Diesel Tanks Done Right

PART 2 Securing, supporting, gasketing, grounding, and pressure-testing fuel tanks.

Fuel tank pressure-testing should be carried out before the tanks are installed and again after installation or after existing tanks are breached for cleaning. Identifying leaks while the vessel is at the yard, rather than hundreds or thousands of miles away, is the goal.

Text and photographs by Steve D'Antonio

In Part 1, we described some of the common material choices and best design and construction methods for built-in fuel tanks. Here, I'll focus on tank installation details and protocols.

Securing Tanks

Preventing movement is a critical element of any tank installation, regardless of its material—metal, molded polyethylene, or fiberglass. The prospect of a loose fuel tank shifting in the bilge or engineroom of a vessel in a seaway is terrifying. The best way to secure metal tanks is with a flange welded to the tank and then through-bolted to a permanent structure capable of supporting the loads generated by a full tank in a seaway.

Plastic tanks are typically secured by straps, for which many have molded recesses, or claw clamps—angled sections of aluminum that engage with mating recesses molded in the tank wall. Chafe prevention is essential for cross-linked polyethylene (XLPE) tanks. Neoprene or similar padding should be placed between the tank and

Left—*Integral flanges are an ideal means of securing a tank. Note the shim slightly elevating the tank from the supporting shelf.* ***Above***—*This metal tank is supported from above, but the cushion material is not bonded to the tank, which means it can trap water, leading to corrosion.* ***Right***—*While a claw retainer fits the molded recesses of this tank, it is corroding. Also, even when new the small tapping screws securing it aren't adequate to resist the loads of the full tank.*

the mounting surface, any permanent supports, restraining straps, or clamps. A complicating factor with XLPE fuel tanks is a phenomenon known as hydrocarbon expansion, in which the XLPE expands approximately 2%–6%, or about ¼″ per foot (6mm per 305mm) after being exposed to fuel during the first month of service; thereafter, the tank is stable and will not revert to its original size, even when empty. But that dimensional change must be accounted for during installation. Cleats, straps, claws, or cribs surrounding the tank must be adjustable to accommodate this growth, and they must be checked and adjusted periodically during this initial break-in period.

The American Boat & Yacht Council (ABYC) standard for fuel-tank installation allows for up to ¼″ (6mm) of movement in any completed fuel tank installation. While it's not often I disagree with ABYC standards, this is one occasion. A tank that is allowed to move, even ¼″, is ripe for a chafe-related failure. In my estimation, all fuel tanks should be completely immobilized.

Fiberglass tanks can be tabbed directly to a fiberglass hull (provided proper secondary-bonding techniques are employed) or be secured by flanges, straps, or cribbing. Because fiberglass tanks are not susceptible to rust or corrosion, there is no prohibition on their contact with hygroscopic materials like wood. It's noteworthy that ABYC standards exempt fiberglass tanks from replacement requirements.

Left—*This poly tank is supported with substantial aluminum cribbing. Note the threaded, adjustable attachment post at the lower corner.*
Below—*Cross-linked polyethylene tanks undergo one-time expansion when first exposed to fuel; when placing cleats and other supports, that change in size must be taken into account to prevent buckling.*

Failure to Support

I've seen multiple fuel tanks that failed due to insufficient structural support. Three, all metallic tanks, stand out as examples; in each case, a crack or cracks developed because the tank bottoms were inadequately supported. Note that because of inadequate support, cracks can develop in any part of the tank—the middle of a flat expanse of metal, or in the middle of a weld. (A failure at the weld margin may be an indication of improper weld penetration exacerbated by poor support.)

In one case, the athwartships-mounted tank rested on stringers roughly 6′ (1.8m) apart. The unsupported expanse between the stringers was plainly visible from the bilge area. When the tank was full, the two tons of the fuel caused the bottom to flex. Add the g-forces from the vessel moving through a seaway, and eventually the flexing plate crystallized and cracked, dumping fuel in the bilges. In addition to welding, the repair included adding support under the tank.

In a similar flex-induced failure, a tank of nearly 1,000 gal (3,785 l) spanned the entire beam of a vessel. Located beneath the cockpit, it rested on a closely spaced set of central stringers and on supports located outboard at the tank's extreme ends. Again, when the tank wasn't full, it could hold the weight of the fuel. However, when it was filled, the weight of the fuel (in excess of 3.5 tons) caused the ends to sag, because there was a small gap between the bottom of the tank and these outboard supports—a clear installation defect. Compounding this problem was that this high-speed offshore fishing vessel was designed to endure significant slamming loads. As the tank absorbed these loads, it flexed, which eventually led to its failure at the fulcrum point on the tank's centerline. Interestingly, the crack that developed did so precisely in the middle of a weld bead, indicating that the weld itself, as well as the plate, was sound. The structure simply could not absorb the movement caused by inadequate support.

In the third example, the complex shape of a large set of tanks could not withstand the flexing induced by the weight of the tanks and the fuel, as well as the movement of the vessel. The tanks rested on stringers rather than a shelf. Cracks developed in welds in several locations, and while the welds themselves were suspect, I believe that if the tanks were well supported, they would not have developed leaks.

Complex tanks made up of multiple panels and angles require additional attention. When the bottom of a tank is made up of multiple planes, it's vital that the loaded weight be evenly distributed on all the mounting surfaces, which must match the shape of the tank bottom precisely. If there are gaps beneath any of the horizontal mounting surfaces, the full tank is likely to flex, distort, and settle in areas that lack support.

Unless designed and built to be self-supporting (this usually involves internal reinforcement), tanks ideally should rest on continuous shelf-like structures rather than on

Gaskets and Sealants

Choose inspection-port gasket material carefully. It must be capable of enduring long-term immersion in fuel; and unsupported sections of a gasket, like the sagging center of this one, should be avoided, as they can dislodge and clog the fuel line.

Gasket material around fuel-tank penetrations must be impervious to fuel. Even inspection ports and senders will be immersed in fuel if the tank is topped off to the deck fill. Some gaskets work well for *short* periods of submersion, but the true test is weeks or months of exposure. The preferred material for fuel-tank gaskets is Viton or Buna-N, sometimes called nitrile, in 0.125″ (3mm) thickness, and 50 to 60 on the Shore A durometer scale. These gaskets are firm enough to maintain their shape and still seal tightly against the tank and inspection cover surface. Plus, the material has excellent resistance to hydrocarbons—diesel fuel and gasoline. For inspection ports, the gasket should be donut- rather than disc-shaped to avoid having an unsupported center section, which over time can sag, and pieces can break off and fall into the tank. Note that gaskets can be lightly lubricated with Teflon grease, to prevent binding and to aid removal.

Installers and service technicians should ensure that gaskets are able to maintain a liquid-tight seal on their own. If a gasketed installation requires liquid or paste sealant to achieve this seal, either the gasket surface is scored, warped, or otherwise damaged, or the gasket thickness or durometer number is wrong for the application. Uneven surfaces on some metallic tanks often require thicker, softer (lower durometer

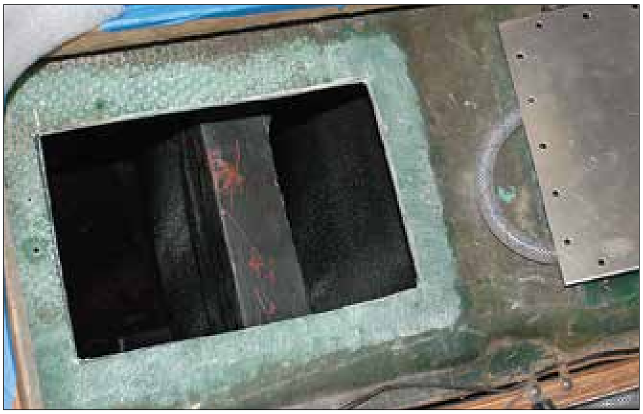
Left—*Poly tanks must be supported along their entire bottom panels while also being protected to avoid the potential for chafe.* ***Right***—*While supporting tanks from above is an acceptable practice, unless specifically designed for it, a tank should not be used to support any structure above it.*

stringers or beams. In completely supported tanks, flexing is minimized if not eliminated. To promote drainage under a metal tank and prevent corrosion in its bottom, 1″-to-4″-wide (25mm-to-102mm), ¼″-thick (6mm) spacers made of nonhygroscopic material (prefabricated fiberglass such as GPO3 or G10 works well) should be *fully bedded* athwartships to the tank bottom on 4″–6″ (102mm–152mm) centers, using a polyurethane bedding compound to fully fill the gap between the tank and spacer. With this approach, the tank can't rest in standing water, and water can't collect between the tank and the spacers. The same method should be used wherever a strap, clamp, crib, or other support is in sustained contact with a metallic tank.

It's normal for an XLPE tank to bulge slightly when filled, but if the tank shows any evidence of deformation as a result of its mounting or is resting on an uneven surface that does not fully support it, the tank is improperly stressed, and its warranty will likely be void.

Finally, fuel tanks should not be used to support other structures such as bulkheads, decks, or cabin soles. I occasionally encounter upright timber sections inserted between the top of a tank and the bottom of a sole or a deckbeam, ostensibly to secure the tank. However, they often unintentionally transmit loads from the above structures to the tank and can lead to tank flexing and failure.

—Steve D'Antonio



Right—*This FRP tank is more than 30 years old and going strong. An ample new access port (gasket flanges yet to be installed) is open for cleaning. It must be sealed tightly with the right gasket material before the tank returns to service. If gaskets require paste sealant to reseal, leaks are likely.* ***Far right***—*A stainless steel "insulator" bushing separates a brass fitting from this aluminum tank to limit corrosion. Note: Unlike gaskets, NPT threaded fittings used on tanks should be liberally applied with paste sealant.*

number) gaskets for a leak-free seal. If your installation will not seal tightly without gasket sealant, it's likely to be plagued by leaks in the future.

Conversely, applying sealants to associated threaded metal fasteners and plumbing installations is essential, but be sure to use a thread sealant suited for fuel applications.

While it's not a requirement, to ensure a leak-free installation, it's a good practice at the design stage to locate all fittings and ports on the top or highest horizontal surface of the tank. Only if the design prohibits access to the top of a diesel tank should inspection ports and supply and return fittings be installed on the side.

Far left—*This recessed, armored sight-glass installation is an ideal protected design.* ***Above***—*You can't see from a distance whether gate valves are open or closed; avoid installing them for fuel applications, including sight glasses like this one.* ***Left***—*Because sight-glass valves must be kept closed except during brief checks of the fuel level, spring-loaded valves are ideally suited for this application.*

Sight Glasses

Many diesel tanks rely on sight glasses as an ultra-reliable means of determining the quantity of fuel in the tank, usually as an adjunct to electric gauges mounted at the helm. They must be equipped with valves at the top and bottom of the sight tube, and the valves must remain closed when the level is not being checked. (Post a placard adjacent to the valve alerting users to this requirement.) Ideally, the valves should be spring-loaded or self-closing and of the 90° rotation ball variety. Avoid gate valves that lack a visual means of identifying whether they are open or closed and are not ABYC compliant.

Because valves on most sight glasses I encounter are *incorrectly* left open, a failure of the tube would lead to a fuel spill, potentially of significant proportions. In a fire, the glass would melt or break, allowing fuel from the tank to feed the flames. For this reason, fuel sight glasses should be designed for the purpose, using flame-resistant materials, and they must be rugged and/or protected so shifting gear, or a person hitting them, can't cause a significant fuel spill.

Pressure Testing

All fuel tanks should be pressure-tested with fittings capped *before* and immediately following installation, with all hoses, valves, and fittings (other than vents, of course) connected, as they would be in normal service.

Here's the ABYC tank pressure standard:

"**33.17.5** After installation, the fuel system of every boat shall be pressure checked to at least three psi (21kPa), or at 1-1/2 times the maximum hydrostatic head to which it may be subjected in service, whichever is greater.

Tank fabricators will nearly always cover repair of tanks that leak under warranty, but the cost of removal and replacement is usually borne by the installer. That's why this new tank is being pressure-tested before it is installed.

"**33.17.5.1** The fuel system shall evidence no leakage under such testing, checked at a minimum of five minutes after application of the test pressure, for systems of 50 gallons (190 liters) or less capacity, with one additional minute for each increment of ten gallons (38 liters), or fraction thereof, above 50 gallons (190 liters).

"**33.17.5.1.1** Test tanks over 500 gallons (1,900 liters) for 50 minutes plus 1/2 minute for each increment of ten gallons (38 liters) over 500 gallons (1,900 liters).

"**33.17.5.2** A leak detection method other than the pressure drop method must be used at every joint except at the deck fill and exterior vent fittings."

It's important to consult the tank's commission plate, which must be visible without disassembly after the tank installation is complete, to verify the rated pressure before beginning the test. Many older tanks are rated for 3 psi test pressure.

During the pressure/leak test, all the tank's fittings, welds, gaskets, and plumbing should be sprayed with a solution of soapy water (the soap should not contain ammonia, as it can adversely affect brass fittings) and checked for bubbles, indicating leaks. This is the time to check all the fittings that will be inaccessible *after* the tank has been installed. Also, look carefully at all welds, as they can exhibit porosity, which will generate bubbles.

During a pressure test, the bubbles in ammonia-free (ammonia can cause corrosion in brass fittings) soapy water reveal a porous weld on a newly manufactured tank.

One might ask, "Why bother to pressure-test a new tank if it has a tagged certification from the fabricator?" The answer is because a fully installed tank failure is unpleasant at best and costly and even dangerous at worst. It's worth the time and effort to perform this simple test, for which the customer should be charged. If the tank is installed and a leak is found, it's likely the fabricator will repair it at no cost; however, they are unlikely to pay for removal and reinstallation, and neither will the vessel owner, leaving the builder or yard to absorb the expense. Additionally, if purchasing a tank from a fabricator, rather than making your own in-house, it should be opened and inspected before it is installed. Accidents happen, even in the best fabrication shops. I've removed metal shavings, plastic caps, and bits of rag from the insides of new tanks.

While metallic fuel tanks must be electrically bonded, connections should never be made with tapping screws or on top of painted surfaces. This bonding connection is correctly achieved with a machine screw.

Bonding

To comply with ABYC standards for static electric discharge and electrocution prevention, all metallic tanks, metallic fuel-fill plumbing and deck fills must be bonded. Bonding connections at fills should utilize a dedicated bonding tab if equipped, or a deck-mounting through-bolt. The bonding wire should never rely on a tapping screw, nor should it be clamped between the hose and filler neck. Even clamping the wire to the filler using a hose clamp is far from ideal. If there's no bonding tab, it's best to drill a hole in a hose clamp band, pass a round-head machine screw through it, fasten with a nut, clean the filler neck surface with a nylon scouring pad, and then tighten the hose clamp and fastener assembly around

Right—*If there's no suitable terminal for bonding fuel-fill plumbing, use a clamp arrangement like this one, but never clamp bare-wire strands between the hose and fitting or directly under a clamp.*

Far right—*This fuel tank is fitted with a bonding "flag" welded to the top and able to accommodate a through-bolt to secure the ring terminals of the green bonding wires.*

the filler neck. The result will be a secure and low-resistance bonding stud.

In addition to static electric discharge, if the vessel is equipped with shore power, a generator, or inverter, there is the potential for an AC "hot" or ungrounded (black, red, or brown) wire to come into contact with a metal tank. If the tank is not bonded, it will become energized. If a crew member then touches the tank with one hand, and a grounded object—the engine—with the other, he or she will receive a shock that will travel across the chest and heart, possibly resulting in injury or death by electrocution. (For more on this subject, see "Shore-Power Fundamentals, Part 1: Good Grounding," *Professional BoatBuilder* No. 192, page 56.) Contrary to a common misconception, bonding a metallic fuel tank will neither hasten nor deter corrosion; it is strictly a tool to dissipate static electricity and prevent electrocution.

Metallic fuel tanks should be fitted with a bonding "flag," a small section of metal welded at a right angle to the tank top and equipped with a hole that can be used to secure a ring terminal with a through-bolt (never a tapping screw). Use a tinned ring terminal for this connection to minimize the galvanic incompatibility of the copper terminal and an aluminum tank. Dielectric grease will further protect the interface from corrosion. The bonding flags, along with *all* hose clamps at the tank and deck fills, should be easily accessible after the tank is fully installed. ABYC standards are clear on this:

> "**33.10.5** Tank connections and fittings shall be *readily accessible* or accessible through an access panel, port or hatch."

Fire Resistance

Finally, regardless of its material, diesel fuel tanks that comply with ABYC standards must pass a fire-resistance test, one that is clearly detailed in ABYC "H-33.20 Non-Integral Diesel Fuel Tank Testing for Fire Resistance." While the test requirements are somewhat complex, the ultimate goal is for a representative tank, filled to one-quarter capacity—as it will be installed in a vessel (a mock-up of a section of the vessel is required)—to withstand exposure to flame for 2.5 minutes. It's incumbent on the boatbuilder to determine from the tank manufacturer whether the material meets the fire-resistance requirements.

Diesel fuel tank design and installation have matured to the point where most defects, failures, and shortcomings are readily known, which means they can be easily avoided by refit yards and builders. Does a long-lasting, leak-free, serviceable tank cost more? Perhaps, but the dividends for owners and operators are clear and well worth the cost. PBB

About the Author: *For many years a full-service yard manager, Steve now works with boatbuilders and owners and others in the industry as Steve D'Antonio Marine Consulting. He is an ABYC-certified Master Technician and sits on that organization's Engine and Powertrain, Electrical, and Hull Piping Project Technical Committees. He is also technical editor of* Professional BoatBuilder.

PBB Resources

Tools

A standard pressure gauge from any auto parts store

Sight glasses: ldi-industries.com

Relevant ABYC Standards

E-2 Cathodic Protection (Bonding)

H-33 Diesel Fuel Systems