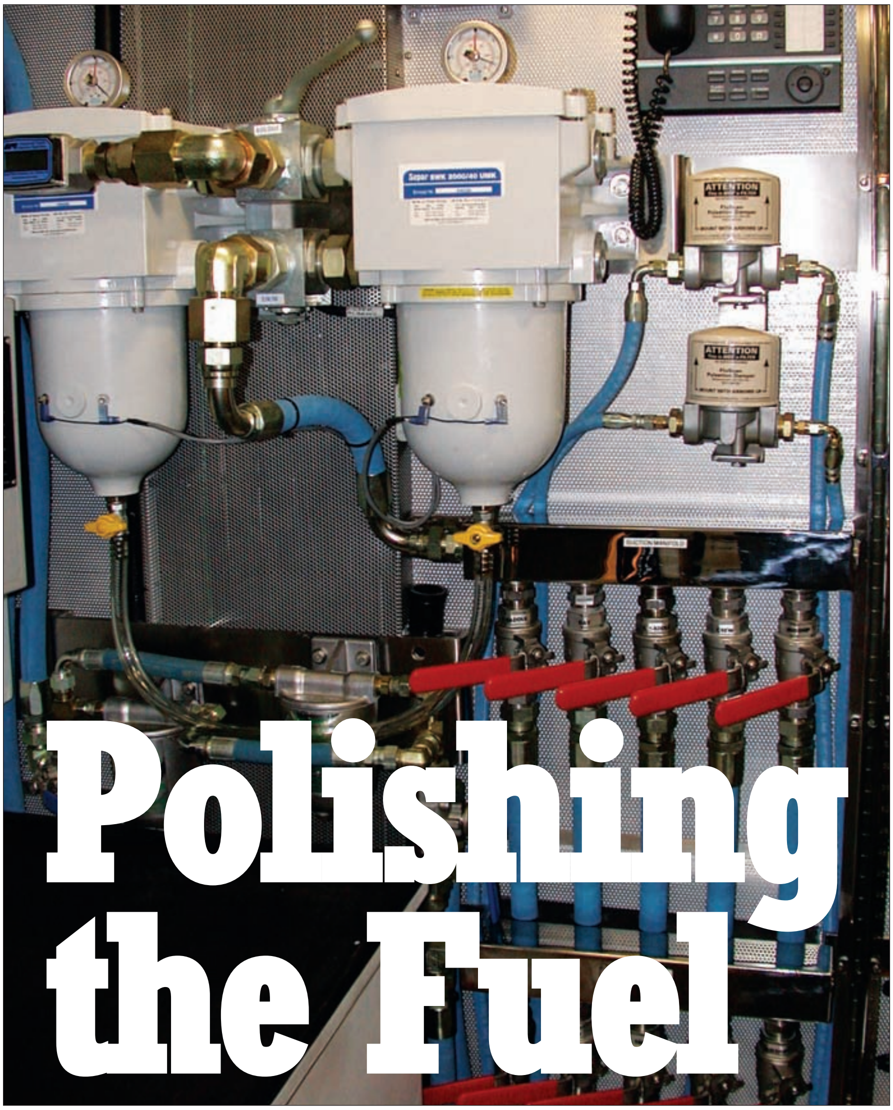


Polishing the Fuel

Fuel contamination can ravage a diesel engine and its fuel system. Which is why more and more boatyards and boat owners consider fuel-polishing equipment a necessity, not a luxury.

Text and photographs by Steve D'Antonio

Above—*True fuel-polishing systems remove solids and water that threaten engine reliability and shorten the lives of metal tanks.* ***Right***—*Grossly contaminated primary fuel filters will cause engines to shut down when least expected.*

During a recent visit to a marine diesel engine Web site, I typed the words "fuel contamination" in the discussion forum. It elicited dozens of threads in response: "dark fuel, looks like soot"; "algae in tank"; "water in fuel"; "contaminated fuel tank"; "how to clean tank"; "old fuel clogging filters"; and more. There's no shortage of fuel-contamination-related problems out there, so it's just a matter of time before you and your customers experience them firsthand. Which brings us to the subject at hand: fuel polishing.

Briefly put, this process increases fuel filtration and boosts fuel flow through storage tanks by means of a pump and series of filters—on a loop plumbed independently of the engine supply line.

In a conventional engine installation, all that stands between contaminated fuel and the vulnerable power plant are the primary and secondary fuel-line filters. While any filtration is better than none, not all filters are effective against the many and various contaminants often found in marine diesel fuel and tanks.

If properly engineered and installed, the primary and secondary filters for engines and generators *typically* provide clean fuel. When faced with more than average contamination, though, or if poorly maintained, the filters quickly choke. In the best-case scenario, fouled filters will shut down the engine rather than allow contaminated fuel to make its way to the sensitive fuel injection system, where clearances are often measured to the ten-thousandth of an inch.

If you find you must change fuel filters frequently to keep a given engine running smoothly, then it's the fuel system—and likely the tanks—that need attention. What contamination does to a vessel's metallic fuel tanks is worth serious consideration. Filters may prevent contamination from reaching the engine, but they do little to keep the tank itself clean. Accumulated material, often including water, that lurks in the bottom of the tank can cause damage and promote further fuel contamination.

Part of the problem is that diesel fuel stored in the tanks of many vessels isn't consumed and replenished frequently. As the fuel ages it oxidizes, and water almost certainly enters the tank with changes in ambient temperature and humidity. If the fuel taken aboard is already contaminated with water or *asphaltine* (a naturally occurring residue found in diesel fuel; more on that in a moment), this will only hasten its demise and further endanger the tank.

A proper polishing system

will keep fuel and tanks free of debris and contaminants, allowing the engine's primary and secondary fuel filters to remain cleaner, thereby reducing fuel-related engine maintenance and failures.

Bad Fuel

The effects of fuel contamination range from minor smoke and loss of performance, to more severe tank corrosion, and engine shutdown and damage.

Abrasive dirt particles are especially harmful fuel contaminants. Despite the fact that clearance between the finely machined components of a fuel injection system is just 1 to 3 microns, the most damaging particles range from 5 to 15 microns in size. Smaller particles pass through and typically cause little damage, while much larger particles can't fit into the narrow gaps. The real risk from hard contaminants such as 10-micron quartz, say, is that they can lodge in smaller high-pressure fuel passages that cyclically expand and contract. The engine damage caused by abrasive dirt particles in the fuel is usually limited to the plungers of in-line injection pumps and unit injectors, and the rotors of distributor-style pumps.

Water is among the most common contaminants of marine fuel systems. Even if deck fills and vents are properly installed, water often finds its way into the tank in the form of vapor. As fuel is consumed, water-laden air can be drawn into the tank. Once the tank and the fuel within cool, water will condense on the walls of the tank and even on the fuel itself. Specification D975 for diesel fuel, issued by the American Society for Testing and Materials, calls for no more than ⅒ of 1% water content by volume. If more water is present in the fuel, it is technically "off spec."

Water promotes corrosion on ferrous and aluminum alloys; that could be everything from the tank to fuel system plumbing, lift and injection pumps, injectors, and high-pressure fuel piping. Water also reduces the lubricity of diesel fuel that's essential in enabling the close tolerances of fuel injection systems. And, water provides a habitat for biological growth, resulting in so-called *bio-mats*, which clog fuel pickup tubes and filters, and produce hydrogen sulfide, a weak acid. Along with water trapped beneath and within bio-mats, hydrogen sulfide can corrode metal fuel tanks, particularly aluminum ones. Enough water contamination can interfere with combustion and lead to

Top left and right—*Conventional diesel fuel tanks can be expected to accumulate water, tar-like asphaltine, and other debris over time. The water leads to additional contamination—as a medium for biological life that can grow in diesel tanks.* ***Bottom left and right—****Fuel contamination not only leads to clogged filters and engine failures, it also damages metal tanks. Here, a steel tank and an aluminum tank show the effects of water accumulation.*

engine performance problems and possible stoppage.

Finally, prolonged exposure to water can shorten the life of paper-based fuel filter elements, putting the engine at further risk from other contaminants.

After water, the most common contaminant in marine fuel is asphaltine, a tar-like substance. Because asphaltine tends to precipitate out of fuel in storage, it accumulates on the bottoms of fuel tanks. Aeration of fuel, in turn, tends to produce asphaltine clumps, which also sink to the tank bottom, creating an ooze-like pavement.

When agitated by refueling or rough seas, the asphaltine and other contaminants from the tank bottom become suspended in the fuel; even small amounts of asphaltine can overwhelm the best primary and secondary fuel filters.

Polishing System Basics

A dedicated polishing system should circulate fuel to remove particulates, asphaltine, water, and microbes. In order to keep fuel and tank clean, *the polishing system must pump a volume equivalent to that of the tank in about two hours*. If it takes much longer than six to nine hours to turn over the fuel in a tank three times, the volume of the pump is probably inadequate. Unlike the movement of fuel from low-volume fuel supply pumps, the higher velocity achieved by larger pumps induces fuel movement in the tank, preventing accumulation of asphaltine, water, and other settling contaminants. However, it's unlikely that this scouring can remove long-term accumulated contamination.

In my opinion, to turn fuel over in a reasonable amount of time *and* to derive the desired fuel movement, a polishing system should rely on a pump with a minimum capacity of 100 gal per hour (378 liters per hour). Anything less will augment existing engine filtration, but can't really be considered a true polishing system.

System Design

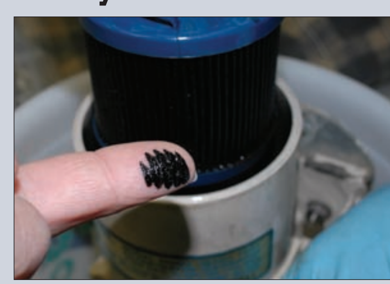
Filters—In an effective polishing system, the desirable high flow rate must be matched with adequate filter capacity. For instance, a pump capable of moving 200 GPH (757 lph) or more should be installed only in conjunction with a filter, or tandem filters, capable of supporting the volume and velocity of the fuel being polished. If the filter can't handle the flow, its water-separating ability may be impaired. In addition, the pressure could damage filter media, allowing contaminants to flow back to the tank.

Pumps—The pumps for high-volume fuel filtration typically fall into two categories: *multi-diaphragm* or *geared*. Flexible-impeller pumps are typically not durable enough. Small piston pumps used for supplying fuel to an engine don't have the requisite capacity.

Because of the high volumes of fuel they must pump, polishing systems often require large filters.

Tanks can become severely contaminated after five years, or a single season, or even after a single fill-up. It's impossible to predict, and that reality argues strongly for fuel polishing.

Every Micron Matters



Their ratings may sound "absolute," but in fact, few fuel-filter elements are precisely manufactured sieves that trap every particle over their rating size. Actually, those filter elements are designed to capture a *percentage*, albeit a high one, of all particles above a given size. Most Racor elements, for example, claim a capture rate of 90% or better.

Racor Aquabloc filter elements are made from a combination of microglass and cellulose fibers ranging in diameter from 0.5 to 30 microns, and treated with a chemical that will minimize the passage of water molecules.

A micron is simply a unit of measure one-millionth of a meter. By way of comparison, a grain of salt is 100 microns, a human hair 70 microns, and bacteria about 2 microns.

—Steve D'Antonio

***Far left*—*A high-volume pump like this one is the guts of any effective polishing system.* ***Left*—*The only sure way to know when the filter in a polishing system requires replacement is by the amount of vacuum generated while the system is operating. Once the pump shuts down, the vacuum usually drops back to zero. The red recording drag needle on this gauge shows the maximum vacuum created, well after the system has run.*

Most diaphragm pumps are quiet, can be run dry without suffering damage, and are strong self-primers.

Geared pumps are known for their rugged durability and extremely long operating lives. These, too, are capable of self-priming, but most manufacturers recommend they not be run dry for very long. The portable polishing and fuel transfer system I've relied on in a boatyard for over a decade has a geared pump, which required no service or repair after hundreds of hours pumping contaminated fuel.

The five-chamber rotary variety provides the best balance and least vibration of the diaphragm pumps—but, be certain its diaphragms are made of *Viton.* A trademarked product manufactured by DuPont, it is an extremely fuel-resistant rubber-like material. Indeed, any polishing system pump should have Viton seals, and all of its components should be resistant to *bio*diesel exposure.

Pump motors designed to operate in the marine environment will be more reliable. Look for stainless or nonferrous hardware, tinned marine-grade wiring, chafe- and vibration-protected cabling, and UL/CE classifications.

Geared and diaphragm high-volume pumps are vulnerable to overheating if the plumbing they're connected to is too small, restricting fuel flow. Similarly, a pump inadvertently operated against a closed valve could burst a hose, fitting, or filter body. High-volume pumps in polishing systems should incorporate a safety device, preferably a pressure switch, to prevent this type of catastrophe.

Monitoring—Additional accessories to quality polishing systems include sensors to indicate an accumulation of water in the fuel system's filter bowl, along with vacuum gauges. A vacuum gauge should be of the recording type, so the operator will know, without having to constantly monitor a dial, the maximum vacuum pulled while polishing was under way. Some polishing systems include a remote vacuum/water-sensor alarm, which sounds if the filter becomes clogged or the bowl fills with water. Such an alarm can be wired to automatically shut down the pump when it triggers.

A polishing system's control panel should include a timer to turn it off after the cycle has concluded. Such timers range from simple rotary dials to sophisticated digital arrangements that can be programmed to start and stop on a cyclical, recurrent basis. A simple on/off switch makes it too easy for the operator to turn the polisher on—and then forget to turn it off.

Most polishing systems rely on a simple timer control mechanism, calibrated in gallons. Others with more sophisticated controls incorporate digital displays and timed polishing sequences.

Power—The final component is a power source for the system. A 12VDC supply may seem like a logical choice on most boats, but it's not that simple. Direct-current motors in polishing systems are usually expected to deliver trouble-free operation for between 1,000 and 1,500 hours before requiring brush replacement or other service.

Alternating-current motors, on the other hand, are typically brushless. It's not unusual for industrial AC motors to run for many thousands of hours before requiring repair or replacement. Although that advantage might seem abstract—since it would take 10–13 years to accumulate 1,000 hours on a pump operating for 6–9 hours a month—AC motors, as a rule, are a bit easier to install. The wiring is smaller and there's no voltage drop. By way of comparison, a 200-GPH AC pump draws about 3 amps at 120V, while a 150-GPH (567-lph) DC pump requires about 10 amps.

Installation

Plumbing—Correctly plumbing the polishing system to the tank is the critical aspect of installation. The system should be an entity unto itself, *not commingled with the existing fuel system in any way.* That includes, most importantly, its connection to the fuel tank. The vessel's existing fuel lines, valves, pickup-and-return tubes, and tank fittings are typically too small to accommodate the polishing system pump's capacity.

Because adding those pickup and return tubes to an existing fuel system can be labor intensive, many installers simply skip this step; instead, they parallel the polishing system with the

The majority of a polishing system's expense is in the installation. Here, a technician custom-bends pickup tubes; they'll enter the side of a tank, but still be able to pick up from the bottom.

engine's own supply-and-return connections at the tank. There are reasons why that's a bad idea:

• Many polishing systems require 7⁄8″ (22mm) ID or larger hosing, which is much larger than the typical engine supply lines.

• Intermingling fuel polishing and delivery systems also compromises the integrity of the fuel supply to the engine. The more fittings, valves, and hoses that are attached to this system, the greater the likelihood of an air or fuel leak.

• Finally, a polishing system that is paralleled with the engine's fuel supply system often cannot be operated while the vessel is under way because it could create excessive vacuum in the fuel supply to the propulsion engine.

Pickup and return tubes dedicated to the polishing system should be placed at opposite ends of the tank, with the pickup at the lowest end of the tank to facilitate water removal. Note that the pickup should be placed closer to the bottom of the tank than the engine's fuel pickup tube.

There should be approximately 3⁄8″ (10mm) clearance between the polisher's pickup and the tank bottom. Any less, and the flow might be restricted; any more, and it might hinder the removal of water.

The polishing system return should incorporate a drop tube that also extends nearly to the bottom of the tank, preventing aeration from fuel splashing back into the tank. This detail serves two purposes: it reduces oxidation of fuel in the tank, and reduces the risk posed by the compression of air in the fuel. The latter

Polished Fuel, Shiny Tank

A few years ago, one of the most able technicians in the yard I managed at the time came into my office with a solemn look on his face. He confessed that, while adding winterizing stabilizer to the fuel tank of a vessel we'd built, he inadvertently allowed the small foil seal found under the caps of most chemical containers to fall into the tank's fill port.

Granted, I wasn't happy this had occurred, but I was pleased he'd told me about it. And, it really wasn't as bad as it sounded. Fortunately, the 150-gal (567-l) tank was equipped with inspection ports, so all we had to do was pump the fuel into three clean drums, open the port, remove the foil, and then button things back up. I told him to proceed. He returned to my office a couple of hours later and said I should come over to the boat; he wanted me to see something. I was expecting the worst.

Since we'd built the boat, her owner had placed about 600 hours on the engine, traveling from our yard on the lower Chesapeake, to Annapolis, the Bahamas, then north to New England, and finally back to the yard. I knew the owner and delivery skippers had taken on fuel in various locations in two countries. When I peered into the open inspection port I was amazed to see the tank's bottom was shiny aluminum; indeed, it looked nearly as clean as the day it was welded shut.

This boat's secret weapon against fuel contamination? A high-capacity (150-GPH) fuel-polishing system that the owner operated with religious regularity.

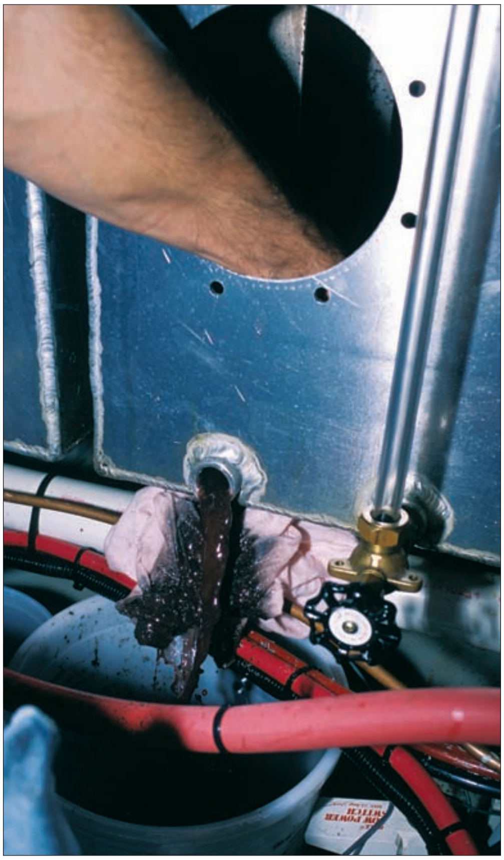
I was sold. *—S.D.*

occurs when air is drawn into the engine's fuel injection system, leading to erratic operation under load, or rough idle.

If a polishing system is being installed on a new vessel or with a new tank, then incorporating a sump or well within the tank for the pickup tube will further aid the removal of water and sediment.

Alternatively, if a polishing system is being installed on a tank that's been in service for some time, then it's important the tank be thoroughly cleaned before polishing commences. Removing several years' worth of solidified asphaltine or bio-mats is simply beyond the capabilities of even the best polishing system.

Installing the polishing system's pickup and return tubes often also requires the opening of existing tank inspection ports, or putting in new ones, and provides a great opportunity to clean the tank and inspect it for corrosion and other damage. Pickup tubes can be installed in the



***Left—**Any diesel tank designed and built without a cleanout/ inspection port does a disservice to the vessel's owner or operator. Diesel tanks—even those with a polishing system—will require cleaning at some point in their lives.* ***Below—**This welding boss has been welded to an inspection port installed on an existing fuel tank, allowing a stand-alone polishing system to be retrofitted in place—without having to weld on board.*

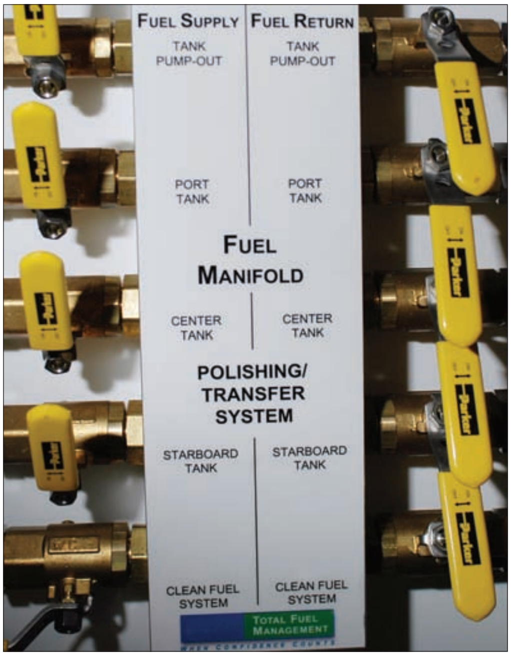
inspection port covers with a device known as a *welding boss*. The welding boss is a threaded fitting into which the pickup or return tube can be screwed. (It's easier to weld these fittings to the inspection port than directly to the fuel tank, which can be difficult and dangerous if the tank is not properly gas-freed.)

Many vessels have multiple fuel tanks. In that case, a polishing system supply-and-return manifold will enable the operator to selectively polish fuel in individual tanks, or to move fuel from one tank to another while it's being polished. Multiple tank installations also allow the operator to polish fuel *before* it's consumed.

The design and installation of that manifold can be one of the more costly aspects of a polishing system installation. It must be: large enough to avoid fuel restrictions; leakproof; and clearly and logically labeled. Suitable manifold materials include steel, stainless steel, bronze, brass, and aluminum. Although copper alloys such as brass and bronze do contribute to fuel oxidation, in this limited quantity such oxidation typically doesn't present much of an issue.

I prefer to plumb polishing systems in particular, and fuel systems in general, with Parker 221FR or equivalent braided steel-reinforced fuel hose and field-assembled brass-threaded insert fittings, or metallic tubing *other than copper*. Avoid materials that are not fuel rated, as well as those that do not meet the American Boat & Yacht Council's two-and-a-half-minute fire-resistance standards. (Note: nearly all plastic or non-metallic plumbing and manifold assemblies, such as those for oil-pumpout systems, fail to meet those standards.) With the correct ports and valves, the manifold may be able to take on fuel from another source, or to offload fuel.

Finally, the manufacturer of the fuel polishing system—the pump, filter, control panel, and manifolds—should warrant this equipment against leakage. The installation, which includes all other plumbing, hoses, valves, and tank fittings, should be similarly warranted against leakage by the installer. Ideally, fuel tanks that have been opened or altered for polishing system installations should be pressure tested in accordance with ABYC and the tank manufacturer's guidelines—*before* they are refilled with fuel.



Manifolds are necessary in multi-tank polishing systems. They must be designed to minimize flow restriction, be leak free (O-rings are preferred over NPT pipe threads), and be clearly labeled.

Safety and Compliance

All plumbing, as well as the overall installation of any fuel polishing system, should comply with ABYC guidelines set forth in Section H-33, "Diesel Fuel System," of the Council's Standards and Technical Information Reports.

Highlights of that section include: the need for proper grounding of all metallic components in contact with fuel; fire resistance of all components in the engine compartment plus some outside of it; properly labeled valves; hose connections equipped with permanent end fittings or at least one metallic hose clamp of a specified band diameter; proper support of fuel lines and valves; and the installation of fuel shutoff valves at every tank fitting or connection.

ABYC's *electrical* guidelines also apply to the pump motor, and control a portion of the installation. I've printed and bound copies of this chapter alone, and handed it to technicians to refer to while laying out and installing fuel and polishing systems—a practice I've put into place for other critical tasks and their relevant ABYC standards.

Operation

Once you have the polishing system in running order, educate the customer or operator about it. Although such systems are relatively hands-off, they do require an understanding of their working principles and maintenance procedures.

On start-up, the filter elements should be fairly coarse—10 to 30 microns. Once the fuel has been turned over through this filter several times, sequentially polish it by switching to a 2-micron element. Monitor the filter vacuum. If it climbs into the red, switch back to a coarser element and continue polishing. Always keep coarse and fine elements aboard.

Under normal circumstances, the fine element will be adequate; but, if a load of heavily contaminated fuel is taken on, it may be necessary to revert to sequential polishing in order to step back down to a fine element.

Vessel owners and operators whose polishing systems function regularly find the practice virtually eliminates the need for replacement of primary and secondary fuel filters. I recommend that the filters be replaced annually, even if they show no signs of contamination.

Costs and Conclusions

A proper, high-capacity, high-quality polishing system professionally installed aboard a vessel with multiple fuel tanks can cost between $10,000 and $40,000, or more. So, do polishing systems pay for themselves?

Well, a thorough manual cleaning of contaminated fuel tanks, along with disposal or filtering of the fuel within, can easily cost half that—and this doesn't even take into account damage that may have occurred to the engine or tanks as a result of the contamination.

More to the point, perhaps, the cost of losing power under way because of contaminated fuel may be incalculable should it happen off a lee shore with poor holding ground on a stormy night, or in a busy shipping channel.

One thing's certain: Anyone who's ever experienced the gut-wrenching feeling of watching an engine's rpm inexplicably fall, only to go below to the engineroom and find a fuel filter full of obsidian ooze, will consider a good polishing system worth its weight in clean diesel fuel many times over. PBB

About the Author: *A former full-service yard manager and longtime technical writer, the author now works with boat builders, owners, and others in the industry as "Steve D'Antonio Marine Consulting LLC." His book on marine systems will be published by McGraw-Hill/International Marine this fall.*