



## CHAPTER 83

# Safety and Survival at Sea

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*It is difficult for us to grasp the idea that parts of our planet remain in an almost primordial state of wildness and isolation. There are only a few places left on Earth where merely getting across them is an achievement: Antarctica ... the Sahara ... the Southern Ocean ... the wilderness of ice or sand or water or terrible places where nature retains power over humans to terrify and diminish.*

—DEREK LUNDY, *GODFORSAKEN SEA*

## Introduction

The greatest wilderness on Earth is the sea. It covers two thirds of the planet and, with the exception of the sun, has the greatest influence on global weather patterns. Although it may take hours or days to succumb in other environments, death at sea can happen in less than a minute. Compared with desert heat, high-altitude hypoxia, and polar subzero temperatures, water is the most hostile and life-threatening natural environment for inadequately equipped survivors.

The 1979 Fastnet Race distinguished itself as the worst disaster in the long history of ocean yachting. A surprise killer storm crossed the Irish Sea between southwest England and southern Ireland and exploded without warning in the midst of the Fastnet racing fleet. Suddenly, 2700 men and women in 303 ocean sailing yachts unwittingly became participants in hundreds of incidents of survival at sea. Winds of force 10 (55 knots) with much stronger gusts, and seas as high as 50 ft (15 m) knocked down 48% of the fleet until their masts paralleled the water; 33% of the fleet experienced knockdowns substantially beyond horizontal, including total inversions and full 360° rolls in the case of at least 26 yachts. Despite a massive response of rescue personnel and equipment, 24 yachts were abandoned and five of those sank. Fifteen sailors died and 136 were rescued from disabled yachts or the water. The official Fastnet Race Inquiry noted, “The

common link among all 15 deaths was the violence of the sea, an unremitting danger faced by all who sail.” It concluded: “The sea showed that it can be a deadly enemy and that those who go to sea for pleasure must do so in the full knowledge that they may encounter dangers of the highest order.”<sup>1</sup> The Fastnet storm had two positive results. Boats, safety gear, and safety procedures were improved dramatically, and sailors began to talk realistically about the risks of sailing and came to regard safety as a necessary discipline. The first public safety at sea seminars were held in Annapolis and New York in the shadow of the Fastnet shock. Since then, hundreds of safety and seamanship seminars have been held across America and in other sailing locations.

Twenty years later, on the edge of the Southern Ocean, the Sydney to Hobart race between the southeast coast of Australia and the island of Tasmania became a terrifying ordeal for 115 yachts. Within a day of leaving harbor, an explosive low-pressure cell, a “southerly buster,” formed over the fleet as it entered Bass Strait. In its aftermath, six men died, 55 were rescued, and 12 boats either sank or were abandoned. One hundred participants were seriously injured and five drowned. Fractured ribs, lacerations, and head trauma were the most common injuries. The 330-page investigation report recommended strict guidelines for improved safety gear, life rafts, and telecommunication equipment.

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## Who's At Risk?

For ocean racing sailors and voyaging seafarers, most emergencies and accidents still occur during extreme weather conditions created by violent ocean storms. In contrast, most recreational boating accidents in the United States occur in fair weather with flat to one-foot seas, light (0 to 6 mph [0-10 km/hr]) winds, and good visibility. The majority of these accidents are close to home on inland lakes, ponds, rivers and coastal bays, the major areas of pleasure boating.

Analysis of U.S. recreational boating accident statistics for 2008, the most recent data available from Coast Guard in their annual report "Recreational Boating Statistics 2008," indicates there were 709 boating fatalities in 2008 (685 in 2007). Capsizing and falls overboard from open motor boats, rowboats, canoes, and kayaks accounted for more than half of the fatalities. The most common types of vessels involved in open accidents were open motor boats (43%), personal water craft (23%) and cabin motorboats (15%). The Coast Guard Recreational Boating Accident Report Database (BARD) shows an average of 5,000 recreational boating accidents annually. Seventy percent of all accidents involve operator and passenger controllable factors. The remaining 25% involve boat or environmental factors. Careless/reckless operation, inattentive and inexperienced boat operators boating at unsafe speeds without proper lookout, and risky passenger/skier behavior cause most fatalities and injuries. Ninety percent of deaths occurred on boats where the operator has received no boating safety instruction. Collision with another boat is responsible for the greatest number of nonfatal injuries. Flooding/swamping, collision with a fixed object, falls overboard, and water skier mishaps, rank 2nd, 3rd, 4th, and 5th in accident rank, and account for 60% of fatalities. Open motorboats less than 26 feet in length and jet-ski personal watercraft (PWC) comprise two-thirds of the water craft involved in collisions, and are the vessel types with the most casualties and deaths. Alcohol is a leading contributing factor in recreational boating fatalities, responsible for at least 20% to 25% of deaths. These statistics indicate that one of the greatest threat to a boater's safety in "home waters" is the inexperienced operator heading directly toward you at excessive speed, unaware that you are dead ahead. Extra vigilance is required in order to take evasive action to avoid collision. Two-thirds of all fatalities in accidents on sailboats and small nonmotorized craft are from drowning, and 90% of victims are not wearing a lifejacket (see discussion below). Seven out of 10 drowned boaters are from boats less than 21 feet long. The full report can be reviewed on line at [http://www.uscgboating.org/statistics/accident\\_statistics.aspx](http://www.uscgboating.org/statistics/accident_statistics.aspx).

Fractures, lacerations, contusions, head injuries, and low back sprains are the most frequent injuries in boating. Burns, hypothermia, amputations, carbon monoxide poisoning, and dislocations are next most common. Open motorboats and personal watercraft are the craft most frequently involved in passenger injury from trauma, while canoes and rowboats account for 33% of boaters suffering hypothermia.

Mastering seamanship and survival skills requires training and experience. The ultimate challenge for every mariner is to confront and handle the fears that frequently render a person helpless in a survival situation. Survival depends on philosophical, psychological, and physical preparation along with good seamanship.

## Health Issues at Sea

### SEASICKNESS

Seasickness is a common and significant medical illness for mariners at sea, often responsible for maritime rescue operations. During stormy weather, mariners frequently consider seasickness a medical emergency and justification for medical evacuation. Each year, seaworthy yachts are abandoned because their exhausted and despondent crews have lost the collective will to persevere. "They are wet, seasick, scared, and want to go home," observed a merchant marine captain (personal communication with author).

Seasickness is a self-limited condition; symptoms subside as one acclimates over 2 to 3 days. The balance center's ability to

adapt to new sea conditions is commonly called "getting your sea legs." Nearly everyone will develop seasickness with sufficient stimuli; however, individual susceptibility is enormously variable. Pregnant women are highly susceptible, especially in the first trimester.

At best, seasickness (*mal de mer*) is moderately disabling. It can lead to rapid mental and physical deterioration marked by progressive dehydration, loss of manual dexterity, ataxia, loss of judgment, and loss of the will to survive. Fatalities from seasickness have occurred because of poor seamanship and complications arising during hazardous emergency evacuations.

Seasickness impairs cognitive function. Sailors often lose the ability to multitask, making it difficult to analyze and integrate complex data, which leads to impaired judgment and faulty decisions. Cognitive failure is also expressed as loss of short-term memory. This impairment makes it difficult to engage in problem solving. Compounding this problem are the medications used to prevent or treat seasickness. Their side effects may include drowsiness, confusion, and loss of concentration. The underlying mechanism of seasickness involves a conflict of sensory input processed by the brain to orient the body's position. Someone positioned in the cabin of a heeling or rolling boat is inviting seasickness. Below decks, the eyes oriented to the cabin sole and ceiling detect no tilt from vertical, while fluid in the inner ear's vestibular system (semicircular canals, and the otolith organs) constantly shifts. Position sensors (proprioceptors) in the neck, muscles, and joints send additional signals, depending on how a person shifts and secures himself from falling. This mix of sensory data from the eyes, inner ear, and position sensors arrives in complex and conflicting combinations, creating a "sensory conflict" that activates the emetic center in the brainstem. According to Dr. Charles Omen, Director of the Man Vehicle Space Lab at MIT and an authority on motion sickness, sensory conflict is a sensory cue "expectancy" conflict, not an intermodality conflict. It occurs when signals from the inner ear don't match expectations based on one's own commanded self movement, or concurrent visual or proprioceptive cues. In response to this "sensory conflict," there is activation of a complex and not well-understood anatomic connection between the vestibular nuclei in the brainstem, the cerebellum, and the autonomic and emetic centers. Stimuli from the vestibular and visual systems can independently initiate symptoms. Sickness occurs most commonly with acceleration in a direction perpendicular to the longitudinal axis of the body, which is why head movements away from the direction of motion are so provocative. When these stimuli are presented in isolation in the laboratory, visual stimulation is more important than vestibular input in causing motion sickness. There is no increase in symptoms when combined stimulation is applied. Blind people can become seasick; the conflict arises when input from the vestibular system does not match the individual's expectations derived from previous motion experience. The intensity of conflicting input can be amplified when compared to these expectations. Deaf subjects are susceptible to motion sickness. If the semicircular canals and otolith organs produce sensory cues that are incongruous, seasickness ensues. If the visual system indicates movement but the vestibular system does not (in-flight simulators and movie theaters), motion sickness may ensue. Medication is more effective in preventing symptoms than in reversing them. Therefore, anti-seasickness medication should be administered before leaving port, or the night prior to departure (Table 83-1). One should begin any trip well hydrated and free of the after-effects of alcohol, which impairs vestibular function by sensitizing the vestibular apparatus to motion. One is advised to eat lightly. Anecdotal reports favor eating carbohydrates rather than protein, but no conclusive study favors any particular food or diet. Many sailors favor eating soda crackers or bread. One should try to snack on bland foods throughout the day, even if anorectic, to maintain energy levels until meals are regularly tolerated. Cheese and crackers, energy bars, fruit, trail mix, dry granola, and popcorn work best. Drinking small amounts of fluid frequently is recommended to avoid dehydration. Many sailors believe drinks high in vitamin C prevent seasickness; however, there are no data to support this notion.

**TABLE 83-1 Medications for Seasickness**

| Medication                        | Dose                                                 | Interval                                         |
|-----------------------------------|------------------------------------------------------|--------------------------------------------------|
| Diphenhydramine, (Benadryl) (OTC) | 25-50 mg tablet                                      | 6-8 hr                                           |
| Dimenhydrinate, (Dramamine) (OTC) | 50-100 mg tablet (max 400 mg/day)                    | 4-6 hr                                           |
| Meclizine (OTC)                   | 12.5-25-mg tablet (max 100 mg/day)                   | 6-8 hr                                           |
| Bonine (Meclizine) (OTC)          | 25-mg chewable tablet                                | 6-8 hr                                           |
| Cinnarizine (Stugeron)            | 15-mg tablet (max 100 mg/day)                        | 6-12 hr                                          |
| Scopolamine (Transderm Scōp)      | 1.5-mg skin patch                                    | 72 hr                                            |
| Scopace                           | 0.4 mg (max 2.4 mg/day)                              | 8 hr                                             |
| Promethazine, (Phenergan)         | 12.5/25/50-mg tablet, suppository, deep IM injection | variable intervals depending on dose/preparation |

Ginger is often recommended as an antiemetic and may be clinically useful in individual cases. However, there are very few controlled trials. In one trial, ginger was tested in a double blind, randomized, placebo-controlled study of 80 naval cadets in rough seas. Seasick cadets were given a gram of ginger or placebo hourly for 4 hours. Ginger significantly reduced vomiting and cold sweats, and minimally decreased nausea and dizziness. Ginger is readily available in 500-mg capsules in health food stores and sold in marine stores as Sailor's Secret. The suggested dose is 1000 mg every 6 hours, starting one-half hour prior to the trip; it is less effective when given to someone who is already nauseated. The capsules can be supplemented with foods containing lower concentrations of ginger, such as gingersnap cookies, ginger ale or tea, and candied ginger. Too much ginger may cause heartburn; people with gallstones should not take it, because it can provoke an attack of biliary colic by stimulating the flow of bile.

Both field and laboratory experiments have documented the efficacy of acupressure in preventing seasickness. However, some experts on space and motion sickness still consider acupressure no better than placebo. One sea trial showed that acustimulation suppressed the symptoms of motion sickness. Pressure should be applied on the Neiguan P6 point of the forearm over the median nerve. This is found two to three fingerbreadths proximal to the wrist joint between the two prominent finger flexor tendons. There are commercially available elastic wrist straps with plastic studs that create pressure over the P6 point. A wristwatch-like device is sold to deliver transcutaneous electrical stimulation to the median nerve; these have not been proven useful for seasickness, but have many advocates.

Recommendations for preventing seasickness are directed toward reducing sensory conflict by limiting the time below decks while underway. This will help the eyes to see what the "the ears are feeling." After departure, stay on deck and amidships (center) or aft (toward the stern), where pitching and rolling are less severe. Obtain a broad view of the horizon using direct and peripheral vision. This provides a stable and level point of reference. Avoid close visual tasks such as prolonged reading, writing, and navigation. Avoid areas with fumes (especially diesel) and odors that can stimulate nausea. Continue medication for preventing seasickness at the suggested intervals; try tapering the dose after the first or second day.

The early signs and symptoms of seasickness are yawning, sighing, dry mouth or salivating, drowsiness, headache, dizziness, and lethargy. With sustained exposure to the stimulus, gastric emptying is inhibited. Pallor, cold sweats, belching, nausea, dry heaves, and vomiting ensue. Some persons don't have gastrointestinal complaints but experience headache, apathy, and depression. The side effects of some anti-seasickness medications mimic seasickness, creating a diagnostic dilemma. The window of opportunity for early intervention is often missed because early signs are not recognized or the victim is in denial.

At the first sign of seasickness, one immediate remedy for many is to take the helm and steer. The active mental and physical activity to steer the ship, together with the visual focus on the horizon and waves, presumably creates neural feedback loops that help to reorient the body's equilibrium. One should stand and feel the waves, and steer the boat by reference to clouds, the horizon, distant marks and oncoming waves, posturing to anticipate the boat's motion by "riding" the waves. Wave riding synchronizes sensory input and expectations of motion. As best possible, one should keep the head, shoulders and upper body balanced over the hips, to stay in balance and gain postural control gracefully, as though the body was truly "gimbaled" on the deck. Sitting in the cockpit, one can still ride the waves and watch the horizon. Chuck Omen, an authority on motion sickness developed the concept of wave riding. He advises: "Don't sit or lie inert in the cockpit, passively letting the motion toss you around. Postural anticipation of the boat's motion is the natural cure for seasickness." Debilitated seasick persons can easily fall or be washed overboard. They should always wear a safety harness on deck and be closely monitored. In storm conditions, the safest place to be secured is below in a bunk.

If symptoms progress, one may lie down in a secure, well-ventilated bunk, face up with eyes closed and head still in an attempt to sleep. Parenteral antinausea medications include the phenothiazine derivative promethazine hydrochloride (Phenergan). This drug has powerful antidopaminergic, anticholinergic, and antihistamine properties. The latter effects predominate (see other side effects below). Anticholinergic side effects include constipation, xerostomia, blurred vision, and urinary retention. Phenergan should be used with caution in persons with decreased gastrointestinal motility, gastrointestinal obstructions (partial or complete), urinary retention, urinary obstruction (partial or complete), benign prostatic hypertrophy, xerostomia, or visual problems. Rare but serious adverse effects of promethazine include extrapyramidal reactions.

Promethazine is useful for prophylactic and active treatment of seasickness and can be administered as a suppository, by deep IM injection, and orally as a tablet or syrup. NASA astronauts use a combination of intramuscular or oral promethazine with oral dexedrine (to counter the drowsiness induced by promethazine). Some sailors prefer prochlorperazine suppositories for nausea, and many have used ondansetron oral disintegrating tablets (Zofran) to treat nausea and vomiting. Zofran does not, however, prevent seasickness.

Transdermal scopolamine hydrobromide (Transderm Scōp patch) is the most popular anticholinergic agent used for prevention of motion sickness. Scopolamine prevents motion-induced nausea by inhibiting vestibular input to the central nervous system, resulting in inhibition of the vomiting reflex. It may also act directly on the vomiting center. The drug is delivered via an adhesive patch placed behind the ear 4 or more hours before departure; the patch will last for up to 3 days, often with minimal side effects. The most common adverse effects are dry mouth (66%) and drowsiness (17%). Other undesirable side effects include blurred vision (which may persist for weeks), dry mucous membranes, short-term memory loss, and problems denoted by the well-known mnemonic "hot as hell, dry as a bone, blind as a bat, mad as a hatter." To reduce the dose of scopolamine, allow only half of the intact patch to contact the skin by placing the other half onto a Band-Aid or tape attached to the area. Do not disrupt the integrity of the disc by cutting it. Follow the directions carefully, wash hands thoroughly after application because temporary blurring of vision and dilation of the pupils may occur if the drug is on your hands and comes in contact with the eyes. Apply only one disc at a time. Scopolamine is contraindicated for children, persons with narrow-angle glaucoma (remove the patch immediately if eye pain occurs suddenly), and men with prostatic hypertrophy. Long-term use may produce withdrawal symptoms such as nausea, dizziness, headache, and equilibrium disturbances. Scopolamine in pill form (Scopace) is an alternative to the patch. The chief advantage is the dosing flexibility. The fixed dose from the patch may be excessive for small individuals and inadequate for larger people. Taking the lowest effective dose can minimize side effects. The current recommendation is one tablet (0.4 mg) or two (0.8 mg)



1 hour prior to departure, and one to two tablets every 8 hours as needed thereafter.

The antihistamines meclizine (Bonine) and dimenhydrinate (Dramamine) are available over the counter (OTC) without prescription. They are effective for many sailors, as are the other prescription medications listed in Table 83-1. The popular antihistamine cinnarizine (Stugeron) is not sold in the United States, but is available OTC in Europe, Bermuda, Mexico, and Canada. It can be obtained legally from <http://www.canadadrugsonline.com>. It is favored by many sailors because it is less sedating than all the other antihistamines and has fewer reported side effects (described below).

Side effects of over-the-counter antihistamines include drowsiness, dry mouth, blurred vision, irritability, urinary retention, dizziness, and headache. Meclizine (Bonine) is thought to cause less drowsiness and confusion. Antihistamines cause thickened bronchial secretions, and should be used with caution in people with asthma and chronic obstructive pulmonary disease. An effective nonprescription drug for drowsiness is the decongestant pseudoephedrine, which is available in 30 to 100 mg; caffeine 200 mg is also useful and may potentiate the beneficial effects of promethazine. The newer generation of nonsedating antihistamines is ineffective in preventing seasickness.

All therapies are subject to placebo effect, and there are no well-controlled trials comparing and evaluating different treatments. Many products cite only testimonials. The protection conferred by drugs is a matter of degree; there is no magic bullet to prevent seasickness in everyone. It is not uncommon for one drug in a category (e.g., antihistamine) to be effective and a related drug to provide no benefit; the same is true for side effects. Evaluate medication side effects before boating. If all else fails, follow Samuel Johnson's 18th-century advice: "To cure seasickness, find a good big oak tree and wrap your arms around it."

## HEALTH MAINTENANCE AT SEA

The "Fearsome Five" are health issues that must be addressed to maintain optimal physical and mental performance: food (calorie depletion), fluid (dehydration), Fahrenheit (hypothermia), fatigue (sleep deprivation), and fitness (injury, illness, infection).

**Food.** Keep the crew well fed, and prepare high-calorie and simple carbohydrate meals for the beginning of the trip. Avoid spending time in the galley following departure in order to prevent seasickness. Have snacks readily accessible.

**Fluid.** Fluid loss at rest in a thermoneutral environment (82° to 86° F [27.8° to 30° C] and 50% relative humidity) is via the skin, lungs, and kidneys. Each organ has an obligate daily loss of approximately 500 mL. Minimal daily body water loss is therefore 1500 mL. Headache, nausea, lethargy, apathy, lightheadedness, and lower blood pressure can develop with a deficit of 1 to 2 L (3% to 5% of total body water); these symptoms mimic seasickness and heat exhaustion. Exposure to sunny, hot, breezy, and dry conditions promotes increased fluid loss from skin and lungs, increasing "insensible loss." Boaters are more susceptible to dehydration during this "ideal boating weather." Sailors tend to drink inadequate amounts of fluid for multiple reasons. The ship's tank water may not contain fresh-tasting potable water. In rough weather, it is often difficult for crew to go below to use the head, and it becomes especially problematic if they need to remove foul weather gear while below. Under these conditions, self-imposed water restriction is sometimes practiced to reduce the urge to urinate. Men suffering from prostatic hypertrophy may voluntarily restrict fluids in order to urinate less frequently. Some of the drugs for seasickness accentuate urinary retention in men with benign prostatic hyperplasia, compounding the problem. Seasickness accompanied by nausea and vomiting frequently causes dehydration. Everyone must take measures to prevent dehydration. The crew must monitor fluid intake and schedule a brief change of course in rough seas, so that it can safely go below decks. It is essential to store plenty of clean fresh water in the ship's tanks and if necessary, store commercial bottled water. It is good advice to hydrate in the absence of thirst and to monitor urine volume and color, which should be copious and light tan.

**Fahrenheit.** Hypothermia (see Chapters 5 and 6) may develop acutely when someone is suddenly immersed in cold water, or over a period of hours to days during prolonged exposure to the elements. Mild hypothermia, defined as a core temperature above 90° F (32.2° C), is the only level that can be treated aboard a boat. Deeper levels require evacuation to a medical facility. Sustained uncontrollable shivering is the most reliable and earliest sign of a drop in core temperature. Other early clues are alterations in motor skills and changes in mental status. As blood is diverted from the muscles and nerves, there is loss of manual dexterity, large muscle coordination, and strength. Clumsiness while performing simple tasks, such as adjusting binoculars or using navigational instruments, is apparent. Walking safely on deck and working with lines and gear becomes hazardous. Subtle changes in mental status cause impaired judgment, confusion, and disorientation. There are changes in personality and frequent errors in judgment. Initial treatment of a fully conscious and shivering mildly hypothermic person with a core temperature above 90°F (32.2° C) is to prevent further cooling and heat loss. The person is still capable of rewarming himself and does not require evacuation. Shelter the victim from wind and water. Replace wet clothing with multiple layers of dry insulating garments after the skin is completely dried. If dry clothing is not available, provide an extra vapor barrier with added foul weather gear. A windproof layer minimizes convective and evaporative heat loss. When practical, wrap the victim like a burrito in blankets, sleeping bag, sails, or sail bags. Provide calories with simple carbohydrate foods and sweet liquid drinks, and allow vigorous shivering to continue in order to generate rewarming heat. Warm liquids are psychologically beneficial but will not influence rewarming rates.

Warming the skin directly inhibits shivering and should be avoided. Warm showers will not be sufficient to warm the core; they may cause vasodilatation and severe hypotension. Hot showers should not be used to treat chronic (exposure) hypothermia or acute (immersion) hypothermia. Many downed airmen and navy personnel were rescued at sea during World War II, and sent to the showers for rewarming, only to suffer "circumrescue collapse." Victims of hypothermia from immersion in cold water for a long period of time are especially susceptible because of dehydration.

**Fatigue.** Sleep deprivation and fatigue lead to cognitive errors, poor judgment, mood changes, and sometimes hallucinations. Sailors often have irregular sleep schedules, prolonged watches, and difficult sleeping conditions. The challenge is to improve sleep efficiency. Sleep cycles have light and deep stages of rest. A 1-hour nap can quickly bring about the deeper restorative sleep stage. Regular watch and sleep schedules, and napping to reduce fatigue, are recommended. Many medications for seasickness cause drowsiness, which disrupts the regular sleep schedule.

**Fitness.** Soft tissue extremity injuries, usually caused by trips and falls during sailing maneuvers, are common, especially in heavy weather. Being caught in lines or struck by objects are frequent factors. The usual injuries are contusions, lacerations (especially of hands), sprains, and strains. Severe injuries, such as fractures, concussions, and dislocations, are not common. Most injuries occur in the cockpit or on the foredeck. Sheets, blocks, lines, and deck hardware contribute to most injuries.

Seasickness, sunburn, and dehydration are the most frequent illnesses, and together with marine-related infections, comprise the most common illnesses for cruising sailors.

## Gear and Equipment

### LIFE JACKETS

Annual Coast Guard recreational boating fatality statistics underscore the need for boaters to wear life jackets. In 2008, for example, 510 (72%) of 709 recreational boating fatalities were due to drowning. The vast majority of these cases involved boats under 26 feet including open motorboats, personal water craft, canoes, and kayaks. Each annual report estimates that at least 85% to 90% of these drowning deaths could have been prevented

if a life jacket had been worn. Life jackets help prevent drowning in water at any temperature, but they are vital to simply combat the lethal effects of cold water. Few boaters routinely wear life jackets, and most people put them on only in storm conditions. The main reasons for veteran sailors not wearing life jackets are discomfort and inconvenience. All the conventional (foam or kapok-filled) type I offshore life jackets and type II near-shore life vests are bulky, uncomfortable, and awkward to wear; they are too warm in summer, and limit mobility. The common type III vest is comfortable and wearable, but has poor reserve buoyancy and freeboard (distance from the water to the mouth); it cannot turn the unconscious victim face up (righting ability) and cannot support the head (maintain an airway). It is suitable only for calm water and should be worn only by active boaters who are able to swim, or in situations where the chance of a quick rescue is assured. Life jackets should be selected according to comfort and practicality in order to maximize compliance. Non-swimmers, children, and inexperienced crew should wear life jackets at all times whenever on deck or in an open boat. Everyone on deck should wear a life jacket in heavy weather, at night, when visibility is reduced, when the boat is traveling quickly, or traversing cold waters. In warm waters, experienced boaters who are strong swimmers must acknowledge a degree of risk by not wearing flotation.

Inflatable vests have a flat and lightweight design that allows them to lie flush against the body so they do not restrict movement. They have excellent wearability and superb flotation capabilities. The vests provide as much as 35 lb (16 kg or 150 newtons) of buoyancy, compared with 22.5 lb (10 kg) in type I and 15.5 lb (7 kg) in type II and III. In most cases, added buoyancy enables the person to float higher, making it easier to breathe, and reduces the risk of aspirating seawater in rough sea conditions. By keeping the head and chest higher out of the water, it is easier to adopt the heat escape lessening position (HELP) (see Chapter 75). With buoyancy high on the chest, there is also better righting ability and head support. The offshore model can be purchased with an integrated safety harness (Figure 83-1).

The U.S. Coast Guard has approved a wide variety of inflatable life jackets, including models listed as type I, II, III, or V. Versions are available with different buoyancies (16, 24, 35, and 60 lb [7.25, 10.89, 15.88, and 27.22 kg]), with and without a safety harness. Water-activated inflatable vests should be worn at all times by nonswimmers, because they might panic after falling overboard; children must be older than 16 years and weigh more than 80 lb (36 kg) to legally wear these vests. Even strong swimmers should consider wearing a water-activated model. Head injury from a surprise fall or an inadvertent jibe might render a person unconscious and leave him face down in the sea with a deflated manual vest. More importantly, any sudden, unexpected



**FIGURE 83-1** Comfortable, lightweight, and convenient integrated safety harness and water-activated inflatable life vest. It is Coast Guard approved and features both a backup ripcord and an oral inflation system.

immersion can be very disorienting, especially when compounded by reduced swimming ability due to clothing, footwear, and gear. Wearing an inflatable vest that automatically responds to immersion solves the issue of having to find the “jerk to inflate” lanyard. The newest models have inflators that have a single point indicator to show if the vest is armed with an unused CO<sub>2</sub> cylinder. It provides an almost foolproof method for the user to determine whether the life jacket is properly charged and ready for use. The new inflators will not deploy unless the wearer is immersed in water and will not be activated by spray, humidity, rain, or a rogue wave boarding the boat, as some older models have done. All automatic vests have a manual back-up ripcord for inflation, plus back-up oral inflation tube.

Like all mechanical systems on board ship, inflatable vests require regular inspection and maintenance according to the manufacturer's instructions. Every season, someone should orally inflate the vest (after removing the CO<sub>2</sub> cylinder) and leave the vest inflated for 24 hours to check for leaks. Further advice is to inspect the water-soluble bobbins and replace them as scheduled (generally every 2 years); conduct an in-water test to experience the righting ability of the vest; and prior to each use, unscrew the CO<sub>2</sub> cartridge to make sure the seal is not punctured. One must know how to rearm and repack any inflatable vest according to instructions. Always care for a life jacket as though one's life depends on it.

Boaters who resist wearing any type of vest may tolerate an inflatable vest packed in a compact belt pack. Carried worn around the waist, it is the least cumbersome of any flotation device. After inflation in the water, the horseshoe-shaped device must be pulled over the head and secured with straps to the chest (similar to the position of a regular inflatable life vest, while the swimmer works to stay afloat; it offers 22 to 35 lb (10-16 kg) of buoyancy. This device is not suitable for non-swimmers or children.

When boating in cold weather, a float coat can be worn either with or in lieu of a life jacket. In addition to providing 15.5 lb (7 kg) flotation, the coat offers excellent protection against hypothermia and cushions the rib cage from traumatic injury during a fall.

One should test and wear any new vest in a pond or pool and practice the HELP position. The wearer should float in a slightly reclining position with the water rising no higher than armpit level. Life jackets should be close fitting, with small arm holes. Children require a properly fitted model with crotch straps to prevent the vest sliding up over the arms and head. Common size ranges for children's life jackets are 0-30#, 30-50#, and 50-90#. The best life jackets for children under 50 lb (23 kg) should have a bi-fold head support and small pillow of flotation in the back to right a face-down wearer and keep them face-up in the water. Some children require a safety harness (see below) to keep them aboard. Never buy an oversized life jacket, expecting the child to grow into it in the future. Incorrect sizing of a life jacket compromises usefulness and may have tragic consequences.

An immersion (survival) suit is the ultimate protection from hypothermia and drowning. It blends the properties of a life raft and dry suit. Features include a watertight full-length zipper, watertight hood, face seal for wind and water protection, detachable mitts, neoprene wrist seals, integral boots, inflatable head pillow for optimum flotation angle, water-activated safety light, whistle, and buddy line. Their general bulkiness (one size fits a 110- to 300-lb [50- to 136-kg] person) and built-in gloves make them impractical for continued wear while actively working aboard ship. The Coast Guard now requires personnel on board their vessels to wear a dry suit when ocean water temperature is less than 10° C (50° F), and a less bulky antiexposure suit with insulating underwear and clothing when temperatures are between 10° and 15° C (50° and 59° F). A type III life jacket is still necessary, to provide adequate flotation if a head pillow and flotation are not integral to the suit.

One potential disadvantage of survival suits (as with water-activated inflatable life jackets) is that their buoyancy may impede escape from an overturned craft. The person may become trapped in the cabin, under the cockpit, or under the trampoline of a multihull. “When the trampoline is on top of you, buoyancy

is your enemy,” said one multihull sailor, who barely survived after capsizing his vessel while wearing his survival suit. One should always don the suit topside and move away quickly from a rolling, unstable craft. There should be a suit for each crew member when cruising in water below 15° C (59° F). Crew should read the instructions; there is a specific technique and sequence for getting into the suit, pulling the hood over the head, zipping, and closing the face flap. In practice, the suit should be closed and made watertight in less than 60 seconds, inspected regularly for any tears or deterioration, and have the zippers lubricated with Zipper-Ease or other zipper lubricant. A partially closed immersion suit serves only to keep the victim afloat and alive until he dies of the cold shock response or succumbs to immersion hypothermia.

If one has to enter cold water voluntarily (e.g. to free a fouled propeller) without the protection of a specialized suit, take the following steps in anticipation of the cold shock response: Improve an immersion or wetsuit by dressing in a foul weather suit and snugly wrapping the ends of the sleeves, legs, and waist with duct tape. Wear thermal underwear or insulating fleece under the suit. Stockings, gloves, and a hat will complete the outfit. Pour warm water slowly through the open collar and saturate the clothing covering the torso, then seal the neck. Put on a life jacket and safety harness, with the tether held by an alert crew member. Enter the water slowly, and feel the water seep through all the openings. When breathing is under full control, proceed with the task.

### SAFETY HARNESS

Always wear a safety harness in rough weather, at night, and whenever on deck alone, out of sight of crew, or when both hands are occupied. In heavy weather, wear a harness even while steering from the relative protection of the cockpit. Adjust the harness to fit snugly around the chest, two inches below the armpits. It should be constructed with webbing at least two inches wide, and have a breaking strength exceeding 3300 pounds (1450 kg). Tethers connect the harness to through-bolted deck fittings or to a dedicated jackline, made from either uncoated stainless steel wire or webbing running fore and aft to a through-bolted pad eye or cleat. Designate padeyes or jacklines specifically for the cockpit that can be reached from the companionway, so that crew can clip on before entering the cockpit. The jacklines should be continuous, allowing the crew to roam without having to unclip the harness. Low stretch webbing is preferable to wire and rope because it will not roll underfoot, and tends to lie flat on the deck. Wire jacklines should be inspected for broken strands, and webbing and rope for UV damage and weakening. Marine rope is subject to chafe and to a 50% loss of strength at knots. Tethers should be no more than 2 m (6.6 feet) long with an elastic cover to help to keep it from dragging underfoot; a second tether 1 m (3.3 feet) long helps triangulate support and ensures continuous contact with the ship while changing to different positions. It is also best for use in confined places such as the cockpit and at the helm's station. Ideally, it should be attached to the boat in a way that will not allow the wearer to be dragged in the water alongside or behind the boat. This may not always be possible. Unfortunately, sailors have drowned while being dragged by their harness and tethers. The shackle at the chest should be a quick-release snap shackle that can be released under load in case the wearer is trapped under a capsized boat. The ship's end should have a locking snap hook that can be opened with one hand, and not one that will self-release from a U-bolt.

Don the harness before going on deck, and secure the tether before climbing up the companionway. While on deck and underway, hook onto the windward (uphill, upwind) jackline whenever possible. One is more likely to fall down to leeward, and the shorter length of the tether will keep a person on deck instead of dragging him through the water. Women should not adjust the chest strap below their breasts. Injury may occur from the upward force that is placed on the harness when it suddenly comes under tension; some harnesses are designed for females to avoid possible injury. Inflatable life jackets are available with integral safety harness. This convenient combination may be the

most important piece of personal safety gear at sea. A harness not only will keep crew aboard and prevent separation from the vessel if overboard but can guide escape from an overturned craft, especially when someone is disoriented.

## Emergencies at Sea

### CREW OVERBOARD

#### Remaining Aboard

Falling overboard (most often from collision) and then drowning is the most common cause of marine fatality in recreational boating and commercial shipping. In stormy weather, the safest location is in the cabin. Following these rules can prevent virtually all man-overboard incidents:

1. Remain sober, especially if you expect to go on deck for any reason.
2. Wear nonskid footwear when working on deck and have nonskid paint or pads in critical work areas.
3. Walk in a crouched position with a low center of gravity and wide-based stance when the boat is rolling, heeling, or pitching.
4. If the boat's motion is too violent to allow a person to stand, then crawl or slide along the deck.
5. Use a safety harness (with two shackles) as a “third hand,” secured to a strong attachment point.
6. Use a safety harness whenever going aloft in the rigging or climbing any superstructure.
7. Avoid leaning overboard with all your weight on a lifeline or stanchion.
8. Know the location of secure handholds and grab rails so you can find them at night.
9. Know the safe routes to avoid tripping on deck hardware, vents, and hatches, especially at night.
10. Do not urinate from the afterdeck in rough weather unless you are kneeling and attached with a safety harness.
11. Wear a safety harness whenever seasick; vomit into a bucket rather than leaning overboard.
12. In heavy weather, sleep in the harness and be ready to attach the tether to a cockpit padeye before coming on deck.

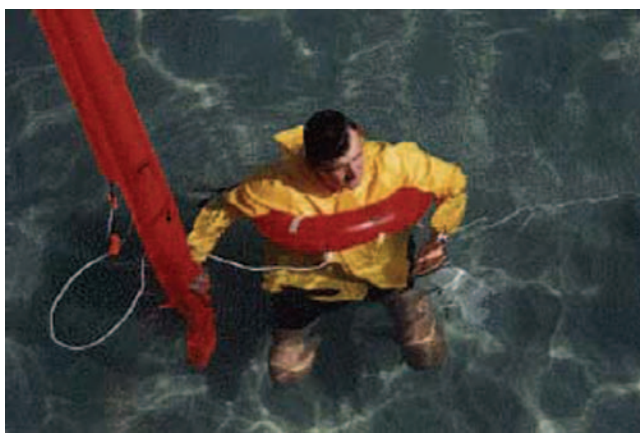
#### Recovery of Crew Overboard

Do not swim to the boat you fell from unless it is completely disabled and unable to maneuver. Conserve strength and reduce heat loss for the rescue. Whenever possible, get out of the cold water (e.g., onto a capsized or partially submerged boat, or rocky ledge) and stay out of it, no matter how low the air temperature and wind chill effect. Water saps the body's heat up to 25 times faster than air at the same temperature. Clothing insulates the body and is relatively weightless in the water.

Time is the critical factor in recovering a person overboard. A well-rehearsed rescue under expert leadership with clear communication during the rescue maneuvers is most likely to succeed. When someone is observed falling overboard, shout “Man overboard.” Designate at least one crew member to spot and point to the victim continuously without losing sight of him (not even for an instant). Floating objects should be thrown overboard, including buoyant cushions, horseshoe buoys, ring buoys, and extra life jackets, in order to litter the water surrounding the victim. The gear may provide extra flotation and will help mark the area for the spotter. Unfortunately, most of these objects will drift faster in winds over 10 knots than a person can swim, so the man overboard (MOB) cannot expect to retrieve a thrown life jacket after falling overboard.

Special equipment designed for locating and retrieving a person overboard should be deployed immediately. This gear should be ready for easy deployment and must release instantly. Too often, the gear is protected against accidental loss by extra wraps of line to the stern pulpit or rigging. Any delay in releasing COB gear will leave it too far from the victim. A crew overboard pole is a 12- to 15-foot (4- to 5-m) floating flagpole that is ballasted to remain upright in rough seas. Without the drogue accessory (a parachute-shaped device to slow a vessel's drift





**FIGURE 83-2** This man overboard module consists of an inflatable horseshoe shaped buoyant device, a 6-foot (1.8-m) inflatable locator pylon with a light, and a self-opening sea anchor. Both inflatable devices are fully inflated within 7 to 10 seconds after deployment from the canister (usually mounted on the stern pulpit).

downwind), it will quickly drift away from the designated area. A man overboard module (MOM) automatically deploys a CO<sub>2</sub>-activated horseshoe buoy and a 6-foot (2-m) inflatable locator pole equipped with a drogue and water-activated, lithium-powered light (Figure 83-2). A variety of lights have been developed to serve as rescue beacons. The overboard marker strobe marks the site and illuminates the scene for the rescuers. It automatically activates when thrown into the water. Waterproof personal rescue strobe lights attached to a life jacket can flash for 8 hours at 1-second intervals and are visible a mile away. Other personal strobe lights can last up to 60 hours, with variable rates to conserve battery power. A U.S. Navy whistle has a special flat design to prevent the whistle body from holding water and dampening the sound. Attach one to every life jacket.

Electronic overboard alarms are available for crew; these are small transmitters alerting the mother ship receiver. The personal alarms are activated when they contact the water or when manually turned on (Figure 83-3, [online](#)). All onboard GPS units have a MOB function, which, if activated, will create a waypoint at the vessel's position when pressed. It will also make the waypoint "active," so the vessel can return to the latitude and longitude of the person at the time of the fall. The GPS is a powerful search and rescue tool, but is not a substitute for maintaining strict visual contact and using signal lights and markers. The inherent small degree of error with GPS in marking the waypoint of the MOB is magnified in heavy winds, large seas, and strong currents, because the person may drift downwind or down-current while the boat returns to the scene. GPS receivers receive signals from U.S. Air Force satellites and then compute the location accurately to within 10 m. It may still be impossible to locate the person in rough seas or during reduced visibility.

Rather than rely on the ship's emergency locator beacon, sailors can wear them on their person. A small unit can be worn (on a life jacket) by a crew member as a personal locator beacon (PLB). Weighing as little as 17 ounces, and not much larger than a cell phone, it also transmits on the 406- and 121.5-MHz frequencies. The battery life for this compact unit exceeds 24 hours. PLBs do not float upright in the transmitting position. The transmitter requires manual activation and must be held out of the water with the antenna pointed skyward (Figure 83-4). It would be difficult to do this without wearing a life jacket. Some units have an integrated GPS to yield location accuracy to within less than a 300-foot (91-m) radius, versus a 3-mile (5-km) radius from the 406-MHz beacon operating alone. The problem is that most boats, other than professional rescue vessels [or SAR aircraft], are not equipped with a receiver capable of locating the source of the "homer" beacon on the PLB. All PLBs require registration with NOAA. A less technical signaling device designed for night use is the Rescue Laser Flare. This is a handheld light that produces a visible line of laser beam to attract the attention of search

boats and aircraft within a 10- to 20-mile radius (Figure 83-5, [online](#)).

### Crew Overboard Maneuvers

The goal in overboard recovery is to return as quickly as possible to the MOB using the simplest maneuver. Begin the process immediately. A boat traveling at a speed of 8 knots moves away from the MOB at about 13 feet (3.9 m)/second or 800 feet (243.8 m)/minute. At that rate, half a mile is traversed in 3 minutes. Motorboats should reduce speed and return in a simple circle. Sailboats under power alone can return by simply circling back and approaching downwind of the victim. Establish contact by using a heaving line, such as a floating polypropylene line in a throw bag. If the boat is drifting downwind, slowly advance forward to complete the recovery over the leeward side, being careful to not drift on top of the victim. Sailboats under sail should approach on a close reach, which allows the vessel to speed up or slow down as necessary by changing course.

The "quick stop" recovery maneuver is designed for rapid MOB recovery. This method enables the boat to reduce speed immediately by turning into the wind while trimming in the mainsail and keeping the headsail (jib) aback. Thereafter, the helmsman keeps the boat turning downwind while steering to remain close to the victim. After passing abeam of the victim, the jib is dropped (or furled), and the boat heads up to the wind (on a close reach) to stop alongside the victim at an angle of about 60 degrees to the wind with the sails luffing (flapping into the wind). By sailing the final approach to the MOB on a close reach, the sails can be fully luffing or trimmed in to maintain forward movement if short of the mark. The technique is similar to picking up a mooring under sail. The boat can also be left beam-to-wind with the sails luffing while contact is made with the victim. The engine can be started and left in neutral, ready to be used if needed in the final approach. Rescuers must ensure all lines are aboard before engaging the engine, to avoid fouling the propeller. It is advisable to return to neutral when close to the victim. The main danger to the victim is being sucked under the stern while the propeller is turning and the boat is moving forward under power.

The direction of approach to the victim used by the rescue boat is controversial and involves judgment based on many variables, including the sea state, wind strength, drift of the boat relative to the victim, maneuverability of the boat, and condition of the MOB. If the seas are large, approach to leeward (downwind) of the MOB so the boat cannot fall off a wave and injure the person in the water. Gentle seas permit an approach to windward (upwind) with a slow drift down to the victim. The boat will always drift faster than the person in the water, so have retrieval gear ready.

An injured, hypothermic, or unconscious person (not waving or looking at the rescue boat) requires assistance by a rescue swimmer, who should take steps to avoid the cold shock response. The rescue swimmer should be tethered to the boat during recovery of the MOB. Ideally, the rescue swimmer should be trained in water rescue and lifesaving techniques and be able



**FIGURE 83-4** Personal locator beacons (PLBs) are now small enough to be carried by each crew member.



**FIGURE 83-7** Successful rescues of a crew overboard requires consistent methods for contacting the victim, and for getting him or her back on board.

to recognize the warning signs of panic as he or she approaches the victim. If the MOB is unconscious, assume possible head and neck injury, and stabilize the cervical spine before hoisting the victim out of the water. The life jacket itself may be used to control the head and neck if it is tightened in the upper chest area.

The goal is to have the MOB back on the boat as quickly as possible. Practice the different techniques and decide which method and modifications work most effectively. The Lifesling, developed to enable one person to retrieve a person overboard, is a flexible floating collar that doubles as a hoisting sling (Figure 83-6, online). Deploy the collar from the stern pulpit and deliver it by repeatedly circling the victim, much as a ski boat maneuvers to deliver the towrope to a fallen water skier. After securing the horseshoe over the head and under the arms, pull the victim back to the boat and hoist him in the apparatus with the assistance of a halyard and winch (Figure 83-7). Lifelines are an obstacle to bringing the MOB back on deck, but are an important source of protection for the remaining crew. You may elect to secure lifelines at the stern (or transom) with lashing rather than shackles or pins so they can be easily cut and released in a recovery should the need arise.

If the crew has lost sight of the victim, immediately call for assistance. A mayday call on VHF-FM channel 16 will notify the Coast Guard and simultaneously alert all ships in the area monitoring this channel. The last known position should be obtained using GPS or reference to any navigational buoys and landmarks on shore. Rescuers should perform repeat searches of the area, because it is easy to miss someone in poor visibility or choppy seas. The victim will be far more likely to be located if he has the correct gear. Ideally, this includes a high-visibility (orange or yellow) life jacket with reflective tape combined with a safety harness, personal strobe light, loud whistle, packet of waterproof self-launching meteor flares, fluorescent dye marker, and a PLB or other crew-overboard alarm. Perhaps the most important factors for a successful rescue are the crew's familiarity with the boat and the MOB equipment, and their teamwork, leadership, and expertise developed from practicing the maneuvers. A full review of the 2005 Crew Overboard Rescue Symposium conducted on San Francisco Bay can be found at <http://www.boatus.com/foundation/findings/COBfinalreport>. This study reviews the challenges for a successful recovery, required skills of the crew, preferred recovery maneuvers, and equipment that can be helpful in locating and retrieving

#### BOX 83-1 Sources of Flooding

1. Failure of through-hull fittings involving the following systems: head, galley, wash basins, shower sump, bilge pumps, centerboard pins and cables, engine exhaust, engine cooling, deck and cockpit drains, bait box, drain plugs (for small boats), knot meter sensor, depth sounder sensor, propeller shaft stuffing box, shaft struts, shaft log, rudder post, keel bolts
2. Failure of hose connections, clamps, pipes, and fittings
3. Open hatches, companionways, portholes, and ventilators
4. Siphoning of seawater back into the boat because of poor system design or failure of a check valve
5. Collision with large floating or submerged objects
6. Structural failure in hull, deck, or rigging
7. Punctured hull from overboard broken spars (e.g., after dismasting)
8. Clogged scuppers or cockpit drains
9. Waves entering the cockpit of a outboard powered motorboat thru the transom engine cut-out

the victim. It is a "must" read for every boater. It is also available in a slightly different format from US Sailing on the web site <http://www.ussailing.org/safety/Studies/COB.pdf>.

#### FLOODING

Flooding, and the potential for sinking, is a threat to every boater. Boat U.S. Marine Insurance examined 50 claims from recreational boats that sank while underway, ranging from a tiny personal watercraft to a 54-foot ocean-going sailboat. The full report is on the web site at <http://www.boatus.com/foundation/guide/index.html>. Thirty-four percent of the boats sank because of leaks at thru-hulls, outdrive boots, or the raw water cooling system/exhaust. The single most critical reason small motorboats flood in open water relates to transom height. Engine cut-outs may be only inches above the waves, and the motor well may not protect the cockpit. Often, weight distribution of passengers and gear to the stern contributes to the problem.

Flooding may occur from failure of systems or construction (6% of the boats sank after coming down hard off of waves and therefore splitting open), or structural damage from collision and extreme weather (Box 83-1). Before abandoning ship, quickly assess the damage. The limiting factor is time. Stock the proper tools and repair supplies in a damage control kit (Box 83-2), and know how to respond quickly and skillfully. Assign duties to the crew before departure so that they know what to do in the event of flooding (and crew overboard, fire, grounding, and dismasting). Duties include damage control, radio transmission of a Mayday (can be cancelled later if necessary), and preparation to abandon ship.

#### BOX 83-2 Damage Control Kit

- Assorted hose clamps and tools to adjust them
- Conical wooden plugs, preferably secured at each through hull, and spare foam plugs
- 3M Fast Cure 5200 or epoxy putty sticks
- Caulking gun, extra cartridges
- Triangular collision mat, spare plywood for patches
- Water-activated fiberglass repair fabric (Syntho-Glass)
- Pruning saw with spare blades, bolt, and rigging cutters
- Drifts matching size of clevis pins
- Duct tape, electrical tape, and self-amalgamating tape
- Self-tapping stainless steel screws, threaded rod, bolts, nuts, and large washers
- Extra buckets



Early detection of flooding is crucial for an effective response. Make frequent visual inspections of the bilge, engine room, galley, and head while underway, and maintain watertight integrity at all times. The most reliable way to keep a boat afloat is to keep the water on the outside. Hatches for the main companionway, engine room, lazarettes, cockpit lockers, fish holds, and elsewhere require gaskets and proper dogging (locking) devices to ensure watertight seals; secure them while underway. Boats flood from the top-down as well as from the bottom-up! After a knockdown or wave breaking over the cockpit, water may go straight below decks if the companionway drop boards are not in place. These boards require robust dead bolts capable of locking from both sides. Severe flooding, with damage to the electronics, navigation station, and engine, usually results from top-down flooding.

Discharge plumbing requires seacocks. Regularly inspect through-hull fittings, the engine drive shaft stuffing box, clamps, and hoses. Avoid using polyvinyl chloride (PVC) or any other domestic plastic plumbing fittings for through-hull fittings below the waterline; they can easily break off or fracture if struck by shifting stores. The preferred materials are Marelon (reinforced plastic) or bronze, together with stainless steel hose clamps. Post a diagram in the cabin showing the locations of all through-hull fittings and the routes of connecting hoses. Keep seacocks accessible and unobstructed and be able to find them blindfolded. Install U-shaped antisiphon loops above the highest waterline (it changes as the boat heels). Without these loops, water can siphon back through the hose and into the bilge.

Reliable bilge pumps are the best defense against flooding (Figure 83-8, online). An excellent pump can buy time for locating and plugging the leak. However, no pump, manual or electric, can keep up with even a modest-sized hull breach. If a boat is equipped with an automatic bilge pump (or pumps), install a cycle counter on the pump and an “on” light to alert the crew when the pump is activated. A second emergency pump mounted above the first, using a separate float switch, can provide added pumping capability if the first pump cannot keep up with the leak. In this case, an alarm installed in the circuit can alert the crew to flooding.

Keep the bilge clean and free of debris to avoid clogging the pump strainer. Perform regular inspection and maintenance of the entire pumping system. Aluminum-body bilge pumps corrode from the inside out, especially while retaining saltwater. They may appear to be in perfect condition, yet be completely useless. Hoses crack with age, rubber components become dry and brittle, valves jam, and moving parts deteriorate through wear and corrosion. To guarantee reliability, disassemble, inspect, and clean manual bilge pumps annually. Bilge pump handles should be easily accessible and secured with a lanyard in the vicinity of the pump to avoid loss after a knockdown or rollover. Offshore boats require at least two manual bilge pumps, one operable from above decks and one below decks. Know the capacities of the boat’s compartments and have a means to pump out any that flood. Test the pump’s capabilities by intentionally flooding the bilges (preferably with fresh water), and monitor how long it takes to pump out the water.

The volume of water rushing in depends both on the size of the breach and its depth below the waterline. A 1-inch (2.5-cm) diameter hose disconnected from a seacock 1 foot (30 cm) below the waterline allows 20 gallons (75 L) of seawater per minute into the cabin; a disconnected open seacock the same diameter just 2 feet (60 cm) below the waterline admits three times that amount of water. A boat equipped with the largest manual double-action twin-diaphragm bilge pump can pump a maximum of 36 gpm, a limit easily surpassed by the examples given. It is therefore critically important to locate and stop the leak, rather than fight what may be a losing battle by pumping to prevent sinking.

As the water rises in the cabin, a leak becomes more difficult to locate. The inflow rate decreases as the depth of water in the boat increases, because the pressure gradient is reduced. At a critical level of flooding, the inflow rate may slow sufficiently to allow pumps to handle the volume, so do not stop pumping. A point of zero net flooding may be reached from the inherent buoyancy of the boat as it settles in the water (another reason

the ship should not be abandoned unless it continues to flood). Many small wood and fiberglass boats float when fully flooded or swamped. Boats less than 20 feet (6 m) in length constructed in the United States after July 1972 are required to have sufficient built-in flotation to remain afloat when swamped. Small boats (e.g., daysailers, small open motorboats) can obtain additional buoyancy by lashing down unused life jackets, cushions, and fenders to increase flotation.

A tapered, soft, dry wood plug sized to fit a leaking through-hull fitting can serve indefinitely as an adequate seal; it will swell to seal the fitting or any small puncture in the hull. Take the plugs out of the damage control kit and attach them to their respective through-hull fittings with lanyards; this will make them instantly available and help the crew find them in the dark. Forespar’s TruPlug is a new damage control product. It is a tapered circular cone-shaped plug about 9 inches (23 cm) tall and 4.75 inches (12 cm) across at the base made of foam that is a spongy but firm cellular material, and is coated with a flexible sealer adding strength and color. It can be used as a temporary or emergency plug in boating applications where water would enter a circular, oval, or irregular hole caused by emergency mechanical failure or hull breach due to impact. Its ability to be twisted or jammed into irregularly shaped holes gives it an advantage over tapered wooden plugs.

Large holes can be overlaid with a collision mat (Figure 83-9) placed outside the hull to supplement a temporary interior patch (see below). The mat is a piece of heavy canvas or vinyl-coated fabric with grommets and lines that enable it to be positioned and secured on the exterior surface. It is held in place by pressure and lines. Collision mats can be purchased or improvised by using a small sail or awning material, although it is a mistake to make the mat too large; generally 4 feet (1.2 m) on an edge of the triangular shape is adequate. The water pressure automatically spreads the patch over the hole to form an effective seal and holds it in place. A commercial hull repair kit features flexible oval concave sheet metal plates with rubber gaskets. A bolt is welded to the intended exterior piece. The idea is to slip one oval through the hull breach, then back it from the inside with the second metal plate and tighten both together with a thumbscrew.

Lacking special equipment, any soft, pliable material, such as a life jacket, mattress, blanket, towel, cushion, clothing, or foam pad, can be used to slow water rushing through a jagged break in the hull. When placed against the exterior hull, the suction effect created by flow and hydrostatic pressure will generally provide some clamping pressure to the plug or patch. If a plug is positioned from inside the cabin, shore it with a board and brace it with a pole (e.g., oar, mop handle, boat hook, whisker pole, strut, bunk rail). The eventual solution to a hull repair may start with a crude internal patch to slow the flow of water and buy time, followed by an external patch, followed by an improved



**FIGURE 83-9** Triangular patches made from coated fabrics can be held in place with lines attached to each corner.

internal patch with plywood and bracing. The vessel's pumps may then be able to handle the remaining leaks.

Underwater patching compounds can be used to bond a solid plate over the hole or to impregnate an expandable material or packing to serve as plugging material. There is great variability in cure speed, ease of mixing, mixed viscosity, and adhesiveness. Some products work only on specific hull materials (e.g., wood, fiberglass, or aluminum). Supplement repairs with other measures to help slow the inflow. Heel the boat away from the area of damage to decrease hydrostatic water pressure. This is easy to accomplish under sail. For powerboats, shift heavy items to the side opposite the leak and slow forward speed if water is entering a hole in the bow.

When ingenuity and improvisation fail to stop flooding, the U.S. Coast Guard can supply a portable gasoline-powered dewatering pump to assist a sinking vessel. The unit is simple to operate and comes in a waterproof barrel with hoses, gasoline, and illustrated operating instructions. When dropped from an aircraft into the sea, a retrieving line will be also dropped to the deck crew. It takes two people to lift the barrel from the sea onto the deck. The standard CG P-1B dewatering pump can pump 120 gpm at 10-foot (3-m) lift, and is capable of running 4 to 5 hours on a tank of gas. The P-1B pump, known as the "drop pump," is likely to be carried by helicopter and by any of the various Coast Guard rescue craft. A larger pump, the CG P-6 (classified as a dewatering/fire fighting pump) is carried by Coast Guard search and rescue ships and is placed either onboard or passed via lines, depending on weather conditions. Pump capacity is 250 gpm at 12-foot (3.6-m) lift; it runs 4 to 5 hours on a tank of gas. Both pumps are dramatically more effective than even the most robust manual or electric bilge pump. However, 250 gpm is equivalent to the inflow of water from a 3-inch hole (a relatively small breach) only 2 feet below the waterline; any larger hole at this depth will exceed the capacity of even the P-6. Remember to run either pump outside, not in an enclosed space where carbon monoxide may accumulate. Refuel them only after the engine is stopped. As with all safety equipment, these pumps can be confusing to operate for nonprofessionals, especially at night with a boat that's threatening to sink from under you. Attendance at a Safety at Sea seminar or other survival training is highly recommended as a way to become familiar with infrequently used safety gear.

Some oceangoing cruising vessels are built with watertight compartments to confine flooding to a limited area. Maintain watertight bulkheads. Know the location of watertight doors and how to operate them.

If flooding and sinking are inevitable, the captain should consider running the boat onto shore.

## FIRE

Uncontrolled fire is a disaster aboard ship. Fires aboard wood and fiberglass boats have the potential to double in size every 10 seconds. Approximately 7500 pleasure boat fires and explosions occur annually; of these, 10% are declared total losses. More than half of the 2700 fire-related injuries incurred each year occur on small, open motor boats. According to statistics compiled by Boat U.S. marine insurance company claims investigations ([www.boatus.com/seaworthy/fire/default.asp](http://www.boatus.com/seaworthy/fire/default.asp)), the leading causes of fires on boats (55%) are AC and DC wiring faults. The most common electrical problem is related to chafed wires. Many fires are started by battery cables, bilge pump wires, and even instrument wires chafing on hard objects like vibrating engines or sharp-edged bulkheads. The DC voltage regulator is responsible for 25% of electrical fires. Eleven percent of fires are started by the boat's AC system, frequently at the shore power inlet box. A small number of fires every year are caused by AC heaters and other household appliances that have been brought on board. Nearly a quarter of boat fires (24%) were started by overheated propulsion systems. Frequently, an intake or exhaust cooling water passage was obstructed, causing the engine to overheat and begin to melt down hoses and impellers. These fires tended to be less serious, but because of the amount of smoke and the fact the fires come from areas with flammable fuels, they appeared more threatening. Often the fires were simply smoldering rubber,

## BOX 83-3 Fire Prevention at Sea

1. Sniff the engine compartment before starting a gasoline engine and before starting the electric bilge blower. (Bilge blowers are ignition protected, but it's still a good idea.)
2. Ventilate the bilge; run the bilge blower for at least 4 minutes before starting a gas engine.
3. Use appropriately sized marine-grade wire. Periodically inspect wiring for cracks, charring, and deteriorating insulation. Wiring connectors and terminals should be tightly set and periodically inspected for looseness. Each electrical circuit should have fuses or circuit breakers according to ABYC Standard E-11.
4. Battery compartments must not be completely enclosed, and must allow hydrogen gas to escape through the lids of the battery boxes. Even sealed AGM and gel batteries can generate hydrogen gas if overcharged.
5. Consult a professional to develop an appropriate ship's grounding system.
6. Observe all precautions when taking on fuel. Close all hatches and ports before filling the tanks, and extinguish all flames.
7. Never leave the stove unattended while in use.
8. Store extra fuel on deck in approved plastic containers, or in a locker that is sealed from the main cabin and drains overboard.
9. Store outboard motor and fuel tank on deck.
10. Transfer gasoline and other flammable liquids from one container to another on deck or off the boat.
11. Inboard engines require meticulous inspection and maintenance. Perform a routine visual inspection of any operating engine and the exhaust system. Keep seawater strainers for the engine cooling system clean. Become an expert in examining and repairing all components of the fuel system. On vessels with an engine room, consider having a mirror-finished piece of stainless which will make it obvious if you have a fine spray of fuel or other liquids in the air.
12. Install a heat-activated automatic fire-extinguishing system in the engine compartment, together with smoke and flame detectors.
13. Properly store fuels, solvents, paints, brushes, and combustibles in a deck storage locker. Keep all rags in metal containers with the lid tightly closed. Do not keep oily rags below decks or in the engine compartment.
14. Place fire extinguishers away from the intended area of use so that they are accessible, and have them inspected and maintained on a scheduled basis.
15. Read the extinguishers' instructions periodically, and practice on a controlled fire away from the boat.
16. Remove extinguishers from their brackets and invert them several times to ensure that the agent inside is loose and flowing.

until the engine compartment was opened, allowing fresh air to enter. Lightning is a major cause of boat fires at marinas in Florida. Box 83-3 lists ways to prevent fires aboard ship.

The explosive potential of fuel depends on its chemical properties and where the vapors accumulate in enclosed, unventilated spaces. Hazardous liquids are classified according to flash point, the lowest temperature at which a liquid releases enough vapor to sustain burning. Flammable liquids, such as gasoline, turpentine, lacquer thinner, and acetone, have flash points below 38° C (100.4° F), meaning they release enough vapor at common ambient temperatures to form burnable and explosive mixtures. Combustible liquids, such as diesel oil, kerosene, and hydraulic fluid, have flash points above 38° C (100.4° F).

Gasoline is the most hazardous fuel; 60% of fuel-related fires are caused by gasoline. Typical problem areas are fuel lines, connections on the engine, and leaking fuel tanks. The first warning sign is usually a gas smell. Vapors can ignite from heat in the engine compartment and from liquid spills over hot engine parts. One teaspoon (5 mL) of gasoline can vaporize and cause an explosion, and 1 cup (237 mL) of gasoline has the explosive

potential of several sticks of dynamite. Vaporized gasoline is heavier than air, so it accumulates in the lowest part of any enclosed space. That is why it is critical to run the bilge blower for at least 4 minutes before starting the engine. Diesel fuel is much less explosive. However, pressurized diesel fuel spurting from a burst fuel line will ignite and burn when it strikes something hot, such as the exhaust manifold. Charging batteries generate hydrogen, which accumulates in the battery compartment or in the compartment overhead; the gas is lighter than air, highly flammable, and potentially explosive. Sparks from a nearby electric motor may set off an explosion from excess hydrogen produced by overcharging.

The best way to manage a fire is to install a properly sized, automatic discharging extinguisher system, which interrupts combustion with chemical materials or gases. Fire-suppressing alternatives to halon gas (which is now banned because it breaks down atmospheric ozone) are fluoropropane and fluoroethane (FM 200 and FE-241, respectively). These fire suppressants can be automatically discharged from extinguishers by devices that sense ultraviolet radiation or temperatures above 79° C (174.2° F). Automatic systems should also have a manual trigger for activation. Halotron is a new “no residue” agent for portable extinguishers and a good alternative to the older dry chemical powders, which leave a messy, highly corrosive, and destructive residue. When using portable extinguishers, discharge them into the engine compartment through small fire ports to avoid introducing large quantities of fresh air to the fire. Remember to have the engine shut down either automatically or manually when fighting fire in the compartment. Automatic shutoff for diesel engines and generators, and engine room blowers, are now required in the event of an extinguisher discharge. Diesel engines consume large volumes of air when running and can quickly deplete the extinguishing agent. Let the area cool before opening hatches or inspection ports, lest the entry of air start the fire anew by diluting the concentration of extinguishing agent or by introducing oxygen.

A popular galley stove fuel is liquefied petroleum gas (LPG), either propane or butane. Both are highly explosive, heavier than air, and may accumulate in the bilge. Free propane in the bilge, like gasoline, is a bomb waiting to go off. Proper LPG tank installation requires a completely self-contained vapor-tight locker opening only above decks. A drain should be located at least 20 inches (51 cm) from any opening to the boat's interior and should not be submerged while the boat is underway. A pressure gauge connected to the LPG cylinder valve will help to indicate a leak somewhere in the system. It is not, as many believe, intended to show the quantity of LPG in the tank. A regulator to reduce the pressure in the gas line to the stove and an electric solenoid valve complete the delivery system. Seek expert professional assistance when installing the complete fuel supply system. As of April 2002, propane cylinders must be equipped with an overfill protection valve, because overfilled cylinders may explode after overheating.

Leaks in the line can be detected with an electronic gas detector or “sniffer” installed in the bilge and beneath the stove. If the alarm sounds, turn off the LPG solenoid, and turn on the blower and run it until gas is no longer detected by smell or by an electronic sensor. The system should be pressure-tested for leaks periodically, especially after rough weather or repairs or maintenance to the system.

To check for a leak, open the cylinder valve with the solenoid switched on and all appliance valves closed, and record the pressure gauge reading. Next, close only the cylinder hand valve to see if the pressure drops over intervals of 3 to 5 minutes; if it does, there is a leak. Soapy water can be used to look for the source of the leak. Needless to say, never look for the source of a leak with an open flame.

To avoid accidents after cooking, switch off the solenoid first, let the burner continue to flame until the line is cleared of gas, and then turn off the burner. When appliances are not in use or the boat is unattended, close the cylinder valve. Never use the stove as a cabin heater; the flame can deplete a cabin of oxygen and asphyxiate the sleeping crew. Carbon monoxide, a colorless, odorless gas, is a byproduct of incomplete combustion; severe exposure can be lethal. Mild early symptoms consist of fatigue,

sleepiness, headache, malaise, nausea, vomiting, and ataxia (loss of balance); these are also the symptoms of seasickness. Carbon monoxide detectors are the most effective defense against this potentially fatal problem. Install them in each cabin.

Stove alcohol is also hazardous, especially if one burner is accidentally extinguished and liquid alcohol used in priming the burner pours onto an adjacent flaming burner, causing a flare-up. A nonpressurized burner can also re-ignite if refilled with alcohol while still hot. Alcohol fires can be extinguished with fire blankets or wet towels. A grease fire on the stove can be extinguished with these items or by liberally sprinkling the fire with baking soda. A good precaution is to place a kettle of water on the burner before lighting it; this helps to contain any high flames arising from excess alcohol used in priming the burner.

The Coast Guard requires all recreational vessels to have portable fire extinguishers ([Figure 83-10, online](#)). The standard multipurpose dry chemical extinguisher (filled with monoammonium phosphate) and the newer dry chemicals discussed previously can be used on all types of fires: class A, B, or C. They extinguish and suffocate the fire by preventing access to oxygen. A major drawback is the extremely brief window of opportunity provided to put out the fire. The common B-1 extinguisher discharges completely in just 10 to 13 seconds. Units with greater capacity simply deliver more chemical over the same period. Because of the short discharge time, more than one fire extinguisher should be available to cope with a large blaze.

The Tri-Class extinguishers work on Type A fires by forming a crust of material over the burning materials, thereby isolating the fuel from oxygen. This same characteristic makes cleaning up after the discharge of a Tri-Class extinguisher very difficult.

Direct the nozzle to the base of the fire with a sweeping, side-to-side motion. Fires extinguished with dry chemicals should be considered a hazard until they cool down to room temperature.

Dedicate one portable extinguisher to the engine compartment, a second to the galley, a third to the area under the fore hatch, and place the fourth (and largest size practical to stow) in a cockpit locker. One should never have to walk more than half the boat's length to reach an extinguisher. The ideal location for a portable extinguisher in a closed compartment is next to the exit door. Fires involving common combustible solid material can be brought under control by cooling them with large amounts of water. Fires involving flammable or combustible liquids can be smothered to remove the oxygen by using a fire blanket. Electrical fires can be difficult to extinguish because the source of the heat (a shorted wire) can reignite the fire even after a fire extinguisher has been used. Terminating the electric power can often control electrical fires, especially when a short circuit is generating sufficient heat to cause other materials to combust. Every boat must have a main battery switch and/or AC breaker to turn off the entire electrical system. Water does not extinguish electrical fires, but may be effective on the resulting Class A fire after the electrical circuit has been disconnected. See Box 83-4 for fire fighting guidelines.

## COLLISIONS WITH OTHER VESSELS

International rules for preventing collisions at sea, referred to as COLREGS, define the responsibility of ships when collision is possible between two boats, as when crossing each other, overtaking, or meeting head on. Although the *stand on* vessel, which has the right of way over the *give way* vessel, is permitted to hold course and speed, the rules require that both ships take any actions necessary to avoid an imminent collision. In the presence of large ships, small boats must be especially vigilant. Consider any tow vessel, large freighter, or tanker operating on inshore waters to be restricted in maneuverability. Rules 3 and 18 of the Inland Navigational Rules make it clear that a sailing vessel does *not* have right of way over these vessels. As a professional tug captain declared, “If it looks like it is going to be close, it already is too close.” In commercial traffic areas, maintain a deck watch at all times, and hail any approaching ship on very high frequency (VHF) channel 13 (or 16 if no response) if uncertain of the ship's course or intentions. Be prepared to take defensive action. If two vessels are in a crossing situation and the bearing



**BOX 83-4 Guidelines for Fighting Fire at Sea**

1. Attack the fire immediately at the source. Detection and reaction time must be immediate, before the fire burns out of control. Prepare a plan that has been shared with the crew so that everyone knows the location of equipment and their responsibilities.
2. Initiate a mayday call immediately if this can be done without exposing the crew to the fire. The purpose is to alert ships in the area in which the crew may have to abandon ship.
3. When fire is discovered, all crew should be on deck as quickly as possible with life jackets and fire extinguishers in hands. Ensure that the life raft is away from the fire. This is another good reason to store life rafts on deck or in a deck-accessible locker.
4. Slow the boat to reduce relative wind, and steer to keep smoke and flames clear of the crew and vessel. Keep the fire on the downwind side of the ship, exposing the smallest amount of the boat's structure to the flames.
5. The crew should always have a clear escape route when fighting a fire.
6. Cut off the source(s) of the fire (e.g., fuel supply, electric current, and ventilation system). Turn off blowers, and stop the engine.
7. Shut off the air supply to the fire. Close the hatches, doors, and vents to all compartments free of people.
8. If you must open a hatch to discharge a portable extinguisher, beware of burning your hands or face. As fresh air enters the compartment, the fire will rise to the air source and flare up. The safest way to open a hatch is to wear gloves and stand on the hinged side of the hatch while it is opened. A "fire port" that allows a fire extinguisher to be discharged without opening an engine compartment can be retrofitted to boats easily.
9. If the fire is too large or out of control, abandon ship before the fuel tanks explode.
10. Check the engine compartment frequently to detect smoke/fire

(angle) between them remains constant, collision is inevitable. Visibility from the pilothouse of a large vessel may be partially obstructed by containers, fishing gear, or other items on deck; small craft may not be seen by the ship's lookout or pilot, show up on radar, or be granted right of way. This is a common cause of collisions along the shipping lanes around the world for all commercial and recreational small craft.

A relatively new tool for avoiding collisions is the Automatic Information System, or AIS, which is required on SOLAS vessels (over 300 T) and which recreational and smaller commercial vessels can use. AIS transceivers consist of automated VHF radios that transmit information about the ship (or small vessel), which are intended to prevent collisions due to better information about nearby vessels, as well as provide information about the vessels' identities (Name and MMSI number). Large ship AIS receivers are Class A, which transmit more information, more frequently, and with more transmit power than do the Class B transceivers, which are used on non-SOLAS vessels and recreational boats. The two systems are compatible, but the Class A system is more robust, since the damage caused by ship collisions are far greater than between ships and boats. There are also relatively inexpensive AIS receivers that do not transmit data about the mothership but allow access to the information being transmitted by the AIS-equipped vessels in the vicinity.

AIS transceivers/receivers may incorporate a display that allows the other vessels to be plotted, provide a list of the vessels and their threat potential, or provide this information to a chart-plotter, network display, or radar. Alarms can be set to warn if another vessel will pass within a certain distance, so that the vessels posing the greatest threat are highlighted.

Comparisons between the benefits of radar and AIS are common, but the best solution is to have and use both technologies. Radar can detect not only large vessels but also buoys, non-AIS vessels, shorelines, rocks, etc. Radar requires experience

to operate and interpret. AIS provides critical information about vessels equipped with transceivers, but no information about other threats.

Radar is invaluable in poor visibility (*Figure 83-11, online*). At night or in fog, radar can be used to identify other ships, hazards to navigation, squalls, and other local weather that may endanger a vessel.

Small, affordable radar units are available for recreational boaters. Most units are simple to operate; skill with their use comes with practice, study, and patience. The radar horizon is a function of the radar antenna height and the target height. The higher each is located above sea level, the better the range of visibility. Modern units integrate a variety of data, including electronic bearing lines, rings that give a fast reference point to a target, and the variable range mark (VRM), which marks the range to a target at a particular time. These data are invaluable for avoiding collision with another vessel. Many units can be integrated with the global positioning system (GPS), and electronic charts, and interfaced with computers for precision course plotting and tracking during navigation in narrow and complicated passages. A big advance in collision avoidance is ARPA (automatic radar plotting aid), which works in conjunction with the main radar and is required by COLREGS rule 7 to be used whenever risk of collision exists. It provides automated long-range scanning, sounds an alarm when a vessel comes within a predetermined distance, calculates the speed and bearing of other vessels, and automatically calculates the course alternatives needed to avoid collision.

One problem common to units on small boats is that during storm conditions, large commercial ships and yachts may be lost on the radar screen because of the mass of echoes from nearby tall waves. The intense reflection of radar signals from the sea is called sea clutter. Fiberglass and wooden boats and wood spars are nearly invisible to radar. Regardless of construction, all boats should have a radar reflector mounted at all times while in shipping lanes, on the open sea, or under conditions of reduced visibility. Ideally, a reflector should provide consistent reflective performance in all directions (most do not). The larger the reflector, the better the reflection. The effective area increases with the fourth power of the diameter of the device. Doubling a reflector's diameter increases its effective area 16 times.

Transponders make a vessel more obvious on the other vessel's radar screen. This device receives the radar signal and transmits it back to the radar unit with a signal that is electronically enhanced and stronger than one from a passive reflector. Unfortunately, most of the radar transponders available to recreational boaters transmit in the X-band and not the S-band, which is what ships use at sea.

An important function of radar is the ability to maintain an electronic guard zone. The radar scans this zone, which is preset as a circle of a given radius, and sounds an alarm when a new target enters the guard zone. Unfortunately, commercial ships and solo ocean racers may rely on this while they run on autopilot without a lookout on deck. This is a clear violation of rule 5 of the COLREGS: "Every vessel shall at all times maintain a proper lookout by sight and hearing."

For collision avoidance, many cruising sailboats install a masthead strobe light. Although these are highly visible, they are not accepted internationally as legal running lights, and the Coast Guard does not recommend them. A flashing strobe light may be interpreted as a distress signal, paradoxically inviting an unwelcome convergence of ships. Shining a powerful spotlight on the mainsail, turning on spreader lights, or igniting a white "anti-collision" flare can be an effective alternative means of alerting a ship to the danger of collision. It is recommended that cruising sailboats have masthead running lights for coastal and offshore cruising (to extend the range of visibility), in addition to deck-level lights for meeting, crossing, and passing maneuvers when vessels are nearby. The LED tricolor masthead light combines sidelights, sternlight, and all-round white light. It is noted for its energy efficiency, durability, longevity, and brightness. The U.S. Coast Guard Navigation Rules, International-Inland, specifies light requirements for every description of watercraft. Details can be found on the web at <http://www.boatus.org/onlinecourse/reviewpages/boatustf/project/info2c.html>.

**BOX 83-5 Preventing Collisions at Sea**

1. Post a lookout with a 360-degree view of the horizon.
2. Know the rules for steering and right of way.
3. Use radar (if available) and running lights. A tricolor masthead light is most visible and cannot be obstructed by sails or other gear.
4. Use an AIS (Automatic Information System) to allow you to plot large vessels on your chartplotter or AIS display.
5. Mount radar reflectors, and place them at least 4 m (13 ft) above the waterline.
6. Do not assume other boats have operational or unobstructed running lights. Be aware outside of U.S. waters that navigation lights on foreign ships may not match standard configurations.
7. Observe Rule 7 of the COLREGS: "When a vessel has any doubt as to whether a risk of collision exists, she shall assume it does and avoid it." Be prepared to change course and speed.
8. Ask yourself, "Can I be seen?" If you cannot see the wheelhouse windows of a ship, they cannot see you. Deck cargo, cranes, and containers can make it impossible for watchkeepers on a ship to see you up to three miles forward of the vessel. Do not assume you are seen, even in daylight.
9. If you hear a foghorn, stop and let the other ship steer around you.
10. If a collision threatens, sound the danger signal (five or more short blasts on the horn), and take whatever actions are necessary to save your boat.
11. Maintain radio contact with other ships in the area. VHF channel 13 is the bridge-to-bridge channel. Use VHF channel 16 if there is no response.
12. Avoid congested shipping routes if possible, and avoid navigating in the harbor's incoming and outgoing traffic separation lanes designated for commercial traffic. If you have to cross the traffic lanes, do so at right angles and remain in them for the shortest possible amount of time.
13. When your boat is in the way of another vessel, the right of way does not automatically grant you safe passage. Regardless of the COLREGS, be prepared to take evasive action. Caution is the primary rule of the sea to avoid collision.
14. To avoid collision with another vessel, make early and obvious changes in course and/or speed. Port-to-port is a good rule for most head-on passing situations (sound one whistle). In overtaking situations, one whistle means you are overtaking on the starboard side of the overtaken vessel, and two whistles mean the port side.
15. Give large ships a wide berth. Whenever possible, avoid meeting or overtaking tugs near river bends, bridges, and narrow channels.
16. Observe the bearing of an approaching vessel (the direction relative to you). If the bearing does not change, and if the distance between the two boats is decreasing, you are on a collision course.

COLREGS, International regulations to prevent collisions at sea.

Mariners should recognize the different patterns of lights displayed by commercial ships. Beyond U.S. coastal waters, many ships do not always show the appropriate lights. The risk of collision is therefore increased. Box 83-5 reviews measures to prevent collisions at sea.

Sailors crossing the North Atlantic in summer along a great circle route to Europe need to beware of colliding with icebergs. Every year from February to July, more than 10,000 icebergs are separated from Greenland glaciers. Global warming will have a profound effect on the number of icebergs in any given area, and in fact may increase local production as ice shelves fragment and costal water temperatures change. At least a thousand icebergs drift in the Labrador Current south and east of Newfoundland and become a hazard to mariners above 41° north latitude. Navigation around icebergs is complicated by dense fog often present over the Grand Banks region and some difficulty of

detecting icebergs with radar. U.S. and Canadian Coast Guards broadcast iceberg reports twice daily. The International Ice Patrol broadcast times and frequencies can be obtained by telephoning the International Ice Patrol in New London, Connecticut, at (860) 441-2626 or on the web at <http://www.uscg-iip.org>.

## Thunderstorms and Associated Weather Events

A single thunderstorm generally encompasses an area less than 2 miles (3 km) in diameter. It lasts approximately 30 minutes, with marked fluctuations in wind, temperature, and barometric pressure. The National Weather Service (NWS) considers a thunderstorm severe if it produces hail at least  $\frac{3}{4}$  inch (2 cm) in diameter, winds 58 mph or stronger, or a tornado. Of the estimated 100,000 thunderstorms that occur on inland and coastal areas in the United States, 10% are classified as severe. Eighteen hundred thunderstorms occur at any moment around the world, totaling 16 million a year. A squall line is a fast-moving row of violent thunderstorms, often more than 100 miles (160 km) long. An intense cold front 40 to 300 miles (64-483 km) behind the squall line contains most of the gusting winds and rain normally found in the front. It is visible on radar. To the naked eye, it appears as a wall of boiling black clouds arising from the sea.

Rapid growth of cumulus clouds is the primary indicator of a forming thunderstorm. The faster the clouds build, the more violent the resulting storm, because steep pressure gradients within the cloud generate high winds. Within the thunderhead are columns of rapidly sinking air called *downdrafts*. Downdrafts along the leading edge of the thunderstorm form the gust front. This zone of advancing cold air is characterized by a sudden increase in wind speed. Strong and highly localized downdrafts are called downbursts, the smallest of which are microbursts. Airplane pilots refer to these as wind shear.

Downbursts are extremely intense concentrations of sinking air. On reaching the surface, they fan out radially in all directions, often generating winds at the gust front in excess of 150 knots. They are short-lived, typically lasting less than 15 minutes. A single thunderstorm can produce a series of downdrafts affecting an area several miles long and persist an hour or more. Blowing spray under or slightly ahead of the storm may be the only indicator of its presence. A gust front often precedes a microburst. The combination of these two extremely strong and shifting wind systems can blow equipment and personnel off the deck and can easily capsize small craft and large sail boats.

In the United States, squalls occur predominantly during the spring and summer in association with thunderstorms generated by towering cumulus clouds (*Figure 83-12, online*). The larger the cloud's size (and radar echo), the more wind potential in the cloud. The taller the cloud (especially above 20,000 feet [6096 m]), the more energy potential for stronger winds. Most squall formations occur at night when cloud tops radiate heat back into space, enhancing their ability to grow. Squall-generated winds rarely strike without warning. A rapid fall in temperature is the precursor of a local storm. The bigger the drop, the stronger the winds, and rain that precedes the wind suggests stronger winds are coming. Occasionally, thunderstorms may form with the building of the cumulus cloud and not be associated with the typical rain, thunder, and lightning. These violent winds are called white squalls. The only warning may be the sudden appearance of a cold, shifting wind with an increase in velocity. Large sailboats, such as the clipper topsail schooner *The Pride of Baltimore*, have been knocked down and sunk by these unexpected powerful winds. In May 1986, a sudden storm rumbled across the Atlantic and unleashed its strength over a small patch of the Bermuda Triangle. With furious precision, its 70-knot winds overwhelmed the 97-ton, 110-foot clipper ship heading home from Europe; survivors reported that the ship immediately barrel-rolled in the heavy wind and sank.

To avoid or prepare for the potential fury of a thunderstorm, the mariner must monitor local weather conditions. The National Oceanographic and Atmospheric Administration (NOAA) transmits on VHF-FM radio recorded messages, which are repeated every 4 to 6 minutes, and updated every 2 to 3 hours with the

**BOX 83-6 Storm Warnings**

1. Small craft advisory: generally associated with sustained winds 18 to 33 knots (19-38 mph [30.5-61.2 km/hr]) and/or sea conditions dangerous to small boats.
2. Gale warning: sustained winds 34 to 47 knots (39-54 mph [62.8-86.9 km/hr])
3. Storm warning: sustained winds over 48 knots (55 mph [88.5 km/hr]). If winds are associated with a tropical cyclone, the storm warning display indicates forecast winds of 48 to 63 knots (55-73 mph [88.5-117.5 km/hr]).
4. Hurricane warning: sustained winds of 64 knots (74 mph [119.1 km/hr]) and greater as the result of a tropical cyclone
5. Special marine warning: winds of 35 knots or more generally lasting less than 2 hours. These are usually associated with an individual thunderstorm or an organized series of thunderstorms, as in a squall line.

latest local information. The broadcasts usually can be received 20 to 60 miles from the transmitting antennas. The stations are identified on the radio channel display as WX-1, WX-2, and WX-3. Nationwide, more than 860 transmitters provide coverage to all 50 states and the adjacent marine areas. In many areas, the Coast Guard broadcasts weather information on VHF channel 22. Listings of schedules and frequencies for coastal and offshore weather broadcasts are available in a number of publications, including the *Admiralty List of Radio Signals*, Volume III, and *Reed's Nautical Almanac*. Box 83-6 lists the definitions of weather warnings.

Many newer VHF radios have a weather-alert function known as Weather Watch. When the radio receives a special warning signal from NOAA, it sounds a special alerting tone, signifying an urgent NOAA weather forecast. Some radios automatically tune to the active weather channel, whereas others require manual tuning. In 1997, NOAA improved their severe weather warnings by encoding both the area affected by the severe weather and the nature of the severe weather (e.g., hurricane, winter storm, high wind, severe thunderstorm). Called SAME (Specific Area Message Encoding), this feature is intended to make weather warnings more customized so that users will not tune out possibly life-saving warnings. Offshore sailors can receive a variety of high-seas marine weather broadcasts with single-sideband (SSB) high-frequency (HF) radios. The U.S. Coast Guard broadcasts National Weather Service high-seas forecasts and storm warnings from each coast. All broadcasts are upper single side-band (USB) HF, with additional broadcasts on MF. The time schedules and frequencies for these transmissions can be found in the *U.S. Defense Mapping Agency (DMA) Publication 177, Radio Navigation Signals*. A less comprehensive list for specific locations can also be found in *Reed's Nautical Almanac*. For schedules and much more information on National Weather Service marine products, visit <http://www.nws.noaa.gov/om/marine/hfvoice.htm>.

The U.S. Coast Guard sends a facsimile of a weather chart (weatherfax) from their East, Gulf, and West Coast communication centers. These marine weather charts are updated every 6 hours and available within 3.5 hours of the valid update time. Weatherfaxes contain graphic charts and forecasts compiled by the NWS; they are broadcast on high-frequency radio bands between 3.5 and 30.0 MHz. Lists of transmitters, frequencies, and times can be found in *Reed's Almanac* or online at <http://www.nws.noaa.gov/om/marine/fax.pdf>. The NWS Internet page at <http://www.nws.noaa.gov> lists all weather charts broadcast over SSB. This site contains text forecasts, ocean current and surface analysis charts, wave charts, buoy reports, and prognosis charts for weather outlooks of 12, 24, 36, 48, and 96 hours (500-millibar [mb] charts).

Onboard cellular connection, modem, and laptop computers are required to obtain this Internet information. Beyond cellular range, a dedicated weather fax unit or SSB, laptop, or weatherfax module is needed. New software can integrate weather forecasting with optimal routing for safety and sailing performance. Weather files (called GRIB files) can be downloaded and overlaid onto an electronic chart, and routing formulas can

then be applied incorporating the specific boat's known performance characteristics. Mariners can obtain sea state and weather data directly from NOAA buoys moored offshore by using the Web. The National Data Buoy Center website is <http://www.ndbc.noaa.gov>; clicking on a specific station shows data gathered by the buoy in the preceding minutes.

NAVTEX is a worldwide land-based radio navigation warning service, transmitting text-only messages (in English) to a dedicated onboard receiver. The unit can be programmed to receive both specific stations and message categories; it can print out area weather forecasts, gale warnings, navigation warnings, ice warnings, and relayed distress messages on the assigned frequency of 518 kHz. Vital messages (e.g., gale warnings, search and rescue information) activate an alarm in the receiver as the message is being printed. Even without expensive electronic equipment, mariners can predict changes in local weather by using their own observations. Know the cloud types or use a photo atlas of cloud formations to identify the variety of clouds. During the day, a sailor can learn to recognize a squall line, the growth of cumulus to a cumulonimbus cloud with its characteristic anvil head on the downwind side (a thunderhead), and the cloud sequence and wind changes of an approaching cold and warm front. "Mare's tails and mackerel scales; soon it's time to shorten sails," refers to cirrus and cirrocumulus formations (long puffy clouds at high level, commonly known as a mackerel sky). This cloud formation signifies unsettled weather with the approach of a warm front. Two weather concepts can be helpful for predicting changes in the weather: the "crossed-winds rule," popularized by the meteorologist Alan Watts, and Buys Ballot's law. The crossed-winds rule states that whenever the upper level wind flow (determined by observing the direction of the cirrus clouds at 20,000 to 30,000 ft [6096-9144 m]) and lower level surface winds are crossed, the weather is going to change. Buys Ballot's law states that in the Northern Hemisphere, when you stand with the wind blowing at your back, a high pressure will be at 90° to your right, and a low pressure 90° to your left (remember "low-left"). If the application of crossed-winds rule and Buys Ballot's law indicates a low is approaching, the weather will certainly deteriorate; expect a warm front with increasing winds and rain. Once past, a cold front follows. If the upper-level flow either matches or directly opposes the surface wind, the weather is likely to remain stable for a while.

During daylight, a band of low, dark, and smooth tubular roll clouds can often be seen at the leading edge of a squall, preceding a cold front. The faster a roll cloud approaches, the stronger the wind is likely to be, and the more agitated the sea appears under it. When the sea is observed beneath the roll cloud, the cloud is about two miles away; because clouds typically move at about 25 mph, the face will arrive in about 5 minutes.

A barometer is one of the most important weather instruments onboard a small boat. One to 4 hours before an approaching thunderstorm, there is a sharp drop in barometric pressure of about 1.5 mb. If the atmospheric pressure is fluctuating very little, it means the weather is likely to remain stable. A pronounced rise in pressure heralds fair weather.

Sea state is also a valuable clue to changing weather patterns. Large ocean swells precede a heavy weather system, whereas chop without swells often reflects a local, more isolated, and temporary disturbance. An alert observer can calculate the distance between a vessel and a thunderstorm within earshot. Lightning's distance from an observer can be determined by noting the time between the flash and the bang of associated thunder. For each 5-second count from flash to bang, lightning is one mile (1.6 km) away.

Because it is impossible to predict the power of thunderstorms, mariners should always prepare for a major change in visibility, wind, and sea state.

**LIGHTNING**

Lightning is one of nature's most destructive phenomena (see Chapter 3). Boating, fishing, and swimming rank second only to playing sports on an open field as the most dangerous activities associated with a lightning strike. Although the odds that an individual will be struck and killed by lightning are 1 in 3 million,



the odds for a boat being struck are greater. A cruising sailor in Florida, the lightning capital of America, can expect at least one strike to his boat in its lifetime.

Lightning protection systems do not prevent lightning strikes. They may, in fact, increase the possibilities of the boat being struck. The purpose of lightning protection is to reduce the damage to the boat and the possibility of injuries or death to the passengers from lightning.

Tall and narrow objects, with highly charged and focused electric fields, are likely to attract lightning. Metal itself does not attract lightning. A sailboat mast, radio antenna, fishing outrigger, fishing rod, and even persons standing in a motorboat all make good targets. In a marina or anchorage, the boat with the tallest mast is most vulnerable to a strike.

The most critical factor initiating the streamer emanating from the boat is not only the height of the boat's mast, but also its electric potential. The crackling bluish-green light sometime seen in a ship's rigging at night during thunderstorms is not lightning, but a type of electrical discharge (corona discharge) called St. Elmo's fire. It may even appear like a stream of fire as it trails from the mast. Magellan's storm-battered crew regarded the "fire" as a sign of divine protection by St. Elmo, the patron saint of mariners. Captain Ahab saw St. Elmo's fire and reassured his ill-fated crew aboard the whaler *Pequod*, "The white flame but marks the way to the white whale."

St. Elmo's fire occurs when there is a large difference in electrical charge between the mast and the surrounding air. This causes air molecules to be split apart by the voltage streaming off the mast, and the resulting gas begins to glow. Do not climb the rigging to check it out; there are 30,000 volts per centimeter of space surrounding the masthead!

Lightning is far too erratic and unpredictable for absolute protection to be possible. The degree of protection and the best way to accomplish it are controversial. Many experts advocate a system of providing an adequate conductive path from the masthead through to the water by the shortest, most direct route possible, utilizing an elaborate bonding system. All wire rigging and large metal objects should also be connected to an underwater ground plate. This is especially important for boats constructed from wood, composites, and fiberglass; these non-conductive hulls impede the passage of the electrical charge to the water. Steel and aluminum hulls with traditional aluminum spars are excellent conductors of electricity and can carry electrical charges to the ground with ease. The objective of bonding is to prevent injury to the crew, catastrophic damage to the boat, and severe damage to electrical systems and electronic equipment. Even with the best system, this is not always accomplished. Without grounding, a bolt of lightning will find its way to the sea from the base of the mast, usually through some part of the hull. As a minimum, the mast should be fit with an air terminal. This consists of a solid  $\frac{3}{8}$ -inch copper or  $\frac{1}{2}$ -inch aluminum rod attached to the top of and extending at least 6 inches above the vessel's mast. Its skyward tip should be rounded. The path to the ground must be a highly conductive material of low resistance so that the current passing through will not create heat sufficient to melt the conductor. The bonding system must be complete. Half measures may invite massive electrical charges into the boat and then fail to provide a safe path to the water; it would be preferable to remove the half measures and sail without a bonding system (other than one exclusively for the electronics). Copper wire with a minimum of 4 American Wire Gauge (AWG)—not 8 AWG, as previously suggested—is required in salt water, and a ground plate (with sharp rather than round edges), ideally made of solid copper or bronze with a dimension of at least 1 square foot (30.5 cm), is recommended. It should be located as close to the mast as possible on the bottom exterior of the underwater hull.

Lead keels on sailboats make excellent ground plates only when properly connected to the base of the mast and if not encapsulated with fiberglass. Some motor and auxiliary sailboats use the exposed surface of the engine prop and shaft as a ground plate. With engine grounding, damage may occur from the heat generated by a powerful strike. All masts constructed of wood or other nonconductive materials (carbon fiber with epoxy resins) require wire or a solid copper strap from the masthead to the ground plate.

Lightning can also generate a side flash, which is the secondary flow of current from the surrounding charged area to some object near the path the strike follows to the water. This current is especially dangerous to crew who are accidentally near the path to the ground. Simple grounding of the mast to the ground plate prevents major hull damage but does not prevent these side flashes. As the current follows a designated path to the ground, another electric potential is created between the ground system and the objects surrounding it. The entire boat becomes high voltage, and the secondary electric current, the side flash, is created. The concept that a 45-degree cone-shaped zone of protection is created under the mast is not true. Lightning has directly penetrated this mythical area of safety, and you can still be electrocuted by voltage along the deck surface, and by side flash if the mast is struck. The key to preventing secondary current flows is to equalize the voltage of all the metallic objects on board by establishing a common electrical ground for the entire boat; that is, a complete bonding system. Any area capable of collecting a large static charge, each piece of metal equipment on board, and all electronic instruments and radio equipment must be bonded to the same discharge system used to protect the boat from the effects of the initial lightning strike. This is accomplished by connecting #6 gauge copper cable from all metal objects to the common ground. This includes shrouds, stays, tanks, rudder, engine blocks, electric winches, pulpits, pedestals, arches, radar masts, seacocks, etc. Switching off or disconnecting electronic equipment is advised, but will not necessarily protect it. Portable electronics, computers, handheld GPS, and radios can be placed in the galley oven, which acts like Faraday cage, or in a designated grounded metallic box. Everything electronic that uses modern microprocessors is vulnerable in an electrical storm.

Crew members may become part of the current path if they are in contact with, or come between, two different metal objects that are not interconnected (e.g., by grasping the stanchion or rigging while holding an aluminum steering wheel). The best protection in the event of a direct lightning strike, even if the boat is grounded and bonded, is to remain low in the boat (preferably in a cabin) and away from metal objects, wiring, and electric conductors (Box 83-7).

## OTHER WEATHER PHENOMENA

Waterspouts are maritime tornadoes. Although less common than lightning and downbursts, they are generated by the same dynamic forces found in the squall line at the leading edge of an advancing cold front or in a rapidly building summer afternoon thunderstorm. The danger inherent in a waterspout lies in the powerful revolving winds, which may exceed 250 mph (400 km/hr), and the very low pressure at its center, which may cause tightly enclosed spaces to explode. Waterspouts are visible during the day, when the majority of them occur, and can also be located and tracked by radar. The average forward speed is 30 mph (50 km/hr), but may vary from nearly stationary to 70 mph (120 km/hr). An area of turbulent water in the distance is the earliest visible sign of a waterspout; as it approaches, spray rises upward and joins the funnel cloud with its characteristic snakelike, gyrating appendage. Waterspouts usually last only 30 to 60 minutes. Preparation of the boat and crew is similar to that for a thunderstorm. Because a waterspout is relatively narrow, steering a course perpendicular to its projected path (the direction the clouds are going) is a logical avoidance maneuver.

A hurricane is a type of tropical cyclone—an organized rotating weather system that develops in the tropics. Tropical cyclones are classified as:

- Tropical depression—an organized system of thunderstorms with a closed low-level circulation and maximum sustained winds of 38 mph (33 knots) or less.
- Tropical storm—an organized system of strong thunderstorms with a well-defined circulation and maximum sustained winds of 39 to 73 mph (34 to 63 knots).
- Hurricane—an intense tropical weather system with a well-defined circulation and sustained winds of 74 mph (64 knots) or higher.

**BOX 83-7 Protecting Crew from Lightning Injury**

1. Get out of the water. If possible, get off the water and away from the water.
2. Get off the beach. If stranded, squat down and place legs and ankles together. Keep surface area of the body in contact with the ground to a minimum. Spread people out to maximize the possibility that some will survive a lightning strike.
3. If possible, get off the boat, including boats at anchor or in a marina.
4. Remove wetsuits and other wet clothing. Put on dry clothing and foul weather gear, hat, and boots, and a personal flotation device. Wet bodies make good electric conductors, but wet foul weather gear may provide protection by lowering surface resistance and guiding the current around you.
5. Remove all metal articles, especially jewelry, scuba tanks, and weight belts.
6. Avoid direct contact with all metal objects, including handrails, engine, stove, rigging, and spars.
7. Do not touch any of the boat's installed electrical equipment, including navigation instruments and radios. Use a hand-held VHF radio for emergency communications during the storm.
8. Do not simultaneously touch two metal objects, such as the engine throttle and spotlight handle.
9. Stay away from the mast, stays, shrouds, and wet sails.
10. Stay out of areas where bridging between two highly charged areas, or side flashes, may occur. These areas include the foredeck, between the mast and the head stay, or a seat between an outboard engine and the portable metal fuel tank or steering wheel.
11. If caught in a storm while on a sailboard, lower the sail and mast and sit down on the board.
12. If fishing or trawling, stop and lay the rods and trawls horizontal in the boat.
13. Put nonessential crew and passengers below decks, in the center of the cabin. Stay out of the companionway, engine room, and head. If there is no cabin, stay low in the boat.
14. If possible, put the boat on autopilot to minimize contact with a metal wheel.

The Saffir-Simpson Hurricane Scale is a 1 to 5 rating based on the hurricane's intensity. Category 1 has sustained winds up to 95 mph; category 5, sustained winds in excess of 155 mph. In the western North Pacific Ocean, hurricanes are called typhoons ("super typhoons" have sustained winds exceeding 150 mph) and in the Indian Ocean, cyclones. On average each year, 10 tropical storms, six of which become hurricanes, develop in the Atlantic Ocean, Caribbean Sea, or Gulf of Mexico.

The center (eye) of a hurricane is relatively calm. The most violent winds and rainfall are found in the eye wall, a ring of thunderstorms 50,000 ft (15,240 m) high. Coastal sailors seeking harbors of refuge from the destructive wind and sea still have to prepare for the greater threat of the storm surge; this is a large dome of water, often 50 to 100 miles (80-160 km) wide, that sweeps across the coastline where the hurricane makes landfall. The surge of high water, topped by huge waves, is devastating. In the summer of 2005, Hurricane Katrina flooded and destroyed cities of the Gulf Coast with its 20-ft storm surge. When given the choice, some sailors head out to sea, risking their lives to save their boats. This may be a reasonable strategy for a battleship, but rarely a prudent decision for an offshore sailing craft. The best tactic for dealing with the fury of hurricanes at sea is to avoid them. Although recommendations include placing the boat in the so-called safe or navigable semicircle and avoiding the strongest winds surrounding the eye of the hurricane, the safest course is to stay out of their path.

In the Northern Hemisphere, the wind blows counterclockwise around the eye. Facing into the wind and stretching the right arm back 120 degrees will point at the eye of the hurricane. In the Southern Hemisphere, the wind blows clockwise around the eye. Facing into the wind and stretching the left arm back

120 degrees will point to the eye. In the Northern Hemisphere, the strongest winds are to the right side of the hurricane's path, where the forward speed over the water adds to the local wind speed; this is the more dangerous semicircle. In the Southern Hemisphere, the strongest winds are on the left side of the path.

Hurricane track forecasting has acknowledged limits and errors, and the U.S. National Hurricane Center is not infallible. Hurricanes are inherently unpredictable, even when the best computer models are used to predict their path. In October 1998, when category 5 Hurricane Mitch (the fourth-strongest Atlantic basin hurricane in recorded history), slammed into Honduras, the 286-ft, four-masted, steel-hulled *Fantome* was doomed. Despite every evasive action taken by the experienced captain (based on the updated forecast track), the massive hurricane swirled menacingly into his path and eventually sank the cruise ship with loss of the entire crew. The plots of the ship's daily locations off the coast of Central America and those of the hurricane exactly overlap each other, as though Mitch was stalking the ship before finally devouring it.

The expected track error for a hurricane is 100 miles (160 km) on either side of the predicted track for each 24-hour forecast period. For a 72-hour forecast, an error of 300 miles (480 km) to the left or right of the predicted forecast track can be expected, and for 96 hours, 400 miles (650 km) to either side is applied. That would make the storm's potential swath for destruction 800 miles wide, a considerable area to avoid if a vessel can only travel at 6 to 7 knots in storm conditions. In order to take meaningful evasive action, a hurricane needs to be monitored at least every 6 hours, which is the official forecast interval for the NWS Tropical Prediction Center. The National Hurricane Center in Coral Gables, Florida, provides advisory updates on developing tropical storms and hurricanes 24 hours a day. Voice recordings can be heard by calling 305-229-4483 or online at <http://www.nhc.noaa.gov>.

## SEA CONDITIONS

In storm-tossed seas, expect larger, more dangerous waves; their height varies, and some can be double the height of the average waves in a given area. Strong tidal currents, common near inter-island passages, inlets, canal exits, and river mouths, can interact with wind-driven waves to produce high waves and perilous conditions. The same concept applies to adverse currents. When a current's speed approaches or exceeds 25% of the speed of oncoming wind-driven waves, the current stops the wave energy from moving forward; wave energy builds vertically until the steep waves begin to break, endangering small craft. Check tide and current tables in the regional *Nautical Almanac* to calculate the optimal time for safe passage by coordinating the local weather with the predicted currents. Try to avoid sailing parallel (beam-to) to high breaking seas; the curl of a plunging breaker can easily capsize a boat. Capsizing may occur in seas that are not exceptionally high. On December 21, 2004, the 75-foot *North-ern Edge*, with six fishermen aboard, capsized off the New England coast in a snow squall with 15-foot (5-m) seas and 35-mph (56-km/hr) winds (an average North Atlantic winter storm). The lone survivor said, "We were dredging (for scallops) ... then came a wave and the boat was hit broadside, and it just flipped." The bodies of the other five fishermen were never recovered from the 40° F (4° C) water after the U.S. Coast Guard searched a 1,850-square-mile (4791-sq-km) area for more than 40 hours. None of the fishermen were wearing survival suits. According to a preliminary investigation, the watertight door to the engine room and forward compartment was open, but the scuppers to the main deck (the openings along the deck that allow water to escape) were closed.

## Emergency Communication and Distress Signals

### CELLULAR TELEPHONES

According to the U.S. Coast Guard, sailors use cell phones more often than marine radios to call for assistance simply because more boaters carry cell phones than VHF radios aboard their

craft. The cellular phone has many disadvantages when used in search and rescue (SAR). Currently, 10 to 20 miles (16-32 km) offshore is the average effective range of cellular phones; range is determined by line of sight to the cell antenna. Therefore, use is restricted to high-traffic areas where there are both cellular antennas and relay stations. Gaps in transmission make them unreliable, even for coastal use. Cellular communication is private, in contrast to the more public (party line) broadcast over VHF radio; this excludes potential assistance from boats that might be in the immediate vicinity. In SAR operations, no practical way exists to maintain continuous communication with a number of rescue craft via cellular phone. The Coast Guard is unable to use radio direction finding equipment to locate the vessel in distress if it is calling on a cellular frequency, as it can with the VHF-FM signal. The cell phone has limited battery power and longevity, and the phone does not like getting wet. Every boat should have a portable or fixed mounted VHF radio. VHF transmission allows the Coast Guard's new Rescue 21 system to locate a vessel more quickly and efficiently when Digital Selective Calling (DSC) is used in conjunction with a GPS unit (see below).

If a cellular phone is the only communications link on board, extra charged phone batteries and a waterproof pouch are needed. A comprehensive list of emergency phone numbers should include local hospitals and physicians, regional Coast Guard stations, harbormasters, and maritime towing services.

The Iridium communication system is similar to the cellular phone, but utilizes low earth-orbiting (LEO) satellite constellations. Iridium is the only phone providing reliable worldwide coverage without gaps. These portable phones can be used for voice transmissions and for receiving e-mail and Internet communications. Satellite telephones require a clear view of the sky to operate (the antenna must be visible to the satellite), or they may be used with a docking station and remote external antenna. Cost ranges from \$1 to \$2 per minute. When the mast comes down and the antennas for the SSB and VHF are lost, a satellite phone may be lifesaving, especially when help is out of range of the hand-held VHF radio. A satellite phone is a valuable addition to the abandon ship bag. It should be carried in a waterproof bag together with a list of the critical phone numbers of the rescue coordination center and Coast Guard communications centers for the areas in which one will be sailing.

### VHF-FM MARINE RADIOS

The VHF-FM radio transceiver is the most popular, user-friendly, inexpensive, and reliable form of marine communication. It is the single most important radio system. It is easy to use, even for crew with minimal experience. The VHF signal range is limited to line of sight and therefore depends on the height of the transmitting and receiving antennas. A transmission range of 15 to 30 miles (25-50 km) can be expected between boats having masthead-mounted antennas. The VHF radio is limited to near-shore, ship-to-ship, and ship-to-shore communication. Communication is not private, which is a distinct advantage in maritime emergencies and SAR operations. VHF is the open party line connecting all vessels within the signal range. Any boats in the area monitoring distress channel 16 will possibly receive the distress call. In the new Rescue 21 system (see below), Coast Guard rescue boats and aircraft are equipped with radio direction-finding equipment that can precisely locate the direction from which the VHF-FM signal is being broadcast.

Cruising boats should have both a fixed mounted radio wired to the ship's electrical system as well as a portable hand-held VHF radio (Figure 83-13). After a knockdown or capsizes, a hand-held radio can operate independently of the ship's radio antenna (the mast may have been lost or the antenna damaged). It is indispensable in SAR operations and helicopter evacuation, when one is required to be mobile and on the deck. Hand-held radios can also be used to communicate with the mother ship from a dinghy, and are essential for communicating with rescue personnel from a life raft.

During an emergency, use the more powerful, permanently installed radio for the initial distress call. In the spare parts inventory, include an emergency antenna that can be inserted into the



**FIGURE 83-13** Waterproof VHF radios can make an effective crew overboard alarm, by allowing the victim to contact the mother ship or other vessels in the vicinity.

VHF radio jack to allow short-range communication should the boat be dismantled (the same problem can befall a powerboat if its antenna is broken).

The range of the portable unit is up to 5 miles (8 km). To conserve batteries, the user should transmit only when a ship is in sight and whenever a message is received (even if the calling ship is not in sight). Transmitting uses 15 times more battery power than does receiving; transmitting at full power uses dramatically more power than at low (1 W) output. Although range of a hand-held radio is less than a high-power fixed-installation VHF radio, reliable communication can be established with any visible aircraft or vessel.

The new multichannel VHF survival radios are ideal for life raft or lifeboat use: They are waterproof, submersible to 10 feet (3 m), and float. The operating life with the lithium battery is a minimum of 8 hours. Normal hand-held VHF radios sink, so they should be placed in a foam flotation case for protection. The most important VHF channel is channel 16, the distress and safety frequency (156.8 MHz). This calling frequency is used to initiate contact between any two vessels and is the only frequency constantly monitored by the Coast Guard. When a radio is not active on another channel, it should be left eavesdropping for distress calls on channel 16. Table 83-2 lists other VHF-FM channels often used by pleasure craft.

Rescue 21 is an advanced maritime computing, command, control, and communications system designed to manage communications for the U.S. Coast Guard and significantly improve the rescue of boats in distress. When completed, this VHF-FM communications system will replace the current National Distress Response System installed and deployed during the 1970s. Rescue 21 will cover 98% of the 95,000 miles (153,000 km) of coastline, navigable rivers, and waterways in the continental United States, Alaska, Hawaii, Guam, and Puerto Rico. Rescue 21 improves on the NDRS with the following enhancements: direction-finding equipment with 2 degrees of accuracy, enhanced clarity of distress calls, simultaneous multi-channel monitoring, upgraded playback and recording feature for distress calls, reduced coverage gaps, and full support of DSC. The rescue 21 system relies on digital selective calling as the preferred hailing system for transmitting mayday calls and for establishing voice radio communication on the marine VHF band. These radio installations will include manned Coast Guard shore stations as well as Coast Guard vessels operating in coastal waters. The new technology enables the Coast Guard to obtain multiple lines of bearing to a mayday call, and determine with precision the location of the vessel in distress. As of spring 2010, Rescue 21 covers 34,912 miles of coastline, and will be completed in stages over the next few years.

### SSB-HF RADIOS

For communication offshore, beyond the VHF range, a more powerful and elaborate SSB radio transmitter is required. The SSB's clear advantage over the satellite phone is that a transmitted



**TABLE 83-2 Useful Marine Channels (VHF Radio)**

|            |                                                                                                                                   |
|------------|-----------------------------------------------------------------------------------------------------------------------------------|
| 06         | Intership safety communications                                                                                                   |
| 09         | Boater calling. Use this to initiate contact with other boats, and ship to shore (hailing channel). Commercial and noncommercial. |
| 12         | Port operations, traffic advisories                                                                                               |
| 13         | Intership navigation safety (bridge-to-bridge). Use this channel to contact a ship when there is danger of collision.             |
| 14         | Port operations and some Coast Guard (CG) shore stations                                                                          |
| 16         | International distress, safety, and calling                                                                                       |
| 22A        | Working CG ships and shore stations, CG marine information broadcasts                                                             |
| 68, 69, 71 | Noncommercial intership and ship to coast                                                                                         |
| 70         | Digital selective calling (voice communications not allowed)                                                                      |
| 72         | Noncommercial intership only                                                                                                      |
| 78A        | Noncommercial intership and ship to coast                                                                                         |
| 87A, B     | Reserved for AIS digital communications                                                                                           |
| WX 1 to 7  | NOAA (National Oceanic and Atmospheric Administration) Weather radio broadcasts on 162 MHz                                        |

distress message will be heard by anyone who may be listening. Medium-frequency/high-frequency marine radio-telephone equipment operates between 2 and 26 MHz using SSB emissions. This equipment can also be used to receive high seas weather broadcasts (see discussion on thunderstorms and weather) and, in combination with a laptop computer and a special HF modem, can provide an easy and relatively inexpensive way to send and receive e-mail. The five principal SSB e-mail system providers for the recreational market are CruiseEmail, MarineNet, SailMail, WinLink, and SeaWave. Each provider uses a different software package with the Pactor-2 or Pactor-3 modem. E-mail is not just for social exchanges; it offers cruising boats a safety advantage for communicating safety-related data to boats around the world. Depending on the radiofrequency band and atmospheric conditions, communication range may be several thousand miles. See <http://www.sailmail.org> for excellent information about using the SSB for e-mail. Another popular use of the Internet is the phone program Skype. This service allows mariners to retrieve voice-mail, and to make and receive telephone calls by connecting a microphone and headset to a laptop computer while connected to the Internet.

The international distress and calling frequency is 2182 kHz, located in the medium-frequency range. The frequency 2182 kHz is used for distances from 20 to 100 miles, day or night. The frequency 2670 kHz is designated for distress and safety communications with the U.S. Coast Guard. On the high-frequency bands, the frequencies 4125 kHz (Channel [Ch.] 450), 6215.5 kHz (Ch. 650), 8291.0 kHz (Ch. 850), 12,290.0 kHz (Ch. 1250), and 16,420 kHz (Ch. 1650) have all been designated for distress and safety calls. The high-frequency transceivers can call and receive voice and digital communications to and from anywhere in the world on land and sea. The Coast Guard transmits voice and weather information on various marine HF frequencies. The transmitters cover the Atlantic and Pacific Oceans, Caribbean, Gulf of Alaska, and Gulf of Mexico. Up-to-date schedules and frequencies are on the web at <http://www.nws.noaa.gov/om/marine/hfvoice.htm> and <http://www.weather.gov/om/marine/hfvprod.htm>. The best way to select an optimum emergency frequency is to listen to the quality of a radio broadcast. A station that your radio receives loud and clear will also provide good reception for your broadcast at that time. SSB is an excellent receiver for voice weather and weatherfax broadcasts, as discussed previously. Optimal use of a marine SSB radio requires some instruction and practice. Marine Radio (ShipCom) in Mobile, Alabama, is the sole provider of worldwide ship-to-shore HF SSB (and VHF in some locations) radiotelephone service in the United States. Complete information regarding these radiotelephone channels can be obtained by calling (251)-666-5110 or at <http://www.shipcom.com/services>.

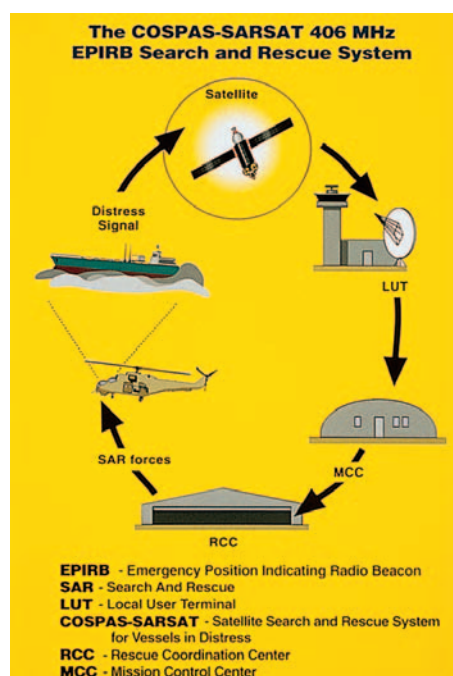
## GLOBAL MARITIME DISTRESS AND SAFETY SYSTEM (GMDSS)

Since February 1, 1999, ships and coastal stations have not been required to monitor the traditional distress frequencies, such as VHF channel 16 or 2182 kHz. However, until the new Global Maritime Distress and Safety System (GMDSS) is implemented, the Coast Guard and many recreational and commercial ships will continue a radio watch on these frequencies. The GMDSS is a worldwide infrastructure, controlled from a shore-based communications center, to coordinate assistance to vessels in distress. This fully automated system uses satellite and digital communication techniques that requires upgraded radio equipment and communication protocols to accomplish this, GMDSS simplifies routine communications at sea and facilitates regular weather forecasts, navigation warnings, and distress relays in the form of maritime safety information (MSI). DSC technology permits a VHF radio (with DSC capability) to call another radio selectively using digital messages, similar to the modem on a computer. As with a direct-dial telephone call on land, only the vessel called receives the initial message. Every vessel has its own unique Maritime Mobile Service Identity (MMSI) number. The radio must therefore be registered in order to be properly identified in an emergency or to be called directly by another boat using a DSC radio. To obtain and register your MMSI number, go to the Boat U.S. website <http://www.boat.us.com/mmsi>, or the Seas Tow website [http://www.seatow.com/boating\\_safety/mmsi](http://www.seatow.com/boating_safety/mmsi). The vessel's MMSI is registered in the Coast Guard's national distress database together with information about your boat. For VHF radios, channel 70 (156.525 MHz) is authorized exclusively for distress alerts, safety announcements, and calling using DSC techniques. No other uses are permitted. Distress messages can be sent automatically with DSC radios. The vessel's identity is permanently coded into the unit, and its position can be determined from the data output of a GPS receiver linked to the radio. On a DSC-equipped radio, the receiver sounds an alarm if it receives an "all ships call" (distress or otherwise), group call, or a call specifically to that vessel.

A distress alert (equivalent to mayday) can be also sent to a shore-based rescue coordination center (RCC) covering the area. Once the alert has been sent, the radio will automatically repeat the call at intervals between 3 and 4 minutes until the RCC acknowledges receipt of the message on channel 70. Subsequent communication should continue on channel 16 or another selected frequency for voice transmission. A verbal mayday can also be sent immediately on channel 16 after the first alert. Some DSC-equipped transceivers can listen simultaneously on channel 70 for DSC and channel 16 or other channels for voice transmission.

To make a ship-to-ship or ship-to-shore call on DSC, the nine-digit MMSI number of the station to be called must be keyed in on the radio together with a proposed working radio telephone channel (which is not private) for subsequent voice communication. This announcement is transmitted on channel 70 and should be acknowledged on channel 70. Four VHF channels are available for special use within the GMDSS: channel 06 is for SAR coordination, channel 13 for intership safety of navigation (bridge to bridge), channel 16 for distress and safety, and channel 70 for DSC alerting.

The GMDSS also utilizes satellite communication links, such as the International Maritime Satellite Organization (INMARSAT), to provide long-range global communication. Geostationary (geosynchronous) INMARSAT satellites cover the whole world between 70° north and 70° south latitude (there is no coverage at the poles, and spotty coverage in the Southern Ocean). The satellites completely orbit Earth over the equator at an altitude of 22,500 miles (36,210 km) over a period of 24 hours, allowing them to remain stationary over fixed points. They provide high-quality worldwide speech (voice is full duplex, just like a telephone), data, and facsimile communication as well as reliable distress alerting and follow-up communication within the GMDSS. Products in the INMARSAT Fleet Broadband systems vary in size, price, power consumption, and transmission speed. INMARSAT C is the gold standard for global marine data communication. It offers digital data messaging (no voice) and is the only two-way



**FIGURE 83-14** Anatomy of a rescue. The 406-MHz emergency position-indicating radio beacon (EPIRB) sends a digitally coded signal to a low-Earth-orbit satellite, which relays the signal to a nearby ground receiving station (LUT). The location of the EPIRB is calculated and forwarded to the nearest mission control center (MCC), which matches the EPIRB user's registration with the specific signal. These data are relayed to the local rescue coordination center (RCC), which initiates the search and rescue. (Courtesy ACR Electronics.)

marine satellite data message system approved for GMDSS safety at sea. The hardware is small enough to fit in any boat. It can send a distress signal at the touch of a button and easily be integrated with a GPS receiver. Pressing the distress key sends a message with the ship's identity and location to the nearest RCC. More information about GMDSS can be obtained from the Coast Guard website <http://www.navcen.uscg.gov/marcomms/gmdss/default.htm>.

## EMERGENCY BEACONS

Emergency position-indicating radio beacons (EPIRBs) are handheld portable radio transmitters that can transmit signals interpreted as mayday calls (Figure 83-14). These signals are the satellite-linked equivalent of a 911 call for mariners in distress. In the absence of a marine radio, an EPIRB is the most important piece of signaling equipment. An EPIRB should be used only as a last resort when all other means of communication have failed, and when there is a life-threatening emergency. It should be located in a readily accessible location.

EPIRB signals are transmitted on established distress frequencies 406/121.5 MHz. The signals are monitored by the global COPAS-SARSAT (search and rescue satellite-aided tracking) satellite system coordinated by the United States, Canada, France, and Russia. This system is a constellation of polar orbiting and geostationary satellites fitted with transponders to receive the distress signal and locate the beacon. The polar satellites orbit 600 miles (966 km) above the earth and have an orbit time of 105 minutes.

The first-generation class A and class B beacons are no longer in use, having been replaced by the superior Category 1 and 2 EPIRBs and PLBs. The second-generation 406-MHz EPIRB provides the most reliable worldwide coverage. Satellites with 406-MHz transponders can store the signal in memory until a ground station is in view and then can retransmit the signal. The distress signal is quickly relayed to a ground station called a local user terminal (LUT), passed on to the mission control center (MCC), and relayed to the appropriate maritime rescue

coordination center (MRCC). The satellites are able to compute the position of the beacon within 2 km (1.24 miles). The 406-MHz EPIRB transmits a digital signal with a unique identification code, which can be instantly identified through an NOAA encoded-transmission program. If the unit is properly registered with NOAA, vital information regarding the vessel can be passed on to SAR units. All registered EPIRBs are issued a dated decal that provides proof of registration and includes a unique 15-character hexadecimal code, registration expiration date, and the vessel's eight-digit registration code. Every owner who registers an EPIRB receives a sticker from NOAA printed with the beacon's registration number. This number should be verified to match the ID number on the beacon before it is attached to the unit. If the numbers do not match, the beacon is not properly registered. According to NOAA, 30% of beacons are never registered by their owners. Registration can be done online at <http://www.beaconregistration.noaa.gov/>.

Still another reason to register an EPIRB is to prevent unnecessary search and rescue operations. According to the Coast Guard, 96% of all EPIRB distress signals are false alarms resulting from faulty or accidental activation. If the Rescue Coordination Center is able to phone the contacts listed on the beacons' registration form, in almost all cases, they can validate the legitimacy of the distress signal.

Personal locator beacons (PLBs) also broadcast on 406 MHz and the homing frequency 121.5 MHz. PLBs have several limitations compared with EPIRBs, including 24-hour transmitting time and inability to float upright (or float at all). Their benefits include being compact and less expensive. They are a good back-up emergency communications device. The newest generation of EPIRBs is the 406-MHz unit with a GPS interface or a built-in GPS receiver. The GPS-enabled beacon (also called a self-locating beacon) transmits its exact location within 100 m, using GPS-derived latitude and longitude coordinates, along with the EPIRB signal. It utilizes polar orbiting satellites and new geostationary search and rescue (GEOSAR) satellites in high Earth orbit. GEOSAR satellites receive the signal as soon as the beacon is activated. Position information is continually updated and stored every 20 minutes in the unit as long as it maintains a direct connection to the GPS receiver.

All EPIRBs have a homing signal at 121.5 MHz. This is the homing frequency used by SAR vessels and aircraft equipped with radio direction-finding equipment to locate the craft in distress. Once activated, the EPIRB should be left on until the emergency is over; to update the position, it must broadcast continuously. EPIRB radio signals cannot penetrate water, wood, metal, or fiberglass (the unit must be outside the cabin), but the signals will be received when transmitted from inside a life raft, on deck, or on the water's surface. All Category 1 and 2 EPIRBs will transmit for at least 48 hours at  $-40^{\circ}\text{C}$  ( $-40^{\circ}\text{F}$ ).

Many cruising sailors believe a 406 EPIRB alert will bring rescuers in a matter of hours, or at most a couple of days. These expectations are unrealistic in many parts of the world. Although the SARSAT system and RCCs that support 406 EPIRBs save more than 1000 lives each year, the system is far from perfect. Some nations responsible for RCCs covering specific areas have failed to ratify the Search and Rescue Convention of 1979, and even after signing, lack the resources to meet their obligations under the guidelines. They are not equipped to carry out effective SAR operations in their designated area, and understandably, SAR may not be a top priority for the planet's poorest countries.

On June 8, 2002, when the 32-foot Down East cutter *Leviathan* went down in a storm off the island nation of Madagascar, a 6-hour EPIRB signal was not picked up by the RCC in Madagascar; the rescue center is not available on a 24-hour basis. Rescue ships and planes were not immediately diverted to the beacon's location, and 10 days passed before an air search was launched in the Western Indian Ocean. By then, the task was futile; the cruising couple and lifeboat were never found.

Potential delays justify carrying a second 406-MHz EPIRB when cruising in remote areas and far offshore. While the EPIRB is activated, continue signaling by all the other methods available. EPIRBs with lithium batteries have a shelf life of 10 years (although the recommended battery replacement interval is 5 or 6 years), making it feasible to store one in the life raft. If a single



**BOX 83-8 Visual and Sound Distress Signals at Sea**

1. If other vessels are in sight, stand in an unobstructed area and slowly and repeatedly raise and lower outstretched arms as though you are flapping wings.
2. Sound a foghorn (SOS: 3 short blasts, 3 long, 3 short), ring a ship's bell, or blow a whistle continuously.
3. At night, point a flashlight at another boat and flash SOS (dot dot dot, dash dash dash, dot dot dot) repeatedly.
4. Fly the ship's ensign upside down, or fly the recognized distress flag: an orange flag with a black square under a black ball. Any square flag with a ball shape above or below is also a recognized distress signal. Wave any brightly colored clothing or foul weather gear attached to a paddle or pole

EPIRB is carried on a vessel, it should be packed into an abandon-ship bag or other storage area for safety gear, unless it is mounted in a special bracket for automatic activation and deployment.

**VISUAL AND SOUND DISTRESS SIGNALS**

The simplest signaling strategies and devices are often overlooked. Box 83-8 lists some simple signaling techniques. Visual pyrotechnic distress signals have a replacement interval of 42 months from the date of manufacture and are labeled with expiration date somewhere on the device. Expired flares can be kept onboard as spares, but will not be counted in the vessel's inventory.

Hand-held flares have varying effectiveness for attracting attention during daylight (Figure 83-15). Luminosity ratings range from 500 to 15,000 candlepower. The lowest rated flares are virtually invisible in daylight at  $\frac{1}{4}$  mile (0.4 km), and the highest rated flares are only slightly more visible. For daytime use, orange smoke devices are the most effective way to attract attention. SOLAS-graded smoke canisters are superior to hand-held smoke flares. They float and emit orange smoke for 3 to 4 minutes. Immediately after ignition, throw the canister in the water downwind of the craft. Smoke signals have a visible range of 1 to 3 miles (1.6-5 km) in daylight, depending on the wind. Helicopter pilots find smoke signals highly visible and especially useful to indicate the strength and direction of the wind at sea level (Figure 83-16).



**FIGURE 83-15** Hand-held flares are reasonably effective during the day, and dramatic at night. They also produce white smoke that can be distinctive for aerial searchers.



**FIGURE 83-16** Coast Guard rescue swimmers carry multipurpose pyrotechnics, including effective smoke flares, which show wind direction and to make their own recovery easier for air crews.

After sunset, consider a flare's luminosity, burn time, and attained altitude. Use an aerial flare (meteor or parachute) to attract attention or alert a ship at night, and then ignite a hand-held flare to guide the rescue craft to your location. Because of the curvature of the earth, sighting distances are limited. A high-altitude flare enables a ship beyond your line of sight to be alerted. The greater the height, the longer and farther the signal can be seen by a distant viewer. A parachute flare at 1000 feet (305 m) is seen as a brief flash of light on the horizon from 40 miles (64 km) away, but from 20 miles (32 km), it appears to be 500 feet (152 m) above the horizon and is visible longer. Luminosity and burn time are more important than altitude to help assisting craft home in on the ship's location. The rated visible range assumes a ship in the area has an alert lookout standing on the bridge watching for and anticipating the signal, on a clear night with calm seas.

Whenever possible, choose flares meeting SOLAS standards (International Convention for Safety of Life at Sea). There are three SOLAS pyrotechnic types: a red hand flare that burns for 60 seconds at 15,000 candela; a red rocket parachute flare that soars to 1000 ft (305 m) and lasts for 40 seconds at 30,000 candela; and a 4-minute smoke canister. All three are self-contained (need no additional gear to operate), waterproof, and what is found on commercial ships and life rafts.

All pyrotechnics are hazardous. They can melt life-raft rubber and burn skin. Hand-held red flares may drip considerable ash and slag. Point them downwind while holding them high, at arm's length, away from the raft or boat deck, and over the water. Be in a stable position in the raft or boat when igniting a flare. Remove all adhesive fastenings and covers on the flare and be sure to identify the end from which the rocket or flare exits. After the signal is activated, turn away from the intense glare to protect the eyes. If a rocket or flare fails to ignite immediately, it may not ignite at all or there may be a lag time before firing. Hold the flare and count to 60. If there is still no ignition, throw the flare into the sea. Never look into a flare tube to see why it failed, and never put it back in the raft. Treat it as an activated and live explosive.

Parachute flares are designed to attract the attention of potential rescuers out of sight over the horizon. For practical purposes, a parachute flare has a useful range of about 10 miles (16 km), regardless of its rated range or altitude (they soar to 1000 feet [305 m]). These flares drop slowly beneath a nonflammable parachute and burn for 45 seconds. The SOLAS models burn the brightest and longest. Red is the distress signal, but a white parachute flare provides far more illumination than does a red one. The same is true for meteor (rocket) flares. They should be fired downwind at an angle just slightly less than vertical. The main body of the rocket is contained within the launch tube. After activating the firing mechanism, hold the tube with both hands, wearing gloves or with a dry cloth, to prevent the tube from slipping due to recoil.

Red meteor (aerial) hand-launched or pistol-launched flares (Figure 83-17) should be also launched downwind approximately 80 degrees above the horizon. These flares are less effective than parachute flares because burn time is only 5 to 9 seconds. It is





**FIGURE 83-17** Pyrotechnic signals (flares) need to be appropriate for the time of day and the distance offshore.

best to fire them in sequence—the first to attract attention and the second about 10 seconds later to confirm distress and general position. Because of their generally lower altitude and brightness, visibility is limited to 3 to 5 miles (5–8 km) at night. Because of these limitations, these flares are best suited for guiding nearby rescuers to the boat, after it has been spotted.

Do everything possible to attract attention with signal mirrors, flashlights, kites, or any other means before using flares. Do not fire flares in the direction of high-flying commercial aircraft. They cannot see your signal when they are flying at 30,000 feet (9144 m). Do not waste all the flares when the first ship or low-flying aircraft appears, because it might pass close by without seeing your signals. Flares are labeled with expiration dates; keep expired flares on board for a while, then schedule a time to practice using them (notify the Coast Guard and local authorities).

Signal mirrors are inexhaustible devices and more effective than flares in daylight. Mirrors are especially useful when trying to attract the attention of aircraft, even those flying at high altitudes. Aim the signal at the front end of the fuselage while the airplane is still in the distance and coming toward your vessel. The flash from a signal mirror can be seen up to 40 miles (64 km) from the air on a clear day. If a plane is heard, begin signaling with the mirror, because the aircraft can see the flashing light before the plane comes into view. Mirrors are also useful at night. Like reflector tape, they reflect back a ship's searchlight, making the raft or ship easier to locate in the dark. Utilize the entire crew to improvise signals with other reflective materials, such as compact discs, foil space blankets, jewelry, eating utensils, fishing lures, and credit cards.

Coast Guard rules state that every boat must carry a device capable of producing a 4-second blast audible from half a mile (800 m). This requirement can be met with chemical-propellant horns (that can damage ozone), lung-powered horns, and whistles. Plastic horns threaded into a metal canister often malfunction. Have at least two aboard, with a big inventory of spare canisters. Virtually all hand-held horns are barely audible at half a mile and are inaudible at three-quarters of a mile (1.2 km). The same is true for lung-powered horns and whistles, which are barely audible at a quarter of a mile (400 m). In the absence of a working sound device aboard ship, try striking the inside of a large pot with a metal spoon or winch handle to create a continuous, albeit crude, bell-like sound.

Rescue ships and aircraft use radar to locate a life raft or vessel in distress. Visibility on the radar screen can be improved by

using an electronic radar reflector known as a search and rescue transponder (SART). Once activated by an incoming radar signal (the interrogating radar), it is capable of sending back an enhanced electronic signal to any commercial radar located on a ship within a 10-mile radius and up to 50 miles (80 km) on the radar screen of an aircraft flying at 3000 feet (914 m). It is much more effective than a simple radar reflector. Fluorescent dye marker can be seen by airplanes and has a daytime visibility of 2 to 5 miles. In moderate weather, it will last for half an hour; in rough weather, it will rapidly dissipate. Use it whenever an aircraft is expected or the raft is beneath a known flight path. The sea anchor will keep the drift rate the same as that of the dye.

Hand-held waterproof strobe flashers offer portable, compact signaling and can flash for hours on a single replaceable battery. Although not an internationally recognized distress signal, they are effective when supplemented with other recognized distress signals.

## The Decision to Abandon Ship

There are many reasons to abandon ship. Flooding, fire, or collision generally causes sinking if not quickly controlled. Only when the vessel is about to sink or is burning out of control should the crew abandon ship. The adage “always step up to the life raft” means it is recommended to abandon the vessel no sooner than when the decks are awash. Consider all options; do not abandon the ship before it abandons you! Abandoning ship prematurely puts the crew at greater risk than remaining with a disabled craft. With rare exception, a floating disabled vessel is always your best lifeboat. The mother ship provides a stronger and more visible rescue platform than does a life raft. It is better stocked with provisions and equipment for communication and survival; conditions will always be harsher in a life raft.

## HOW TO ABANDON SHIP

Before abandoning ship, the first priority is to dress warmly and put on a life jacket. Layer on as much warm and quick-drying clothing as possible. If a survival suit is available, wear that instead of a life jacket, but bring the jacket for later use in the raft. One crew member should broadcast a mayday message on all available radios: VHF-FM channel 16 (good up to a 20-mile [32-km] range) and SSB 2182 kHz (good beyond 50-mile [80-km] range). Make a satellite telephone call to contact someone who can continue coordinating the rescue after abandoning ship. Repeat the coordinates of the ship's location slowly and distinctly. Activate a 406-MHz EPIRB. Simultaneously, other crew should launch the life raft and locate the abandon ship bag (a survival kit). It is recommended to augment the modest amount of survival gear found in most life rafts by having select items packed inside the raft container at the time of its annual repack (include VHF radio, EPIRB, food, water maker, medical kit, signal pack, sharp knives). However, it is not recommended to put those items in the raft if they might be needed independently. Those items can be packed into a waterproof bag securely attached by a short line to the raft.

Each crew member should have an easily accessible pre-packed waterproof bag containing extra dry clothing, personal medications, passport, prescription glasses and sunglasses, personal strobe, safety harness and tether, wallet, and any other personal valuables and necessities. If the ship's bag has been properly stocked, little else is needed from the sinking ship except synthetic blankets (not down sleeping bags, which never dry), jerry jugs of fresh water (two-thirds full so they float), extra food (especially high-carb sports bars), and navigation tools. If time permits, additional communication and signaling equipment should be collected from the stricken vessel, even if equipment was already placed in the bag or raft. This includes a 406-MHz EPIRB, a SART (if available), and a waterproof hand-held VHF radio. In a life raft, one can never have too many EPIRBs, radios, flares, and fishhooks (Box 83-9).

There are three loosely defined classes of life rafts: ocean, offshore, and coastal. These classes refer to the areas in which the vessel normally operates and reflect differences in size, design, construction, quantity of survival stores, and kinds of

**BOX 83-9 Abandon Ship Bag for Ocean Passage****Personal**

1. Personal Medication
2. Crew Passports (or photocopy), cash, credit cards, watch, prescription glasses, sunglasses
3. Notebook and pencils

**Signals and Communication**

1. Registered 406-MHz category II COSPAS/SARSAT emergency position-indicating radio beacon (EPIRB) preferably with GPS
2. Waterproof and submersible portable VHF hand-held radio transmitter with spare batteries. (Optional) Hand-held satellite phone in waterproof case with RCC and CG phone numbers
3. (Optional) Search and Rescue Transponder (SART)
4. SOLAS flare kit, smoke signals, canister and lung-powered horn, ship's bell, whistle, kite, dye marker, signal mirror, rescue streamer
5. Radar reflector
6. Waterproof binoculars
7. "Cyalume" chemical light sticks, rescue laser light
8. Waterproof LED flashlight with extra batteries
9. Strobe light with spare batteries

**Protection**

1. Survival suits, survival blankets, gloves, spare sunglasses, hats (items vary with area voyaging)
2. Expanded medical pack with extra seasickness medications, SAM splints, narcotics, sunscreen, lip balm, emollient skin cream, tampons
3. (Optional) Backup sea anchor and line

**Sustenance**

1. Portable reverse-osmosis desalinator (Katadyn Survivor 06 or equivalent)
2. (Optional) Fishing harpoon and spear gun with spare heads, extra fishing gear
3. Knife, can opener, sharpening stone, small cutting board, scissors, storage bags, eating utensils, nylon mesh bag, waterproof bags, zip-lock freezer bags, sponge
4. High-carbohydrate, low-protein energy bars, water packets
5. Collapsible bucket, urine bottle, toilet tissue, female hygiene supplies
6. Comprehensive survival manual, fish identification book, cards, reading material
7. Collapsible water containers

**Tools**

1. Tools, or multi-tool
2. Dive mask
3. Duct tape for raft repair and crew repair
4. Raft patching clamps

equipment. To be a survivor, a person must manage the emergency, remain alive, and be successfully rescued. For coastal cruisers on a small boat, an inshore rescue platform (e.g., Rescue Pod or Rescue Raft) can afford a level of safety and protection. It bridges the gap between survival suits and life rafts. Although not recognized as a lifesaving device (e.g., a life raft), it is a good solution as an emergency craft for near-shore (inshore) cruising on a small boat lacking storage space for a conventional life raft. For a variety of reasons, it should not be seen as a substitute for a coastal life raft. It is only suitable for use on protected bays, sounds, and inland waters, especially in warm waters. A stable inflatable or rigid dinghy can also serve to support the crew on inland waters and very near shore in an emergency requiring abandoning ship. Coastal rafts are rated for open water, mostly protected or within 20 miles of a shoreline. Most rafts have a single buoyancy tube and either a manually or automatically erected canopy. Ballast systems vary, ranging from a single ballast bag about the size of a loaf of bread to the four large bags

included in the better coastal models. Some coastal rafts have two identical stacked flotation chambers, an insulated foam floor, and a self-inflating single-arch canopy. This is ideal for offshore fisherman and coastal cruisers who need a light, compact raft, but its equipment must be augmented with a well-stocked abandon ship bag. Offshore rafts are designed to ISAF specifications, and are most appropriate for boats encountering real offshore conditions for a relatively short duration, but are not taking a transoceanic voyage. SOLAS Trans-oceanic Life Rafts are intended for the toughest conditions, with water temperatures below 41° F (5° C). These rafts include the most extensive amount of equipment and are the most heavily built, to allow self-sufficient survival for extended periods of time. They are often carried aboard boats in around-the-world races.

Have the life raft serviced annually by an authorized service facility and be present when the raft is both unpacked and repacked. One has a vested personal interest in seeing how well the job is done, and this is an invaluable opportunity to become familiar with all components of the raft.

A six-man inflatable life raft approved by SOLAS for ocean service (SOLAS A) has an extensive inventory of survival equipment. Review this list to eliminate redundancy in the abandon ship bag. The SOLAS B raft is designated for limited service. It carries no food, water, or fishing kit. These rafts also carry half the number of flares and smoke signals found in SOLAS A life rafts. Ocean-service rafts (and some lower specification rafts) are designed for use in rough offshore conditions. They are constructed with two complete, stacked inflation chambers. One flotation chamber is sufficient to support the number of people for which the raft is rated.

Give careful thought to how and where the life raft is stowed. The raft should be securely stowed either on deck, with hardware capable of withstanding the shearing forces due to capsize, or in the cabin.

If storing the raft on deck, you must use a canister version to maintain watertight integrity of the packed raft. It is recommended that you also use a hydrostatic release, which will release the raft from its cradle and allow it to float to the surface if the crew cannot manually launch it before the boat sinks. If the raft is stored below decks, make sure it can be launched within 15 seconds or less, and use a valise raft. It will be lighter and somewhat less expensive, but much less waterproof than the canister model. For offshore racers, rafts stowed below cannot be heavier than 40 kg or 88 lb.

The lid on a deck locker or lazarette is likely to open in a knockdown or capsize, unless it closes with deadbolts. Carry SOLAS-grade rafts on deck in hydrostatic release brackets.

If the boat has a dinghy, prepare to tow it behind the raft. It is useful for storing additional supplies and can be used with an improvised sailing rig. Although a solid dinghy is less seaworthy in a storm than is a life raft, it is far more durable against shark attack and is immune to chafe. A dinghy has more maneuverability and strength than a raft.

To launch the raft, the canister should be thrown overboard on the downwind (leeward) side of the boat and then inflated. It is dangerous to inflate a life raft aboard the ship with the CO<sub>2</sub> cartridge because the raft may become wedged in the rigging of the sinking ship or be punctured accidentally. Attach the line coming out of the canister (painter) to the boat before the raft is inflated. In the confusion surrounding an emergency, this critical step is sometimes forgotten, and after the raft inflates, it drifts away. A sharp jerk on the outstretched painter triggers the CO<sub>2</sub> cartridge and inflates the raft. If the first pull is unsuccessful, give a second, stronger tug. If the raft fails to inflate in the water, however, bring it aboard and inflate with the hand pump.

Station one person with a knife by the painter, prepared to cut the line. Another safety knife is located in a pocket by the entrance of the raft to cut the painter should the ship begin to sink after the crew has entered the raft.

Once everyone is aboard, get away from the sinking vessel quickly by paying out all the painter line. Risks for the raft and its occupants at this moment include being struck from below by surfacing wreckage or becoming entangled with the boat's rigging if it rolls and sinks. If the boat remains afloat, attach a quick release line to it. The wreckage is always easier to spot

than a small life raft; it remains a source of additional food and supplies, and may be salvaged later.

Large-capacity rafts, usually found on commercial ships, are often mounted in a cradle with an automatic disconnect device called a hydrostatic release mechanism. This mechanism can be manually activated by pressing a button, which releases the straps holding the canister to the cradle, or it may have a snap shackle or other quick-release in series with the hydrostatic release. The canister can then be dropped overboard. In the event the boat begins to sink before the life raft is launched, a hydrostatic release mechanism will open when the vessel sinks to a depth of 10 to 15 feet, allowing the canister to float to the surface. As the vessel sinks to the end of the painter's length, it will jerk the painter and initiate inflation. The specially designed weak link on the cradle where the painter is attached is designed to break and free the raft from the vessel completely before the sinking boat pulls it under. An unoccupied inflated raft will blow downwind quickly, certainly faster than someone in a life jacket can swim. If in the water while the raft inflates, hold onto the raft or painter.

Full inflation normally takes less than 30 seconds. If possible, allow time for the canopy arches to inflate completely before boarding. The additional pressure caused by body weight may cause gas to escape through the pressure-relief valves before full inflation has occurred. If entering the raft before it is fully inflated is unavoidable, crawl under the collapsed canopy.

When possible, try to remain dry and enter the raft directly from the sinking boat rather than from the water. If you enter the water, ease yourself in to avoid the cold shock response. Even when wearing a survival suit, it is much more difficult to enter the raft from the water. The effort can be exhausting or impossible without assistance. All rafts are strong and stable enough so that you can jump directly onto the canopy and supporting arch tube when entering the raft. If jumping is necessary, it is preferable to jump into the entrance from as low a height as possible; climb down a ladder, or lower yourself down with a line. Be careful not to jump on top of the occupants or tear the canopy. The canopy serves to collect rainwater, helps to keep the raft dry, and shields survivors from the elements.

When entering from the water, use the automatically deployed boarding ladder and handholds at the entrance to the raft. Most rafts have either one or two webbing ladders, which are difficult to climb. Other products may have a stirrup, while the best will have a boarding ramp. When purchasing a raft, ask yourself whether you could pull yourself up out of the cold water and into the relative security of the raft using the boarding methods provided. If the crew is forced to enter from the water, the first person into the raft should throw the heaving line to the others. The line has a rubber doughnut-shaped quito attached to the end and will allow a person to hold on firmly. It is important to get everyone out of the water quickly. With the recovery of each crew member from the water, a significant volume of water enters the raft, adding to what may enter through wave action. If you recover someone unconscious, be sure not to leave him or her lying facedown in this water. Some experts suggest that the fittest be recovered first, so they can distribute themselves in the raft to assist with stability and attend to the injured. If you must swim away from the raft to help a crewmate, be certain you are attached to the craft with a safety line.

The hissing sound heard after inflation does not signify a leaking or defective raft. The relief valve is simply releasing excess gas pressure. Immediately after the release of the CO<sub>2</sub>-nitrogen mixture into the raft's interior space, ventilate the life raft thoroughly and periodically thereafter. Inflate the floor separately with the manual pump to provide insulation from the cold sea. Because the craft is so vulnerable to capsize (see below), it is extremely important to inventory and then secure all equipment as it comes aboard. Check the life raft for any damage or leaks and the crew for any life-threatening injuries. Activate the EPIRB immediately and leave it on.

The first medical action should be distribution of seasickness medication. In a life raft (sometimes referred to as "an inflatable vomitorium"), everyone is susceptible to seasickness, especially in the first 24 hours. Make the raft as dry as possible, and remove wet clothing. Close the door, and huddle together to conserve

heat. Do everything possible to conserve body heat, strength, and spirit, and prepare for rescue.

Life rafts have ballast pockets under the floor to trap seawater and thereby increase stability. Unfortunately, if the wind gets under the craft as it rises on a wave, it can still capsize. A capsize is most likely immediately after launching when the raft is empty. Have one or two of the fittest, heaviest crew members board the raft early to provide stability and ensure that the ballast water pockets are filling. They can also assist in transferring additional equipment and help others into the raft. The raft may even initially inflate upside down; most rafts can be properly righted from the deck of the boat without entering the water.

No immediate danger exists if the raft capsizes with crew inside, because sufficient air is available in the space under the canopy. It is necessary to enter the water in order to right the raft, however, since it is unlikely to right itself unless rolled again by successive waves. With the raft empty, pulling on the righting straps at the bottom can right it. Kneel on the downwind side with feet braced on the CO<sub>2</sub> cylinder, and lean back. The raft will right itself easily when the wind catches it.

To prevent recurrent capsizes in heavy wind and seas, additional measures need to be taken. Every raft is equipped with a cone-shaped sea anchor. This device is essential in rough weather. It provides stability in high winds, helps to prevent capsizing in rough seas, serves to aid in directional control of the raft, and helps reduce drift. The benefit of reducing drift in storm conditions is controversial, because the raft may become sluggish with the sea anchor deployed. If sea room is sufficient, the occupants may be more comfortable and the raft less likely to capsize if it is allowed to drift at the same rate as the waves. Deployment of the sea anchor is automatic on some rafts. Stream the sea anchor after the raft is clear of the sinking vessel. Check that the rope does not become entangled, and protect the raft from chafe at the point where the rope is attached. Weight distribution is also critical to avoid capsize. Position most of the crew on the windward side, the same side from which the sea anchor is deployed, to act as ballast. Weight on the windward side reduces the chance of the raft being lifted and flipped over by the wind. In seas with high wave crests, be prepared to maintain the raft's balance and quickly shift as needed to prevent capsize in the opposite direction.

Since a survivor can quickly become separated from a capsized raft, have everyone attach a line to the handholds if capsize is possible. Whenever a craft capsizes, gather the crew in the water and check that no one is under the overturned raft. Everyone should return as quickly as possible to avoid the progression of the cold shock response and hypothermia, and to conserve precious energy.

## Preparation for Rescue: Life in the Raft

After successfully abandoning ship and securing both crew and equipment in the life raft, prepare for rescue. Panic, fear, helplessness, and hopelessness can easily defeat the best-equipped and most experienced crew. A crew that is optimistic is more likely to survive. If the EPIRB is activated in busy shipping lanes, the probability of rescue in a few days is high. In Pornichet France, the Center for the Study and Practice of Survival proposes the following "seven tools of the mind to help you survive":

1. Size up the situation rationally. Analyze and evaluate all options and plan the best course of action. Consider the resources available, the time frame, and risks.
2. Understand and control. Get in touch with your feelings. Identify and acknowledge your fears; own and control them.
3. Risk the least, achieve the most. Evaluate and estimate the risks of any course of action. Ask what can be done to lessen the risk, and consider if the crew can handle the increased stress.
4. Value your reason for living. Find your own personal reason for wanting to survive. It will motivate you and powerfully counter any urge to give up.



5. Imagine new ways to do things. Use unconventional, lateral thinking. Improvise and try imaginative, creative solutions to problems. Trust your intuition.
6. Victory comes with time. Time is your asset, and problems often resolve themselves if given the opportunity. Avoid looking for quick solutions. Rushing a task often leads to failure.
7. Enrich yourself with a permanent positive mental attitude. Appreciate that you are alive, and keep your sense of humor.

## SIGNALS AND WATCH SCHEDULES

Review how to use each type of distress signal. Take inventory of the signaling devices available, and agree on priorities for their use. Turn on the EPIRB and leave it on. The battery is good for 48 hours, during which time the signal should have activated an SAR operation and transmitted an updated location.

The most important duty aboard the raft is to maintain a continuous and effective lookout for rescue boats and airplanes. Create a watch schedule to rotate duties every 2 hours. The lookout's responsibility is to monitor changes in the weather, wind, and sea conditions and to look for signs of nearby land and passing ships. In calm seas, make intermittent observations while standing up in the raft. The visible horizon is 2.6 nautical miles if the observer's eye is at 5 feet (1.5 m); raising the eye to 10 feet (3 m) (standing up in the raft as it rides on a swell) adds another mile. Other crew should monitor the well-being of the sleeping survivors. Their duties include providing first aid and comfort to injured victims, fishing, making potable water, organizing the stores, keeping the log, bailing, and maintaining the raft.

## RAFT MAINTENANCE

The raft is subject to tears, punctures, chafe, and structural deterioration, which cause air chambers to leak and lose watertight integrity. As the raft deflates, it begins to flex and chafe. The buoyancy chambers should therefore be kept taut with no apparent folds. To prevent overinflation, the pressure relief valves must be operational during the daytime to let off heated expanding air. This is especially important in the tropics. As the temperature drops at night, the raft should be reinflated with the manual pump.

Protect the raft against sharp, pointed, and abrasive objects such as knives, tools, fishhooks, spears, fish bones and teeth, shells, belt buckles, jewelry, and pens. All pointed tools must be kept sheathed or wrapped except when in use.

Attached to the canopy are internal and external dome lights. These help survivors find the raft at night when abandoning ship and provide interior lighting. These battery-operated lights last 12 to 24 hours, so turn them off when not in use. They are not intended to be rescue lights.

## HEALTH ISSUES AND HYPOTHERMIA

Everyone in the raft should take medication to help prevent seasickness. Whenever possible, take medication before abandoning ship. If sea conditions permit, leave the door of the raft open to permit the crew to view the horizon and allow circulation of fresh air. After seasickness, no other condition is more debilitating than chronic sleep deprivation. Sleep deprivation causes decreased alertness with blackouts of attention, which become increasingly prolonged and frequent. A groggy, inattentive lookout can easily miss the opportunity to observe and signal a passing ship. Conversely, the person may begin to hallucinate and see ships and planes. Impaired responsiveness to new situations and inability to make quick decisions further jeopardize the rescue. Try to rest. Stretch out to relax muscles that are constantly working to keep the body stable in the raft. Insulate the recumbent body against heat loss, especially from the cold floor of the raft. Always keep the double bottom of the floor of the raft fully inflated and make every effort to keep the raft dry. Lying in water accelerates heat loss from the body. Hypothermia, rather than exposure to severe weather, is the greatest threat to survival

in most abandon-ship scenarios. Line the floor with sails, tarps, and extra clothing. The double layer floor also protects against the bumps of sharks, dorado, and other fish. In tropical climates, spraying salt water directly on the skin or clothing to cool the body by evaporation is not recommended. Salt-encrusted skin is more likely to break down and become infected. Dry clothing protects the skin from painful saltwater boils and other bacterial infections. Apply an emollient to knees, hands, elbows, and buttocks to decrease skin abrasion. Common lubricants that moisturize the skin are petrolatum, mineral oil, and baby oil. Any area of skin breakdown should be smeared with an antiseptic or antibiotic cream and covered with a dry dressing.

Hypothermia is likely if the raft repeatedly capsizes, the occupants are constantly wet, or the floor of the raft is poorly insulated and floating in cold water. A new SOLAS requirement for survival craft is a thermal protection suit for each crew member. These suits are ideal for keeping a person warm and dry in the survival craft. Foil space blankets made of aluminized Mylar are useful as sun reflectors on the canopy, and they effectively minimize heat loss through radiation. A Mylar blanket reduces body heat loss by 80% to 90%. However, the major heat loss in raft survivors is by conduction through the raft floor, against which a foil blanket affords little protection.

## WATER

To prevent heat-related illness and dehydration, it is imperative to drink water at regular intervals. If possible, keep drinking until the urine is light tan in color.

In tropical climates, keep clothing on to help reduce fluid losses and prolong the cooling effect of evaporative heat loss. Wear long-sleeved shirts, trousers, and a hat. Clothing protects skin from sunburn and reduces passive heating from solar radiation. Apply a waterproof sun protection cream to exposed areas of the face, hands, arms, neck, and feet. Stay in the shade of the raft canopy and make sure the raft is well ventilated. The best rafts have a double canopy with an air layer in between that acts as insulation from the heat of the sun and from severe cold. Space blankets with a reflective surface may also be tied over the canopy to reflect the sun's rays. Deflating the raft's floor chambers helps to cool the raft. It may be tempting to take a dip in cool seawater if you feel very hot. Be sure there is no hazardous marine life in the area and that you have the strength and ability to climb back aboard; post an alert lookout.

The body's requirement for water depends on body weight, individual physiology, degree of exertion, diet, ambient humidity, and temperature. The average person can survive approximately 12 days without a supply of fresh water (the longest reported survival is 15 days); however, they will remain fit for only 5 to 6 days, and then become delirious. Body water losses in excess of 8% to 10% of body weight cause significant deterioration in mental and physical performance. Hallucinations and delirium from hypernatremia (high serum sodium) are common with progressive dehydration; death occurs with acute dehydration when water loss approaches 15% to 20% of body weight. By contrast, complete starvation leads to death in 40 to 60 days provided there is enough fresh water to drink. Decrements in physical and cognitive performance do not begin in well-hydrated individuals until they lose 10% or more of body weight acutely. Fit and healthy individuals are able to maintain normal work capacity during short periods (less than 10 days) on severely restricted diets. For the average adult at rest, the daily energy expenditure is 1400 kilocalories. Reducing activity to a minimum decreases the requirement for food and water.

The human body resting at sea level in a thermoneutral environment (air temperature 28° to 30° C [82.4° to 86° F]) and 50% relative humidity will lose approximately 500 mL (17 ounces) daily through insensible loss from the skin, 500 mL from the lungs as it humidifies inspired air, and 500 mL from the kidneys to excrete metabolic waste. Therefore, an estimated 1500 mL (1.6 quarts) is the minimal daily body water loss; at 35° C (95° F), 2500 mL is required. Besides drinking water, another source of water is that produced from the metabolism of food. This amounts to about 350 to 500 mL per day with an average mixed diet. The net result is, ideally, a minimum exogenous water requirement

of about 1 L/day (1 quart/day). Carbohydrate and fat metabolism contribute to body water stores, whereas protein metabolism is depleting. The kidneys require 2 to 3 mL of water for every gram of protein ingested in order to excrete the urea from protein metabolism. This obligatory loss of body water may hasten death from dehydration long before death from starvation could occur.

Water requirements change dramatically with exercise, sweating, diet, and ambient conditions. The evaporative loss from the action of sunlight in an open boat in the tropics is estimated at 5 pints (2.4 L) per day if the body is at rest.

Life rafts, if they have any water rations, generally carry 1 L per person in 125-mL sachets; some rafts only carry as little as a pint per person. It is recommended that castaways should restrict water intake to about 600 mL (20 ounces, or 1.25 pints) daily, unless supplies are plentiful. However, this is not the absolute minimal requirement. Analysis of protracted voyages in life raft during World War II found that the critical amount of potable water for survival was 110 to 220 mL (4-8 ounces) per day. This figure was based on the relationship between survival rates and availability of water in 121 life raft voyages involving 3616 men. Reviewing 1314 men at risk who drank only 4 to 8 ounces, 96 (7%) died. Consumption under 4 ounces resulted in much higher death rates. In a subgroup of 62 men who were adrift in two boats for periods of 37 and 49 days with water rations between 4 and 8 ounces, only one died.<sup>2</sup>

Hand-operated, portable reverse-osmosis desalination units contain a semipermeable membrane that allows only fresh water to pass through when pressurized to approximately 800 psi. Using a motion similar to that employed with garden shears, these water makers produce a cup of water in 15 minutes, and can hydrate as many as 25 individuals indefinitely if operated continuously. An added benefit is that the units remove bacteria, viruses, protozoa, and other contaminants.

Rainwater can be collected with the canopy of the life raft. An exterior gutter collects and routes the water to a large container for storage. Daily washing of the canopy with seawater, whenever practical, can help to remove the buildup of salt deposits. In a heavy sustained downpour, allow the rain to rinse the canopy before the water is collected.

Fish and other sea creatures contain water with extremely low salt content in their eyes, flesh, and cerebrospinal fluid. Fish blood has a high salt concentration and is not recommended. Juices can be pressed out of the flesh by twisting pieces of fish in a cloth. The blood from sea birds and turtles is also a source of hydration for castaways.

Seawater is not potable. After continuous exposure to the harsh elements, intolerable thirst may drive castaways to drink seawater. Succumbing to this overpowering temptation is a major cause of death and actually hastens the process of dying. Seawater is approximately four times saltier than blood. Drinking seawater usually causes immediate vomiting. If ingested and absorbed, seawater triggers a process of osmosis in which free water is shifted from the intracellular space into the blood and other extracellular fluids to restore equilibrium. The fluid shift dehydrates every cell in the body. It is postulated that reduction in the intracellular fluid of brain cells causes the reported madness in those who have drunk large quantities of seawater.

Survivors can reduce body water loss by optimizing the use of shade and the convective cooling effect of the sea breeze. In tropical climates, maintenance work on the raft should be limited to the cooler evening or early morning; one should rest during the heat of the day.

In the high latitudes, old sea ice is a good source of water. Sea ice loses its salt content after one year. The ice is brittle, bluish in color, and has round edges. New sea ice is gray, salty, opaque, and hard. Melting the ice allows tasting and judging the salinity. If the temperature drops to freezing, seawater can be collected in a can and allowed to freeze. Fresh water freezes first. Therefore, the salt concentrates in the center, forming slush surrounded by ice containing very little salt. Sea ice should not be confused with ice from an iceberg. Water from melted iceberg chunks is glacial fresh water. As a last resort, chewing a piece of gum or cloth will help to moisten the mouth and reduce thirst.

Unless survivors are assured of an early rescue or have a reverse-osmosis watermaker, they should consume no water in

the first 24 hours, and utilize the body's reserves. Thereafter, survivors should restrict intake to about 500 mL (just over a pint) a day. If water is plentiful, drink up to 1 L (just over a quart) daily. Nutrition is the last priority for survival. If rescue is expected to take many days or weeks, plan to eat very little for the first 3 days. Thereafter, begin the lifeboat rations of carbohydrates. Save some rations until rescue is imminent, when extra energy will be needed.

## FOOD

Life raft rations are similar to energy bars; they are high in carbohydrates and low in salt. They are bland, slightly moist, and sweet. Their primary purpose is to provide sugar in order to reduce catabolism and dehydration and thereby extend survival time. They should be regarded as more of a medicine than a meal and should be consumed as such. A daily ration should provide between 600 and 1400 kilocalories. Do not eat dry food unless water is available, and limit protein intake to conserve the body's water. With two quarts of fresh water available daily, eat as desired.

Fish are usually the mainstay of a diet at sea once survival routine and water consumption have been established. The raft casts a dark shadow beneath the surface, which appears as a safe haven for a variety of fish, especially dorado ("school dolphin"). With practice and patience, fish can be taken near the sea surface with a harpoon, gaff, or speargun. Care must be taken not to puncture the raft with these devices.

Successful fishing with a speargun requires proficiency. Refraction makes it difficult to hit the fish, so it is advised to minimize these effects by aiming straight down at the target, rather than obliquely. The ideal area to strike is just behind the gill cover. Attach all fishing gear to the raft with a lanyard to avoid losing it. Trailing a line with a baited hook can catch fish far from the raft. Bait can be obtained by using the guts, stomach contents, or thin strips of flesh from the first fish caught. Lures can be made from any shiny object.

At night, fish are attracted to bright lights. Instead of a flashlight, try a signal mirror or any other shiny surface to reflect moonlight onto the water.

When bringing a fish aboard the raft, use a cloth or piece of canvas to wrap the fish. Both dolphin and wahoo, which have serrated teeth, thrash wildly when they come out of the water. Wounds from fish heal poorly and easily become infected. Have a cutting board ready to kill the fish quickly by cutting through the spine right behind the head. A large fish can be stunned with a blow to the top of the head at eye level, and simply covering its eyes will calm it down sufficiently to position it for a quick kill.

Certain fish are inherently poisonous (see Chapter 72); these are usually located around shoals and reefs in shallow waters. These include pufferfish, porcupine fish, and the ocean sunfish (*Mola*). Any fish with spines or bristles instead of scales should not be eaten.

As a general rule, do not eat any fish that smells bad after storage. If uncertain about the safety of a fish, test it first for edibility. If it burns, stings, or tastes bad on the tip of your tongue, do not eat it. If it has an acceptable taste, try a small piece every hour for 3 to 4 hours initially, and if there are no ill effects after 12 hours, you can assume the food is edible. To save fish for future meals, cut the flesh into thin strips about an inch wide and half inch thick, and spread it out to dry in the sun on a flat surface. If you cut the strips with the fibers running the long way, the strips can be hung on a piece of string and allowed to dry in the open air under the raft canopy. Fish spoils within hours in the heat, so start drying some as soon as it is caught. Fresh-caught fish (except tuna), as well as dried turtle and bird meat, are good for days when the heat and humidity are not too high. Most ocean fish can safely be eaten raw. Freshwater fish should not be eaten raw, because they harbor parasites.

Seaweed is valuable in two ways. As a floating nest, it can harbor a variety of small edible creatures, including small fish, barnacles, crabs, and other crustaceans. All kelp and almost all brown and green seaweed are edible. Red seaweed is highly toxic, and any seaweed that tastes bitter may be one of the rare

poisonous varieties. Leafy green seaweed can be dried for storage. Before eating seaweed, wash it in fresh water to eliminate any toxic plankton and salt that may be adhering to the weed. Seaweed must be chewed well and swallowed only after it becomes a soft paste. It has limited nutritive value because the carbohydrates are not digestible and the cellulose has laxative properties.

Plankton also has a high cellulose and chitin content and cannot be ingested in large quantities. Some toxic plankton are difficult to detect. The red tides that cause paralytic shellfish poisoning result from the blooms of dinoflagellates (see Chapter 62).

Many sea creatures follow a raft. There are reports of killer whales attacking small boats, but no documented accounts of attacks on life rafts. Other dolphins and whales may accompany the boat, but are not likely to harm the survivors in a raft. Sharks can be a menace as they swim about the raft for days or even weeks and drive away other potentially edible fish. The shark's habit of frequently bumping a raft with its abrasive skin causes wear on the flotation chambers. Every effort should be made to avoid attracting sharks. Take special care to dispose of blood and offal at night, preferably when the raft is moving. Try not to create a waste trail for the sharks to follow, and bring hooked or speared fish aboard as quickly as possible.

Sea turtles' sharp claws and beaks can damage a raft or cause lacerations, so always bring them aboard cautiously by holding the hind flippers, then flipping them over onto their backs; they can easily be killed by severing the vital arteries on the underside of the neck and collecting the spurting blood in a cup. The blood must be consumed immediately, because it coagulates in about 30 seconds. Draining the blood also preserves the quality of the meat for storage and future use. The eggs, heart, and bone marrow are edible, but the liver should not be eaten. Dry whatever meat is not immediately consumed. The bones inside the flippers have tasty marrow. Turtle eggs are rich in protein and fat. If the liver is crushed, the skimmed oil can be used as skin oil. Use the shell to bail the raft.

All seabirds are edible, but catching them may be more luck than skill. Their beaks and wings can be dangerous, so grab them by the feet. Float a baited hook on the water (fish guts are best), and let the bird hook itself. After the bird is hooked, throw a piece of canvas or article of clothing over the bird. With the head and beak well covered, compress the chest to suffocate the animal, or twist and quickly pull its neck. Rather than plucking the bird, slit the skin over the breastbone and peel off the skin with the feathers intact. The entire bird, except for the intestines and the small green gallbladder, is edible. The flesh may contain bioluminescent substances from ingested plankton, giving the dead bird a ghostlike glow at night, but it is nontoxic. The forewings and legs make excellent bait, and the feathers can be made into fishing lures.

## Rescue and Evacuation of Sick and Injured

Transferring personnel from a boat or a life raft to a rescue ship or helicopter entails risk for everyone. It may well be the most dangerous aspect of the survival ordeal.

### AMVER

The Automated Mutual Assistance Vessel Rescue System (Amver) provides resources to help any vessel in distress on the high seas. Amver, sponsored by the U.S. Coast Guard, is a unique, computer-based, and voluntary global ship reporting system used worldwide by search and rescue authorities to arrange for assistance to persons in distress at sea. With Amver, rescue coordinators can identify participating ships in the area of distress and divert the best-suited ship or ships to respond. Some 12,000 ships from over 140 nations participate in Amver. An average of over 2800 ships are on the Amver plot each day. These merchant ships are not designed for SAR and their crews may not be trained for recovering survivors from small boats or life rafts under storm conditions. Offshore, however, they may be the only rescue option. For more details see <http://www.amver.com/>.

In ship-to-ship rescue, collision between the vessels is the greatest risk. Be prepared to lose your vessel in this situation. The typical scenario is of a large merchant ship with very limited maneuverability approaching a smaller vessel in distress with almost no maneuverability. Bringing a small boat alongside a commercial ship in a gale cannot be practiced. "Even under ideal circumstances, it is highly dangerous, heart in the throat, adrenaline-fueled action," said a transpacific racing sailor who abandoned ship and was aided by a huge container ship. Unless the rescue craft is designed for rescue work, the captain and crew experienced, and the seas relatively calm, it is much safer for the boats and crew to use a smaller craft to transfer personnel between the boats. The options include a rigid-hull inflatable boat (RHIB), a lifeboat, or even a life raft. In rough seas, never secure a boat or raft to the rescue vessel. The constant battering of the two hulls is likely to damage and may sink the smaller craft. Whether to approach the rescue vessel upwind or downwind depends on the wind, sea, and size and relative drift of the two vessels. The advantages and disadvantages are similar to those for retrieving a person overboard. Becoming pinned and capsizing are risks when sitting in the lee (downwind) side of a large, rolling ship.

The transfer of personnel between ships is also hazardous if sick, injured, or exhausted crew are required to climb a cargo net or pilot ladder. Under the best of circumstances, it can be extremely difficult even for a healthy crewman.

A large rescue ship most often approaches upwind of the survival craft unless the ship's rate of drift is much greater than that of the craft. This provides a calmer sea in the lee of the rescue vessel as it slowly drifts down to the survivors' craft. If the sea anchor is deployed, be sure to pull it in to prevent entanglement in the rescue vessel's propeller. Remain calm, and do not rush to board the ship. Wait to see if a lifeboat or rescue swimmer is lowered to facilitate the transfer. Attempt to communicate on channel 16 with the rescue craft to coordinate the rescue. Clarify and follow instructions carefully to ensure safety. If the raft is to be lifted aboard with injured survivors, be sure the floor is fully inflated. Attach the lifting lines to the towing bridles on both sides of the raft, and attach two steadying lines to each side as well.

Never attempt to scramble up a net, pilot ladder, or Jacob's ladder without a safety line. When boarding a rescue ladder, wait until the craft being departed is on the crest of a wave. At that moment, transfer to the ladder. This drops the survival craft down while you are ascending and eliminates the danger of the craft rising up on a wave and striking you. The safest procedure is to be hoisted up to the deck in a harness by a deck cargo crane.

## HELICOPTER EVACUATION

Helicopter emergency evacuation and rescue have now become commonplace within 300 miles (483 km) of the coastline. A detailed briefing is radioed to the crew when the helicopter is en route to the vessel in distress. Assign a crew member to monitor the radio and listen for the pilot's radio briefing on channel 16 VHF radio, 2182 or 4125 kHz on SSB radio; maintain radio contact with the pilot until the evacuation is completed.

All loose gear onboard must be well secured, including cockpit cushions, coils of line, winch handles, dive gear, hats, and clothing. Any gear not secured on deck will become a flying missile in the 100-mph downdraft generated by the helicopter. This debris may be sucked into the intake of the helicopter's engine or become tangled in the rotor blades.

All crew on deck should wear lifejackets. Add extra clothing layers because the helicopter's downdraft creates a wind-chill effect. Avoid shining flashlights on the helicopter; the light may blind the pilot and rescue team. For the same reason, never fire aerial flares in the vicinity of a helicopter.

The transfer device is either a rescue basket or a Stokes litter (Figure 83-18). Selection depends on the victim's medical condition and the necessity to remain horizontal during the hoist. The horizontal position is particularly important for persons with spine injuries or severe hypothermia. A basket is the preferred device for lifting. It is easy to enter, especially in rough weather, and has positive flotation so that it will not sink. Just climb in





**FIGURE 83-18** Coast Guard HH-60 Jayhawk helicopters carry a wide variety of gear to hoist victims and to assist crews in saving their vessels.

and fasten the straps. The basket will settle on the sea surface, enabling someone in the water to float into it.

A “horse collar” sling is a padded loop that is placed over the body around the back and underneath the armpits. The hoist is made with the line in front of the face. Always wear a PFD when entering the basket or hoist, and follow the directions for securing the safety straps.

The helicopter builds up static electricity traveling to the rescue scene, and the charge is transferred down the cable to the basket. Allow the basket to touch the deck or the water first to discharge any static electricity. Failure to follow this procedure will give one a strong, but nonlethal, electric shock. The orange steadying line, which is lowered first, is safe to handle and will not produce any shock.

Unhook the hoist cable only if it becomes necessary to move the litter below decks; let the cable free to be hauled back. When it is lowered again, allow the hook to ground on the vessel, and then reattach it to the rescue device. Never attach the hoist cable or the steadying line to any part of the vessel or life raft, even temporarily. The winch operator, who is intently watching the hoist cable, will react and instantly sever the cable from the hauling winch to prevent disaster.

If a Coast Guard helicopter picks up survivors from a life raft, the downdraft from the chopper’s blades may capsize it, especially if the raft has small ballast pockets. Similarly, rafts loaded to capacity with crew become increasingly unstable as the occupants are removed and winched aboard the helicopter. The survivors should sit on the roof and on the inflated support arch to decrease the amount of surface exposed to the downdraft.

| TABLE 83-3 Coast Guard SAR Helicopters |                                                 |                         |
|----------------------------------------|-------------------------------------------------|-------------------------|
| Model                                  | HH-60 Jayhawk                                   | HH-65 Dolphin           |
| Crew                                   | Pilot, copilot, rescue swimmer, flight mechanic |                         |
| Maximum takeoff weight                 | 21,884 lb (9926.42 kg)                          | 9480 lb (4300 kg)       |
| Engines                                | 2 × 1890-HP gas turbines                        | 2 × 934-HP gas turbines |
| Maximum speed                          | 180 knots                                       | 165 knots               |
| Range                                  | 700 NM                                          | 365 NM                  |
| Duration                               | 6.5 hours                                       | 3.5 hours               |
| Capacity                               | 4+6                                             | 4+5                     |

Evacuate the strongest crew from the raft last. A rescue swimmer from the helicopter crew will assist when a sick or injured crew member is transferred from the ship, or crew are required to jump into the water in order to be hoisted aloft.

The raft may also be used as an intermediate rescue platform between the distressed vessel and the helicopter. This is especially useful if the boat’s mast and rigging interfere with the positioning of the helicopter or threaten to entangle the basket hoist. In this situation, the raft is allowed to drift downwind, attached to the distressed vessel by a line. The helicopter pilot cannot see the raft directly below. The winch operator therefore guides the rescue operation. When being winched up by cable and harness, follow directions to secure yourself, and keep on your life jacket. With an integrated safety harness and inflatable life vest, it is much easier to put on the helicopter’s rescue harness when not encumbered by a bulky life vest. It may be preferable to leave the vest uninflated when being hoisted from the ship.

The helicopter has enormous potential for safe and effective SAR. The U.S. Coast Guard operates two types of helicopters (Table 83-3).

To view an excellent instructional video for recreational boaters on helicopter rescue, go to the Cruising Club of America web site: [http://www.cruisingclub.org/seamanship/seamanship\\_safety\\_heli.htm](http://www.cruisingclub.org/seamanship/seamanship_safety_heli.htm).

The C-130 Hercules is the largest of the U.S. Coast Guard SAR fleet, with a range in excess of 1000 miles (1609 km). It can air drop an enormous amount of lifesaving equipment, including dewatering pumps, life rafts, and survival and signaling equipment. The most recognizable airplane in the CG fleet is the Falcon jet. This medium-range, fast-response plane flies at 350 knots and has a 2000-nautical-mile range. Sophisticated onboard electronics, including infrared scanners and surface search radar, allow the jet to fly a variety of search patterns on autopilot.

REFERENCES

*Complete references used in this text are available online at [www.expertconsult.com](http://www.expertconsult.com).*





**FIGURE 83-3** Crew overboard alarms are capable of alerting the vessel's crew to an emergency, while storing the precise coordinates where the crew member fell overboard.



**FIGURE 83-5** Rescue Laser flare beams emerge as a straight line. At a distance of 10 miles, some models project a vertical line 3600 feet (1100 m) high. The target will see a distinctive large flash of light.



**FIGURE 83-6** The Lifesling has become the preferred man overboard recovery system. The flotation horseshoe collar with attached retrieving line can be thrown or towed to the overboard person and used as a lifting sling to hoist the crew member back on board. An inflatable model comes in a throw bag.



**FIGURE 83-8** Large vessels may elect to have substantial emergency pumps onboard, which can keep up with flooding from modest hull breaches. Note also the crew overboard device on the pushpit and the throw rope.





**FIGURE 83-10** Dry chemical fire extinguishers should be inspected to ensure the pressure gauge indicates a full charge and should be inverted regularly to unpack the extinguishing agent.



**FIGURE 83-11** Although radar reflectors can increase the visibility of your vessel to other radar-equipped vessels, an active radar watch is still the best technique for collision avoidance.



**FIGURE 83-12** Mariners have to be continually vigilant for changes in their environments. Rapidly approaching storm fronts call for reduced sails, harnesses and tethers, and secured hatches.

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