Editorial: Engine Room Fire; Lessons Learned – Feature: Compression and Leak-Down Testing

From the Masthead

Engine Room Fire; Lessons Learned

Of all the tragedies that can befall a vessel, fire is, in my opinion, the most catastrophic. Flooding and sinking of course represent emergencies, however, the crew can at least take to life boats or rafts, or even swim for it if necessary. Where fire is concerned, flame and smoke can make escape impossible, thereby dooming those aboard to a hot, smokey or watery grave. Additionally, fires frequently spread with astonishing rapidity, taking many by surprise, thwarting efforts to extinguish them, while cutting off escape routes.

When a serious maritime casualty occurs within the US and its territorial waters, or aboard a US flagged vessel (or aircraft), the National Transportation Safety Board (NTSB) is tasked with the investigation, to determine the cause, and to offer recommendations for prevention of similar events; in their own words, “The National Transportation Safety Board is an independent federal agency charged by Congress with investigating every civil aviation accident in the United States and significant events in the other modes of transportation—railroad, transit, highway, marine, pipeline, and commercial space. We determine the probable causes of the accidents and events we investigate and issue safety recommendations aimed at preventing future occurrences”.

If you have a curious mind, and you are a gearhead, casualty investigation reports generated by the NTSB can make for both fascinating and illuminating reading; and those involving marine losses are of particular interest to me, as there are nearly always lessons to be learned, ones that I can apply in my work as a consultant.

In the case of this casualty, there were thankfully no deaths, and only one injury to a crew member; there was no flooding. The vessel was, however, seriously damaged and the financial loss significant.

In October of 2023, the 300-foot excursion cruise vessel Ocean Navigator, while moored at the Ocean Gateway Terminal in Portland, Maine, experienced a fire in the engine room, one which caused an estimated $2.4 million in damage.

The fire originated in on of the vessel’s two 1000 hp diesel generators, both of which were powered by CAT 3516B engines.

The vessels 3rd engineer and a motorman were in the process of investigating high exhaust temperature alarms on one of the vessel’s engines when they noticed a minor oil leak on the one running generator, appearing to come from a loose bolt on a crankcase access plate. They retrieved tools to tighten the bolt. After sitting down next to the engine to begin work, the initial event occurred. From the report, “The third engineer and the motorman went to the ECR [engine control room] to get tools to tighten the bolt and then returned to the inboard side of the no. 2 auxiliary engine. According to the third engineer, as soon as they sat beside the engine, at about 0710, 'it exploded, and fire immediately spread across and above the generator.' Once inside the ECR, the third engineer noticed that the motorman's coveralls were on fire. The third engineer stated that he 'tried to put out the fire on [the motorman's] coverall' before they ran up to deck 1 to the ship's hospital to receive first aid from the ship's doctor." The motorman received burns to approximately 40% of his body.

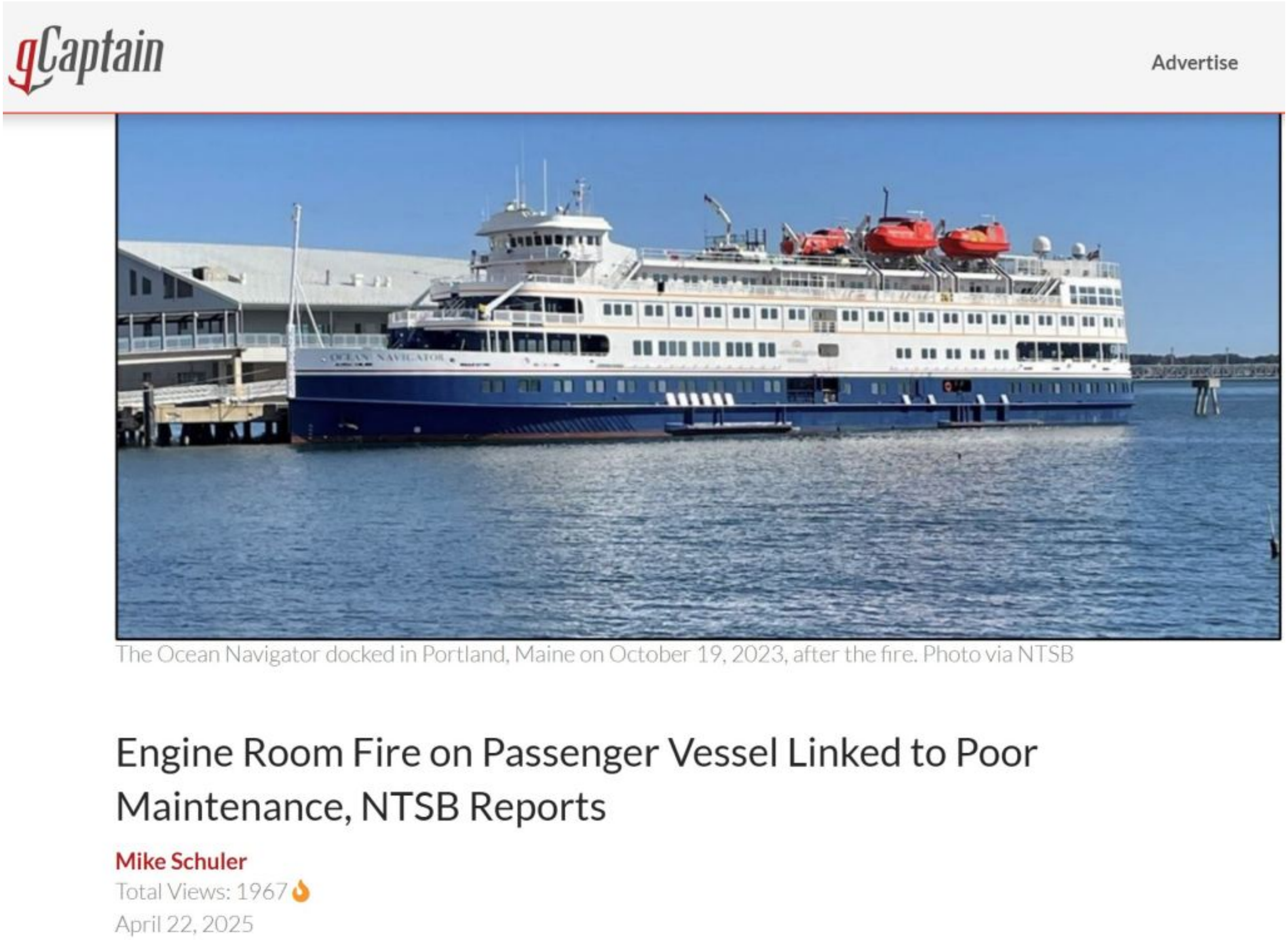
The crew reacted quickly and appropriately, "The chief engineer closed the quick-closing valves to the engines (stopping fuel supply to them), and the fire team shut down all ventilation fans, *fire dampers*, and watertight and fire screen doors, and prepared fire hoses", (the italics are mine, this is a valuable feature on any engine room's ventilation inlets) This action starved the fire of oxygen, which extinguished it; the fixed fire fighting system was not activated.

Investigators later determined the curious chain of events that caused the catastrophic engine failure and subsequent fire. The engine was damaged beyond repair, "Investigators noted a hole about 10 inches high and 16 inches wide on the inboard side of the engine block in the area of the nos. 12 and 14 cylinders where the lower portion of the no. 13 connecting rod had been ejected".

The engine utilized a deep sump which had a capacity of 213 gallons of lube oil, and the vessel was equipped with a centrifugal lube oil purifier, which was used to purify oil in each of the vessels four engines (two propulsion and two genset, all of which used identical CAT 3516Bs).

Caterpillars extended lube oil drain interval calls for an oil change, "every 1,000 hours of operation, *unless analyzed using their proprietary oil analysis program* (italics are mine)".

Further investigation revealed that the vessel’s crew had last changed the entire quantity of lube oil for the casualty generator about 13 months before the failure, however, the engine had operated more than 5,000 hours with this lube oil in the engine (while the oil filters had over 3,000 hours on them), exceeding the manufacturer’s recommendation by five times.



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The Ocean Navigator docked in Portland, Maine on October 19, 2023, after the fire. Photo via NTSB

Engine Room Fire on Passenger Vessel Linked to Poor Maintenance, NTSB Reports

Mike Schuler

Total Views: 1967

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Failing to change oil within an engine manufacturer’s prescribed interval leads to fire and injury.

Ultimately it was determined that this failure was the result of debris entrained in the lube oil system, “possibly due to the crew exceeding manufacturer recommended intervals for changing the lube oil and oil filter elements—which caused catastrophic mechanical damage to the engine.” I believe the NTSB was being generous with its use of the word “possibly”.

There are two morals to this story. One, follow the equipment manufacturer's maintenance instructions. Two, be prepared for onboard fires with a firefighting protocol. The crew's quick action to deprive the fire of air likely saved the vessel. The complete NTSB report can be accessed here.

This month's Marine Systems Excellence eMagazine feature covers the subject of engine cylinder compression, and leak down testing. I hope you find it both useful and interesting.

Compression and Leak-Down Testing

A manometer is a tool that can be used to measure crankcase pressure, which in turn is an indication of the condition of the engine's piston rings and cylinder walls.

A mechanic tells you your engine is "worn out" and needs to be rebuilt, or replaced, but how can you quantify what he or she is telling you? Definitively determining the condition or health of your engine is anything but subjective, unsurprisingly all that's required are the right tools and the requisite knowledge for their proper use.

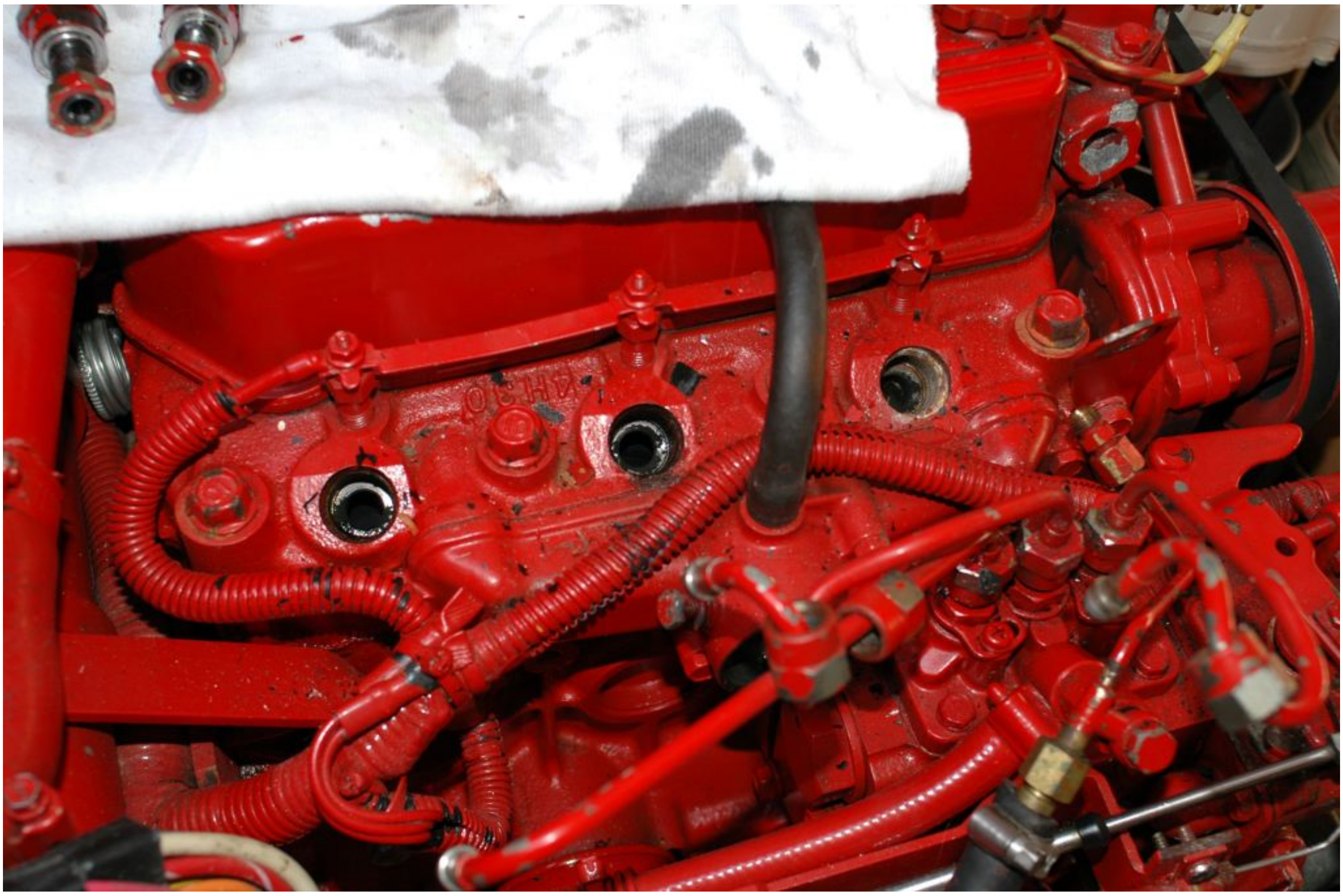
Any internal combustion engine relies on compression of a gas, air or a fuel/air mixture, created by a reduction of cylinder volume, which occurs as a result of each piston's upward movement. In both gasoline and diesel engines the expansion of that compressed gas in an "explosion", or more accurately a controlled burn, of the fuel and air is what generates a pistons' reciprocal motion or "power stroke", which is then transformed to rotational energy via a crankshaft, and ultimately propulsion via the flywheel and it's connection to the reverse gear or transmission. In order for this system to work efficiently, the seal established between the moving pistons and cylinder walls is vitally important, and it's no small feat as all the parts are very hot metal, moving at high speed, over the course of tens of thousands of linear feet/meters, over thousands of hours of running time.

While this process is critical for any engine, it's especially important in diesel engines, as they rely on heat generated by very high compression (a function of Boyle's Law, as the air is compressed its temperature increases, in this case dramatically) to ignite fuel that's injected into the cylinder. It's why diesels are sometimes referred to as "CI" or compression ignition engines.

Because the cylinder pressure in a diesel engine is much

higher than a gasoline engine, the tools used to measure compression are different. Here, both diesel (in the gray metal box) and gasoline (in the red plastic box) compression tool kits are shown.

Testing the compression that is generated in either gasoline or diesel engines is relatively straight forward, and doing so can provide a picture of the condition of the cylinder, piston, rings, exhaust and intake valves. The first and simplest test relies on an aptly-named compression tester. This is inserted into, and in place of, the hole where a spark plug, glow plug or injector would be located. The engine's ignition and fuel system are then disabled to prevent it from starting during the test. Once that's done, the engine is cranked or turned through several revolutions using the starter, and the pressure generated by the piston is recorded by the gauge. The pressure readings are then compared to those provided by the engine manufacturer for a "healthy" engine.



A compression test requires the removal of injectors (or glow plugs if present) on a diesel engine, and spark plugs on a gasoline engine.

While the compression test is valuable, it can only provide a pass or fail grade, it’s unable to provide details or clues as to where the fault may lie, and how serious it may be. Enter the leak-down tester; this device is similar to the compression tester in that it is plugged into the cylinder via one of the aforementioned ports, however, instead of using the engine’s rotation to generate pressure, it utilizes an external compressed air source, typically a shop compressor, which is pumped into the cylinder. The tool is equipped with two gauges, one measuring the pressure of air available to the cylinder and another which measures air pressure maintained within the cylinder (for this reason the tool is sometimes referred to as a differential leak-down tester). The amount of leakage is a direct indication of wear or damage within the cylinder, however, the areas from where the air leaks out of the cylinder can tell a mechanic a great deal about what needs to be done to fix the problem.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Differential leak down test tools are used to help narrow down the source of compression leakage. The engine does not need to be turned over for this test, however, a steady source of compressed air is required.

Air leaking from the intake or exhaust manifolds indicates worn respective valves or seats, which is comparatively easy to repair in that it only requires cylinder head removal, while air leaking from the crankcase vent often foretells something more ominous, worn or damaged piston rings or scored cylinder walls (leakage at the piston rings, known as blow-by, is a subject that will be covered next month), which in turn requires major disassembly, and a likely engine rebuild or replacement.

These tools, in the hands of those who understand how to use them, and interpret their results, remove much of the guesswork from engine diagnostics.