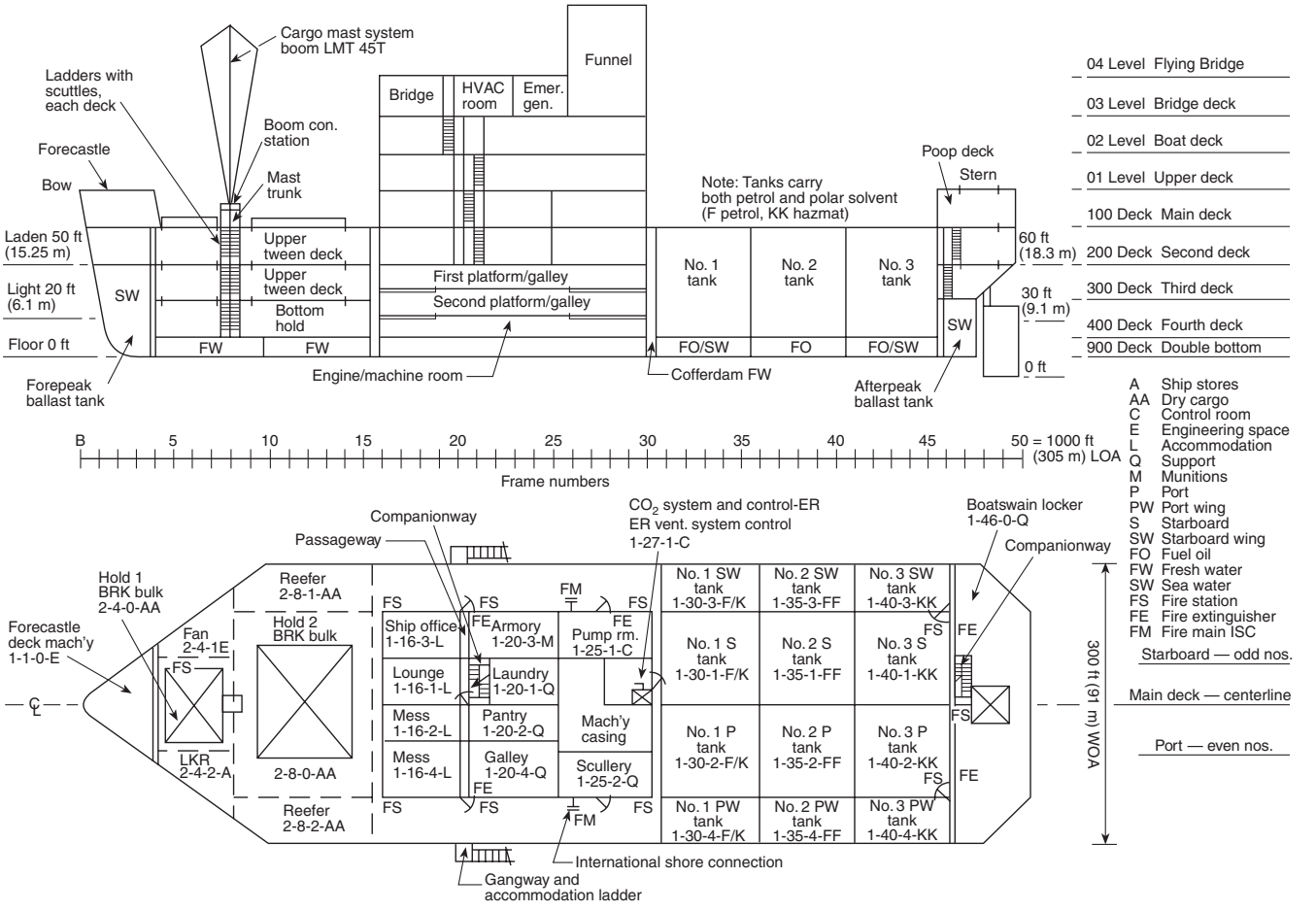

FIGURE 5.3(e) Multipurpose Ship.

fire department's arrival. The captain also should know which systems aboard ship are available and can be used.

5.4.2 Deck Department.

5.4.2.1 The deck department consists of one or more mates and other sailors. In port, the mates often are responsible for the cargo functions of the ship, including on-loading and off-loading.

5.4.2.2 The chain of command flows from the captain to the chief mate *(see Figure 5.4.2.2)*. The chief mate is responsible for stowage of the cargo and the maintenance of the ship's stability. The chief mate can have several assistant mates who assist in the performance of assigned duties.

5.4.3* Engineering Department.

5.4.3.1 The engineering department on a ship is responsible for the ship's propulsion and steering, as well as all of the ship's mechanical and electrical systems.

5.4.3.2 The engineering department is led by a chief engineer, who can have several assistants who assist in maintaining the ship's systems.

5.4.4 Steward Department.

5.4.4.1 A large steward department is found on ships that carry passengers. This department is similar in function to the staff at a hotel. It is responsible for passenger comfort.

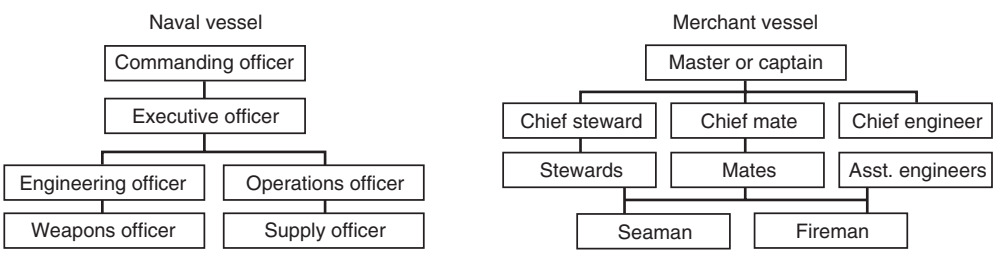

FIGURE 5.4.2.2 Command Organizational Structure.

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5.4.4.2 Typically, the department is led by a chief steward, who is responsible for a large staff. This department is the source of most knowledge regarding passenger accommodations.

5.4.5 Crews of International Origin. A ship's crew can be made up of people of various nationalities. As a result, there can be serious communication problems because of language barriers. The level of fire-fighting expertise and willingness to get involved in incident mitigation can vary from vessel to vessel.

5.5 Shipboard Fixed Systems.

5.5.1 Introduction. Ships, unlike barges, have built-in fixed fire systems to extinguish shipboard fires. Experience has encouraged ship designers to improve these systems to a high degree of efficiency. Crews generally are trained to use these systems. However, the number of trained crew members aboard a ship during a fire emergency and the initial damage done by a fire to the equipment or access to the fire system can render the condition of the system suspect. The system might or might not be operating properly. It might or might not have been used properly by the ship's crew and could be partially or fully expended.

5.5.2 Common Problems and Concerns.

5.5.2.1 Maintenance. While a marine environment demands the best of maintenance programs, continuous changes in operating personnel can result in ship systems that are not as well maintained as those that are based on land.

5.5.2.2 Hardware Compatibility. With the exception of U.S. ships, components of shipboard systems are supplied by companies throughout the world in many configurations. Fittings and thread types and sizes are examples of equipment that could prevent a land-based fire fighter from connecting to a shipboard system.

5.5.3 Fire-Main Systems. The primary intent in the design and construction of a fire-main system is to provide the crew with protection for its ship. Therefore, such systems are designed for use by nontrained fire fighters. The design intent is similar to that of Class II standpipe systems as defined in NFPA 14.

5.5.3.1 Fire Mains. Fire mains are configured either as loops or as "dead-end" (riser) mains. The loop obviously is preferred, because a break on the fire main between the pump and the fire can be valved off and water can be pumped to the fire from an alternate route.

5.5.3.2 Branch Lines. Branch lines run from the fire main to the fire station. The pipe diameter is usually 1½ in. to 2½ in. (38 mm to 64 mm) or the equivalent.

5.5.3.3 Fire Stations. Fire stations usually consist of a hydrant with the required hose and nozzles. Stations should be located so that all portions of a ship can be reached by streams from two separate fire stations.

5.5.3.4 Fire Pumps. Fire pumps aboard ships vary greatly in capacity, but they usually are designed to provide much less water than their land-based counterparts. For this reason, augmenting or bypassing the ship's fire pump should not be done without careful consideration. Overpressurization can cause rupture of the piping or result in the operation of the relief valve. Relief valves might be set as low as 125 psi (862 kPa).

5.5.3.5 International Shore Connection. The international shore connection is a device that has the ship's coupling on one end and an adjustable flange on the other end. Shoreside fire departments need to provide the opposite connector, which consists of an adjustable flange on one end and the fire department's coupling on the other. This connection is similar to a standpipe system in a building. It is important that the pressure is regulated to ensure that 150 psi (1034 kPa) is not exceeded. Many fire-main relief valves are set to relieve at 150 psi (1034 kPa) or lower pressure and may discharge into the engine room bilge, adding to stability problems. Departments should consider pressurizing the ship's system to ensure that fire-fighting capabilities on the vessel are maintained. Systems like sprinklers on passenger vessels or car carriers may be critical to prevent the spread of fire. Additionally, the systems may be valuable to protect exposures on board the vessel. When a department is pressurizing a sprinkler or standpipe system, ship engineering personnel should be notified. The maximum allowable pressure for the fire main system should be obtained before charging the international shore connection.

5.5.4 Water Sprinkler Systems. Sprinkler systems are not widely used aboard U.S. vessels due to the construction methods employed. The most common use of sprinkler systems by U.S. vessels is for the protection of living quarters, ammunition lockers, public spaces and adjacent passageways, or vehicular decks on roll-on/roll-off vessels and ferries. Their primary function is to protect the vessel's structure and limit fire spread while providing escape routes.

5.5.4.1 Components. Sprinkler system components are similar to those of the land-based systems of the country that constructs the vessel. Exceptions relate primarily to the system's connection to the water supply. The source of water for all shipboard water systems is through the sea suction (strainer), which must be kept free of debris in order to remain effective.

5.5.4.2 System Types. Sprinkler systems are usually of the automatic (wet pipe) or manual (deluge type without detection) type. If the system is charged (wet pipe), a pressure tank maintains the necessary pressure. Piping and tanks are filled with fresh water. Dry-pipe systems are common if the system is subject to freezing.

5.5.4.3 Stability. One of the greatest concerns for all water systems is the effects of the usage of water on the vessel's stability. The amount of time the system has been in operation and the system's flow rate should be obtained immediately upon the arrival of the fire department. The ship's fire control plan should be consulted for the location of the system or the zone control valves, or both.

5.5.5 Spray Systems (Exposure Protection). Spray systems are similar to manual sprinkler systems, except that heads or spray nozzles are installed so that their streams are directed at the area to be protected/cooled. Water-mist systems are being found on vessels in many of the places previously protected by halon. In addition, larger systems are available that could take the place of CO_2 systems.

5.5.6 Foam Systems. Foam systems usually are designed to protect only engine rooms or cargo storage areas, or both. The duration of foam discharge is limited, and water usually continues to flow after the foam concentrate supply is exhausted. The ship's fire control plan should be consulted for information regarding these factors.

5.5.6.1* Foam Proportioning. Ship systems use various methods of mixing water, foam concentrate, and air to produce foam. The ship's fire control plan should be consulted to determine whether the system can be resupplied with foam concentrate or pressure can be augmented.

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5.5.6.2 Low-Expansion Foam Systems. Low-expansion foam systems provide vapor suppression with foam blankets that are applied directly to flammable liquids. To be effective, coverage needs to be complete. The quantity of foam needed is calculated according to the total surface area of the area to be protected. These systems are installed in engine rooms as well as cargo areas.

5.5.6.3 High-Expansion Foam Systems. High-expansion foam systems provide vapor suppression by completely filling the volume of the space protected. These systems are installed in enclosed spaces such as engine rooms. Flooding a compartment with high-expansion foam results in reduced visibility for fire fighters.

5.5.7* Carbon Dioxide (CO_2) Systems. Carbon dioxide systems are designed to protect enclosed spaces or portions thereof. They are used to protect cargo spaces, pump rooms, generator rooms, and engine rooms. Some smaller systems are used to protect areas such as paint lockers, galley ranges, and duct systems.

5.5.7.1 Life Hazard. Although CO_2 is a mildly toxic gas, it is extremely hazardous to humans when present in concentrations sufficient to extinguish shipboard fires (upwards of 30 percent by volume, in many cases). Also, visibility usually is obscured during discharge of CO_2. For these reasons, entry into spaces where CO_2 has been discharged never should be attempted without self-contained breathing apparatus (SCBA).

5.5.7.2 Predischarge Warning. Due to the life hazard posed by CO_2, a predischarge warning alarm should be installed in all spaces protected by CO_2 systems. Following evacuation, all doors, hatches, ventilation, and other openings should be closed or covered and all machinery should be shut down. The ship's fire plan should be consulted for instructions on these procedures.

5.5.7.3 System Operation. If the system has not been discharged prior to the arrival of the fire department, the fire plan should be consulted and procedures for discharging agent should be followed carefully. Assistance from the crew should be obtained where available. If the system has not been discharged and personnel are to work in the space, provisions should be made to ensure that the system cannot be discharged inadvertently. In addition to a predischarge warning, discharge delays normally are required for spaces used by personnel to allow for escape. CO_2 systems, like other shipboard fixed fire-protection systems, are difficult to support or augment from outside sources. It is critical that no agent be wasted. Once the involved space has been properly prepared and the system discharged, the on-scene personnel should not enter the space prematurely. Qualified personnel with appropriate testing equipment should be used to test involved areas to ensure that the fire is out before opening the fire scene to outside oxygen sources. Cargo fires can take many days to extinguish with CO_2.

5.5.7.4 System Types.

5.5.7.4.1 Total Flooding. Total flooding systems are designed to protect entire spaces such as engine rooms and cargo holds (larger, manually activated–type systems) or equipment storage areas (smaller, automatically activated–type systems).

5.5.7.4.2 Local Application. Local application systems are designed to apply CO_2 directly to the hazard that is being protected (pumps, motors, electrical equipment).

5.5.7.5 System Storage.

5.5.7.5.1 Low-Pressure Systems. Low-pressure systems are seldom used aboard ship. The advantage of the reduction in the storage space needed is offset by the difficulties of servicing the system. These systems may be found on foreign vessels and non–United States (U.S.) vessels and roll on/roll off (ro/ro) vessels.

5.5.7.5.2 High-Pressure Systems. High-pressure systems can contain a large number of cylinders (often in excess of 100). They can be located in a designated storage area. Prior to the system's actuation, all cylinder fittings should be checked for tightness, as they might have been connected improperly following servicing. Excessive leaks in system piping can result in the storage room atmosphere becoming unsafe. Precautions should be taken to protect the personnel in this area.

5.5.7.6 Delayed Discharge. If all cylinders are not needed on initial discharge, they can be discharged at appropriate intervals to maintain proper concentration levels. Engine rooms might need all available CO_2, while cargo spaces might need a partial discharge.

5.5.8 Halon Systems.

5.5.8.1 Marine halon systems are used primarily to protect the same types of hazards for which land-based halon is used (e.g., electronics equipment, high-value records, machinery spaces, pump rooms). These systems usually are smaller in size and generally use the same design criteria found in NFPA 12A.

5.5.8.2 "Pre-engineered" systems are smaller systems that protect areas such as unattended engine spaces on small craft.

5.5.9 Dry Chemical Systems. Dry chemical systems usually are designed to protect galley ranges and duct systems. On liquefied gas carriers, fixed dry chemical systems are installed to protect cargo deck areas and loading station manifolds.

5.5.10 Twinned Agent Systems. Twinned agent systems are used on some ships to protect helidecks or other areas where flammable liquids might be handled. They contain potassium bicarbonate–type dry chemical for knockdown and aqueous film-forming foam (AFFF) for vapor coverage.

5.5.11 Steam Systems. Steam for smothering fires usually is generated by main or auxiliary boilers. To be effective, the steam pressure needs to be 100 psi (690 kPa) or greater. The output of the steam-generating equipment should be 1 lb (0.45 kg) of steam per hour for each 12 ft^3 (0.03 m^3) of volume protected. These systems are not common in the marine industry today but can be found on older vessels. Under no circumstances should steam systems be used on nitrates, sulfates, or explosives. The steam extinguishing systems should be operated only by the ship's crew.

5.6 Ship's Operating Systems.

5.6.1 Introduction.

5.6.1.1 Because a ship is a self-contained unit, its operation is dependent upon and comprised of various internal systems and sources of power. These sources provide power for functions such as movement; electricity; HVAC; water/sewage; and cargo-handling capability.

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5.6.1.2 Subsections 5.6.2 through 5.6.8 provide the land-based fire fighter with a general understanding of these systems. Vessel systems are complex and may be hazardous to operate. Vessel systems should only be operated by qualified members of the vessel's crew.

5.6.2 Generators. Vessels are equipped with their own electrical generating systems. Electrical power is supplied throughout the ship by various distribution systems. Generators usually are driven by steam turbines or diesel engines. Most ships also have a self-starting emergency generator that supplies vital equipment and emergency lighting; most small vessels [less than 500 gross tons (454 m tons)] and barges have a manually connected emergency power source or none at all. While in port, the vessel might draw its electrical power from shore.

5.6.3 Ventilation.

5.6.3.1 Most ships are a maze of enclosed metal spaces that need to be provided with air exchanges on a regular basis. Exchanges usually are accomplished by mechanical systems that can be similar to those in land-based structures.

5.6.3.2 Usually, the initial procedure during a ship fire is to shut down all ventilation systems during the containment phases of fire fighting.

5.6.4 Fuel Systems. Fuel oil systems aboard ships include tanks, piping, pumps, and associated equipment. The associated equipment is used for heating, straining, centrifuging, measuring, and burning fuel oil. The fuel oil transfer system can be used by the ship's personnel to effect vessel stability and trim by transferring fuel from tank to tank.

5.6.5 Communications Systems. Large ships are dependent on communications for their efficient operation. Systems can include electric and electronic telephones and voice-powered telephones. Voice tubes are sometimes provided between a ship's wheelhouse and engine room for use in an emergency. Portable radios commonly are used by the ship's personnel throughout the vessel.

5.6.6 Cargo Handling. The main purpose of a merchant ship is to transport cargoes safely and quickly from one place to another. Types of cargoes vary and necessitate different types of ship and shore loading and discharging mechanisms. Some types of cargo-handling gear include winches and booms, derricks, cranes, floating cranes, roll-on/roll-off ramps, shoreside gantries, and pumping systems. Trained personnel are needed to handle ship cargoes. The ship's cargo-loading manual may be needed if cargo has to be off-loaded or shifted during fire-fighting operations. This manual is required to ensure that the vessel's equilibrium is maintained. Failing to use the manual during off-loading or shifting cargo could cause serious structural damage to the vessel or could cause stability problems. The master of the vessel should be consulted prior to moving any cargo.

5.6.7 Mooring and Anchoring Systems.

5.6.7.1 Vessels are secured to docks with various configurations of mooring lines and wires. These mooring systems need to be monitored because of changes in the tide and current. Broken moorings can set the vessel adrift, resulting in personnel becoming stranded on the burning vessel and separated from their shoreside supply lines.

5.6.7.2 Anchors are connected to vessels by heavy chain or cable, which is manipulated through a device known as a *wildcat/windlass*. Anchoring is a specialized evolution of seamanship and necessitates proper training to be performed safely and successfully.

5.6.8 Inert Gas Systems. The design and purpose of the inert gas system is to exclude oxygen or air from the void tank spaces of liquid bulk carriers. These gases usually are manufactured on board the ship. The inert gas can present a hazard to fire fighters.

Chapter 6 Vessel Stability

6.1 Introduction. In combating a fire aboard a vessel, fire fighters should give attention to the volume of water used for extinguishment and its effect on the stability of the vessel. Water applied to a vessel fire can jeopardize the stability of the vessel and the safety of the personnel on board. The application of water should be monitored carefully, and water should be removed in a timely and efficient manner. It is recommended that the IC have a basic understanding of this chapter. However, the IC is urged to consult the vessel's master, engineer, and other experts to determine how much water can be used safely. How and when water is added or removed from the vessel is critical.

6.2 Vessel Stability and Equilibrium.

6.2.1 General. Stability is the tendency of a floating vessel to return to an upright position when inclined from the vertical by an external force. If the vessel returns to or remains at rest after being acted upon, it is in either stable or neutral equilibrium. If it continues to move unchecked in reaction to the external force, it is in unstable equilibrium. An unstable vessel, therefore, is one that, after being inclined, does not find a point of stable or neutral stability, which is essential to maintain vessel stability and to minimize list.

6.2.2 Initial Stability. The ability of the vessel initially to resist heeling from the upright position is determined by its initial stability. The vessel's initial stability characteristics hold true only for relatively small angles of inclination. At larger angles, defined as those over 10 degrees, the ability of the vessel to resist inclining movements is determined by its overall stability characteristics.

6.3 Typical Vessel Conditions. This chapter generally addresses stability with respect to vessels that are floating, that have hulls that are intact, and that are moored or in protected waters. Usually, these conditions exist during the beginning stages of an incident. Stability and weight distribution considerations are relatively simple in these situations.

6.3.1 If, for instance, an explosion has ruptured the hull or the vessel has run aground, the situation will become more complex. These more complex situations can occur singly or in combination and include vessels that are in the following conditions:

(1) Aground
(2) Damaged (holed) with free communication to the sea
(3) Under way with extensive free surface
(4) In dry dock, graving dock, synchrolift, or a similar situation

6.3.2 Unquestionably, expert advice should be obtained any time the stability of the vessel is in doubt. A complete list of consulting resources, including those for vessel stability, should be compiled and maintained. The vessel's crew, who

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should be most familiar with the vessel's stability situation, might not always be available or able to provide an adequate assessment of the situation. *(See Section 6.10.)*

6.4 Center of Gravity. The center of gravity of an intact vessel is the location of the point where all the weights of the vessel can be assumed to be concentrated. The vertical downward force of gravity acts through this point. Knowledge of the center of gravity and its relationship with the vessel's center of buoyancy and righting arm are key factors when determining and controlling vessel stability.

6.4.1 The concept of center of gravity is essentially the same for a vessel as for other mobile equipment, such as an aerial ladder. In essence, the weight of the particular piece of equipment is considered to be concentrated at that point. As an aerial ladder is raised, the unit's center of gravity rises and the forces tending to overturn the vehicle are counteracted by the truck's external stabilization mechanisms (also known as outriggers). Similarly, a vessel's center of gravity also rises as weight is placed higher in the vessel. It differs from an aerial ladder in that it is unable to provide external stabilization mechanisms (outriggers) due to the water around it.

6.4.2 Vessels, therefore, suffer a loss of stability as water utilized in fire fighting accumulates above the original center of gravity. This loss is particularly significant with regard to vessels with large superstructures, such as passenger ships and car carriers. The higher the weight, the more detrimental is the effect. If this vulnerability is not properly understood and controlled, the consequences can impact all fire-fighting efforts severely. It is an integral part of overall strategy.

6.4.3 Free Surface Effect.

6.4.3.1 Free surface, for the purpose of fire fighting, is defined as the tendency of liquid within a compartment to remain level as the vessel is transversely inclined or heeled, provided the compartment has the following characteristics:

(1) Is intact
(2) Is partially filled
(3) Allows the liquid to move unimpeded from side to side

6.4.3.2 The free surface effect of loose water anywhere in the vessel impairs stability by raising the center of gravity in an apparent or virtual sense.

6.4.4 Free Surface Critical Factors. If the vessel is listing or develops a list, liquid flows to the low side of the compartment and results in an athwartship shifting of weight. This movement causes the apparent height of the center of gravity to rise, impairing stability. The critical factors of free surface are the surface area of the liquid and the breadth of the compartment. The length of the compartment is much less a factor than its width. For fire-fighting stability considerations, a liquid's free surface effect is not related to either the liquid's depth or its location within the vessel. Whether the liquid is high or low, on or off centerline, or forward or aft, the reduction in stability due to free surface is the same. However, it is critical that the effect on the overall stability of the vessel be kept under consideration. A weight added high in the ship raises the center of gravity not only due to free surface, but also due to the height above the keel.

6.4.5 Free Surface Reduction. Pocketing is the effect of liquid contacting the top of the compartment or exposing the bottom of the compartment. It reduces the breadth of the free surface area and therefore has a beneficial effect on stability. Similarly, solid fixed objects projecting through the surface (surface permeability) impede the liquid's movement and are of some benefit. Since the positive effects of pocketing and surface permeability are difficult to determine, they should be considered to be an extra margin of safety in free surface assessments.

6.4.6 Combined Effects.

6.4.6.1 The strongest threat to vessel stability from water-induced fire-fighting efforts is encountered when the water is both of the following:

(1) Confined high in the vessel
(2) Free to travel significant distances across the beam

6.4.6.2 The consequences of these combined effects can be devastating. Unfortunately, they sometimes trigger other serious problems. Once the vessel begins to heel, this domino effect can quickly compound an already aggravated situation.

6.5 Center of Buoyancy. If the water that is displaced by the vessel is considered as a single homogeneous unit, the center of the displaced volume of water is considered the location of the vessel's center of buoyancy. This is the geometric center of the underwater form of the vessel. The vertical upward force of buoyancy acts through this point.

6.6 Righting Arm. The perpendicular distance between the force of gravity (through the center of gravity) and the force of buoyancy (through the center of buoyancy) is called the *righting arm* or *righting lever*. It generally is calculated at 10-degree intervals of list for several different load conditions of the vessel.

6.7 Metacentric Height. The true measure of a vessel's initial stability is called the *metacentric height* or GM of the vessel *(see Figure 6.7)*. It is simply a geometric relationship between the center of gravity (G), the center of buoyancy (B), and the vessel's righting arm (GZ) for a given angle of inclination. After listing, B_1 is the new center of buoyancy.

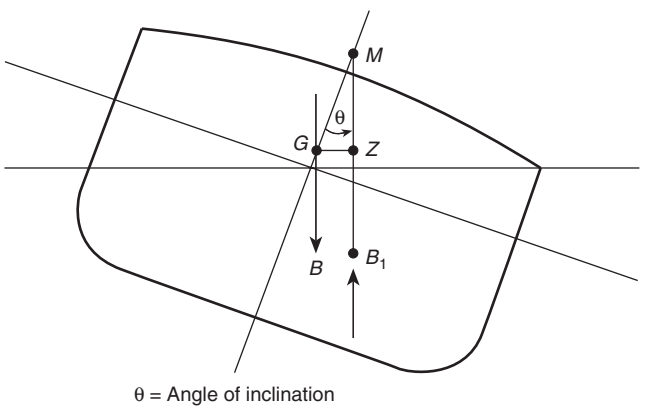

FIGURE 6.7 Center of Buoyancy.

6.7.1 If M (metacenter) is above G, GM is positive. If M is below G, GM is negative. A positive GM indicates that the vessel will tend to float upright and will offer resistance to an applied outside force. A negative GM indicates that the vessel is initially unstable and will cease to float upright when even the smallest outside force is applied. An initially unstable vessel might list only at a given angle and come to rest in a state of

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stable equilibrium. If the negative GM is great enough, the vessel will not come to rest before capsizing.

6.7.2 This relationship between the vessel's stability and GM is only accurate at small angles of heel (below 10 degrees). As list increases, the overall stability of the vessel is the determining criterion. It is interpreted through the stability curves that are normally found in the vessel's trim and stability booklet, generally obtained from the captain. During cargo loading and unloading, accurate values of the ship's stability are rarely maintained.

6.8 Stability Curves.

6.8.1 The ship's officers should identify the curve that most closely represents the ship's current condition of loading. If no curve is considered applicable, the curve showing the minimum stability condition should be determined. If no curves exist, the IC should depend upon the ship's officers, USCG, and others for guidance. The graphic curves depicting the vessel's calculated righting arms at incremental angles of heel are called the vessel's *stability curves*. These curves reveal the overall stability characteristics of the vessel. They are extremely important, since they quickly reveal the maximum righting arms for the vessel at different conditions of loading (different values of GM). The maximum righting arm and, more important, the angle of inclination at which it occurs, is the primary indicator of danger where the stability of the vessel is in serious doubt. A fictitious example of a partially loaded vessel with +2 ft (+0.61 m) GM is depicted in the stability curve shown in Figure 6.8.1.

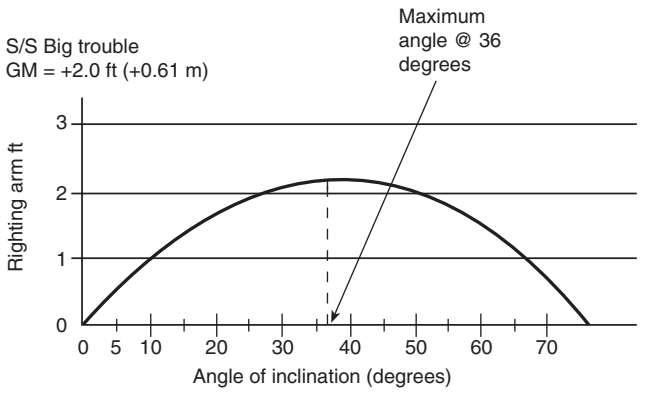

FIGURE 6.8.1 Stability Curve.

6.8.1.1 It should be noted that the maximum righting arm attained in this condition is at an approximate inclination angle of 36 degrees. Generally, this maximum angle indicates the point at which the edge of the weather deck becomes submerged. At this point, stability drops off rapidly. A vessel suffering a permanent list would be in imminent danger of capsizing long before this angle was reached.

6.8.2 The critical angle of list is the point at which it can be assumed that critical events will occur. It is not a point that remains constant in all cases. In some vessels, it could be as much as ½ of the maximum righting arm. In another case, it could be substantially less than this value. The critical angle depends on the conditions that exist on a vessel at the time of a fire. It can be determined only by qualified personnel as a result of stability calculations combined with professional judgment.

6.9 Vessel Stability Concerns. The most important concern regarding vessel stability is the control of the vessel's list. The inability to maintain the vessel at a reasonable degree of transverse levelness (side to side) will seriously impact all fire-fighting operations.

6.9.1 Fire-Fighting Factors Affecting Stability. The introduction of large amounts of water into the vessel as a result of fire-fighting operations is probably the most critical factor affecting vessel list. Other factors include the following:

(1) Intentional flooding of compartments
(2) Movement of personnel and equipment through watertight doors

6.9.2 Stability Factors Affecting Fire Fighting. As a vessel's list increases, so do the concerns related to fire-fighting activities. As the vessel heels, poor footing on slippery decks can slow or stop fire-attack teams. It can be difficult to apply and maintain a foam blanket. Other concerns include the following:

(1) Possible closure problems with automatic fire doors
(2) Increased chance of flammable liquid spills
(3) Strain and possible failure of mooring lines
(4) Restriction and loss of vessel access/egress
(5) Damage or injury from shifting of loose objects
(6) Problems with fixed dewatering drains and suctions
(7) Loss of vessel machinery due to excessive sustained list

6.9.3 Vessel Factors Affecting Initial Stability. In 6.2.2, the stability of the vessel is described as its ability to resist heeling from the upright position at small angles of inclination. This ability, which is a function of the vessel's GM, can diminish rapidly as the incident progresses and depends on current vessel conditions such as the following:

(1) The free surface status of all liquids aboard
(2) Whether or not the hull is intact
(3) The flatness of the hull bottom if it has run aground
(4) Whether the double bottoms are empty or full
(5) The integrity of watertight boundaries if flooded

6.9.4 Internal Factors Affecting Overall Stability. As the vessel destabilizes and list increases to larger angles of inclination, other factors can aggravate the vessel's worsening condition. These include the following:

(1) Shifting of loose objects or bulk dry cargo such as grain or coal
(2) Flooding from unsecured hull openings such as portholes
(3) Movement of items such as unsecured cargo, machinery, or stores

6.9.5 Factors Affecting Underway Operations. The self-propelled movement of a destabilized vessel within a confined waterway can be hampered by operational difficulties. If the vessel is suffering a large list, trimmed by the bow, or drawing a draft that is too tight for the available water, operational concerns should include the following:

(1) The steering system might function improperly
(2) The vessel machinery might not function at large lists
(3) Maneuvering control might be lost due to the vessel's proximity to the bottom
(4) The free surface area might cause the vessel to flop from side to side

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