Issued December 2, 2021

MAB-21/26

Diesel Generator Engine Failure aboard Offshore Supply Vessel *Ocean Intervention*

At 1303 local time on December 19, 2020, the no. 3 diesel generator engine aboard the *Ocean Intervention* suffered a mechanical failure while the offshore supply vessel was anchored off Honolulu, Hawaii.[1] The failure led to the ejection of components from the engine and resulted in a fire in the engine room. The crew isolated the fire before it could spread throughout the vessel. No pollution or injury to the 16 crewmembers on board was reported. Damage to the *Ocean Intervention* totaled $3,046,624.

Figure 1. *Ocean Intervention* under way before the accident. (Source: Oceaneering International, Inc.)

[1] (a) In this report, all times are Hawaii standard time, and 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. DCA21FM012). Use the CAROL Query to search investigations.

Accident type	Hull/Machinery/Equipment Damage
Location	Anchorage B, Mamala Bay, Honolulu, Hawaii 21°17.1′ N, 157°54.5′ W
Date	December 19, 2020
Time	1303 Hawaii standard time (coordinated universal time –10 hrs)
Persons on board	16
Injuries	None
Property damage	$3,046,624
Environmental damage	None
Weather	Visibility 10 nm, scattered clouds, winds east-northeast 23 kts, gusts 30 kts, air temperature 84°F
Waterway information	Bay, depth 60 ft

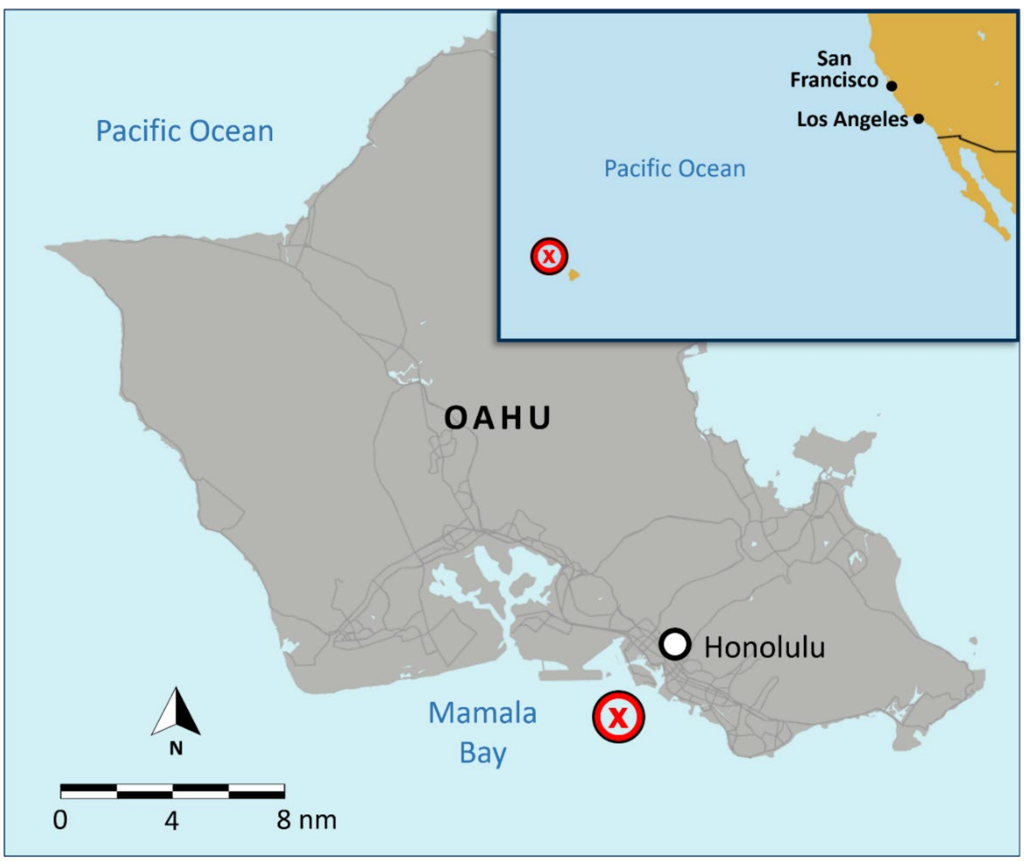

Figure 2. Area of accident where the diesel generator engine failed aboard the *Ocean Intervention*, as indicated by the red *X*. (Background source: Google Maps)

1. Factual Information

1.1 Background

The *Ocean Intervention*, a 243-foot-long, steel-hulled vessel, was built in 1998 and operated by Oceaneering International, Inc. The 2,262-gross-ton multi-service vessel was designed to carry goods, supplies, personnel, and equipment in support of offshore energy operations. It was outfitted with specialized equipment, such as remotely operated vehicles for underwater surveys, inspections, maintenance, and repair of apparatus such as pipelines, oil wells, and other subsea structures.

The diesel-electric vessel was powered by three Caterpillar diesel engine-driven generators (referred to as DGs): two model 3516B 16-cylinder diesel engines (numbered 1 and 3) producing 2,549 hp each, and one model 3508 8-cylinder diesel engine rated for 850 hp. The DGs supplied electrical power for both the main propulsion motors and the electrical system for other vessel services. The vessel's propulsion was provided by two 2,000-hp azimuthing stern thrusters (rotatable pods) supplemented during maneuvering operations with two 1,000-hp bow tunnel thrusters.

1.2 Accident Events

About noon on December 18, 2020, the *Ocean Intervention* was docked in Honolulu Harbor awaiting orders with a partial crew standing deck and engineering watches. Around this time, the engine crew observed that the no. 3 DG, which normally ran at 1,800 rpm, was "hunting" (demonstrating periodic variation in engine speed) while idling between 1,780 and 1,820 rpm. While troubleshooting the hunting issue, the crew inspected and cleaned the magnetic pickup sensor (an electronic device used to control an engine's speed) and replaced the generator control module (an electronic device that controls engine operations). Later that afternoon, the vessel shifted to Anchorage B in Mamala Bay, southwest of Honolulu Harbor, Oahu Island, Hawaii. The crew continued troubleshooting the no. 3 DG and then took it offline at 1605.

After experiencing similar hunting issues on the no. 1 DG the next morning, the crew started the no. 3 DG and put it online about 0330. About six hours later, after consulting a shoreside technical specialist, the crew stopped the no. 3 DG to adjust operational settings on the generator calibration board of the newly installed control module. About an hour later, after adjustments were made on the calibration board, the no. 3 DG was restarted, and the engine was no longer observed to be hunting. About 1050, the no. 3 DG was put online, sharing the electrical load with the no. 1 DG. Two hours later, the no. 1 DG was taken offline and the vessel's electrical load was shifted onto the no. 3 DG.

At 1303, while in the engineering operating station (EOS), the chief engineer and engineer on watch heard “an abnormal sound, similar to something heavy dropping on the deck,” and saw thick black smoke in the engine room. Unaware of the cause of the sound and smoke, the chief engineer activated the emergency stops for all the running DGs, closed the fuel and lube oil tank supply valves, shut down the ventilation fans for the engine room, and closed their dampers. The crewmembers then evacuated the EOS. The emergency generator automatically started and provided electrical power to the emergency electrical switchboard.

Around this time, the mate on watch in the wheelhouse received a fire alarm for the engine room and observed smoke coming from the vents of the port stack. The captain sounded the emergency alarm and used the public address system to direct the crew to muster at their emergency stations. He called the local US Coast Guard and the vessel’s shoreside manager to apprise them of the situation. All crewmembers were accounted for, and two teams (each with two persons) donned firefighting gear.

At 1306, the crew started the emergency fire pump, which was powered from the emergency switchboard, and began supplying cooling water from fire hoses to the exterior surrounding bulkheads and decks above the engine room for boundary cooling. At 1310, a fire team wearing self-contained breathing apparatus conducted a visual assessment of the engine room through a window from the EOS. They observed that the engine room was filled with smoke (visibility was less than 5 feet) yet saw no signs of fire. After all other engineering spaces throughout the vessel were inspected for fire, the crew determined that the smoke was isolated to the engine room. Shortly after the engine room ventilation dampers were closed, the crewmembers noticed a reduction in the amount of smoke coming from the port stack. The engine room CO_2 fixed fire-extinguishing system was not activated.

Crewmembers then began taking temperatures of the decks above the engine room using an infrared thermometer. At 1328, baseline temperatures of 95° and 87° on the port and starboard sides, respectively, were established; thereafter, readings were taken every 30 minutes. Once the temperatures began a downward trend, the fire team reassessed the situation visually from the EOS. At 1518, they reported that the smoke had cleared significantly and there was no sign of fire. At 1945, the chief engineer and two firefighters from a responding marine salvage team entered the engine room and determined the space was clear from any immediate fire danger. On the outboard side of the no. 3 DG they observed a damaged connecting rod, which had been ejected from the crankcase, and determined this mechanical failure was the cause of the smoke and fire alarm.

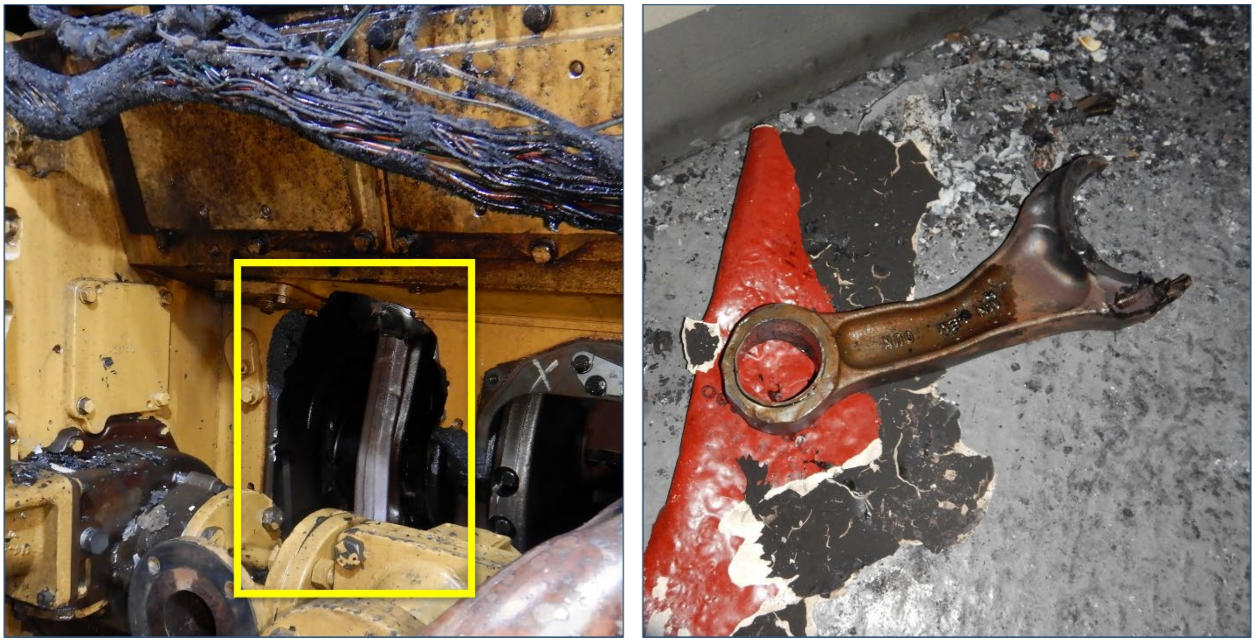

Figure 3. The damaged section of the engine (*left*), as indicated by the yellow square, from where the connecting rod from the no. 3 DG (*right*) was ejected. (Source: Oceaneering International, Inc.; Coast Guard)

1.3 Additional Information

On December 21, two days after the accident, postaccident testing for alcohol and other drugs was performed on relevant crewmembers; all results were negative.[2]

The no. 3 DG was damaged beyond repair. Caterpillar technicians and crewmembers removed the damaged engine from the vessel and replaced it with a spare engine. As a result of the engine failure, the area in the engine room around and above the no. 3 DG suffered smoke and heat damage. Propulsion control systems, lighting fixtures, electrical cables and components, and air ducts required repairs and/or replacements.

1.3.1 Engine Failure Report Findings

Leading up to the engine failure, no abnormal alarms had been received on the engine monitoring system. The no. 3 DG had 20,176 running hours at the time of the failure; the next bearing replacement was scheduled at 22,500 hours. The operating company, who had all the parts for this maintenance staged in Honolulu, was planning on conducting maintenance in the upcoming weeks.

[2] Chemical and alcohol testing was conducted at this time because the testing company could not access the vessel while it was anchored at sea and with an active fire onboard.

The damaged engine was shipped to Louisiana where factory-trained representatives conducted a forensic teardown to document the condition of the engine's various components and develop a failure investigation report. The report concluded that the engine failure sequence began when the no. 1 connecting rod bearing began to adhere to the crankshaft, causing the no. 2 connecting rod bearing to overheat and adhere to the crankshaft as well. As a result, heat began to transfer down to the no. 1 main bearing, causing the bearing to adhere to the crankshaft and thereby spin in the crankshaft bore. As the failure progressed, both pistons contacted the cylinder heads, until the no. 1 connecting rod was pulled from the piston and contacted the crankshaft counterweights and the no. 2 connecting rod. The no. 1 connecting rod was ejected out of the crank case.

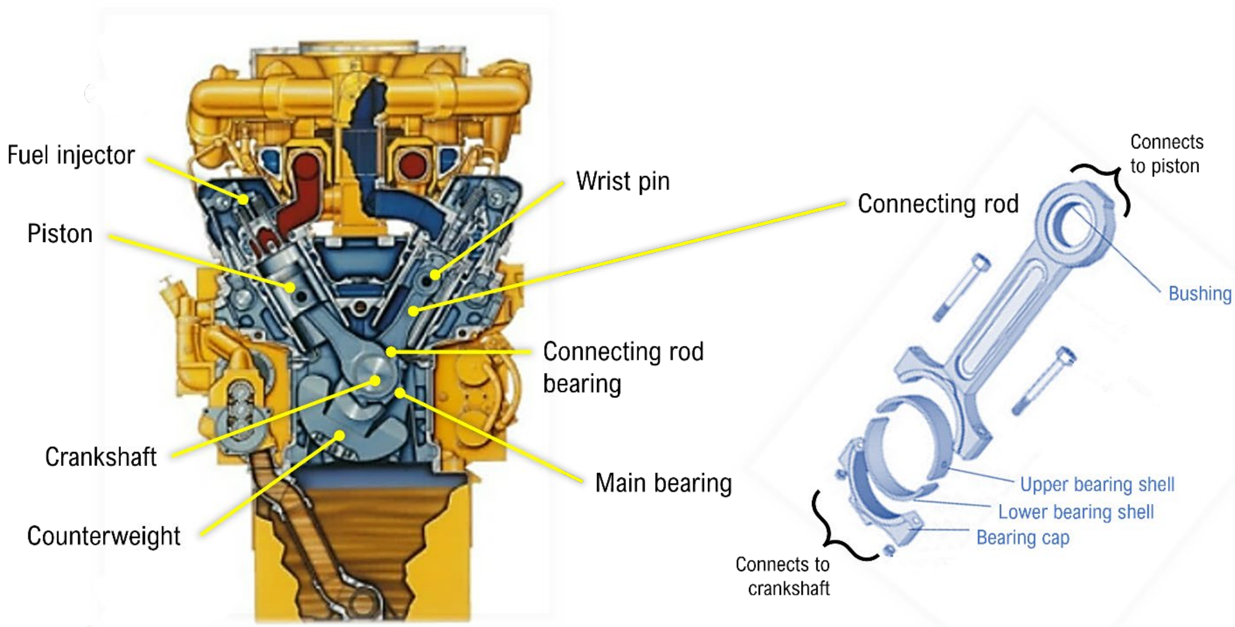

Figure 4. Internal components of typical Caterpillar 3500B diesel engine. (Source: Caterpillar, annotated by NTSB)

The report stated that, as a result of the engine failure, the engine block had been ventilated at the nos. 1 and 2 cylinders, and the nos. 1 and 2 connecting rod bearings had spun and disintegrated into small thin pieces. The remaining connecting rod bearings showed signs of bearing cavitation, some of which appeared "to be severe." Slight grooves appeared on the worn main bearings. Technicians also noted that there were signs of piston-to-cylinder head contact, but all the valves were in place and intact. The no. 2 cylinder injector tip had damage from contact with the piston.

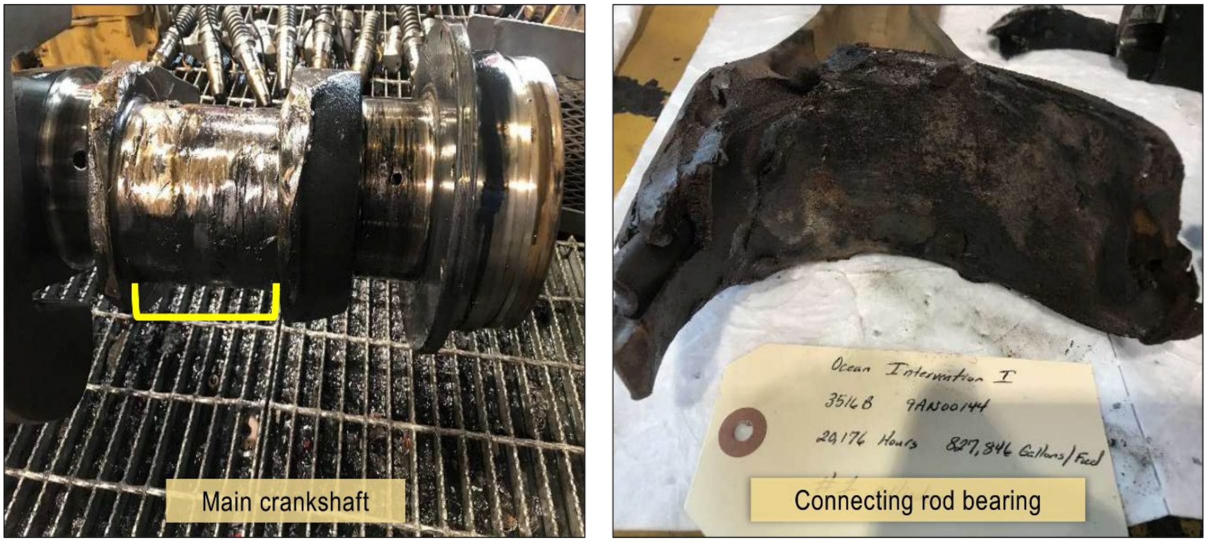

Figure 5. The yellow bracket identifies the damaged area of the main crankshaft of the no. 3 DG (*left*), where the no. 1 connecting rod bearing failed (*right*). (Source: Oceaneering International, Inc.)

According to the report, one of the possible scenarios for the engine failure was a loss of bearing clearance due to fluid on top of the piston. A fluid such as cooling water could have entered the cylinder; however, components from the cooling water system, such as the aftercoolers (a possible source of a cooling water leak), were damaged and unable to be tested for leaks after the engine failure.

Another fluid that could have entered the cylinder was fuel oil from a malfunctioning fuel injector; however, there were no alarms from the engine monitoring system that indicated issues with any fuel injectors on the no. 3 DG before the engine failure.

Another possible cause of the failure was the condition of the bearings. Several of the rod bearings showed signs of cavitation erosion, a degradation of a-bearing resulting from vapor-filled cavities in the lubricating oil that may include loss of material, surface deformation, or changes in properties.

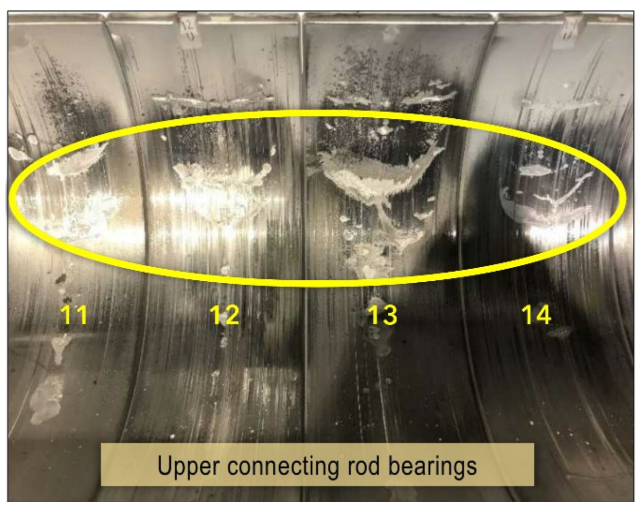

Figure 6. Cavitation erosion in upper connecting rod bearings from the no. 3 DG in cylinder nos. 11, 12, 13, and 14, encircled. (Source: Oceaneering International, Inc.)

The report explained that cavitation erosion was normal over the life of a bearing, indicating that "the [cylinder] number 13 rod bearing showed the most wear and would be considered excessive…If the cavitation erosion became excessive enough, it could cause the bearing to fail and set off the chain reaction" of the failure sequence.

1.3.2 Oil Testing Results

Based on records of engine lube oil analysis for the no. 3 DG from July through September 2020, results for each sample indicated "normal wear." The most recent oil samples were not able to be analyzed, because the package of samples was lost in the mail. Therefore, investigators were unable to identify if there was water or fuel dilution in the months immediately preceding the failure.

1.3.3 Postaccident Actions

Following the teardown of the no. 3 DG, and after reviewing the failure investigation report, the operating company sought the guidance of Caterpillar to proactively effect changes to the model 3516 engines throughout its fleet. To provide increased lubrication to the engine bearings, pre-lube pumps were installed on the engines to provide lubricating oil throughout the engine for a fixed time: after receiving a start signal and before the engine began the starting sequence. According to the technicians, pre-lube systems were offered for the model 3500 engines but were not required. Additionally, the operating company requested that Caterpillar technicians research the feasibility of retrofitting the model 3516 engines with oil mist detectors since the manufacturer did not offer a kit or instructions. These protection devices are designed to activate an alarm when a dangerous mist is detected in the crankcase, possibly preventing an engine explosion. According to the technicians, Caterpillar confirmed that it would be possible to retrofit the engines with oil mist-detection systems.

Lastly, the *Ocean Intervention*'s manager for maintenance and repairs stated that the frequency of inspections for main and connecting rod bearings on the model 3516 engines installed aboard the Oceaneering vessels would be reduced from 21,500 hours to between 10,000 and 12,000 hours to allow the bearings to be inspected and replaced early out of an abundance of caution. The connecting rod bearings would be replaced following inspection, as they were not able to be used again after being opened. The main bearings would only be replaced during these inspections if they showed abnormal wear. The technicians stated that Caterpillar had no issue with increased inspections and staying within the operational maintenance manual guidelines.

2. Analysis

While at anchorage, the crew on the *Ocean Intervention* had been troubleshooting speed variation issues related to the nos. 1 and 3 DGs throughout the morning, which involved replacement and calibration of several electrical components and multiple engine restarts. About 15 minutes after the no. 1 DG was taken offline, which left the no. 3 DG carrying the vessel's electrical load, the no. 3 DG suffered a catastrophic mechanical failure, resulting in cylinder no. 1's connecting rod being ejected through the engine crankcase while running at rated speed. The ejection of the connecting rod allowed atomized oil to be released and ignite, starting a fire in the engine room.

During the postaccident forensic teardown of the no. 3 DG, factory-trained technicians were able to identify the most likely sequence of events that led to the failure of the engine but were unable to determine the root cause due to several unknown preconditions of the engine. The possibility of fluid, such as cooling water or fuel oil entering the cylinder, causing a loss of clearance on the connecting rod bearing and starting the failure sequence was considered as a viable scenario; however, this theory could not be verified due to damaged components and operational alarms not activating before the failure. The condition of the connecting rod bearings, showing signs of cavitation erosion (some considered excessive) was another possible root cause of the failure. If the cavitation erosion became excessive enough, as found on cylinder no. 13's connecting rod bearing by technicians, it could have caused the bearings to fail due to increased tolerances between the components and excessive movement outside of these tolerances.

According to vessel records, all maintenance was completed per the manufacturer's recommendations. The bearings had been replaced 20,176 hours before this failure and were not scheduled to be replaced for another 2,300 operating hours per manufacturer guidance. Although the most recent lube oil analysis reports were unavailable, the previous reports in the months before the failure all showed acceptable results. Engineering watchstanders did not receive any alarms indicating issues with the operational parameters of the no. 3 DG in the minutes preceding the failure. Troubleshooting techniques for the hunting issues that were carried out by the engineering crew were reasonable, given the known conditions, and likely did not contribute to the engine failure.

The failure of the connecting rod bearing and subsequent catastrophic damage opening the crankcase allowed hot pressurized fuel oil to atomize into the engine room and ignite from a hot surface on or near the engine. The heat and smoke damage to the engine room indicated that the fire was concentrated around the no. 3 DG. The crew quickly stopped the running engines, isolated all fuel supplies, shut down engine room ventilation systems, and closed the space's air dampers to effectively starve the fire of fuel and oxygen, which prevented the spread of the fire. Additionally, by using the emergency fire pump, the crew provided cooling water to the exterior overhead and bulkheads to reduce the heat in the engine room. The crew's quick and effective actions resulted in the extinguishment of the fire without putting crewmembers at risk by having to enter the space.

3. Conclusions

3.1 Probable Cause

The National Transportation Safety Board determines that the probable cause of the diesel generator engine failure aboard the offshore supply vessel *Ocean Intervention* was a cylinder's connecting rod bearing adhering to the crankshaft, which led to the ejection of the connecting rod and catastrophic damage to the engine.

3.2 Lessons Learned: Containing Engine Room Fires

Engine rooms contain multiple fuel sources as well as mechanical ventilation, making the spaces especially vulnerable to rapidly spreading fires. The crew of the *Ocean Intervention* effectively contained the spread of a fire by removing fuel and oxygen sources. Vessel crews should familiarize themselves and train frequently on machinery, fuel oil, lube oil, and ventilation shutoff systems to quickly act to contain and suppress engine room fires before they can spread to other spaces and/or cause a loss of propulsion and electrical power.

Vessel	***Ocean Intervention***
Type	Offshore supply vessel
Flag	United States
Port of registry	Morgan City, Louisiana
Year built	1998
Official number (US)	9203227
IMO number	1066873
Classification society	American Bureau of Shipping
Length (overall)	243 ft (74.1 m)
Beam	53.5 ft (16.3 m)
Draft (accident)	13.3 ft (4.1 m)
Tonnage	2,262 GT
Engine power; manufacturer	2 x 2,549 hp (1,900 kW); Caterpillar 3516B diesels 1 x 850 hp (625 kW); Caterpillar 3508 diesel

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