Issued May 9, 2023 MIR-23-08

Diesel Generator Engine Failure on board Offshore Supply Vessel *Ocean Guardian*

On May 27, 2022, about 1435, the offshore supply vessel *Ocean Guardian* was conducting sea trials in Shilshole Bay near Seattle, Washington, when its no. 3 main diesel generator engine suffered a mechanical failure that resulted in a fire in the engine room.[1] The crew extinguished the fire before it could spread throughout the vessel. There were no injuries reported for the 22 crewmembers and contractors on board, and there was no pollution reported. Damage to the *Ocean Guardian* totaled an estimated $1.1 million.

Figure 1. *Ocean Guardian* before the casualty. (Source: Stabbert Maritime Group)

[1] (a) In this report, all times are Pacific daylight time, and, unless otherwise noted, all miles are nautical miles (1.15 statute miles). (b) Visit ntsb.gov to find additional information in the public docket for this NTSB accident investigation (case no. DCA22FM021). Use the CAROL Query to search investigations.

Casualty type	Machinery Damage
Location	Shilshole Bay, Seattle, Washington 47°41.2′ N, 122°25.2′ W
Date	May 27, 2022
Time	1435 Pacific daylight time (coordinated universal time –7 hrs)
Persons on board	22
Injuries	None
Property damage	$1.1 million est.
Environmental damage	None
Weather	Visibility 10 nm, overcast, winds southwest 14 kts, air temperature 61°F
Waterway information	Bay, depth near the casualty about 100 ft

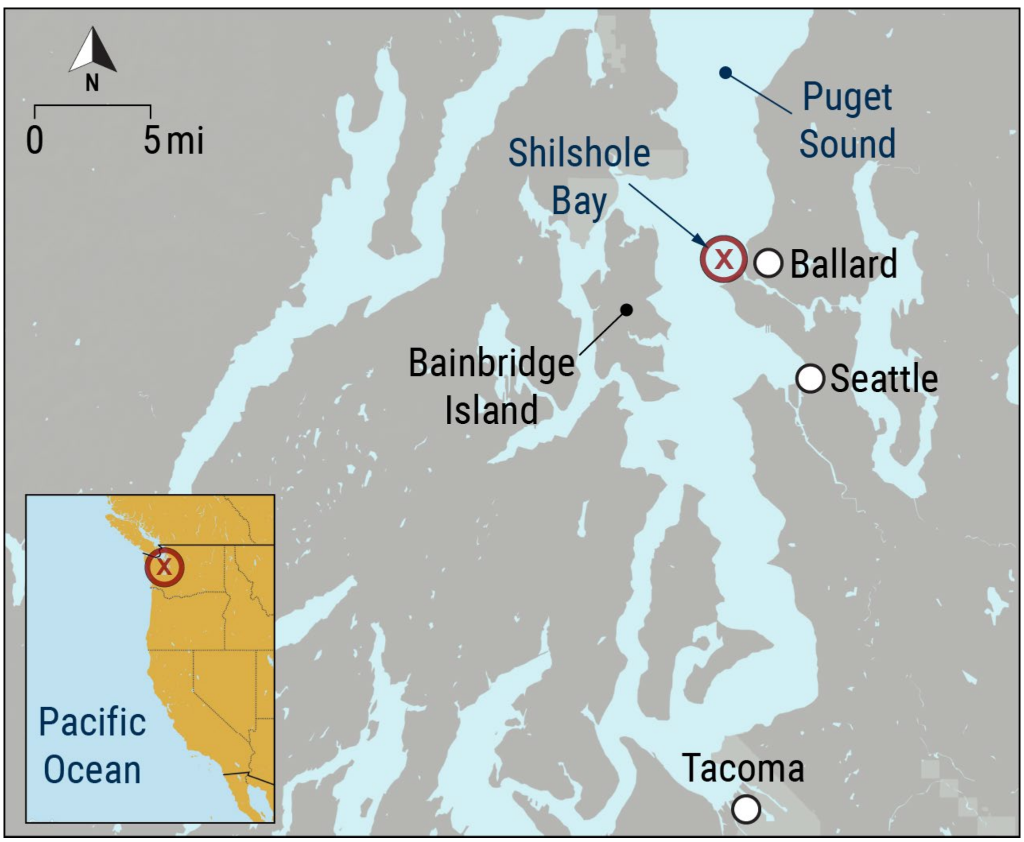

Figure 2. Area where the diesel generator engine failed aboard the *Ocean Guardian*, as indicated by a red *X*. (Background source: Google Maps)

1. Factual Information

1.1 Background

The *Ocean Guardian,* a 260.8-foot-long, steel-hulled offshore supply vessel, was built in 2003 as the *Ken C. Tamblyn*. In March 2020, the vessel was purchased by Ocean Guardian Holding and renamed *Ocean Guardian*; the vessel was operated by Stabbert Maritime Group. The multi-service vessel was designed to carry goods, supplies, personnel, and equipment to support offshore energy operations. The *Ocean Guardian* was powered by four Caterpillar model 3516B 16-cylinder diesel-engine-driven main generators, each producing 2,669 hp. The main generators supplied electrical power for both propulsion motors and the electrical system for other vessel services. For electrical power while moored, the vessel was equipped with a 496-hp auxiliary diesel-engine-driven generator. Two 2,200-hp azimuthing stern thrusters (360° rotatable pods) provided the vessel with propulsion, supplemented during maneuvering operations with two bow thrusters (one tunnel and one retractable azimuthing unit). The vessel was outfitted with a dynamic positioning system, which allowed the vessel to hold station when operational.

1.2 Event Sequence

In August 2021, the *Ocean Guardian* arrived at the operating company's shipyard in Ballard, Washington, near Seattle, for maintenance. During the maintenance period, a shelter deck was added over the aft working deck, two cranes and an A-frame were installed, and additional accommodation spaces were added to the vessel. In January and February 2022, local factory-trained technicians conducted maintenance on all four main diesel generator engines, including top-end overhauls and bearing inspections and replacements as necessary.

In May 2022, the crew performed operational tests of the engines and propulsion control systems at reduced loads while the vessel was moored. In order to perform full function tests of these systems at underway operational loads, the vessel needed to operate in open waters. The operating company scheduled a sea trial during the week of May 23 to test the vessel's engines, propulsion systems, and automatic power management system to ensure proper operation.

On the morning of May 27, the captain held a safety meeting with the 22 crewmembers and contractors aboard and discussed details about the sea trial, including muster locations and responsibilities in the event of an emergency. At 1145, because the vessel's propulsion system had not been fully function tested, two tugboats towed the *Ocean Guardian* away from the shipyard and out of the harbor through the Ballard Locks to Shilshole Bay for the sea trial. About 1245, the captain released the tugboats and requested that one of the tugboats remain nearby to "shadow" the *Ocean Guardian*; the other returned to port.

About 1400, the crew began the trials by testing the functionality of the two bow thrusters. After successful operation of both thrusters, the two stern thrusters were slowly loaded up to about 75% of rated power each. As the electrical load increased on the diesel generators, the crew tested the automatic power management system by setting up selected engines to automatically start, stop, and share the electrical load. The chief engineer stated that the engines were loaded to about 60% of their rated output throughout the trials.

At 1435, with the two stern thrusters about 75% load, and the no. 3 main engine about 30% load, the engineering crew in the engine control room (ECR) heard a "large bang" and observed smoke in the engine room through the ECR window. An engineer in the engine room saw flames near the no. 3 main engine and stated they "looked to engulf most of the engine." Crewmembers on the bridge witnessed "heavy smoke from the stack area." According to the crew, up until this point, there had been no abnormal alarms observed on the engine monitoring system. The no. 3 main engine had been operational for about 4 hours in total since the January-February overhaul.

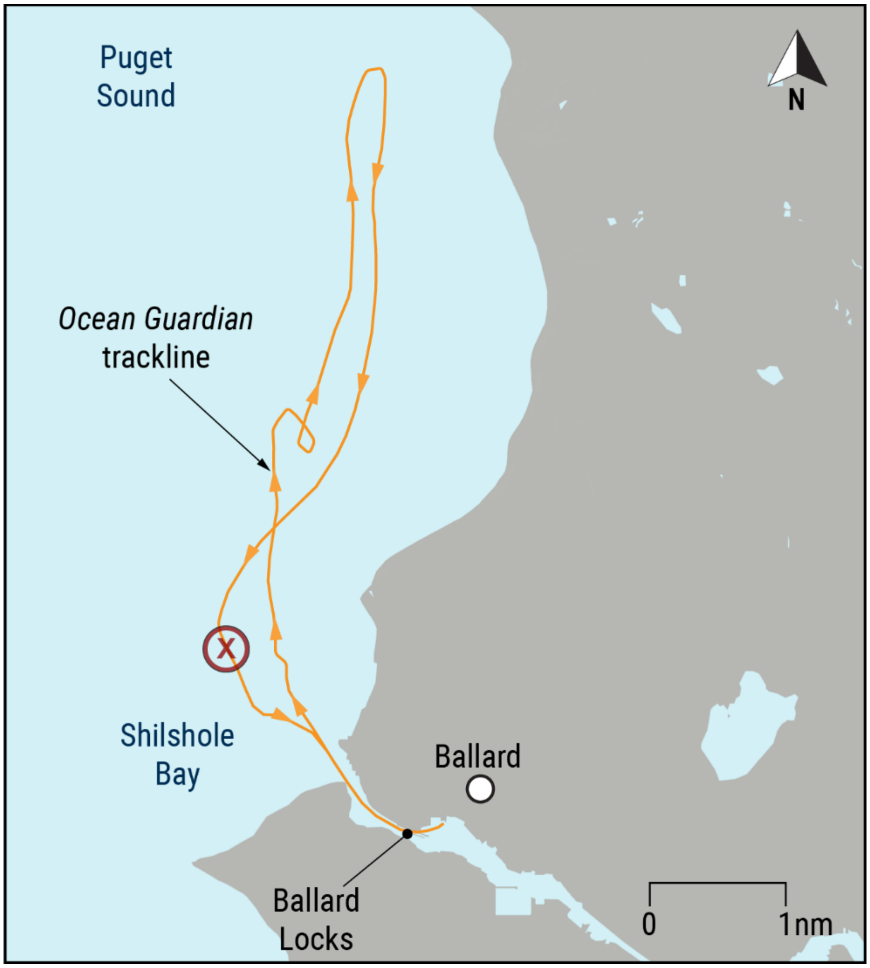

Figure 3. *Ocean Guardian* trackline during sea trials. The area where the vessel's diesel generator engine failed is indicated by a red *X*. (Background source: Google Maps; Trackline source: *Ocean Guardian* electronic charting system)

The chief engineer activated the emergency remote stops to shut down the nos. 3 and 4 main engines from the ECR and reported the fire to the captain. The captain used remote emergency stop switches on the bridge to shut down engine room ventilation fans, close their corresponding dampers, and shut down the fuel supply valves for the engines. Engine room crewmembers evacuated the engine spaces, and after confirming that they had all exited, the captain closed the watertight doors remotely. About a minute later, the chief engineer activated the emergency stops for the nos. 1 and 2 main engines from the ECR.

With all main engines stopped, the vessel lost propulsion and electrical power. The emergency generator started automatically and restored power to the critical electrical systems it supplied. The captain called the two tugboats that had towed the vessel to Shilshole Bay (one had remained to shadow the *Ocean Guardian* and the other had returned to port) for assistance. The second mate mustered and accounted for all crewmembers and contractors. Two fire teams (each with two crewmembers) dressed out in firefighting gear, and the remaining crewmembers gathered multiple fire extinguishers from locations on the vessel and delivered them to the scene.

At 1440, after consulting with the captain, the chief engineer activated the vessel's carbon dioxide (CO^2) fixed fire-extinguishing system to discharge all 28 bottles of CO^2 into the engine room. At 1445, the shadowing tugboat arrived alongside the *Ocean Guardian*, and a bridle was affixed to the offshore supply vessel. In order to check the effectiveness of the CO^2 and look for spot fires, two crewmembers using self-contained breathing apparatus (SCBAs) entered the engine room and observed smoldering fires near the no. 3 main engine. The crewmembers reported the fires to the bridge and extinguished them using handheld fire extinguishers and a bucket of water.

The captain notified the company of the situation. At 1509, the captain and chief engineer declared that the fire was out. The chief engineer inspected the area near the engine and found a crankcase door had been ejected from the engine block and part of the engine block had been "sheared away."

By 1624, both tugs had lines to the *Ocean Guardian*, and about 1630, they began towing the vessel back to the shipyard. Over the next couple hours, crewmembers re-entered the engine room in SCBAs to monitor temperatures of the no. 3 main engine using an infrared thermometer and look for reflashes. At 1658, they found a smoldering fire below the deck plates near the no. 3 main engine and dumped a container of aqueous film forming foam concentrate to extinguish the fire in the bilge. Crewmembers continued to monitor the temperature of the no. 3 main engine and engine room bulkheads and reported that these temperatures declined after the fire was extinguished.

The captain notified Seattle Vessel Traffic Services that he was returning to port. He stated that he did not advise Vessel Traffic Services or Seattle Fire Department of the fire because he did not think it was warranted since temperatures were dropping, boundaries were effective, no other flash fires were reported, and he felt that "everything appeared to be under control."

At 1752, the *Ocean Guardian* was moored alongside the company's shipyard in Ballard. The crew performed roving watches throughout the next several days.

1.3 Additional Information

1.3.1 Damage

As a result of the mechanical failure and ruptured engine block, the no. 3 main engine was damaged beyond repair. The engine block, crankshaft, two connecting rods, counterweights, and other parts of the rotating assembly were damaged. Local service technicians and crewmembers removed the damaged engine from the vessel and replaced it with a spare.

Figure 4. Damage to the crankcase and connecting rod of no. 3 diesel engine (*left*) and engine (*right*).

The area in the engine room around and above the no. 3 main engine sustained smoke and heat damage. Wiring harnesses on the remaining engines, electrical cables, lighting fixtures, walkways, and control cables in the engine room required replacements.

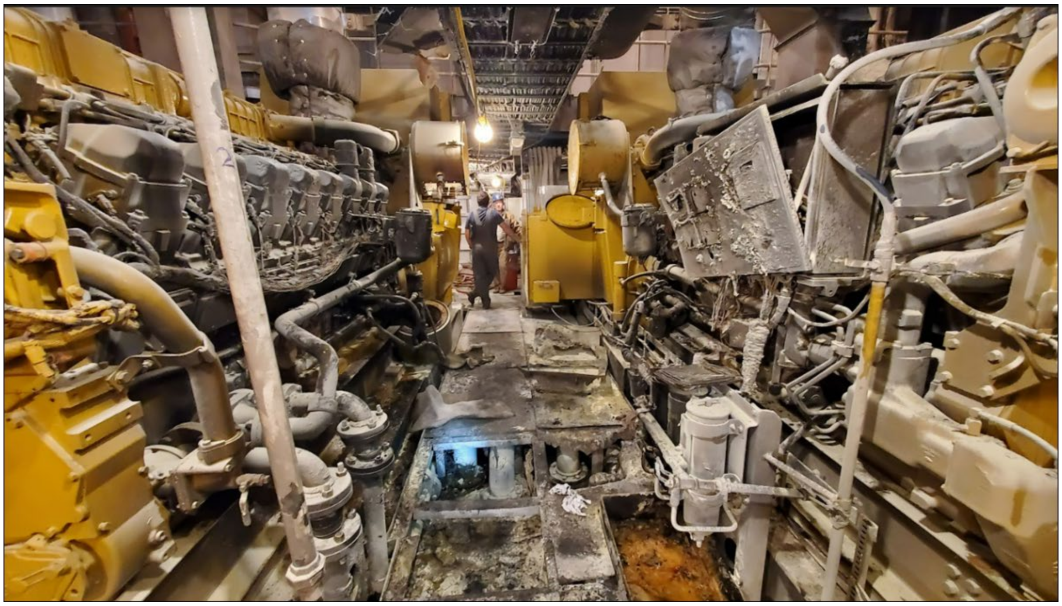

Figure 5. The walkway between the nos. 3 and 4 main engines after the engine failure (looking forward).

1.3.2 Previous Engine Maintenance

When the *Ocean Guardian* was purchased in March 2020, the operating company was provided with limited maintenance records. Attempts by investigators to locate comprehensive vessel engine maintenance histories from the previous owner were unsuccessful.

Each of the Caterpillar 3516B engines aboard the *Ocean Guardian* had 16 cylinders, 9 main bearings, and 16 connecting rod bearings. The connecting rod bearings for transverse cylinder pairs received lubricating oil from the main bearing through a drilled passage located between the two.

At some unknown time before March 2020, the surfaces of the main bearing journals (also referred to as the crankpin) of the crankshaft on the no. 3 main engine had been machined down (cut or shaped on a machine) to a smaller diameter. Machining crankshaft journal surfaces is a standard, accepted practice for this type of engine to repair damaged or worn journals. To smooth a damaged or worn surface, the crankshaft is typically removed from the engine and placed onto a specialized grinding machine. The outer circumference layer of the journal is ground away to a specific dimension and then polished. After the journals have been machined down to a smaller diameter, undersized bearings are used to maintain proper lube oil flow through the bearings. An undersized bearing has the same outer diameter, but it has a smaller inner diameter, which faces the journal, to account for the decreased diameter of the machined crankshaft journal surface.

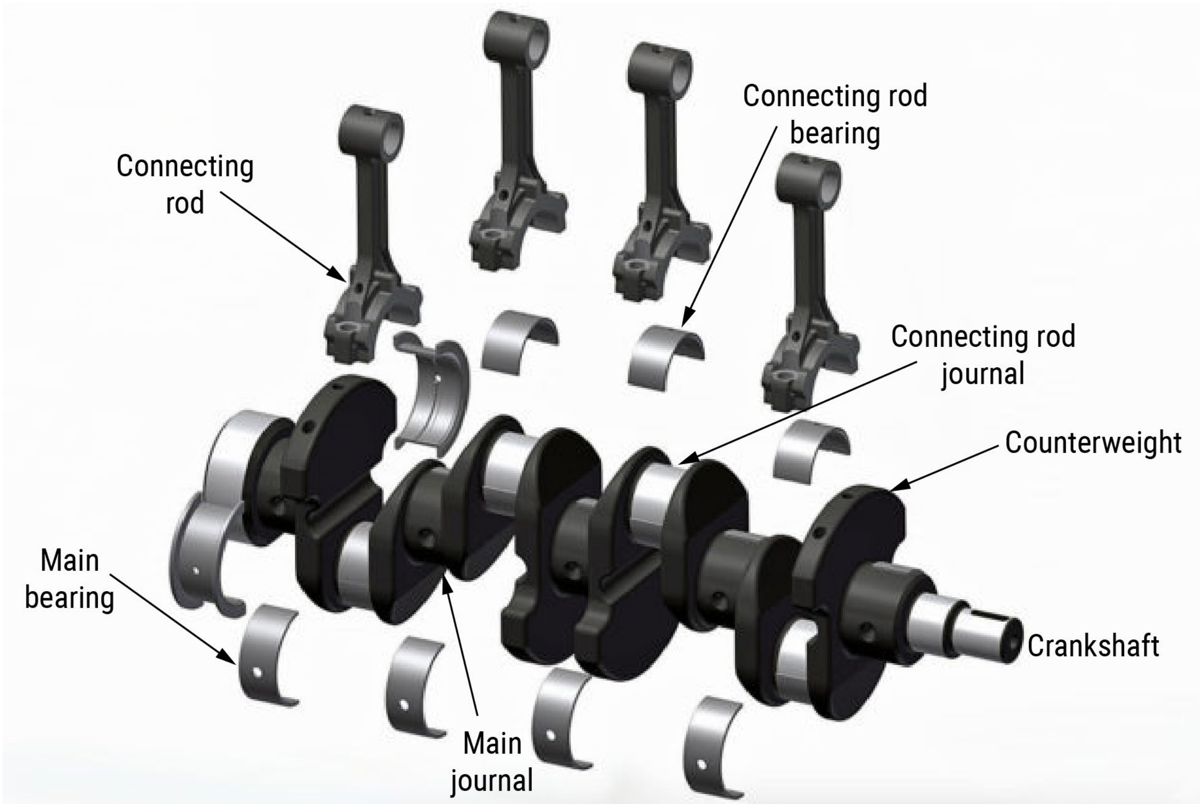

Figure 5. Typical components of a diesel engine crankshaft (not a Caterpillar 3516B). (Background source: enginelabs.com)

The machining reduced the diameter of the crankshaft main bearing journals on the *Ocean Guardian* by 0.63 millimeters (0.025 inches) from an original diameter of 160 millimeters (6.2992 inches) to 159.37 millimeters (6.2744 inches), and undersized bearings (with a smaller inner diameter) were installed. These measurements corresponded with allowable dimensions from Caterpillar, who had a document that detailed two possible journal modifications and corresponding undersized bearing part numbers to be ordered and installed. The *Ocean Guardian*'s local service managers and technicians stated that their normal practice when machining main bearing journals of a crankshaft was to also machine the connecting rod bearing journals throughout the engine at the same time, and vice versa when machining the connecting rod bearing journal surfaces.

Neither the operating company (Stabbert) nor the service technicians received records of this crankshaft main journal and connecting rod journal machining. According to the local service managers, the part number of each bearing could be identified on the side of the bearing shell (see figure below). According to service managers, without removing the crankshaft from the engine, a main journal could not be measured to otherwise determine if it had been modified.

Figure 6. Part number on a typical Caterpillar main bearing. (Source: Stabbert Maritime)

During the January–February 2022 servicing of the no. 3 main engine, service technicians removed and inspected the no. 11 connecting rod bearing. According to the service report, the bearing "did not meet [Caterpillar] specs" and failed inspection, requiring all 16 connecting rod bearings to be replaced. The connecting rod journal surfaces had not been machined down and were fitted with standard-sized bearings. Caterpillar original equipment manufacturer replacement bearings were not available for 85 days, so aftermarket bearings were purchased, delivered 2 weeks later, and installed.

During the same maintenance period, a service technician removed and inspected the no. 6 main bearing on the no. 3 main engine. The technician, who had nearly 10 years of experience, found the bearing was marginal and therefore did not require the remaining main bearings on the no. 3 main engine to be replaced. The technicians did not notate the part number nor the condition of the removed no. 6 main bearing on the service report. According to the local service managers, since all the connecting rod bearings on the no. 3 main engine had been standard sized, the main bearings would be expected also be standard sized, as was normal practice when the journals are machined.

The service company's typical procedure was to replace any bearing removed for inspection with a new bearing, regardless of its condition, to prevent any alignment or torque issues with a previously used part. After removing the no. 6 main bearing, the technician ordered a standard-sized replacement Caterpillar bearing (the bearing ordered was not an undersized bearing with an equivalent inner diameter of the one removed).

After the *Ocean Guardian* received the standard-sized main bearing, a technician who had not previously been involved in the engine overhaul arrived and installed it on the no. 3 main engine. There was no report associated with this service.

1.3.3 Engine Failure Report Findings

After the engine failure, the damaged no. 3 main engine was removed from the vessel and shipped to a Caterpillar service facility, where factory-trained representatives and an independent engineer conducted a forensic teardown to document the condition of the engine's various components and develop a failure investigation report.

According to the local service company's failure investigation report, the engine failed due to a lack of lubrication to the nos. 9 and 10 connecting rod journal bearings. The failure sequence began while the engine was running. The incorrect sizing of the no. 6 main bearing shell allowed lube oil to leak from the larger clearances of the bearing, decreasing lube oil supply pressure to the adjacent nos. 9 and 10 connecting rod journal bearings (which were fed from a cross-drilled galley from the no. 6 main journal bearing) by about 80%. The temperature of the nos. 9 and 10 connecting rod bearings increased rapidly due to the lack of lubrication. Bolts on the nos. 9 and 10 connecting rod bearing caps "overheated, annealed, and fractured." The nos. 9 and 10 connecting rods, bearing caps, and fractured bolts freely moved about the engine block as the engine kept rotating. The report stated that "random collisions amongst the flying parts of the two damaged reciprocating mechanisms (nos. 9 and 10) collided chaotically, damaging everything in the vicinity, blowing open the inspection cover, venting hot oil and blowby gas from the damaged piston above."

1.3.4 Postcasualty Actions

Following the engine failure aboard the *Ocean Guardian*, the vessel's operating company stated that they planned to affix metal plates to each Caterpillar engine in their fleet indicating the status of the main and connecting rod bearing journal diameter sizes and identifying the part numbers of the bearing shells that were installed on each of any machined surfaces. The local Caterpillar service company switched to a new service tracking system to enable the use of technicians' cell phones to upload pictures and reports to improve documentation and sharing information between technicians.

2. Analysis

The offshore supply vessel *Ocean Guardian* was conducting sea trials in Shilshole Bay, when its no. 3 diesel generator engine experienced a catastrophic mechanical failure while at 30% of its maximum load. The engine had operated about 4 hours since being recently overhauled. Internal engine components broke free from the rotating mechanism and struck and ruptured the engine block, allowing hot pressurized oil and gas to be released into the engine room which ignited and started a fire in the engine room.

The crew's response to the fire was timely and effective. They quickly stopped the running engines, isolated all fuel supplies, shut down engine room ventilation systems, and closed the space's air dampers and watertight doors to effectively starve the fire of fuel and oxygen, which prevented its spread. Additionally, activation of the vessel's CO^2 fixed fire-extinguishing system effectively diminished and smothered the fire. After the fire was extinguished, the crew monitored the declining temperatures of the no. 3 main engine as well as the bulkheads surrounding the engine room. Tugboats quickly returned to the *Ocean Guardian* after the captain called for help to hold the vessel's position, ensuring the vessel did not drift as the crew worked to suppress the fire.

Following a postcasualty forensic teardown of the no. 3 main engine by factory-trained technicians, forensic reports indicated that, at an unknown time before March 2020 (when the vessel was purchased by the current operating company), the main bearing journal surfaces of the crankshaft on the no. 3 main engine had been machined down such that each journal's diameter was reduced about 0.63 millimeters (0.025 inches). As a result, undersized bearings with a smaller inner diameter were installed.

During the *Ocean Guardian*'s most recent maintenance period immediately before the engine failure, service technicians identified a standard-sized connecting rod bearing on the no. 3 main engine that did not meet the service company's specifications and, in accordance with their policy, replaced all 16 connecting rod bearings with standard-sized bearings. The service technicians also removed and inspected the no. 6 main bearing.

Because none of the connecting rod bearings they replaced had been machined, the service technicians used standard-sized bearings to replace the main bearing, since it was the service company's expectation that both main bearing journals and connecting rod bearing journals would be machined at the same time.

Due to the impracticality of removing the crankshaft, the only accurate method of determining the diameter of the main bearing journals (without maintenance records) would have been to visually identify and record the part number on the bearing that was removed from the engine. However, there was no record of the main bearing's part number in the service technician's notes; therefore, the technician likely did not identify and record the part number.

The service company's standard practice was to replace any removed bearings with new bearings, so a new standard-sized bearing was ordered and installed. The no. 6 main bearing's incorrect size allowed lube oil to leak from the larger clearances of the bearing, thus decreasing the lube oil supply pressure to the adjacent nos. 9 and 10 connecting rod journal bearings (as was reported in the postcasualty forensic reports). The loss of lube oil supply pressure resulted in a rapid temperature increase of the connecting bearings and subsequent fracturing of the bearing cap bolts on the nos. 9 and 10 connecting rods. As a result, several engine components broke free while the engine was running. These components were strewn about the crankcase, blew open the inspection cover and part of the engine block, and allowed hot oil and gas to start a fire in the engine room.

3. Conclusions

3.1 Probable Cause

The National Transportation Safety Board determines that the probable cause of the mechanical failure of the no. 3 main engine and resulting fire aboard the offshore supply vessel *Ocean Guardian* was the replacement of a crankshaft main bearing with an incorrectly sized bearing during an engine overhaul due to the engine service technicians not identifying the removed bearing's part number, which resulted in the loss of lube oil pressure in adjacent connecting rod bearings.

3.2 Lessons Learned

Ensuring Correct Replacement Parts

When maintenance is performed, correct replacement of machinery components is critical to ensuring safe and reliable vessel operation. Vessel crews and equipment manufacturer technicians should carefully identify and document part numbers of all components removed from shipboard equipment. Tracking systems are an effective form of recordkeeping that can be used to ensure proper replacement part selection for reinstallation.

Vessel	**Ocean Guardian**
Type	Offshore (Offshore supply vessel)
Owner/Operator	Ocean Guardian Holding, LLC / Stabbert Maritime Group (Commercial)
Flag	United States
Port of registry	Seattle, Washington
Year built	2003
Official number (US)	9272060
IMO number	1134805
Classification society	American Bureau of Shipping
Length (overall)	260.8 ft (79.5 m)
Breadth (max.)	60 ft (18.3 m)
Draft (accident)	14.7 ft (4.5 m)
Tonnage	3,183 GT ITC
Engine power; manufacturer	4 x 2,669 hp (1,990 kW); Caterpillar 3516B diesel engines

NTSB investigators worked closely with our counterparts from **Coast Guard Sector Seattle** throughout this investigation.

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