BEST PRACTICES

Oil Change Delayed

Bypass oil filtration offers the possibility of significantly extending oil change intervals, but the condition of the oil must be carefully monitored.

Text and photographs by Steve D'Antonio

One ritual and expense of boat maintenance is the regular changing of engine crankcase oil. Few of us in the industry stop to consider whether it is desirable or necessary to drain and replace oil with a frequency strictly determined by the hours on the oil, the months that have passed, or the gallons of fuel burned since the last change. After reviewing hundreds of fluid analysis reports for crankcase oil, I'm convinced that most of the oil removed from the crankcases of recreational vessels is discarded long before it has reached the end of its useful life. Indeed, in the majority of cases I studied, it could have continued to serve quite effectively. In many vessels whose oil is changed prior to off-season storage, the lubricant has accrued fewer than 100 hours of service and is far from worn out. When

__Above—__Bypass oil filtration doesn't replace standard full-flow filtration but simultaneously runs a small percentage of the crankcase oil through a much finer filter, and has the potential to dramatically extend the effective life of the lubricant. This system on a Yanmar diesel is an original factory installation; noted on the filter cartridge are the date, engine hours, and type of oil in the system at the time the oil and filter were replaced.

Oil Additives: Beyond Lubrication

Lubricating oil plays a demanding and variable role in any engine. Its primary mission is to lubricate between moving metal components such as crankshaft and camshaft bearings, piston rings, valve stems, timing chains and gears, as well as hydraulic/electronic unit injector (HEUI) systems and turbocharger shafts. Especially challenging for oil, turbochargers routinely spin at more than 100,000 rpm, and rely on a so-called oil wedge to create separation between the rotating shaft and its bushings. Also, because the turbine operates in the exhaust gas stream, which can be as hot as 1,000°F (538°C), it relies on lubricating oil to carry away some of that compared to over-the-road trucks, which often go 12,000 or more miles (19,312 km) between oil changes, it's clear that many vessels are likely under-utilizing their oil.

For virtually my entire career I've advocated replacing engine oil prior to winter storage, believing that an engine sitting with used, potentially contaminated, acidic oil would be more likely to deteriorate and fail. Then I began conducting regular fluid analyses that revealed the truth about thousands of gallons of oil being dumped into recycling tanks at boatyards across the country every season: often it's not so dirty after all.

Decades ago, some automobile manufacturers recognized this inefficiency and now rely on onboard algorithmic analysis of driving and ambient conditions to alert the driver when the oil is essentially worn out as a "percentage of life remaining." General Motors pioneered this approach, while Mercedes and BMW have taken a slightly different tack with onboard "labs" in the form of small sensors to monitor the oil for contaminants in real time.

To be sure, oil's life span has much to do with specific engine design, type of use, and operating conditions. Extended periods of low-speed, low-load operation, common among displacement power and sailing vessels, along with extended idling and chronically under-loaded generator operation, promote oil degradation. Likewise, exceptionally hard, high-temperature operation, high-turbo rpm, and hydraulic/electronic unit injectors (HEUI) yield similar results for different reasons. But in my experience, most boats that are conscientiously maintained don't come close to maximizing the effective life of their engine oil. Review the oil analysis reports from a sampling of your customers' vessels, and you'll likely find that the oil's condition, sampled when you changed it, doesn't warrant replacement. (For more on oil analysis, see "Lessons from the Oil Sump," *Professional BoatBuilder* No. 143.)

This full-flow oil filter is standard, but its ability to remove contaminants is limited by the volume of oil it must pass—upward of 30 to 50 gallons per minute (114 to 189 l/min)—to meet the engine's lubrication needs.

Regardless of the lab test results, to many boat owners, crew, and yards it seems negligent to break the habit of seasonal or engine-hour-based oil and filter changes. It certainly doesn't harm the boat to change the oil before it's necessary, but it does harm the environment and squanders a finite resource; and it costs time and money to provide the redundant service tasks.

So how is it possible to increase the time between oil changes without endangering the longevity and performance of the engine? Let's start by looking more closely at the variables that determine oil life.

Filtration

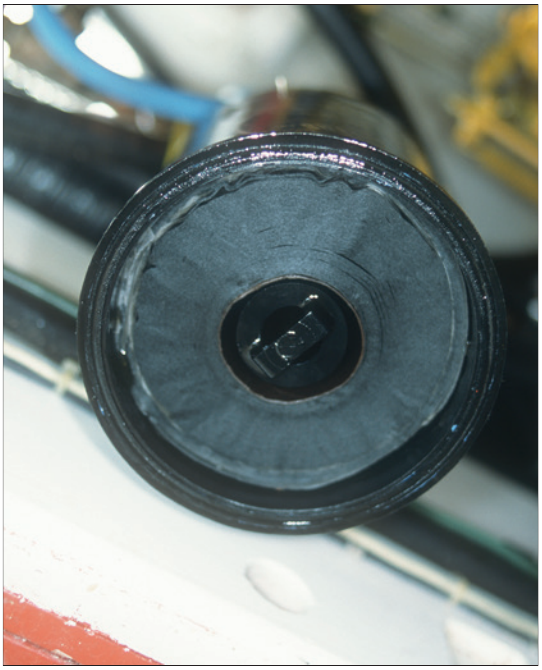
Without filtration, many oil contaminants, particularly metal fragments, would circulate through an engine, impeding oil flow and grinding against moving parts. Fortunately, even the most rudimentary marine diesel engines employ some method of capturing this debris—often a full-flow filter made of pleated paper that filters all the oil as it leaves the engine's oil pump. The challenge is balancing a filter's flow rate, which must match that required by the engine, with the level of filtration it can provide. The typical full-flow oil filter will pass approximately 30 to 50

extreme heat. When the engine is shut down, especially after a hard, high-speed run, the oil surrounding the turbocharger, exhaust valves, and piston rings cooks, undergoing a process known as caramelization, or coking, which substantially diminishes its lubricating properties and often leaves a carbon-based deposit that can be abrasive and impede oil flow.

Lube oil also must remove heat from other critical components such as piston crowns and wrist pins while the engine is running. To that end, many diesel engine pistons have jets that spray oil onto the pistons' undersides, where it absorbs and carries away heat as it flows back to the oil pan. Such extreme heating accelerates the oil's demise.

Many lubrication and oil-analysis experts agree that the four horsemen of the lubricating-oil apocalypse are soot, water, fuel, and glycol. Contamination by soot and water can be dealt with; soot can be neutralized and to some extent filtered, and water cooked off. But fuel and coolant contamination kill your lubricating oil as well as indicate larger failures for the engine overall.

One of lubricating oil's greatest protective roles is its ability to gallons of oil per minute (114 to 189 liters/min). By comparison, the average primary diesel fuel filter, which is often physically larger than an oil filter, may pass between 50 and 100 gal of fuel *per hour* (189 and 379 l/hr). Desired flow rate determines the level of filtration each filter can provide. Oil filters, which must pass comparatively high volumes of oil to provide engines with the lubrication they require, typically operate in the 40-to-80-micron range (a micron is one-millionth of a meter), while fuel filters, which must deliver only the volume of fuel consumed, are typically available from between 2 and 30 microns. This doesn't mean that engine oil won't benefit from finer filtering, but rather, 40–80 microns is as fine a filter as can deliver the flow rates required. It's no secret that better filtering can remove more contaminants from lubricating oil, lengthening its useful service life if flow rates permit. That's where bypass filtration comes in.



This unsophisticated early bypass filtration system employed a standard roll of toilet paper as a filter element.

Bypass Filtration

This process relies on a conventional primary filter that must accommodate the full-flow rate an engine requires, but it adds a secondary, much finer, partial-flow filter. While all the oil still passes through the primary filter, a comparatively

disperse, support, and neutralize common contaminants. Typically these include soot particles; dust, or silica; sodium, or salt; wear metals such as iron, chrome, aluminum, copper, lead, and tin; fuel; water; and glycol, or coolant. Each brand of oil has an additive containing a specific variety of chemicals and metals (comparatively soft ones) to improve lubricity, neutralize acid formation, and reduce wear and foaming. This additive package is often the defining factor that differentiates one brand of oil from another.

Soot and other organic compounds are a powerful detriment to oil's life span. Each and every soot particle ties up oil additives, which neutralize some of its deleterious side effects.

Once the additives are entirely consumed by the volume of soot, chain reactions go unchecked and damage the engine. One of the more destructive oil contaminants is acid, often the result of sulfur contamination mixing with moisture present in the oil or in the air inside the crankcase. Under normal circumstances, even the healthiest engine experiences some blow-by when gases from the combustion chamber above the pistons leak or blow by the piston rings into the crankcase below. Those gases contain a variety of byproducts including water, unburned fuel, and sulfur (all diesel fuel contains some degree of sulfur). Upon reaching the crankcase oil, this caustic cocktail leads to an increase in the oil's total acid number (TAN), a process often referred to as *sulfation*. If acid levels rise too high, polished metal surfaces and bearings can be damaged. To counteract the acid, crankcase oil contains a base additive, which is reflected in its total base number (TBN). Typically, most oils start off with a TBN of somewhere around 10, while anything lower than a TBN of 3 indicates that most of that additive has been taken up by acid contamination, and calls for action—either changing the oil or adding make-up oil.

Oil is also tasked with preventing or reducing the formation of harmful deposits within the engine. If you've ever removed the valve cover cap from an engine and found a sticky, varnish-like, often amber residue, then you've seen this phenomenon. The destructive nature of these deposits cannot be overestimated. They block oil flow at small oil passages and jets, leading to oil starvation, accelerated wear, and ultimately engine failure.

So-called varnish and sludge are produced by nitration and oxidation, wherein organic compounds, when exposed to heat and high pressure while in the presence of nitrogen and oxygen (air), form nitrogen oxides, which cause oil thickening. While additives contained in lubricating oil's additive package will contend with contaminates of this sort to some degree, the oil will eventually be overwhelmed. How quickly this occurs is often a function of operating conditions as well as the engine's design and condition, but once the additives are depleted, the oil will degrade. If the resulting sludge reaches elevated levels before the standard oil change interval, it indicates excessive blow-by, incorrect timing, or an engine that's otherwise out of tune or simply worn out.

The lubricating oil in nearly every diesel engine I've ever owned or worked on turned black, sometimes almost immediately and often after just a few hours of use. As most professionals know, this is completely normal; it is primarily a result of predictable soot production within the combustion chamber, and contamination from oil that remains in the engine after the first oil change.

—*Steve D'Antonio*

***Left**—Not factory original, this bypass filter system, like most, was added after the engine was purchased and installed in a boat. It requires little maintenance save filter replacement, and has serviced thousands of gallons of oil over the years. **Right**—This puraDYN bypass filtration system is fitted with an electrical heating element to promote evaporation of water from oil that regularly circulates at less-than-optimum operating temperature.*

small amount is drawn through the parallel bypass filter at a much reduced flow rate—as little as 6–8 gal/hr (23–31 l/hr)—established by an extremely small orifice that effectively throttles the volume of oil entering the filter.

Reduced flow allows for application of a significantly finer filter media, more like those seen in secondary fuel filtration. Although it varies based on the filter manufacturer, most claim effective removal of particles of 1 micron or smaller. Oil analysis employing particle counting can confirm this. The bypass filter's media surface area is often as large as or larger than that of the full-flow filter's, increasing its ability to capture smaller particles and its capacity to retain contaminants. This ultrafine filtration removes the bulk of the most damaging particles, which means less wear overall.

Soot removal is frequently discussed amongst advocates of bypass filtration. To be clear, soot particles vary in size; many are sub-micron, too small to be captured by a bypass filter. However, as the oil's additive package—a specific blend of chemicals and soft metals added to each brand of oil to improve lubricity, neutralize acid formation, and reduce wear and foaming—is depleted, soot particles tend to agglomerate, forming "clumps" that easily become large enough to be captured by the bypass filter element.

Another related advantage of bypass filtration is the overall increase in oil capacity it adds to the system—a gallon (3.7 l) or more in most cases. More oil means more overall volume, with a proportional increase in the additives available to contend with, neutralize, and retain in suspension contaminants such as soot, nitrates, sulfur, and acid.

Some bypass filtration manufacturers offer filter elements laced with a base additive designed to release slowly into the oil stream—only when heated—to counter acid formation, the most common reason to replace crankcase oil in engines with or without bypass filtration. Also, when the bypass and full-flow filter elements are replaced, additive-rich make-up oil used to fill the replacement filters can reinvigorate the reserved oil's total base number, or TBN (see the **sidebar** on page 24), further prolonging oil life. (Note that analyzing the oil is the only way to confirm such a reversal.)

Bypass filter manufacturers provide element-replacement guidelines. They commonly recommend replacing bypass as well as full-flow filters at intervals in keeping with those specified by the engine manufacturer. The oil should be analyzed when the filters are changed. Eventually, accumulated run time will take its toll, and acid accumulation will drop the TBN to the point that the lubricating oil must be changed to avoid damage to internal engine parts.

Many bypass filtration systems have the additional capacity to address water contamination of lube oil. Some units rely on the claimed ability of the filter media to retain water (though

A Selection of Bypass Filtration Manufacturers

Amsoil: www.amsoil.com.
Gulf Coast Filters: www.gulfcoastfilters.com.
Kleenoil: www.kleenoilusa.com.
Parker Hannifin: www.parker.com.
Puradyn: www.puradyn.com.

one must wonder how much water a filter element can hold, especially if it can't be drained as it can be from a fuel filter), while others rely on an electrically heated evaporation chamber. On boats routinely idled or operated in an under-load condition, the oil frequently fails to warm to its ideal temperature of 160°F (71°C) or higher. Bypass filter heating and/or water removal is desirable in these situations. Units with heating elements (puraDYN, in Boynton Beach, Florida, is the only one I know of that includes this feature) heat the oil to 200°F (93°C), which not only hastens water removal but, it is claimed, also "cooks off" other contaminants such as fuel while pushing the oil into the ideal temperature range. One of the more detrimental side effects of prolonged low-load and idling operation, with oil at lower-than-ideal temperatures, is varnish and sludge formation. Note: While coolant in an idling engine may reach its ideal temperature, oil temperature may remain at less-than-optimal levels.

Installation

Bypass filter installations are relatively simple. Most units have no moving parts, and because of the low flow rate, plumbing is with comparatively small-diameter hose in runs kept as short as possible. Pressurized oil is tapped from an existing port in the engine's oil galley or at the oil-pressure sender fitting. It is plumbed from there to the bypass filter's metering jet, which slows oil flow, typically to a few gallons per hour. Hose for the system should be high pressure, flexible, and no larger than ¼″ (6mm) inside diameter. As oil pressure rarely exceeds 100 psi (0.689 N/mm^2), conventional high-pressure petroleum-rated hose such as the Parker Hannifin, Weatherhead, or Aeroquip armored rated at 3,000 psi (20.7 N/mm^2) is usually specified by the manufacturer.

It's critical to plan installation of all plumbing for a bypass filter so it will be reliable, secure, and out of harm's way. Failure of oil plumbing can lead to rapid and catastrophic engine damage, so expend extra effort to ensure that hoses and fittings in bypass filtration systems are of the highest quality and installed for longevity. Avoid rigid, excessively long, on-engine plumbing-pipe fittings, as they are prone to fatigue failure.

In most cases, manufacturers will supply or recommend installing a shutoff valve at the high-pressure oil supply to the filter. This should be turned off if a leak develops in the filter or filter plumbing. Because the bypass system is installed in parallel with the existing full-flow filter, the former can be taken off-line at any time with no immediate detrimental side effects.

I have never encountered an engine manufacturer who indicated that installing a bypass oil filtration system would call into question warranty coverage. Unless it could be demonstrated that the bypass filtration system caused the failure (if the filter plumbing failed and disgorged all the oil, for instance), the consumer is protected by the Magnuson-Moss Warranty Act, which also prevents engine manufacturers from insisting you use their brand of oil and filters to maintain your warranty. It's worth noting that some engine manufacturers offer engines with bypass filtration from the factory, either standard or as an option.

In Practice

A long-term testing program by the U.S. Department of Energy, designed to evaluate bypass filtration, offers some interesting insights and confirmation of its efficacy. Tests were conducted on a fleet of diesel-powered buses and a handful of gasoline-powered sport utility vehicles used by the Idaho National Laboratory with more than 1 million miles (1,609,344 km) between them. Oil in the vehicles was routinely analyzed, and with the exception of engine malfunctions (none of which was oil related), the oil was found to be sound at the end of each scheduled service interval. Bypass filtration enabled the vehicles to avoid 90% of their scheduled oil changes. In nearly all cases, when oil ultimately needed to be replaced, it was the result of excessively low TBN, oxidation, and nitration.

Another test carried out by Parker

Appropriately sized standard bypass system filters can be installed for almost any type of engine. Plumbing to the system must be robust, with the highest-quality fittings, and installed securely to avoid failures that could threaten the engine. A shutoff valve at the high-pressure supply side of the filter is good protection should a leak develop in the bypass plumbing.

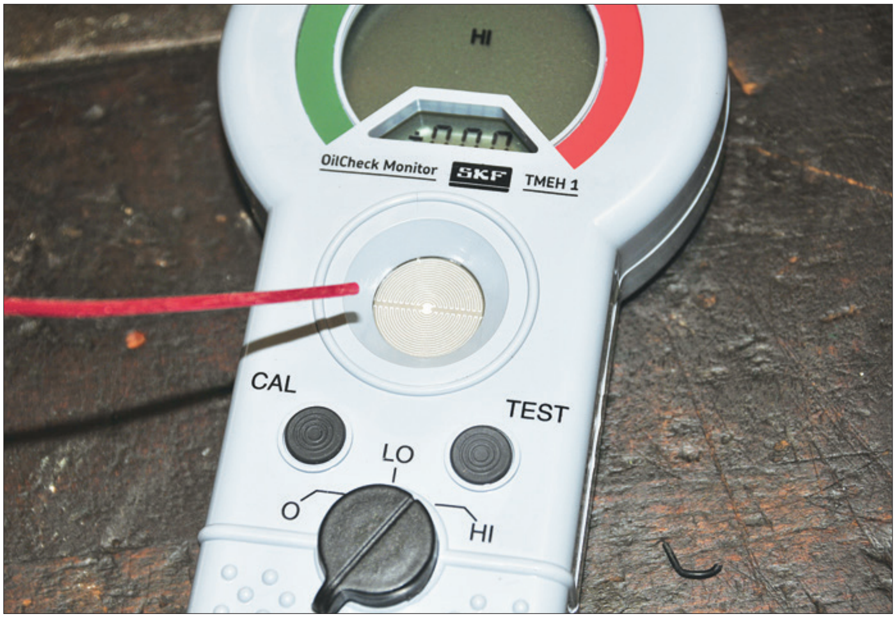
Hannifin, a bypass filtration manufacturer, involved installing its system on an over-the-road truck. Purely for test purposes, and contrary to the instructions provided by most bypass filtration system manufacturers, the oil in this vehicle was not changed at the time of the installation. Subsequent tests counting debris particles indicated that the oil became *cleaner*, up to a point, as it remained in use with the bypass filtration system. That's not surprising per se; it's similar to what might happen as contaminated fuel is filtered through a fine-element fuel-polishing system. Still, it clearly indicates the value of 1-micron filters in bypass systems for engines that had relied on conventional 50-to-80-micron filtration.

Condition-Based Maintenance

A key to successful bypass filtration is routine oil analysis. If they fail to do it, those looking to extend oil drain intervals are flying blind. Most bypass filtration manufacturers predicate their warranty on regular oil analysis carried out at standard drain and filter-replacement intervals. Some manufacturers include a built-in analysis drain valve. These, like all proprietary oil-analysis valves, are designed to draw samples from the engine's pressurized oil loop while the engine is running. This technique, common in many industrial applications, eliminates the need for vacuum pumps and suction hose, and provides the best possible oil samples and the least likelihood of contamination, regardless of whether bypass filtration is employed. This is important, because in my experience, improper sampling technique is the leading cause of anomalous oil-analysis results.

Those who opt for bypass filtration to extend oil life must also adopt a comprehensive oil analysis program to ensure the oil is, among other things, not depleted of the additives that control acidity.

The goal of oil analysis in all cases, and especially in bypass filtration and extended drain intervals, is to alert the



This field oil-analysis tool is particularly useful in remote locations where sending in samples for testing is impossible. While it can't match the capabilities of a full laboratory, the tool can comparatively assess used crankcase oil relative to a sample of the same variety of new oil. ***Left—****The sensor pad is washed with solvent prior to a test.* ***Right—****A sample of used oil on the sensor pad is tested.*

user to the state of additive metals, TBN, wear metals, liquids such as glycol and fuel, and accumulation of soot/solid contamination. As long as the parameters of the oil remain within acceptable boundaries, the oil can continue in service. Ideally, the lab you choose for such regular testing should be familiar with bypass filtration and some of the peculiarities it may present. Most labs are familiar with bypass filtration, and their analysis questionnaires request information about filter type and micron ratings. If the engine is equipped with a bypass filter, it's very important that these details be noted on the sample questionnaire.

For those who wish to benefit from extended oil-drain intervals while operating their boats in remote locales, getting samples to the laboratory can be impossible. While field analyzers are no substitute for full-blown scientific fluid analysis, they are available. I've tried one and appreciate its strengths and weaknesses. Regrettably, it does not give an analysis of the contaminants or their levels in a given sample. Instead, using conductance it provides a comparison between two samples—new oil and used, for instance. Think of it as the automotive dashboard warning light for the condition of the engine's oil; it's not sophisticated, but it can alert you to major discrepancies.

When installing a bypass filtration system, it also makes sense to switch to synthetic crankcase oil. Traditionally, with the comparatively few hours placed on many recreational marine diesel engines, the cost of synthetic oil, even in light of the benefits it provides, has been difficult to justify. However, because of its extended life span and resistance to oxidation and viscosity breakdown, synthetic oil makes good sense in bypass filtration systems.

One might well now ask: Is bypass filtration worth the effort and expense? Before answering that question, let me put engine failures in perspective. In most cases, internally lubricated parts—bearings, bushings, guides, etc.—fail only after thousands of hours of use. While these failures may be rare, they are nearly always catastrophic and costly to repair. So, my answer is yes, even if you choose not to take full advantage of the extended drain interval it affords. Once again, bypass filtration provides a belt-and-suspenders approach to oil filtration that for a relatively small investment ensures engine longevity and reliability. PBB

***About the Author:** For many years a full-service yard manager, Steve now works with boat builders and owners and others in the industry as "Steve D'Antonio Marine Consulting." He is the technical editor of* Professional BoatBuilder, *and is writing a book on marine systems, to be published by McGraw-Hill/International Marine.*