SYSTEMS

Diesel Tanks Done Right

PART 1

The material and construction choices behind good fuel tank design and installation.

Text and photographs by Steve D'Antonio

Above—*Removable sections facilitate easy access to this large tank via a single port large enough for a person to enter. Every chamber of a fuel tank should be accessible for inspection and cleaning.*

A frustratingly common scene plagues my professional life: I'm hunched down in a foul-smelling bilge or engine-room asking myself, "How the heck am I going to get this tank (or these tanks) out of here?" It doesn't have to be this way, because most onboard fuel, water, or waste tank failures are preventable.

Nearly every vessel I inspect requires major disassembly to remove at least the fuel tank/s and often all the tanks. That's not unreasonable for larger enclosed-cabin vessels, motoryachts, cruising sailboats, etc. (Runabouts and center-consoles, on the other hand, should present no such difficulty; their tanks should be removable simply by lifting screwed-in-place hatches or designated soft patches (sections of cabin sole and housetops or sides that can be removed with minimal destruction to replace large components like engines and tanks).

At least for those larger vessels, it seems that tank manufacturers and production boatbuilders should have fabricated and installed tanks designed to last the intended working lifetime of the vessel, or at least planned for the tanks' removal without destructive disassembly. Sadly, many have not. Immediate cost is often the deciding factor, as better-built, properly installed tanks are initially more expensive, while costing owners decidedly less in the long run.

Tank Materials

The primary materials for fabricating fuel tanks are aluminum, steel (so-called black iron is almost always a steel alloy, as yacht tanks have not been made from iron in nearly a century), stainless steel, polyethylene, and fiberglass.

Aluminum is the most popular, for several reasons. It is easy to work with, readily available, comparatively inexpensive, lightweight, strong, and corrosion resistant. The alloy for a fuel tank must be 5052, 5083, or 5086, and a *minimum* of 0.090″ (2.3mm) thick. While the lightest gauge is ABYC compliant, 0.125″ (3mm) is preferable, and 0.250″ (6mm) should be utilized for extreme applications, such as bilge installations, or where maximum durability, longevity, and sacrificial material are desired. Unfortunately, aluminum is anything but indestructible. One of its primary weaknesses is its susceptibility to galvanic and poultice corrosion.

Galvanic corrosion is the interaction between dissimilar metals in the presence of an electrolyte. In aluminum tanks, this process is most likely between a copper alloy fitting (brass or bronze) and the tank while exposed to water, especially salt water. To solve this, ensure that all metals in contact with the tank are compatible with aluminum; there aren't many. Plumbing fittings should be 304 or 316 stainless steel. At the very least, stainless bushings should insulate copper alloys from an aluminum tank. There are examples of condensation dripping off a copper pipe onto an aluminum tank top causing severe corrosion, because the water carries salts of copper, which then lodge in the tank surface and sink deeper and deeper, like hot buckshot melting into butter.

Poultice corrosion occurs when aluminum is in constant contact with a stagnant wet surface, such as raw timber, carpeting, or insulation. The result is a prodigious amount of white, frothy aluminum hydroxide (it looks like freezer-burned vanilla ice cream), which foretells the tank's ultimate failure. The best defense is to limit contact, especially of wet surfaces, with an aluminum tank. It should be surrounded by air and little else.

Above—*Aluminum tanks are common, especially on production-boat models. ABYC-compliant fuel tank identification tags like this one include the material, thickness, and pressure rating. They must be visible after the tank has been installed.* ***Left***—*Copper alloys like this fitting should not touch aluminum tanks. While it has many advantages, aluminum is especially susceptible to dissimilar metal corrosion.*

Steel is strong, inexpensive, and easily fabricated into fuel tanks, but like all ferrous alloys, it is susceptible to rust. Tank exteriors must be primed, painted, and maintained. Periodic inspection requires access to all surfaces, and keeping water out of the tanks is essential.

Two-part foam commonly used for flotation should *not* be used to secure any metallic tank in place.

Mild steel was once popular for fuel tank fabrication, and it remains so for steel vessels. Despite being rust-prone, it has the virtues of strength and relatively low cost. If uncoated, it typically develops a layer of light surface rust at first, which usually becomes more pronounced over time. Thus, the interior of metallic fuel tanks should be uncoated (see the **sidebar** on page 85), while the exterior must be coated to prevent rust. Steel usually rusts from the surface in, retaining its basic shape while getting thinner. Rusting from inside a tank can also become a problem if water accumulates there. In that case, rust often shows up in the primary fuel filter. Hoping to extend the lives of steel tanks, some boatbuilders swathed them in fiberglass; however, this proved a short-lived rust preventative. Once water manages to penetrate beneath the fiberglass coating, often entering around top-mounted fittings or inspection ports, rust progresses, and you simply can't see it. Resin-encapsulated steel tanks should be inspected closely for water and/or rust accumulation between the fiberglass and outer tank wall.

A common culprit is the deck fill, a fitting notorious for leaking onto the tank top, where fittings are located. The water stands on that tank surface and finds breaches in the coating, and corrosion ensues. A useful design feature that should be incorporated into all metallic tank tops is an inboard slope ensuring that any water leaking onto the surface drains inboard, where an alert operator has a chance of seeing it.

Stainless steel is familiar to all industry professionals as a corrosion-resistant alloy well suited to on-deck and some below-the-waterline hardware applications. But it is susceptible to several forms of corrosion, the most prominent of which is referred to as crevice

Left—*Fiberglass encapsulation of steel tanks may seem like a good rust preventative, but because it's not possible to fully enclose the tank around fittings and ports, the tank surface remains susceptible to water intrusion and corrosion.* ***Right***—*Many steel tanks suffer from a counterintuitive type of top-down corrosion, the result of caulking failure around the deck-fill fitting.*


***Left and right**—Stainless alloys must be welded with low-carbon welding rods. Failing to follow this protocol will result in a phenomenon known as weld migration, wherein the area adjacent to the weld of a corner seam or hardware attachment will corrode.*

corrosion. (See "The Power and Peril of Stainless," *Professional BoatBuilder* No. 146, page 48.) If stainless steel is exposed to the stagnant, oxygen-depleted water in bilges, within insulation, or between insulating materials and the tank's surface, corrosion can occur. Thus, the same measures must be applied to stainless-steel tank installations as to aluminum-alloy tanks: elevating the tank above its mounting shelf, using mounting flanges, isolating supporting materials from tank surfaces, and eliminating voids between mounts or supports and the tank.

Say No to Internal Tank Coatings

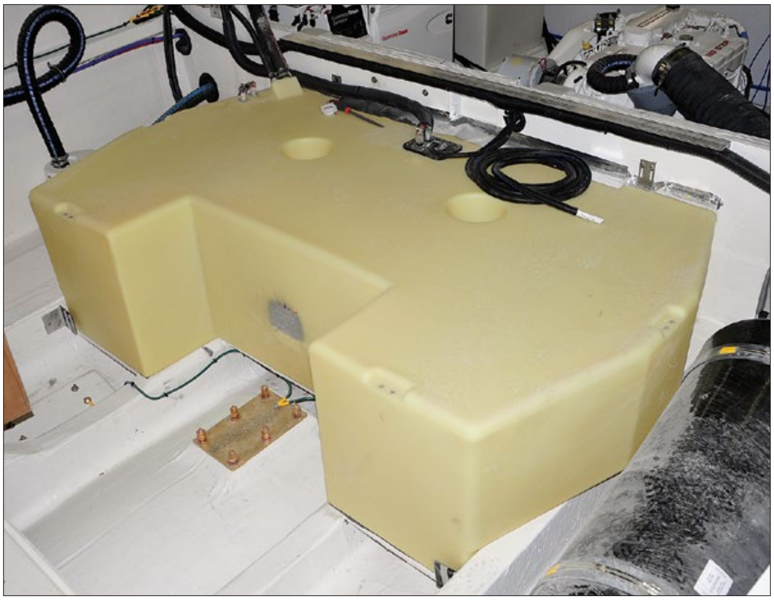
Products designed for internally coating metallic tanks, whether steel or aluminum, are often referred to as slushing compounds and used primarily in the aviation industry. (I've used them on steel tanks in classic-car and motorcycle restorations.) I do *not* recommend them in marine applications for one primary reason: for any coating to tenaciously adhere, the surface, especially a metallic one, must be scrupulously clean and oil-free, and ideally slightly rough. Marine tanks are nearly always baffled, which makes adequate prep, or cleaning a used tank, almost impossible.

While I don't know how common it is to coat aviation tanks, I suspect the procedure is clearly defined by the FAA and probably costly. Here are the preparation instructions for an aviation tank sealant from PPG that I've used in automotive applications: https://docs.td.ppgpmc.com/download/874/2395/amercoat-91. It calls for, among other things, grinding welds and abrasive blasting.

Satisfying those requirements inside a marine fuel tank is unlikely, and doing so after the tank has been in service is even more challenging. Also, the inside of a baffled metallic tank is filled with sharp edges that compromise the coating's coverage, causing it to lift. Once the coating is no longer contiguous, fuel will migrate beneath it, leading to its failure and release—a nightmarish scenario that clogs fuel pickups and filters and has no easy solution short of tank replacement.

—Steve D'Antonio

To meet ABYC standards, stainless tanks must be fabricated from 316L or 317L low-carbon alloy, a minimum of 0.075″ (2mm) thick. Stainless-steel tank fabrication also requires special attention when it is welded. Low-carbon alloy (denoted by an L suffix) must be used to prevent weld migration, which increases the susceptibility to corrosion in the heat-affected zone adjacent to welds. Using the incorrect alloy is insidious in that deterioration typically manifests itself only well after the tank is placed in service.



Above—*Plastic tanks offer a range of advantages; chief among them is their total resistance to corrosion.* ***Right***—*Large plastic tank installations require proper support and chafe prevention, as well as accommodation for hydrocarbon expansion.*

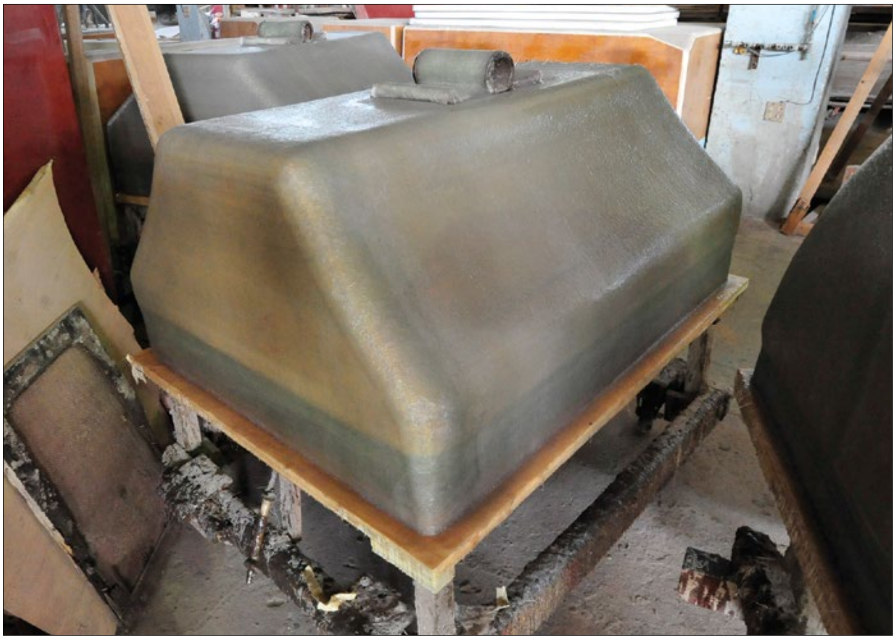
Cross-linked, roto-molded **polyethylene** is a rugged, corrosion-proof, seamless, leak-resistant, lightweight, and comparatively inexpensive tank material that's growing in popularity. Its major drawback is impracticality for custom fabrication (a minimum of about 100 must be produced for roto-molding to be economically feasible), although scores of shapes and sizes are available. There are fabricators who will weld custom polyethylene diesel tanks; however, unlike roto-molded tanks, they are not seamless.

While all tanks are susceptible to chafe to some degree, polyethylene is especially vulnerable. Also, most roto-molded polyethylene tanks do not come equipped with inspection ports.

Careful attention must be paid to poly tank installations due to hydrocarbon expansion (more on this in Part 2). Additionally, all poly tanks must be fully supported across the entire bottom, meaning they must rest entirely on a shelf. Water immersion or exposure is not an issue, so contact with standing water or hygroscopic materials poses no risk.

Installation of plumbing fittings can also be a challenge in these tanks, because as the tank bulges—and larger tanks will—the threads can deform. This can lead to leakage around threaded fittings, although the newest generation of poly tanks is less susceptible to this issue. A note of caution: plastic fuel tanks must be fabricated from cross-linked polyethylene, or XLPE, *not* linear polyethylene, or LPE.

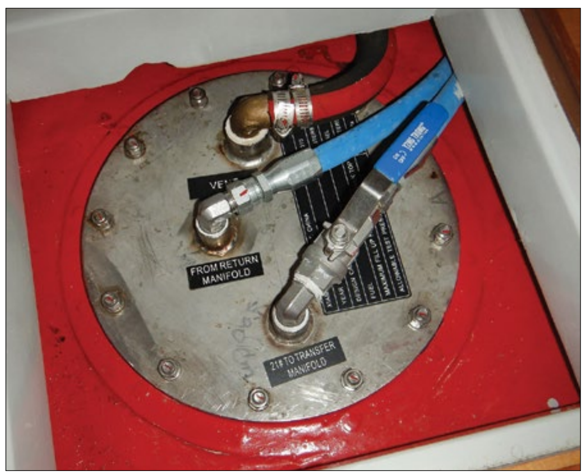
Before the advent of polyethylene, **fiberglass** was the only nonmetallic fuel tank alternative. It is strong and corrosion-proof, but care must be taken to use the proper resin (fuel- and bio-fuel-approved vinylester or epoxy; the exterior must be flame-resistant or made so with an intumescent coating, for ABYC compliance); and meticulous lamination technique is essential. Unless the vessel is specifically designed for it, the tanks should not be integral to the hull, because they may delaminate during



Fiberglass tanks are strong, corrosion-resistant, customizable, and can support baffles and inspection ports. They should last the life of the vessel.

Left—*Installing metallic fittings into fiberglass tanks requires special care. In this case, a flanged-clamp arrangement, similar to a through-hull fitting, has then been overlaminated.*

Above—*This smaller hose fitting illustrates a clamp arrangement that does not rely on the adhesion with resin that's necessary for installing fiberglass tank hardware.*



Right—*Large inspection ports like this one should also be secured with a similar bolted-clamp fitting with a backing ring inside the fiberglass tank.*

severe wracking, as in a grounding, a collision, or improper blocking.

Fiberglass tanks require some special techniques for installing fittings. While vinylester or epoxy resin will seemingly stick to anything, over the long term, it does not adhere well to metal. For that reason, it is not possible to reliably "cast" metal plumbing fittings into a fiberglass tank at the time of layup expecting them to remain leak-free indefinitely. It is better to secure fittings in place. This requires a flange having an inner and outer component whose surfaces are as true and as flat as possible. Prepared with a gasket or fuel-proof bedding material, the components are clamped together with fasteners or screw threads, much like a through-hull fitting.

The inside of an FRP tank should also be smooth and free of any exposed glass-fabric reinforcement, which might capture and retain debris or hinder cleaning.

Preferred installation methods are the same as for other tanks—built-in flanges, shelves, clamps, and cribs—and for some shapes they can be tabbed in place so long as secondary-bonding techniques are employed. Exposure to water from bilges or deck leaks is a nonissue, so these tanks can last the life of the vessel. Hatteras was among the first production builders to install fiberglass fuel tanks. I have had the opportunity to install inspection ports in, access, and clean badly contaminated three-decade-old Hatteras fiberglass tanks, after which they looked like new, but I can make no similar claim for metallic tanks.

Most fiberglass tanks are fabricated like a hull, using a one-piece bottom/side component, which reduces the likelihood of leakage. Baffles are installed next and then covered with a tabbed-in-place tank top.

Above left—*This multipiece fiberglass fuel tank is made from tabbed flat sections. Note the two inspection ports, providing access to each chamber.* ***Above right—****These inspection ports are installed on the side of the tank.* ***Left—****While many OEM fuel tanks do not include inspection ports, they can be added using aftermarket kits like this one.*

Design and Installation Details

One of the most critical features of a good diesel tank built from any material is access to every baffled chamber through inspection ports at least large enough for an adult hand and arm (up to the shoulder) to comfortably fit through (a minimum 6″/152mm diameter). Many tanks have just one inspection port but three baffled chambers. The temptation to install fewer baffles is a false economy and should be avoided, as baffles crucially prevent rapid movement of fuel within the tank, which in turn can create undesirable vessel motion and/or instability. For larger tanks, a single inspection port large enough for a person to enter, along with removable baffle panels, is a viable alternative. While ports are not mandated by ABYC standards, if they are installed, the rules on size, location, and access are clear:

"H-33.10.3. If inspection access opening(s) are installed, they shall have a minimum diameter of 4.75 inches (120 mm) at suitable position(s) for cleaning and inspection of the lowest part(s) of the tank. The access opening(s) shall remain accessible when the tank has been installed in the craft."

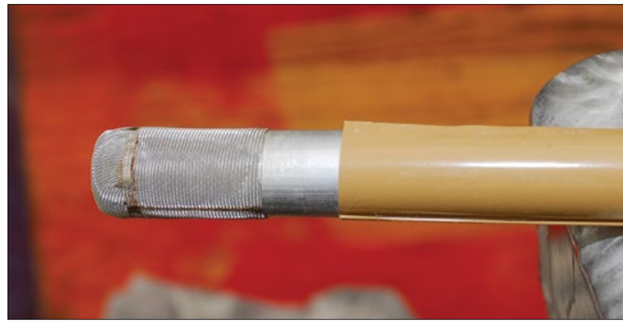
Inspection port(s) should be accessible, ideally without major disassembly, *after* the tank and all surrounding gear have been fully installed. In some cases, this may not be practical, but ports can still be useful even if they are not easily accessible. In the worst case, a tank could be unshipped and shifted, or joinerwork could be removed, to access the ports.

Improper plumbing fittings are another potential weakness in diesel tanks. Ideally, fittings should be attached to metallic tanks using female threaded ports called welding bosses. Because of their large footprint, load distributing ability, and resistance to heat distortion during welding, these ports are far superior to the frequently used conventional pipe couplings,

Left—*This textbook installation utilizes a threaded welding boss* ***(below),*** *bonding connection, and a properly rated, double-clamped fill hose.*

which are prone to heat-distortion resulting in thread leakage. Permanently attached tubular hose barbs are less desirable because of their propensity to crack or break when stressed where they are welded to the tank. This commonly occurs when installing or removing a hose, as is necessary during decades-long service. Each replacement will test the welds around these fittings, not to mention the stress imparted when a crew member or maintenance technician inadvertently steps on an exposed hose barb.

Like all other tank fittings, the fuel pickup tube(s) should be removable and extend down to within approximately ⅜″ to ½″ (10mm to 13mm) of the tank bottom. The bottom of the tube should be cut at a 45° angle and must *not* be equipped with a screen. This design allows most of the fuel in the tank to be used, and constantly drawing up small amounts of water and debris into the pickup and the filter prevents their accumulation. The cut angle also reduces restriction between the tube and the tank bottom, and makes it more difficult for flat debris such as wrappers and bottle lid inserts to be sucked up against the pickup orifice.



While it may seem like a good idea, screens on fuel-pickup tubes are prone to clogging and are not readily accessible. All fuel pickups should be removable for servicing.

Note that screened pickups were once common, but they frequently become clogged in the most inaccessible place—within the tank. Better to let dirt and debris travel to the primary filter, where it can be easily dealt with.

A settling or collection well is a worthwhile addition to any fuel tank design. While any shape will work, round is best, as it has no corners to trap debris. Located in the aftermost or lowest section of the tank, a minimum of 2″ (51mm) deep and 4″–8″ (102mm–203mm) across, this collection area will hold water and other debris heavier than the fuel. A drain, or another pickup tube (often referred

Right*—*Wells in tank bottoms effectively trap water and debris. This welded example has no exterior drain fitting; the tank has a stripper tube plumbed to a suction pump, which, when activated, removes accumulated material.
Far right*—*The well in this tank is equipped with a drain valve, allowing a user to sample the tank bottom to check for water. To minimize unintended fuel leaks, drains like this should have a capped hose.

to as a stripper tube) may be plumbed into the bottom of this well. A tube should be equipped with a 90° fitting and located as close as possible to, but not touching, the bottom of the well. A hand or fuel-rated electric pump, including an electric oil-pump-out system, can be connected to this stripper tube. Operating this pump periodically will keep the tank clean, and sampling the liquid from the collection well will indicate the tank's condition. Additionally, a stripper tube can be used for a backup fuel supply or return if either of these lines becomes clogged or damaged.

Some builders and tank fabricators locate pickups well off the bottom of the tank, reasoning that this prevents the pickup from ingesting water and settled solids. While that may be true, it also allows the accumulation of more contaminants in the tank, which invariably make their way to the pickup as soon as the fuel is agitated when the vessel enters a seaway. Biological growth can survive and thrive within a diesel tank only in the presence of water, and the more water there is, the greater a bio-colony it can support. The settled water and hydrogen sulfide from the bacteria are corrosive to the tank. (See Nigel

Left—*It's not a matter of if, but when, a diesel tank will need to be cleaned. This 15-year-old tank is heavily contaminated with a tar-like substance that was removed with a hot-water pressure washer.* ***Right***—*The exterior coating on a steel fuel tank is as important as the paint on an automobile; without it, rust is sure to follow. Coatings commonly fail where tanks contact mounting surfaces and hard water, so special attention must be paid to those locations during installation and subsequent inspections.*

Calder's "What Grows in the Darkness of Diesel," PBB No. 172, page 36.)

Life expectancy for the average 0.090″-thick (the minimum allowed) aluminum fuel tank is a scant seven years. This has a great deal to do with tank design, installation, and materials, but alloy thickness also plays a key role. While thickness is directly related to strength, it can also afford a margin for corrosion error. If, for instance, a tank begins to corrode due to exposure to water, from inside or outside, additional thickness will give the vessel operator time to discover and correct this problem before a failure occurs. Thus, thicker is nearly always preferable for metallic tanks.

The exterior of all tanks, and metallic tanks in particular, should be accessible for regular inspections. Unfortunately, in many installations this is nearly impossible. The outboard side of the tank is often pressed hard up against the hull, and the tank bottom rests on a shelf. The most desirable compromise is to ensure that the tank is properly installed with its exterior surface as accessible and as visible as possible.

A common error by builders and repair yards is insulating metallic tanks, or allowing insulation from other parts of the vessel, the hull, or engineroom overhead to lie against the tank. Most insulation is hygroscopic (it will absorb and hold water), and thus if allowed to become wet, it will hold that water against the tank surface, corroding the outside.

Among the many prerequisites for a long-lasting metal tank, exclusion of moisture is one of the most important, and it is commonly overlooked. The exterior of metal tanks, particularly aluminum and steel, must *never* be allowed to remain wet for an extended period. This includes immersion in bilgewater (salt or fresh), as well as contact with any hygroscopic material such as insulation, carpeting, or unencapsulated timber. While they may not absorb water, even materials such as FRP, plastic, and epoxy-encapsulated timber can effectively trap and hold it against a tank surface, which can be equally damaging.

While no metal tank should be allowed to have direct contact with timber, aluminum tanks should never be allowed to make contact with pressure-treated timber that relies on copper as a deterrent to decay. Copper is galvanically incompatible with aluminum and will corrode the less-noble metal. I've seen aluminum tanks fail from galvanic corrosion caused by their installation on pressure-treated plywood shelves that subsequently became wet.

In Part 2 I'll explain how to adequately secure, support, and pressure-test fuel tanks, and discuss fuel-resistant gasket material and sight-glass design.

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 Power-train, Electrical, and Hull Piping Project Technical Committees. He is also technical editor of* Professional BoatBuilder.

Resources

Relevant ABYC Standards
E-2 Cathodic Protection (Bonding)
H-33 Diesel Fuel Systems

Aftermarket tank inspection ports
www.seabuilt.com

Plastic fuel tank fabricators
moellermarine.com
tek-tanks.com
kracor.com

Steel and aluminum welding bosses
mcmaster.com/weld-on-tank-fittings