Left—*Though costly compared to a conventional fuel filter, the modern centrifugal separator is compact and efficient, capable of removing tiny particles of debris and water. And, there's no filter element to change.*

Centrifugal Filtration

A variation on century-old dairy separation-technology finds its niche in the engineroom of today's long-range vessel.

Text and photographs by Steve D'Antonio

[Editors Note: Please refer to "So You Think You Know Diesel," page 120, also by Steve D'Antonio.]

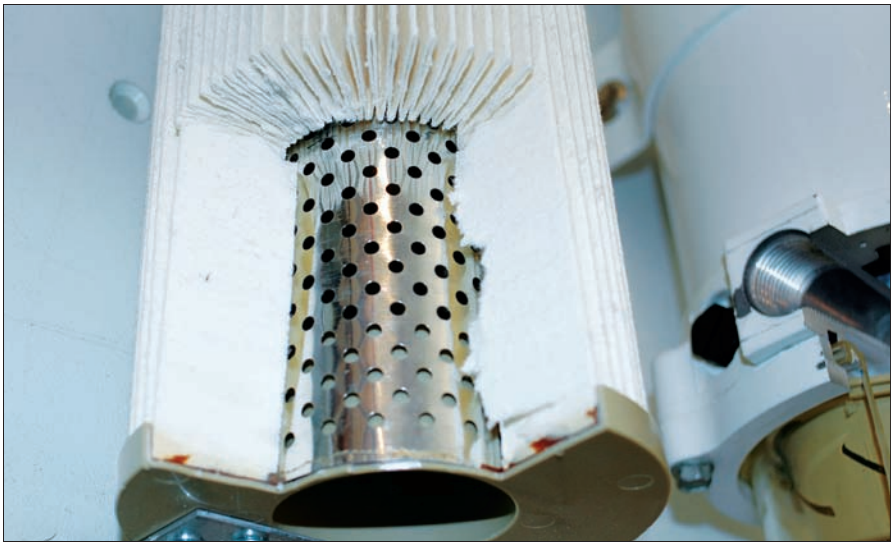
To clean diesel fuel before it reaches a vessel's main engine or generator, many yards take a conventional approach: pass it through various filters made of pleated cellulose or synthetic elements, and a gravity-type water separator.

The element-filter concept is an old one, and over time science has nearly perfected this type of filtration, with most manufacturers claiming 99% or greater efficiency on solids, water, and other contaminants. Given this record, it's hard to imagine there's much room or need for improvement.

Well, today's dominant filter technology may be effective, but it's far from maintenance free. Element filters must be inspected and periodically disassembled and thoroughly cleaned, especially if they're exposed to gross or overwhelming contamination. If they become clogged with asphaltine, biological detritus, or water, they'll do their job by preventing passage of this contaminating matter, along with stopping the flow of fuel, which will cause the engine to surge, behave erratically, or shut down entirely. This isn't a fault. When filters clog, they're performing exactly as they are designed to.

But a qualified improvement over the traditional filter, especially when it comes to polishing or preliminary fuel filtering, is a centrifuge.

Swedish engineer and chemist Carl Gustaf de Laval, though not its inventor, is acknowledged as the father of the modern separating centrifuge. An accomplished inventor in his own right, de Laval worked toward the latter part of the 19th century building high-speed steam turbines with special nozzles of his design (de Laval nozzles), involving reduction gears with lots of lubrication. One challenge he faced: contamination of turbine oil with water in the form of steam. While searching for a reliable, inexpensive method to quickly remove



Traditional pleated-paper fuel-filter elements do a fine job of removing dirt, debris, and water, but there's a limit to their capacity and the volume of fuel they can filter.

water and other contaminants from the oil, he opted for the centrifuge separator principle, a product he'd already improved and developed successfully for other applications.

Interestingly, while de Laval's work with turbines and gear reduction had an impact on the engineering and maritime world—the first steam-turbine yacht, *Turbinia*, sea-trialed in 1894, was for a time the fastest vessel in the world (see *Professional BoatBuilder* No. 113, page 32)—his improvements to the centrifuge went toward less exotic pursuits. In 1878 de Laval patented the first continuous centrifugal milk/cream separator. The Laval dairy separator went on to become an immensely successful product along with his vacuum milking machine, both of which were manufactured under license all over the world. The first commercial application of his centrifuge separator for non-dairy purposes was for processing fish oil, in 1882.

A salad spinner is the most prosaic and clear example of centrifugal force in action. It spins washed greens at high speeds, flinging water out through the holes in the spinning basket, so the salad makings emerge relatively dry. The centrifuge works like an amplifier of gravity. For instance, if you thoroughly mix oil and water, or fine sand and oil, in a blender, the emulsions would remain mixed for quite some time, days or even weeks perhaps. Because of differing densities, they would eventually separate, though not completely. In many cases, a permanent emulsion layer will remain; this is particularly true for liquids such as fuel or lubricating oil and water or coolant. By rapidly spinning this emulsion in a centrifuge, however, the comparatively weak force of gravity that would normally act upon these substances is multiplied several thousand times over. It's not unusual for centrifuges to impart 6,000 times the force of gravity (6,000 g's) on the liquid within while spinning at between 7,000 and 9,000 rpm. By comparison, you might pull 2 or 3 g's when braking or cornering rapidly in an automobile or falling off a large wave while under way in a boat.

Through this enhanced gravitational force, even the smallest particles are slung out of a liquid. Centrifuge manufacturers routinely cite and guarantee particle removal from diesel fuel and light lube oils down to 5 microns, while practical applications suggest particles as small as 0.5 micron are easily removed through a centrifuge's high-speed rotation. Additionally, a centrifuge is capable of separating liquids of different densities such as fuel and water. In many designs, the water is bled off continuously and automatically without requiring any action on the part of the operator.

The rotational energy for nearly

Once a pleated element is packed with contaminants, fuel flow is reduced or stopped; the polishing system is then off line until a new element is installed. Centrifuges can capture and hold a lot of debris without restricting fuel flow. Some require manual cleanout; others are self-cleaning.

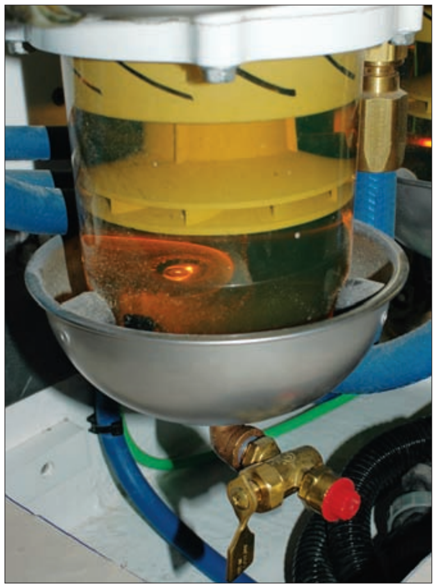
Gross contamination of most conventional paper elements and their filter bodies will bring fuel flow to a halt. In severe cases, even a liberal supply of fuel filters may be quickly depleted.

all centrifugal fuel "separators" (because they lack filter elements, it doesn't seem right to refer to them as filters) is derived from an AC or DC electric motor. Through a gearbox this motor may also operate a feed/discharge pump moving fuel into and out of the centrifuge. In the case of industry-leading Alfa Laval separators, a "water seal" is established inside the centrifuge by *adding* a small quantity of water prior to operation. Because it has a greater density than the fuel, the water creates a seal or dam of sorts that prevents fuel from draining from the separator while it's rotating, but allows water separated from the fuel to drain from the unit.

Most centrifugal separators rely on buffer plates or disc stacks, which further enhance the efficiency of particle and water removal from the fuel (and other fluids). The sinking or slung particles and water molecules strike a cone-shaped disc, which arrests their travel and removes them from the fuel more quickly. Centrifugal force causes these particles and water to migrate to the periphery of the centrifuge's bowl, where the solids adhere to the bowl's surface and the water is pushed out through the water seal. In some models, the solids are also automatically discharged through a "sludge port."

The average fuel centrifuge aboard a moderately sized vessel is roughly the size of a small air-conditioning compressor pallet and weighs between 80 and 150 lbs (36 and 60 kg). It's capable of pumping between 150 and 200 GPH (568 and 757 l). A popular model, the Alfa Laval MIB 303, is at the larger end of these ranges and requires between 450 and 700 watts at 24VDC, 120VAC, or 230VAC. Like most centrifugal separators, it's a hands-off unit: after adding water, you start it and walk away. Water drains automatically, and the bowl needs to be cleaned only when it's full: about a measured cup (0.2 l) of compressed solids.

There's an important distinction that must be made at this stage of our discussion. Quite a few conventional primary-fuel-filter designs advertise, variously, a "cyclone," "turbine," and/or "centrifuge" component that's designed to "spin off *large* particulates and water droplets" (the emphasis is mine). Note that the centrifuge in many primary filters, including those from Racor, Separ, Baldwin, and others, is not a gimmick. It is indeed effective at spinning out *large* particulate debris and water droplets. The speed at which the fuel moves and spins through these *passive* centrifuges, however, imparts a tiny fraction of the g-force of a dedicated, active centrifugal separator. While the filters cited above are effective and desirable components in a primary- and polishing-filter arrangement, as passive centrifuges they are not capable of, nor are they designed to, remove dirt, debris, and water in their single-digit micron or *molecular* form. Thus, despite the word *centrifuge* to describe *one* of the steps such filters employ for water and debris removal, there's little similarity between the



Above—*A gauge that monitors pressure at the clean-fuel outlet of a centrifugal separator will sound an alarm; the feed pump will be turned off if pressure drops beyond a preset limit.*
Right—*Many conventional primary fuel-filter designs include passive centrifuge elements capable of spinning out large particulate debris—but lacking the g-force of a true centrifuge.*

Centrifugal separators like this one (an Alfa Laval MB303) have few moving parts and often operate for thousands of hours with little or no maintenance.

An Alfa Laval separator—installed aboard a 65'/19.8m motoryacht—is plumbed via a manifold to each of the vessel's tanks, and polishes fuel before any is pumped to a day tank.

two processes. They should not be confused.

The last two oceangoing ships I was aboard—the M/V *Endeavour*, a 295′/90m ice-capable expedition cruise ship designed for high-latitude travel (see PBB No. 89, page 16); and the M/V *Ever Renown*, a nearly 1,000′/305m containership—were equipped with centrifugal separators, and with good reason. When you're at sea, cruising far from the nearest port, self-sufficiency is a priority. Centrifugal separators for fuel and lube oil purification, among other things, contribute to that independence, because they require no filter elements, have few moving parts, and are designed to operate continuously for months without service.

Throughout general industry and the scientific community, centrifugal separators are relied on for the purification and separation of all sorts of liquids, from cutting fluids for manufacturing, to wine, beer, and fruit juice processing, to steam-turbine lubricating oil, blood handling, and of course dairy production. Biodiesel refining has also proven to be ideal for centrifugal separation, primarily because it requires the separation of solids from a liquid as well as separation of liquids of differing densities.

Diesel is the fuel so many vessel operators are concerned about (see "So You Think You Know Diesel," page 120). A centrifugal separator/polisher is ideally suited to meet their needs; but centrifugal separators, because of their "active" design, are *not* good primary fuel filters. (For fail-safe primary filtration it's better to rely on something with no moving parts.) Centrifuges work particularly well as polishing system "purifiers" that scrub fuel before it gets to the element filters. They serve this very purpose on the ships I mentioned above, as well as aboard many recreational vessels. The only regular service centrifuges require is periodic replacement of O-rings, and removal of sludge from some models.

So why aren't centrifuges universally adopted in the marine industry? Their price tags. These units require precise machining and robust construction, and, predictably, that comes at a cost. The smallest Alfa Laval separator that would be suited for diesel fuel polishing, the MAB 102B, lists for about $8,500, while the MIB 303 lists for $10,000–$12,750, depending on configuration.

Is it that much better, more effective, and less trouble than a conventional filter to warrant the additional expense? I believe the answer may be yes, depending on the vessel's requirements. Where industrial filtration/separation technology is concerned, centrifuges are the last word in getting dirt and water out with the greatest reliability and least fuss and maintenance. If a vessel is equipped with especially large tanks, or if it's traveling to locations where fuel may be of more questionable quality than usual, or if an owner desires an ultra-reliable and effective polishing system, then the centrifugal separator may be the best approach.

It's worth noting, because these systems are installed primarily in commercial applications like oceangoing ships, and power plants, they are exceptionally long-lived and reliable. Many units are still in service after 30 and, in some cases, 50 years of operation. PBB

A 40-year-old centrifugal separator. It's still going strong aboard an expedition cruise ship that operates from Arctic to Antarctic waters, where fuel filtration is critical but the nearest spare filter-element may be thousands of miles away.

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 marine industry as "Steve D'Antonio Marine Consulting LLC." His book on marine systems will be published by McGraw-Hill/International Marine in 2009.*