

Marine

Regular maintenance of marine diesel engines is key to more uptime and lower life-cycle costs

Modern marine diesel engines have a higher power-to-weight ratio, more performance

Modern marine diesel engines have a higher power-to-weight ratio and provide more performance and fuel economy with lower emissions than ever before. With maintenance schedules optimized by trending analysis, these engines can also deliver the lowest life-cycle costs, greater uptime and exceptional reliability. Here are the essential factors to include in any marine diesel maintenance program.

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Since the invention of the diesel engine more than 100 years ago, these prime movers have found wide application in marine propulsion. They quickly became known for their low operating costs and high reliability. Now, over a century later, marine diesel engines play an even larger part in powering sea-going ships, working boats of every description and a variety of pleasure craft. While modern engines still operate on the same basic compression-ignition principle that the first diesels did, new electronic engine controls, emissions systems, and fuel- and air-delivery systems have vastly changed the engines' overall performance for the better.

The dramatic improvements in power density, fuel economy, exhaust emissions, throttle response and performance have also caused a shift in the way modern marine diesel engines need to be maintained. Whereas older, more primitive diesels were fairly uncomplicated

workhorses that required little more than regular oil changes, they were also smelly, dirty, noisy and fuel-hungry and had relatively poor performance for their size and weight.

Modern marine diesel engines are more complex and require more maintenance than in the past, but they also deliver superior performance, better fuel economy, low emissions and higher reliability. It has been a good tradeoff. Uptime, as it turns out, is more critical today than ever before, because downtime can be very costly to an operator who faces income losses or performance penalties when his boat is unavailable. An unscheduled repair is no longer merely an inconvenience; it is now a financial liability. This emergence of downtime as a financial risk has required a change from the "fix-as-fail" philosophy of the past to the "maintain-to-avoid-failure" mentality that is required today.

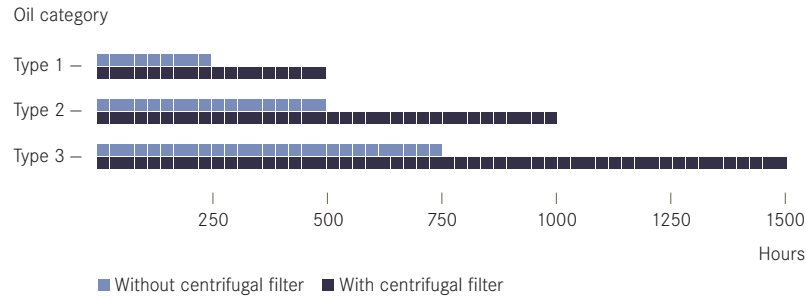
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Oil drain intervals (Fig. 1)

Regular lubricating oil changes are perhaps the most important factor affecting engine durability. To reduce costs without increasing engine wear, use higher quality Type 2 or Type 3 oil in conjunction with an optional centrifugal oil filter to extend oil change intervals.



Note: Recommended oil drain intervals when using diesel fuels with < 0.5% sulfur content. The proper oil drain intervals must be confirmed by means of oil analysis.

For the greatest uptime, it is important to do maintenance on a regular basis rather than with a haphazard or fix-as-fail approach. By utilizing normal downtime periods, maintenance can be done without affecting vessel availability.

Optimizing maintenance with trending analysis

Engine manufacturers tend to recommend maintenance schedules based on typical or average duty cycles or patterns of use. However, duty cycles may vary widely from “average” depending on the type of boat and the application, and this can affect maintenance.

For example, ferries tend to operate at high power for extended periods, followed by periods of idling during loading and unloading. Tugs pushing barges upriver operate for extended periods at high power, while harbor tugs tend to have more intermittent duty cycles. Each pattern of use can increase or decrease the amount of maintenance needed compared with the recommended amount. The ideal way to gauge how to adjust maintenance schedules to match usage is through trending analysis.

Trending analysis involves sampling, testing and record-keeping in order to forecast when certain maintenance activities should be performed. It's a way of optimizing costly maintenance procedures to save money, save time and accurately predict when more expensive repairs may be conveniently scheduled. As this article discusses the various types of required maintenance procedures, it will also discuss how trending analysis can be used to optimize schedules in order to save time and money without compromising reliability.

MAINTENANCE CATEGORIES

Marine diesel maintenance procedures can be grouped into nine broad categories:

1. *Lubrication* – checking levels; changing oil, oil filters; performing oil sampling for trending analysis to optimize oil change intervals and to detect engine wear.
2. *Fuel system* – changing fuel filters, fuel injectors; checking water separators; and doing fuel quality analysis to make sure fuel contains proper lubricants and additives.
3. *Cooling system* – fluid level checks; coolant sampling for trending analysis; draining, flushing and refilling the system when required.
4. *Air intake system* – inspecting and changing air filters; inspecting the turbocharger to make sure there is no fouling of the compressor blades from crankcase gases.
5. *Exhaust system* – inspecting for leaks, corrosion, wet stacking.
6. *Valves and heads* – inspecting, adjusting and recording of valve train wear for trending analysis; inspecting and recording of cylinder head wear for trending analysis.
7. *Emissions systems* – inspecting crankcase ventilation systems, selective catalytic reduction (SCR) systems and diesel particulate filters (if so equipped).
8. *Mechanical systems* – inspecting resilient engine mounts and torsional couplings; general inspecting for leaks, wear or deterioration.
9. *Operating systems* – downloading data from digital engine management system (EMS) to note and review alarm conditions.

Next, we'll look at each of these maintenance categories in more detail and make recommendations on ways to economize through trending analysis.

1. Lubrication maintenance

Regular lubricating oil changes are perhaps the most important factor in engine durability, and the cost of doing them can add up. Most marine engine operators are looking for ways to extend oil change intervals in order to reduce costs of material and labor and eliminate downtime.

A typical large ferry with twin 65-liter engines will require 100 gallons of lubricating oil at about \$15 a gallon every 250 hours of operation. If the ferry operates 10 hours per day using standard, Type-1 oil, it will require an oil change every 25 days at a cost of \$1,500 just for oil. Filters and labor would be extra. Some manufacturers are able to increase oil change intervals to 500 hours with Type-1 oil by installing a larger oil sump, but that tends to increase oil disposal costs. The same thing can be accomplished by switching to higher-quality Type 2 oil, cutting materials, labor and disposal costs almost in half.

Some marine diesel engines come equipped with centrifugal oil filters, which can extend oil change intervals to 1,500 hours when using Type-3 oil, cutting the cost of materials and labor by approximately 70 to 80 percent. See Figure 1. By extending oil change intervals, operators also greatly reduce the hassle and disposal costs associated with waste oil and used filters.

Oil change intervals may be extended even further with the help of regular oil sampling and trending analysis. Oil samples can be taken regularly and sent to a lab for testing and analysis. The oil will be analyzed for contaminants such as water, soot, coolant and metals. Over time, these samples will reveal a trend as to how quickly the oil is aging or the engine is wearing. If the trend shows that the oil and engine are wearing faster than normal for that application, then the oil change interval can be shortened to minimize engine wear. Conversely, if the trending shows less than normal wear, the oil change interval may be extended without undue risk, thereby reducing costs further. Services that analyze lube oil samples

are inexpensive compared to oil changes and usually pay for themselves in savings. (As a general caveat, it is best to always follow the engine manufacturer's recommended oil change intervals to avoid invalidating the warranty.)

2. Fuel system maintenance

Beyond simply changing fuel filters when they get plugged, most vessel owners are unaccustomed to having to do fuel system maintenance on modern marine diesel engines with common rail fuel injection systems. In general, fuel injectors are usually designed to last for the life of the engine. However, there are several reasons why fuel systems now need regular attention.

In order to increase performance and reduce exhaust emissions in modern diesel engines, there have been significant changes to both the fuel and the fuel delivery systems that affect maintenance. For example, to reduce exhaust emissions and prevent contamination of any catalytic aftertreatment systems, the sulfur content of diesel fuel has been drastically reduced from 500 parts per million for on-highway low-sulfur diesel (LSD) to 15 parts per million in ultra-low-sulfur diesel fuel (ULSD) now mandated in many jurisdictions. While lowering the sulfur content of the fuel is good for the air, it significantly reduces the lubricating properties that are inherent in higher-sulfur diesel fuel. As a consequence, fuel pumps, fuel injectors and valves may be subjected to higher rates of wear when using ULSD. To compensate for the missing sulfur, most ULSD now contains a lubricating additive. Vessel operators should always inquire about the quality of the fuel they are receiving.

In addition to the fuel being more abrasive, fuel injection pressures are higher than ever before in order to improve combustion efficiency and reduce emissions in the exhaust. Injection pressures have increased from 1,000 bar (14,500 pounds per square inch) to about 1,800 bar (26,100 pounds per square inch). This puts higher stresses on the injectors and makes them subject to higher wear.



1.

Workboats play a critical role in ship handling and towing, and regular engine maintenance is a key to maximum uptime and performance.

2.

Regular engine maintenance ensures that maximum power is available when it is most needed.

1.

Oil and filter change intervals can be extended by using high-grade oils, centrifugal oil filters and doing regular oil analysis.

2.

On electronic engines, regularly download and review critical engine parameters and alarm conditions to get an early warning of potential problems.

3.

High reliability, low fuel consumption and long engine life are all results of regular marine engine maintenance.



Since the injectors on the latest engines play such a critical role in combustion efficiency and emissions reduction, manufacturers are recommending that the injectors be changed out after 4,500 to 12,000 hours of operation, depending on the engine rating and application. This is because manufacturers of the most advanced engines need to certify that the engine will meet EPA emissions requirements for a certain period of time. The only real way to insure emissions compliance, therefore, is to recommend that the injectors be changed out sooner than in the past.

3. Cooling system

Cooling systems have always been a critical issue for marine engines, but they have become even more important with the advent of modern clean diesels. Today it's not just a matter of checking the coolant level; the coolant itself needs to be chemically monitored and analyzed to make sure it is functioning efficiently. Proper operation of the cooling system is needed to ensure long engine life, fuel economy and low exhaust emissions.

Changes to the combustion process to control exhaust emissions can increase the amount of heat rejection in modern diesels, and this may create greater temperature differentials across the heat exchanger. The high differentials caused by 45 degree F sea water and 180 degree F coolant can cause silicates to drop out of the coolant and deposit on internal surfaces, reducing heat transfer and degrading the lubricating and cooling properties of the coolant.

Other stresses to the coolant come from the exotic metals that are used in today's modern engines, such as iron, aluminum, titanium and copper-nickel. Dissimilar metals increase galvanic corrosion opportunities unless the coolant is maintained at the right pH with the right blend of inhibitors. The same issues are present in the charge-air coolers that are used to cool the pressurized air from the turbochargers and densify the oxygen that improves combustion. Here, temperature differentials are even higher, with charge-air temperatures upwards of 300 degrees F going across the charge-air cooler.

To make sure that the coolant is operating at top efficiency, it needs to be properly tested annually. Coolant samples should be sent to a laboratory to check the pH, identify any metals or salts that are present, and to evaluate the condition of the lubricants and corrosion inhibitors. Testing kits are readily available from your engine manufacturer.

4. Air intake system

To ensure the best possible fuel efficiency, always replace air filters at the manufacturer's recommended intervals. Frequent inspection of the condition of the filters between changes is also important to make sure they are not being contaminated by oil mist from a leaky crankcase or soot from leaks in the exhaust system feeding back into the engine compartment.

Turbochargers are another part of the air intake system, and it is always best to follow the manufacturer's recommendations for inspection, repair or replacement. Turbochargers typically last to mid-life on marine engines – about 15,000 hours – but this varies with each engine and application. In engines with closed crankcase breather systems, watch for possible oil and soot contamination of the compressor blades or the charge-air cooler. Buildup on the compressor turbocharger's blades can slow it down and restrict airflow to the engine, resulting in reduced power and increased fuel consumption. When turbochargers do wear out, they are usually replaced rather than rebuilt because rebuilding requires the vessel to be out of service longer.

5. Exhaust system

During initial engine installation, make sure that the routing of the exhaust system prevents the exhaust from re-entering the engine compartment during operation. If not properly routed, soot can build up on engine room surfaces and clog air filters prematurely. On a regular basis, check for cracks, leaks or corrosion in the entire exhaust system and make necessary repairs.

6. Valves and heads

Valves need adjusting periodically to compensate for the wear that occurs in the valve train. In new engines, the amount of adjustment necessary will be higher until the valves seat in. Traditionally, the valve lash has been adjusted based on a go, no-go test using a feeler gauge. If a valve

clearance was found to be out of compliance, the valve lash was adjusted without ever knowing what the exact amount of wear had been.

Again, here is where trending can help reduce maintenance costs. With today's high costs of labor and downtime, the recommended method is to test early in an engine's life and actually measure the amount of wear on each lifter and record it. Over time, the operator will accumulate a record of how each valve is wearing, allowing a very accurate prediction to be made as to when valves will need to be adjusted in the future.

Trending can also be used to determine wear in cylinder heads. For example, remove a few heads just prior to the recommended change interval to identify any abnormalities and to measure and record the distance the valve head has receded into the cylinder heads. Note whether this is more or less than anticipated. By measuring and recording cylinder-head wear, the operator will be able to predict the rate of head wear in that engine and more accurately schedule future maintenance when it is most convenient.

7. Emissions systems

For most marine applications, the emissions system that requires attention is the crankcase ventilation system. More common on workboats, engines with open crankcase systems all pass some lube oil and combustion gasses into the engine room space, potentially resulting in the plugging of the engine's air filters. Dirty air filters will lead to higher fuel consumption, higher operating temperatures and shorter engine life.

The most advanced marine engines today have closed crankcase ventilation systems that prevent contamination of the engine compartment by capturing oil mist and combustion products from the crankcase. While these closed systems require some maintenance to change filters, they eliminate spills and avoid pollution fines, and result in a much cleaner engine compartment.

8. Mechanical systems

In every vessel, the force generated by the engines propelling the boat forward must be ultimately borne by the engine mounts – the connection between the engine and the boat's hull. These engine mounts are either solid or resilient, and are under intense strain and vibration. Each type should be inspected annually for deterioration of the rubber, loose fasteners or cracks in the castings or studs and replaced if necessary.

Another mechanical system that needs attention is the torsional coupling. These devices are mounted between the marine transmission and the engine's flywheel and help dissipate mechanical shock and stress in the form of heat. Some are fluid couplings, and some just rely on resilient components. During operation, these devices are subjected to heat, fluids and vibration. Since none of these devices ages consistently, it is important to inspect them frequently for wear, cracks or deterioration.



The MTU Ironmen Series 4000 marine engine features a high power-to-weight ratio and advanced common rail fuel injection for the ultimate in fuel economy and throttle response. Its compact design ensures maximum engine room workability, and its low noise and vibration improve crew comfort. With easily accessible components, the MTU Ironmen Series 4000 marine engines are designed for fast and easy maintenance.

9. Operating system

The engine management system (EMS) in today's modern electronically controlled marine diesel engine doesn't require any maintenance. However, it can provide valuable data about the engine that can aid in optimizing and scheduling maintenance procedures. At least once a year, download the data from the EMS and go over any alarm history and the load profile recording. This will tell the operator how the vessel is actually being used and allow comparison with expectations. When done within the first six months on a new engine, the data download can provide important trending information. Most vessels today have Global Positioning Systems (GPS) and devices that track engine rpm and speed, but the EMS data can add many more parameters to help optimize the vessel's operation and maintenance.

CONCLUSION

Modern marine diesel engines require more attention to maintenance than the unregulated workhorses of the past, but the payoffs are better fuel efficiency, more power and performance, higher reliability and cleaner air and water. Workboat operators have to determine the value of uptime to their particular operation and then work with their marine engine distributor to optimize a maintenance schedule that works for their application.

The best way to optimize maintenance is to tailor maintenance tasks to the specific engine/application through the use of trending. By undertaking activities such as analyzing oil and coolant samples, inspecting a few engine components early and recording the wear in the valve train during valve lash adjustments, problems can be identified early. Or, if there is less wear than expected, maintenance intervals may be extended to save time and money without compromising reliability. Regularly scheduled maintenance – optimized through trending analysis – is the surest way of maximizing vessel availability, ensuring reliable performance and minimizing life-cycle costs.

ABOUT MTU

MTU is an off-highway diesel engine manufacturer with more than a century of global experience in producing durable, high-performance diesel engines for industrial and commercial applications. MTU is one of the world's most important providers of diesel engines and propulsion systems for ships, ferries, tugs, river push boats and offshore oil support vessels. Its marine power solutions include the famous Series 60 (425 to 800 bhp), the Series 2000 (540 to 2,000 bhp) and the Series 4000 (940 to 4,690 bhp), all with industry-leading performance, endurance and economy. For higher horsepower needs, MTU also offers the Series 8000 engine, which produces up to 12,200 bhp at 1150 rpm. Sales and service are handled through 25 authorized distributors throughout North America, including a new sales and service center for the Gulf Coast, located in St. Rose, Louisiana.

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