CHAPTER 10

Aids to Navigation

10-1. General. Aids to navigation are used by mariners to determine ship positions and to plan a safe course through a waterway. The proper use of aids requires accurate and up-to-date information on their position relative to the navigation channel, usually involving location on the appropriate nautical charts. Different aids are used to assist in marking harbor entrances, straight channel edges, shoal areas, wrecks and other navigation obstructions, channel centerlines, alternative two-way lanes, and channel turns. Aids include buoys, fixed beacons, lights, sound signals, and electronic systems such as radio beacons, RAdar beaCONS (RACONS), loran, etc. The U.S. Coast Guard is responsible for the design, establishment, and maintenance of all aids to navigation in Federal Interstate waters. The general information provided below is presented to the navigation channel designer to give a brief overview; more details may be obtained in U.S. Coast Guard (1981, 1988a,b) or by contacting the Coast Guard. Figure 10-1 gives two examples of typical ranges and buoys used to mark navigation channels by the Coast Guard.

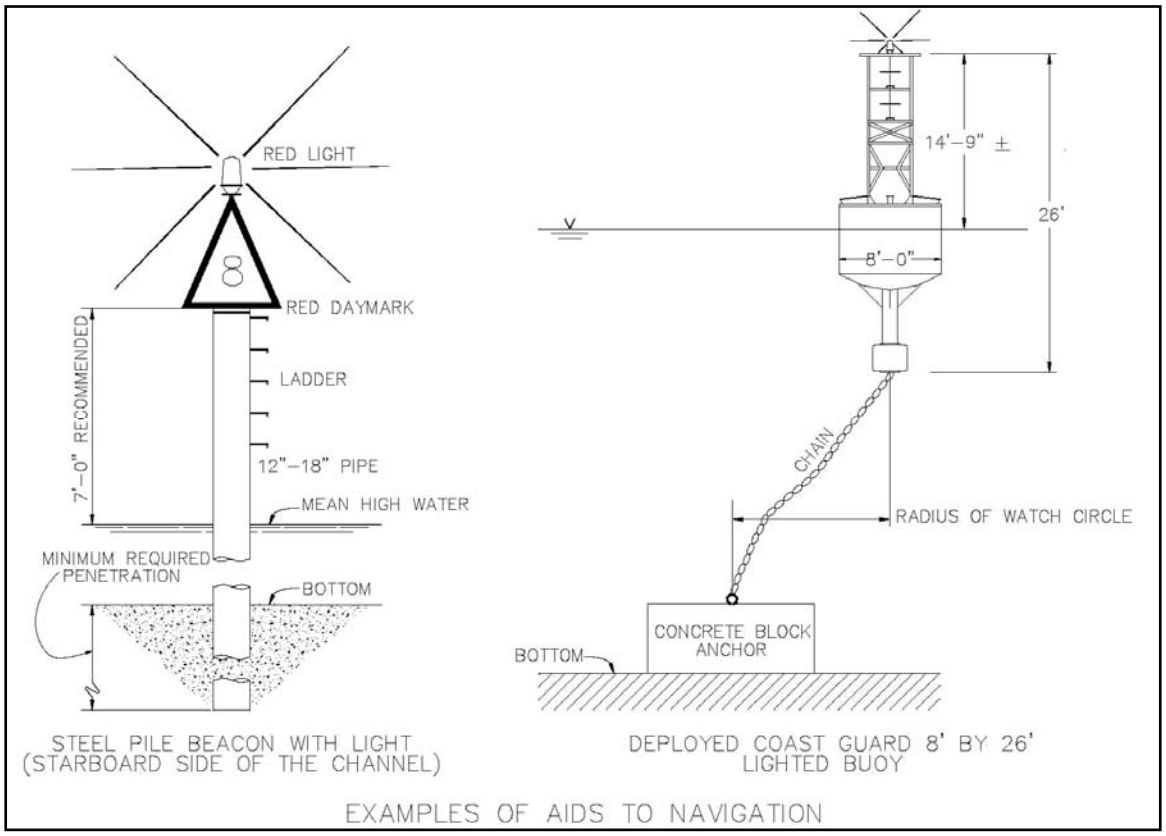

Figure 10-1. Examples of aids to navigation

a. Buoys are floating devices in the water anchored to the bottom with a chain connected to a concrete block. They are located to mark channel boundaries, hazards (such as navigation obstructions, wrecks, or rocks), and channel curves or turns. Some buoys are simple cans and nuns; others are enhanced with lights, sound, radar reflectors, and electronic signals. A unique system of shapes, colors, and numbering or lettering gives the mariner location information and provides

enhanced radar reflectivity. Specially designed buoys are used in ice-prone harbors in the Great Lakes and Alaska.

b. Beacons are fixed structures, generally on pilings in shallow water up to about 4.6 m (15 ft). Beacons may be simple visual day beacons with colored, numbered signboards used to mark channels similar to buoys. Other beacons are enhanced and include flashing lights and radio transmitters; the unique marking system for buoys is also used for beacons. In contrast to buoys, which are limited in height above the water surface, beacons can be built to various heights, thus providing greater visibility at a distance.

c. Ranges are pairs of fixed structures usually located beyond and on the channel centerline at one or both ends of straight channel reaches. Some harbor channels include additional range pairs to mark the center of multiple traffic lanes (quarter ranges). Mariners use the front and rear range markers to provide information on lateral ship position in the channel and thus provide a line for the ship to follow. Ranges are usually on shore or in very shallow waters, with the two markers fixed at different heights, the rear marker always higher than the front. Most important ranges include high-intensity lights for visibility during night transits. Sequentially flashing lights, some in color, are used to distinguish ranges.

d. Lights may be located in conjunction with buoys, beacons, or ranges but are also used as additional fixed aids in certain locations. Each light has a unique color and flashing sequence to help in identification during nighttime navigation. Some lights are designed to provide individual-ized sector coloring over certain portions of their viewing angles for special warnings. Directional lights are used to aid in channel navigation by providing a narrow beam of contrast color along the channel centerline.

10-2. Lateral Aid System. The system of unique aid identifiers used in U.S. Federal waters is nearly uniformly used and is consistent with the International Association of Lighthouse Authorities (IALA). This buoyage system employs an arrangement of laterally located navigation aid colors, shapes, numbers/letters, and light characteristics on each side of navigation channels to provide location information to the mariner. This lateral aid system as implemented in the United States is depicted in Figure 10-2. The system aid sequence is based on the convention of inbound transits from the sea along the navigation channels toward the head of navigation. Generally, this convention conforms to the flood current direction of buoyage.

a. Colors. Red is used to denote the right or starboard side of the channel when entering from the sea. Green marks the port or left side of the channel. Red and white vertically striped marker boards denote midchannel or safe water and are used for ranges.

b. Shapes. A cone-shaped nun buoy is painted red and marks the right channel side. A cylindrical can buoy is painted green and is positioned on the left side. Ranges are rectangular with the long side vertical.

c. Numbers. Aids are numbered from the sea. Even numbers are red and located on the right side of the channel. Green markers are placed on the left side. Ranges are usually given identification letters.

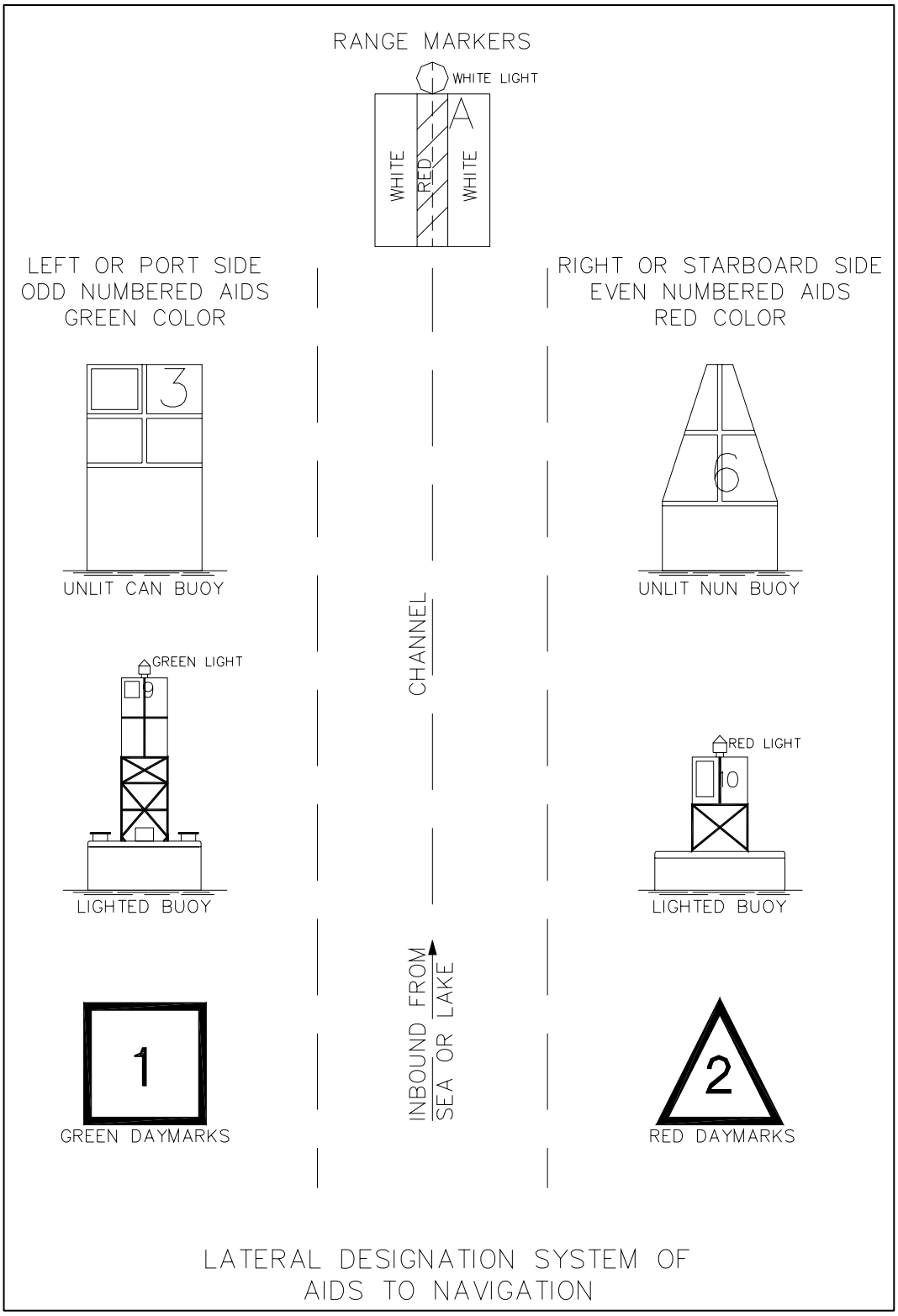

Figure 10-2. Lateral designation system of aids to navigation

d. Beacons. The lateral system also applies to fixed beacons with red triangular markers on the right side of the channels. Green square markers are used on beacons located on the left.

e. Lights. Red lights are also consistent with the system, being used to mark the right side of the navigation channels; green lights signify the left side.

10-3. Seacoast Aids. In addition to harbor channel aids described in paragraph 10-2, the Coast Guard operates an elaborate coastal aid system to help mariners in navigating along the U.S. coastline and in making landfalls from the open ocean. The following two types of aids are used by ship traffic as incoming beacons and departure points by pilots for port calls.

a. Major lights. Each major seacoast port is equipped with one or more primary lights located near the port entrance; this system has replaced most of the lighthouses and lightships. Major lights are high-intensity lights with high reliability located on a fixed structure or tower at heights sufficient to be visible over a long distance. Many of these lights are at heights up to 61 m (200 ft) above the water and are visible up to 40 kilometers (25 miles) away. The structures are often used to collocate other aids to enhance the structure's usefulness with additional electronic devices such as RACONS or radio beacons. Many of these lights are rotating white beacons, although other patterns and colors are also used.

b. Sea buoys. The ocean end of harbor entrance channels is usually marked by one or more special aids called large navigational buoys. These are used as clear designators to help mariners in identifying landfall location from the open ocean. Ships will usually anchor or stand by near entrance sea buoys while awaiting local pilot assistance in navigating from the ocean, across the channel bar, and into a berth in the harbor. Sea buoys provide several additional signals to assist the navigator, generally with a high-intensity light, electronic aids, and a sound signal, such as foghorns, bells, or whistles. Most large navigational buoys are about 12 m (40 ft) in diameter and 9 m (30 ft) or more in height above the water. They are usually located on the centerline of the channel some distance 1.6 to 3.2 kilometers (1 to 2 miles) beyond the end of the channel in deep water with white colors and lights.

10-4. Aid Design.

a. The aids to navigation that are ultimately put in place on a particular navigation channel project are selected after consideration of many factors. The dimensions, alignment, and layout of the project design are affected to an important degree by the aids to navigation. For example, by providing the navigator with better information through more aids to navigation or those with improved accuracy, a new or improved channel could be reduced in width while maintaining an adequate level of safety. It should be possible, therefore, to properly balance the cost and benefits of the aids with the incremental width construction cost. Early consultations with the local Coast Guard district should be undertaken during the channel design process to provide input for the design of the aids.

b. Port regulations and local operational policies can also have important effects on project design. Some of these include navigation traffic controls, vessel speed regulations, limiting some channel reaches to one-way traffic, requiring tug assistance or special steering or propulsion devices, and restricting vessel transits under certain environmental conditions. Regulations requir-

ing certain on-board vessel devices to improve the information available to the navigator also impact channel design. Some of these include radar, depth finders, speed logs, gyrocompass, rate of turn indicators, etc. The availability of a local port VTS may also influence navigation safety and channel dimensions.

10-5. Accuracy.

a. Buoys are subject to deviation about their anchor point, depending upon the depth of water, tidal fluctuations, currents, and winds. Some discrepancy also exists because of uncertainty in precise placement of the buoy. The buoy "watch circle" as shown by a dot or circle on navigational charts is a rough guide to the possible swing of the buoy around the anchor. The reliability of buoys may also be a source of difficulty to mariners because of possible sinking, displacement, or drifting from ramming or dragging by vessels, ice effects, vandalism, and high flooding conditions or waves. Location errors up to two times the water depth are possible.

b. Ranges are probably the best visual aid, being fixed in position, thus providing the high accuracy necessary in ship position alignment. Figure 10-3 shows how ranges are used by mariners to locate their ship position relative to the channel centerline. Location accuracy is dependent on several factors, including length of straight channel reach, width of channel, distance between front and rear range markers, marker height difference, and ship position in the channel reach. Detection distance of range markers is limited due to curvature of the earth and practical height of markers. Visibility in coastal areas can be limited in daytime by fog and haze and at night by background interference from lights and city light glare or glow. This causes a practical maximum length limit on straight channel segments of about 9 to 10 kilometers (5 or 6 miles). Most straight channel reaches are from 3.2 to 4.8 kilometers (2 to 3 miles) in length.

10-6. Aid Arrangement.

a. The spacing and pattern of lateral channel markers (buoys and beacons) have an important impact on the channel design. As a general rule, at least two channel markers should always be visible to the mariner on either side of the channel through a straight channel reach. Because of the normally hazy conditions that prevail at most channels, visibility is often limited to less than 1.5 nautical miles. These two circumstances result in maximum marker spacings of 1.25 nautical miles.; minimum spacing is usually 0.5 nautical miles. Markers can be located along a straight navigation channel in a single-sided, staggered, or gated manner. Simulator research by the Coast Guard has shown the clear superiority of gated markers in straight channel reaches.

b. The minimum requirement is that the inside of all channel turns should be marked. Channel turns can be marked in a variety of schemes, depending on the type of turn, whether cutoff or not cutoff. A cutoff turn would require a minimum of two markers, corresponding to the two changes of inside turn edge. Channel curves can also be marked using various ways. The benefits of providing three markers per turn were also demonstrated using simulation tests by the Coast Guard.

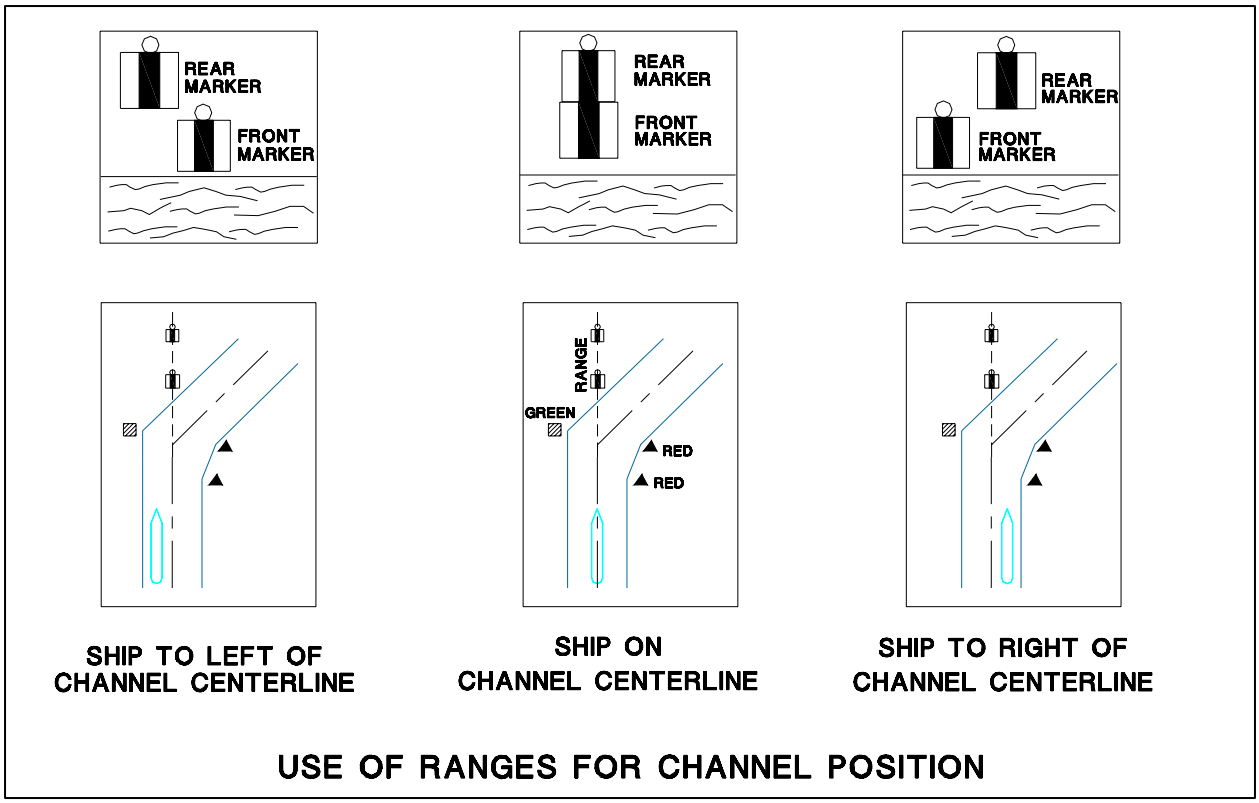

Figure 10-3. Use of ranges for channel position

c. Range markers may be located on both ends of channel straight reaches, or may be located on one end only, relying on a rear view for position location past a turn. Two pairs of range markers are normally used for important channels with strong crosscurrents or wind effects. The accuracy of long channel reaches greater than about 9 kilometers (5 miles) is degraded to a significant degree. The addition of side channel markers (buoys or beacons) to long channel reaches is usually necessary. Redundancy of aids is another important consideration; thus both range markers and side channel markers are used to provide a high degree of reliability.

10-7. Regulations.

a. Navigation in the coastal seas and U.S. waters is controlled by a number of rules and regulations of which the designer should be aware to develop sound engineering designs. The International Rules of the Road (often referred to as the COLREGS) (U.S. Coast Guard 1959) have been agreed to by the seafaring nations under the auspices of the International Maritime Organization (IMO), which is part of the United Nations. These rules have been implemented and agreed to by treaty of the U.S. Government and are part of the Code of Federal Regulations (CFR). Special adaptations have also been made part of U.S. law as pertains to Inland Rules, Great Lakes Rules, etc. Most of the rules apply to specific standards of vessel operation and required equipment. Specific requirements are provided for such activities as designated anchorage areas, lightering zones, regulation of VTS, regulated navigation areas, safety zones, etc. These are explained in detail in the several volumes of the Coast Pilot published by NOAA.

b. Operational rules at particular ports can be used in some instances to improve navigation safety and should be considered as an alternative to channel improvements in some cases. The promulgation of traffic separation schemes to guide inbound and outbound navigation traffic flow is one example of this. These are usually used to mark the approaches to a restricted channel in the ocean port approaches or in the wider, deeper reaches of a waterway or bay. The requirement for local pilotage service is another example of local regulations. States usually have primary jurisdiction in pilot matters; in some localities, the local port authority may exercise responsibility. Some rules are self-imposed by the pilots and may involve maximum ship size limits or tide height and current requirements for ship transiting.

c. The demarcation of port bulkhead lines and pier head lines along a navigation channel is an important function during channel design. The space between the channel limits and the pier head lines is normally used for ships at berth and dredged and maintained by local port authorities. Encroachment into Federal channels by docked ships, sometimes abandoned vessels, is often a problem in some ports. The Corps' review of permit requests should take potential navigation problems and possible channel encroachment into consideration in determining and enforcing permits.

d. Enforcement of applicable rules and regulations is the responsibility of the Coast Guard and is usually delegated to the local Captain of the Port.

10-8. New Technologies.

a. Several new techniques for marking channels and improving navigation safety to replace the more traditional aids to navigation are being studied by the Coast Guard. One of these systems includes the use of satellite-based Differential Global Positioning Systems (DGPS) for accurate (up to 2- to 3-m accuracy) ship location and navigation. The use of electronic navigation charts is another technology thrust area that is also being pursued on the international navigation level. Improved real-time data information systems, especially tides and current data, have been identified by pilots as an important need. Important advances will undoubtedly be made in this area, spurred by the environmental concerns from oil pollution incidents and accidents. These advances will undoubtedly affect operations and channel size requirements.

b. During recent years, two important navigation studies were undertaken in Europe to provide adequate channel access for supertankers to the largest class (up to the 500,000-dwt or Ultra Large Crude Carrier (ULCC) size). These studies were done for the Rotterdam Europort and at the port of Antifer/ Le Havre in France. Accurate ship position data by use of radio electronic navigation aid systems were crucial for keeping channel width to a minimum while maintaining adequate safety. A DECCA navigation chain with a pilot-furnished “brown box” receiver was developed and implemented for Rotterdam. In France, the system was called SAREA and employs an onboard transponder and receiver for use by the pilots. In both cases, strong tidal crosscurrents, wind, wave, and visibility conditions meant a requirement for high-accuracy positioning information. The results proved the safety of the channels and provided an economically viable project that would not have been possible with the required channel widths using standard criteria.