Fixed Firefighting Systems

Permanently installed extinguishers with automatic discharges can respond to enclosed-space fires before a boat's crew even knows anything's burning. Unfortunately, these critical systems and their equipment are often neglected. Or, worse: set up incorrectly.

Text and photographs by Steve D'Antonio

With the prospect of searing heat above 1,000°F (538°C) from burning fuel or fiberglass, fire is a modern mariner's worst nightmare. Faced with a shipboard fire, there are two courses of action: abandon ship or extinguish the flames quickly. The latter is the subject of this article.

While portable and fixed fire extinguishers can use similar agents, or materials, to extinguish a fire, there are important distinctions between the two options. A fixed fire-extinguishing, or FFE, system is permanently installed aboard a vessel. A portable fire extinguisher is a handheld container that must be removed from its mount or bracket and manually activated. The FFE bottle, along with its monitoring and discharge systems, is affixed to the vessel's structure and designed to discharge automatically when exposed to heat.

One of the most important characteristics of an FFE system is that its agent shouldn't harm the equipment and gear it's protecting. Unlike the familiar and messy powdered or liquid agents in portable fire extinguishers, the "clean" FFE system releases gaseous agents that cause no damage and leave behind no residue that might harm or interfere with the operation of mechanical and electrical equipment.

Clean agents must also be electrically nonconductive, and they must evaporate completely.

Different FFE clean agents are appropriate for the two technically defined onboard installation areas: *normally occupied* spaces, and *normally unoccupied* (machinery, tankage, and bilge) spaces.

In areas that might be *occupied*

Right—*Pressure gauges are a useful indicator of a fixed fire extinguisher's readiness, but* weighing *is the only reliable method of determining whether the unit has a full charge. This gauge specifies Halon gas—no longer permitted under a 1987 environmental protocol.*

Carbon dioxide FFE systems are designed to flood protected spaces with concentrations of CO_2 as high as 30%—lethal to humans. Ensure that you, your staff, and customers understand the limitation and *potential hazard.*

when the system deploys, the most common clean agents include Halon 1211 and Halon 1301, as well as HFC-227 (also known under various manufacturers' names including FM-200, FE-227, and Solkaflam 227). But Halon gas was identified as an ozone-depleting material, and in accordance with the Montreal Protocol of 1987, its production ceased in 1994. Aside from depleting ozone, Halon is an ideal clean firefighting agent, with low toxicity and great efficiency—when measured by weight and volume—as an extinguishing agent. Because of those qualities, Halon is still approved for use on airplanes, where weight really matters.

At sea, existing marine Halon systems may remain in service indefinitely, although they may not be refilled after a discharge or leak. When recharged with HFC-227 replacement agent, 50%–70% more of it is required to protect the same space. Even though more is required, the good news is: the safety, effectiveness, and low toxicity of HFC-227 is well established. It's used to protect, among other things, the first draft of the Declaration of Independence, the U.S. military's Distant Early Warning Line radar installations, and portions of the Eiffel Tower. Confirming its low toxicity, HFC-227 is a propellant for asthma-type medical inhalers.

Extinguishing agents for normally *unoccupied* spaces include FE-241 and CO_2. They leave no residue, are nonconductive, and evaporate completely; but these gases will injure and even kill occupants of a space that might flood when an FFE system is triggered. CO_2 is the more lethal. Many individuals, including recreational-, commercial-, and military-vessel operators and service personnel, have died as a result of an intentionally or unintentionally discharged CO_2 FFE system. Because it's an asphyxiant and cerebral dilator and exposure to concentrations as low as 10% can cause death in minutes, carefully consider installing a CO_2 system aboard small boats—particularly recreational boats whose operators are typically not professional mariners trained in the dangers of such equipment. The concentration of CO_2 required to extinguish flame is about 10%. Most CO_2 FFE systems are designed to deliver target concentrations in excess of 30%—well above the lethal level. Another drawback is that compared to other clean agents, more CO_2 is required to protect the same space.

Although FE-241 is not as lethal as CO_2, the manufacturer (Dupont), FFE system manufacturers, and the U.S. Coast Guard specify that it must not be employed in *normally occupied* spaces. The primary reason for choosing FE- 241 is cost: roughly half the price of HFC-227. The target concentration of FE-241 is 9%, while anything over 2.5% surpasses the Environmental Protection Agency's lowest observable-effect level— the point at which an individual's ability to function is compromised. FE-241 is not approved for use in the European Union.

Note that all the agents discussed above, particularly those that are considered "nontoxic" or low toxicity, if delivered in high enough concentrations for long durations, can cause injury or death. Of all these agents, CO_2 carries the greatest risk. If you're building or working on a boat equipped with a CO_2 FFE system,

you, your staff, and your clients should know the risks and safety concerns, and the procedures for temporarily disabling the system when it or an adjacent component is being worked on.

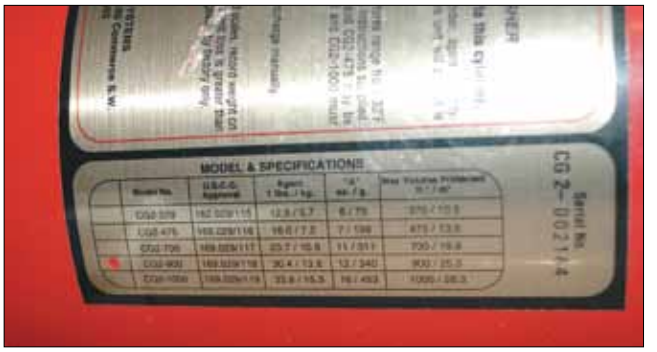
While some boat owners spend an inordinate amount of time in the engineroom, it is technically classified as a *normally unoccupied* space. This in no way lessens the toxicity of any of the aforementioned clean agents should they be discharged into the engineroom while it's occupied, fire or no fire. This is especially true if the agent's concentration is elevated beyond its nontoxicity level: i.e., a bottle designed to flood a 750-cu-ft (21m^3) space is intentionally installed in a 500-cu-ft (14m^3) engine compartment.

As the boat's builder or equipment installer you may, in full compliance with the manufacturer's guidelines, place either popular clean agent, HFC-227 or FE-241 or equivalent, in normally unoccupied spaces. The primary differences are the additional expense and lower toxicity of HFC-227. Because enginerooms are frequently occupied by crew or service personnel, I prefer installing nontoxic agents in *all* locations.

Selection

Like any onboard system, FFE equipment requires proper installation in order to operate correctly and effectively. The onus is on the builder or installer to select the appropriate gear, and to properly install and test it according to the manufacturer's guidelines, and to American Boat & Yacht Council standards if ABYC compliance is sought.

The first step is to determine the volume of the space to be protected. This sounds straightforward enough, but few engine compartments, especially those in smaller recreational boats, are perfectly square or rectangular. To err on the side of caution, I prefer to treat the space as a square or rectangle, relying on the compartment's maximum length, beam, and height to calculate cubic footage. The measurements should also take into account adjoining spaces, such as lazarettes connected to engine compartments by a bulkhead cutout with an aggregate opening greater than 2% of the bulkhead area between them. Ventilation openings or bulkhead ports might be equipped with automatically actuated fire dampers; if so, sizing the extinguishing agent to cover the conjoining space is unnecessary.



Do the math. It's vital that an FFE system be properly sized for the compartment it's protecting. Perhaps counterintuitively, oversizing is discouraged.

When calculating volumes, the ABYC, U.S. Coast Guard, and most FFE *system* manufacturers allow for the deduction of the space occupied by permanently installed tanks. However, many FFE *equipment* manufacturers specifically state that no deductions should be made for installed equipment—engines, generators, etc. When in doubt, follow the instructions of the equipment manufacturer to ensure proper operation and compliance.

It's worth noting that, to comply with ABYC's *Standards and Technical Information Reports for Small Craft*, section A-4, "Fire Fighting Equipment," boat manufacturers must install a permanently affixed placard stating the gross volume of the engine compartment, less permanently installed tankage. Although I've seen few such placards, following this guideline will ensure that future installers of FFE equipment won't have to calculate, perhaps incorrectly, the engine compartment volume.

The capacity of the FFE system that's chosen must be equal to or greater than the volume of the space, and must meet that criterion with a single bottle. Multiple bottles may be installed only in engineered, as opposed to pre-engineered systems, where their combined capacities will meet the volume requirement for a given space, and they are plumbed together with shared sensors, so that all bottles discharge simultaneously.

Two or more bottles may also be installed in a space, provided each one is capable of independently fulfilling the fire-suppressant requirements of the protected space. But, two bottles, each capable of protecting 500 cu ft (14m^3) may *not* be installed in a 1,000-cu-ft (28m^3) engine compartment, unless they're installed as part of an engineered system.

The majority of FFE systems installed in boats under 60′ (18.2m) are commonly referred to as "pre-engineered." They are off-the-shelf single-bottle systems. Typically, the largest are capable of protecting as much as 1,500 cu ft (42.5m^3). When more agent is required than can be delivered by a single bottle, an engineered system may be called for. (Because of the required distribution plumbing, actuation equipment, and delay/warning systems, CO_2 systems are considered to be engineered.) Most manufacturers of pre-engineered

The combined contents of two FFE bottles can protect a given space, provided the pair is designed and engineered to discharge simultaneously.

Left—*Especially large FFE bottles should be located amidships and securely fastened to a bulkhead.*

systems offer engineered systems as well.

While there is an understandable temptation to err on the side of caution by over-estimating the volume of space to be protected, installers should resist it. The low toxicity of agents such as HFC-227 is based on a relatively low-concentration requirement of 8.7%. At that level there's virtually no danger to occupants of the protected space. If the concentration increases, it's possible for people in the compartment to be affected, particularly those with heart or breathing conditions. In high enough concentrations, even low-toxicity clean agents might cause symptoms of oxygen deprivation. Therefore, this clean agent is considered "safe" for an occupied area only at the concentration specified by the manufacturer. Higher concentrations of low-toxicity clean agents may be safely used in spaces such as engine boxes or enclosures that *cannot* be occupied.

Location and Installation

A low-toxicity clean-agent bottle designed to provide coverage for an 800-cu-ft (22.6m^3) space, for instance, measures 32″ (817mm) tall, 7″ (178mm) wide, and weighs nearly 60 lbs (27.2 kg). It's often difficult to find a location to mount this unit. While most manufacturers allow the bottle to be installed at any angle between vertical and horizontal as long as the discharge nozzle is not mounted lower than the cylinder, ideally the bottle should be as close to amidships as possible, on a forward or aft bulkhead. Some FEE systems, particularly those designed for spaces in excess of 1,000 cu ft (28.3m^3), prohibit horizontal mounting.

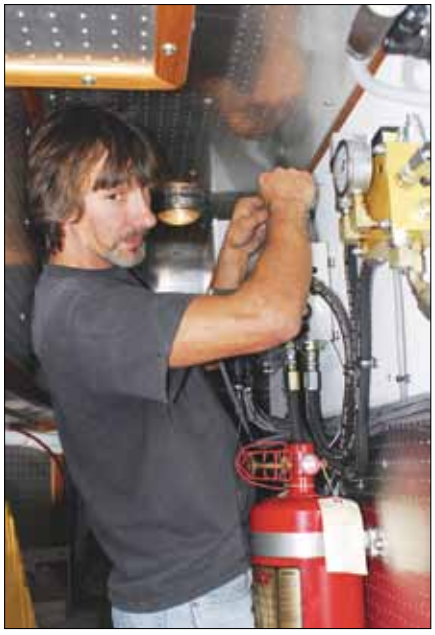
Because the automatic-discharge feature is triggered by heat, the nozzle and its temperature-sensitive trigger should be located as high as possible within the compartment, where the heat will trigger it quickly before a fire can grow. But the trigger should *not* be too close to the dry portion of an engine's exhaust system, which can, within ABYC guidelines, be as hot as 200°F (93°C). Having crunched my skull against more FFE system nozzles than I care to count, I urge that they also be kept out of "head passage" zones. Nor should the bottle be installed where it will be exposed to bilgewater, or where its nozzle mechanism might snag or trip passersby.

The FFE bottle is appropriately secured in a custom bracket. Ideally, the temperature-sensitive nozzle should be mounted as high as possible in a compartment and away from air intakes or forced ventilation.

A bottle installed below or adjacent to an air intake risks delayed discharge, because a downdraft of outside air pulled in by the fire keeps the bottle cool. So, keep FFE installations away from ventilation scuttles.

Finally, the installation location must afford access for periodic inspection, removal, and weighing.

An FFE system bottle can weigh in excess of 100 lbs (45.3 kg). Add to this weight the g-force involved when operating in high seas, or the bulk of a crew member who lurches into it while passing through the engine compartment, and it's easy to see why secure installation is important. A heavy FFE bottle adrift in an



Above—*Careful inspection of this FFE system revealed that it had been discharged for several years. Staff should be briefed to look for gross faults like that during casual inspections.* ***Right***—*Those who work around an FFE system must understand how it functions and how it can be discharged. Locate it out of the way of regular traffic, but still accessible for regular inspections.*

Most automatic discharge nozzles are fitted with an oil-filled glass-vial trigger designed to shatter at 175°F (79°C). This unit is also equipped with an optional manual-discharge mechanism.

engineroom could become a destructive projectile, especially if the nozzle were damaged and gas came jetting out. Self-tapping screws are simply not strong enough. Only substantial through-bolts, and backing plates where necessary, should be trusted to secure an FFE system bottle to a structural bulkhead or other heavily built fixture.

Manual vs. Manual/Automatic

Automatic FFE systems are designed to discharge in seconds when oil in a glass vial in the bottle's nozzle reaches 175°F (79°C); the vial shatters, and the clean agent is released. In addition to automatic deployment, most pre-engineered FFE systems are available with a manual discharge option via a mechanical jacketed control cable routed from the bottle's discharge nozzle to a location outside the engine compartment—preferably at the helm or outside a deadlight-equipped engine compartment hatch, where crew can look into the engineroom to determine if there's a fire. (An engineroom camera could serve the same purpose.) The activation end of the cable is usually a T-shaped or round red handle prominently marked as a fire extinguisher discharge actuator. Pull the handle and the cable activates a lever, breaking the glass vial, and discharging the agent. Install manual controls in plain view rather than within lockers or cabinets. If they *are* enclosed, attach a placard to the locker indicating a fixed fire-extinguisher trigger is inside. Multiple manual discharge locations are highly recommended for larger vessels with multiple helm stations.

To prevent accidental activation, all manual control handles should be equipped with an arming pin that must be removed before the clean agent can be discharged. It's important that you, your staff, and the vessel's owners and crew understand: *the pin must be removed to activate the system*. The pin is usually secured with a small plastic breakaway tie. *Don't* replace the tie with a conventional wire tie, as its breaking strength is significantly higher than the engineered breakaway component. Obtain a purpose-made replacement from your FFE system manufacturer.

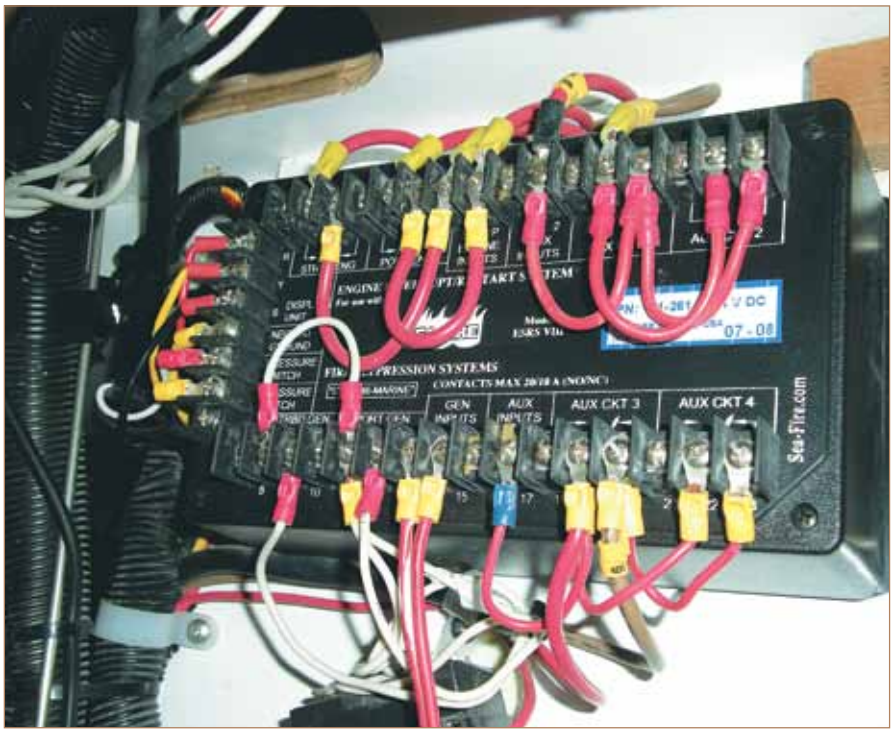
I encounter a surprising number of automatic FFE systems without a manual option aboard production recreational boats. The difference in the cost of materials and installation is negligible at the outset, but if the bottle is not designed for manual actuation, then the cable cannot be added later without replacing the bottle. Remember that the automatic systems won't discharge until the temperature at the nozzle reaches 175°F, which could take some time. It's always better to set off an FFE system manually at the first sign of fire/smoke, rather than waiting for a temperature-activated discharge. Also, manual actuation is required for ABYC standards compliance.

Wiring and Automatic Shutdown

Although most FFE systems—automatic-only or automatic/manual—will operate properly without any electricity, the preferred installation nearly always includes electrical components. As I'll describe below, the electrical interface of an FFE system can be as simple as an LED at the helm station to indicate that the system is fully charged; or as complex as a relay that automatically shuts down engines, generators, vent fans, louvers, and fire dampers upon discharge.

Rather than rely solely on the *electrical status lamp* to indicate a fully charged system, regularly inspect the pressure gauge located on the nozzle.

***Left**—Whenever possible, manual discharge handles should be installed in plain view. If one is placed in a locker, clearly label it to indicate its presence. **Center**—The exposed manual discharge handle is missing its arming pin. **Right**—Be certain you and your customer understand that the indicator light goes out once the system has discharged.*



Optional FFE system relay controls shown here will automatically shut down gear such as engines, generators, and ventilation systems upon clean-agent discharge, whether it's manual or automatic. Relay controls are required for ABYC compliance in diesel-powered vessels, but are worthwhile additions to any system.

If the lamp isn't illuminated, then assume the system is not ready to be used.

While inspecting an otherwise sound eight-year-old powerboat, I found a potentially dangerous problem. In tracking down the reason the FFE's status lamp never illuminated, it didn't seem to matter whether the battery and all accessory switches and breakers were on, or if the engine was running. I also discovered the retaining tie on the manual trigger pin was missing. The FFE system bottle was inconveniently located in a dark corner of a cramped engine compartment. Once I made my way back to it, I found the trigger vial was missing, and all that remained in its place was a vacant hole—the bottle had been discharged. The current owner, the boat's second, was unaware of the potentially disastrous situation. He had never been instructed on the use of the status indicator and gave no thought to its extinguished light. The system had probably been discharged before he took ownership of the boat, six years ago.

Most FFE system manufacturers also offer the option of an *audible/visual discharge alarm* that's easily wired into the nozzle switch. When the system discharges, a red light illuminates and a horn sounds. Such a discharge indicator is now required for ABYC compliance.

The next level of electrical interface for FFE systems is the *automatic engine-shutdown relay*, which can stop a boat's engines, generators, engineroom forced-ventilation system, and/or air intake or bulkhead dampers without any action from the crew or helmsman. Quick shutdown is important because diesel engines will often ingest, run on, and expel clean agents such as Halon, HFC-227, and FE-241 (though not CO_2). A running engine can thus draw the discharged fire-suppressant out of the engineroom before it's able to extinguish the fire.

Passive engineroom air intakes are a source of oxygen for a fire. They too can be closed by relays in the automatic shutdown system to maximize the effectiveness of an FFE.

The same is true of forced-ventilation systems operating when the FFE system discharges. While ABYC guidelines call for installation of a placard at the helm alerting users to immediately shut down engines, generators, and blowers if the fire extinguishing system discharges, doing so can be difficult or impossible when the system discharges automatically and momentarily panics or distracts the operator. Many FFE system manufacturers and the ABYC mandate a shutdown relay for diesel-powered vessels.

Automatic relay shutdown systems are typically equipped with an override *switch to bring affected gear back online after a fire has been extinguished. It's critical that the switch remain in the* normal *position in order for the system to operate properly in normal conditions. If it's set on* override*, the system will fail to shut down connected equipment when the FFE system is discharged.*

A risk with an automatic-shutdown relay is that if manufacturer's installation instructions are not followed, engines and generators could fail to start or run properly when least expected. Also note: if power for the relay-control box comes from the propulsion engine's ignition circuit, *the relay control may fail to function if the engine is not running.* The problem is: if there's a fire when the engine is not running but the generator is, then the generator and any exhaust fans/dampers *will not* be automatically switched off or closed.

I recommend that all relay control systems be energized when *any* "air breathing" equipment is operating in the engineroom. Draw power for the relay control from the load side of the house battery switch, and install a protected circuit breaker or fuse to prevent inadvertently disabling the system. In the event of a fire, battery switches should be turned off immediately *after* the FFE system has been discharged and all equipment has stopped.

Test the system with a simulated discharge: open the circuit at the FFE system bottle-mounted switch while engines, generators, and engineering-space ventilation systems are operating. All should shut down automatically, and be able to

Left—*Some FFE systems are equipped with safety pins that will prevent such systems from being manually discharged during installation or service. The pins must be removed to reactivate the system and permit manual discharge.* ***Right—****Arming pins, which prevent accidental discharge, should be retained only by a purpose-made plastic tie with an engineered breaking strength—never by a conventional wire tie.*

be restarted when the helm-mounted manual override switch is engaged. Ventilation will come on immediately with override unless it has been shut down manually. (Following the test, it's critical that the switch return to the *normal* or non-override position. If it remains in *override*, the automatic-shutdown system will be effectively disabled, and all equipment will continue to operate during an FFE system discharge.)

The override is useful in getting under way after an FFE system discharge, accidental or intentional, or if the relay control system fails or malfunctions. While failure is rare, it happens occasionally, and the override switch can correct the problem temporarily, until the malfunctioning components can be repaired.

If you're called to troubleshoot a vessel whose engines, generators, and/or blowers all refuse to operate

Scheduled and casual inspections of FFE systems should be frequent to protect against defects and flaws—like an obviously damaged manual discharge cable.

for no apparent reason, the automatic-shutdown relay system may be the culprit. Engaging the override switch might help identify the problem and allow the boat to run. Of course, operating with the override switch engaged means the automatic-shutdown relay will not function.

Safety and Inspections

If the FFE system activates either automatically or manually, never assume it's a false alarm, even if flames or smoke aren't visible. Don't immediately open the engine compartment hatch or override the automatic shutdown system (unless you're in harm's way). The clean agent should be allowed to "soak" the compartment for 15 minutes in order to completely extinguish flames and cool smoldering wood, fiberglass, plastic, etc. Engine compartment doors should be equipped with a deadlight to permit inspection before entry to determine if the fire has been extinguished. When opening the hatch, stand by with a handheld fire-extinguisher in case of a flare-up. Fumes from burning fiberglass resin, batteries, rubber, and plastic are a health hazard; don't enter the compartment until it has been well ventilated.

Visually inspect all onboard fire extinguishers monthly, and weigh them at least annually (some manufacturers call for semiannual inspections). Extra diligence is required to thoroughly inspect the various components in an FFE system. Monthly inspections should include confirming that the pressure gauge is in the green zone. When checking the overall condition of the bottle and discharge nozzle, look for rust or corrosion (smaller-system bottles are often aluminum, while larger ones are steel), dents, gouges, or any signs of damage. Also ensure that the bottle remains securely fastened to the boat and that all mounting fasteners are tight.

Per manufacturer's recommendations—annually or semiannually—remove the bottle from its brackets, disconnect the electrical and manual discharge cabling, and

weigh the bottle on a certified digital scale. Traditionally, trained fire-extinguisher service personnel carry out those tasks, but competent yard personnel can be taught how to do them.

Always wear safety glasses when installing, handling, or working on the systems, because gas that is discharging—even if not immediately toxic—can cause frostbite and severe eye injury.

Be cautious when handling pressurized cylinders, particularly those equipped with delicate discharge mechanisms. If the FFE system came with a transport pin, which prevents accidental discharge in transit, then it should be installed at the start, and removed at the end of, servicing. (Nearly every one of the transport-pin-equipped systems I inspect has been in a state that would prevent manual discharge, because, in spite of the large tag instructing installers to do otherwise, the pin has not been removed when the bottle was installed.)

While the bottle is removed, pull the arming pin from the manual-discharge trigger, and work the cable to ensure it moves freely. When the pin is replaced, install a new, original-equipment safety tie.

If the FFE system is equipped with an automatic-shutdown relay, test it as described on page xx, with the boat afloat at dockside, in neutral gear, with no electrical loads on the generator, and the FFE system fully reinstalled and functioning. Typically, a test of the auto-shutdown system requires no more than 10 minutes of a mechanic's time.

Of the many systems I test, about one out of three fails to operate properly. I often find boats whose engines are linked to the automatic-shutdown system, while the generator and ventilation fans are not; or some other combination provides only partial shutdown of engineroom equipment. If that happens on a boat you're servicing, determine the reason for the incomplete coverage, and then recommend to the owner appropriate corrections *in writing*.

Another shortcoming I encounter when inspecting FFE systems is improperly completed inspection tags. In many cases, the inspection tag is either blank, improperly filled out for each inspection date, or lacks the critical cylinder weight confirmation. It bears repeating: a complete inspection includes weighing the cylinder, not just visually inspecting it.

Finally, as well as ensuring that the FFE system you install, service, or inspect complies with manufacturer and ABYC guidelines, be certain the system carries the placards required for proper operation and service. As mentioned before, a detailed description of such signage can be found in ABYC *Standards and Technical Information Reports for Small Craft*, section A-4. PBB

About the Author: *For many years a full-service yard manager and now a contributing editor of this magazine, Steve works with boat builders and owners and others in the industry as "Steve D'Antonio Marine Consulting Inc." McGraw-Hill is about to publish his book on marine systems.*