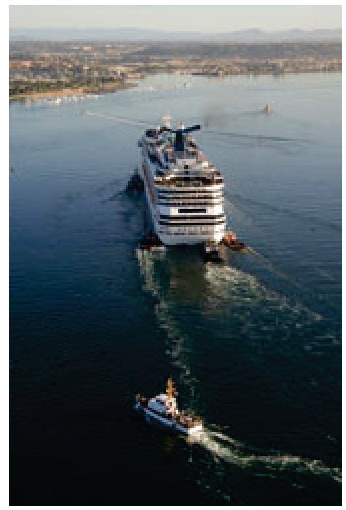
Think **CRANKCASE EXPLOSIONS** don't happen much anymore?

Think Again

At 6 AM on November 8, 2010, the second day of a voyage from Long Beach, CA to the Mexican Riviera, the 952-foot cruise ship Carnival Splendor experienced a fire in her engine room, knocking out all electrical power on the ship. Carnival reported shortly after the incident that a "crankcase split" had caused the fire, apparently the result of a crankcase explosion in one of the diesel engines.



The fire was extinguished by that afternoon and luckily none of the nearly 4,500 passengers and crew members onboard at the time was injured. The crew could not restore power to any of the engines and the ship had to be towed to San Diego over the next three days. Because of the power outage, the ship lacked food service, so passengers were fed rations delivered by U.S. Navy helicopters from the aircraft carrier USS Ronald Reagan. Carnival Splendor arrived in San Diego under tow around sunrise on November 11.

The Panamanian-flagged vessel was built by Fincantieri and entered service in 2008. Since the incident was in international waters, the flag state, Panama, initially led the casualty probe, with the U.S. Coast Guard assisting. Subsequently, for unknown reasons, the Panama Maritime Authority asked the U.S. to take over the investigation. The National Transportation Safety Board (NTSB) assigned staff to conduct the investigation, while Carnival's own engineers and representatives from both the shipyard and the engine manufacturer also investigated the incident. No definitive conclusions have yet been provided, although the focus remains on one of the diesel generators. Initial findings revealed that diesel engine number five in the aft engine room suffered a split of the crank case and caught fire, damaging the engine control room and the electric cabling.

Carnival Splendor broken drive shaft

Carnival estimated that the cost of repairs, transport, refunds, free cruises given to displaced passengers, and the lost revenue from canceled sailings will total $65 million.

In a time when modern automation systems are supposed to prevent the above types of incidents from happening, these events are not rare. According to an eleven-year analysis of its classed fleet starting from 1990, Lloyds Register recorded 143 incidents of crankcase explosions, caused by bearing failures, piston failures, and other types of failures.

Oil Mist Detection

The development of oil mist detectors began in the 1960's, when larger more powerful diesel engines stimulated strong interest in reducing the risk of crankcase explosions by detecting the conditions that occur immediately prior to an explosion.

A crankcase explosion is caused by the ignition of oil mist from a hotspot, with the mist itself being caused by high temperatures on an internal metal surface (e.g. due to insufficient lubricating oil film, high friction loads, etc.). Development efforts focused on monitoring equipment that could detect the onset of a problem, manifested by a high density oil mist. The first crankcase oil mist detector was marketed in the early 1960's. The detection principle was based on the sampling of oil mist from selected points within the crankcase and piping those samples to a central detector usually mounted on the engine, which passes an oil mist detection signal to a control or monitoring system. This design same principle has been retained by many modern oil mist detection suppliers.

Oil mist can provide the first signs of impending problems for all the moving parts of the engine. Temperature and pressure measurements can also provide an early warning of potential problems (e.g. crankcase pressure, bearing temperatures, etc.). Classification Societies require that crankcase oil mist detectors or bearing temperature sensors be installed on larger diesel engines, but the maintenance of this safety-critical device remains questionable, particularly with regard to the aforementioned cruise liner failure scenarios.

An oil mist detection system can avoid damage to the engine and injury to the crew by allowing early detection of engine wear and bearing damage that may create an explosive environment within the engine. Oil mist detectors, when properly used and maintained, are a valuable diesel engine health monitoring tool allowing preventive maintenance actions to be taken at an early stage of a problem. If oil mist readings are recorded, then the increased levels of oil mist will become apparent as wear takes place.

If it is not possible to reliably measure and record crankcase oil mist data directly, another method of predictive analysis is to use crankcase pressure and bearing temperatures as indications of developing engine problems.

Monitoring Crankcase Pressure

Crankcase pressure is an important performance indicator that can be used to detect conditions favorable for crankcase explosions to occur. A high crankcase pressure condition provides an indication of several possible internal engine problems that could lead to a crankcase explosion, such as faulty piston rings, poor combustion or lube oil condition, cylinder exhaust blow by, etc.

By comparing operational performance against a known benchmark, such as a baseline performance model, an early warning of a potentially dangerous situation can be obtained, as well as a true indication of the engine's operational health. Figure 1 shows a typical baseline performance model for crankcase pressure as a function of engine load (BHP). The green line represents "healthy" behavior, showing that crankcase pressure should normally increase slightly with engine load. This relationship was derived empirically from actual diesel engine data, plotted as red dots on figure 1. The red and blue lines represent statistical alarm limits, with the region between these lines representing "normal healthy" behavior. A high crankcase pressure is the condition of interest in avoiding crankcase explosions. As figure 1 indicates, crankcase pressure should normally be at a vacuum for a healthy engine condition (i.e. negative pressure readings).

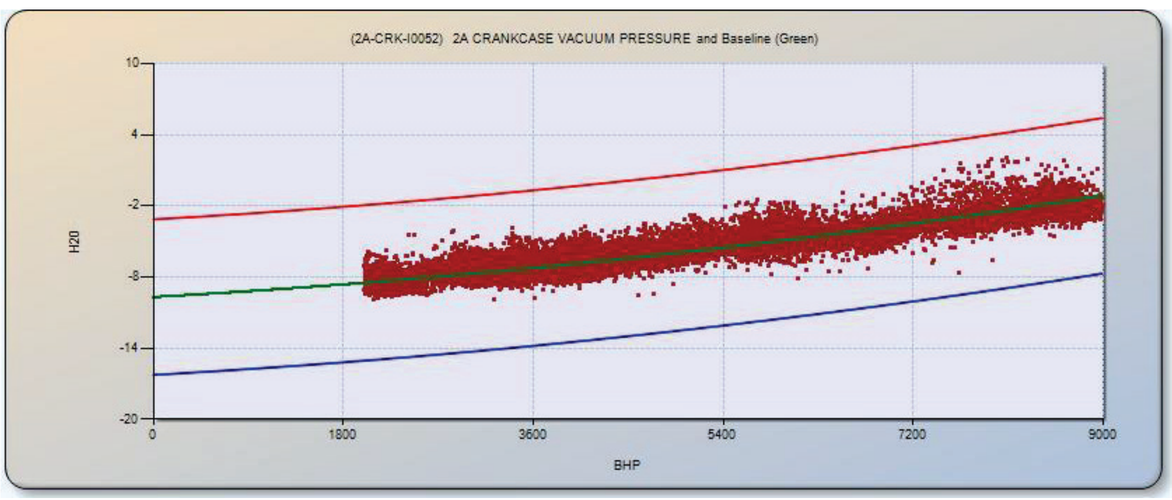


Figure 1 – Crankcase Pressure Baseline Performance across Engine BHP

Degrading conditions for any engine can be identified by comparing measured crankcase pressures to the baseline performance model of figure 1, providing as early warning as possible of abnormal performance. For a healthy engine, the plot of crankcase pressure versus engine load should look very similar to figure 1, with all measurements falling within the normal band.

Figure 2 shows an example of an engine with an abnormally high crankcase pressure and should be cause for immdiate investigation into possible reasons. In this case, crankcase pressures sometime exceed the normal values by as much as 11 inches of H^2O and should be cause for concern, particularly on a ship without an installed oil mist detector.

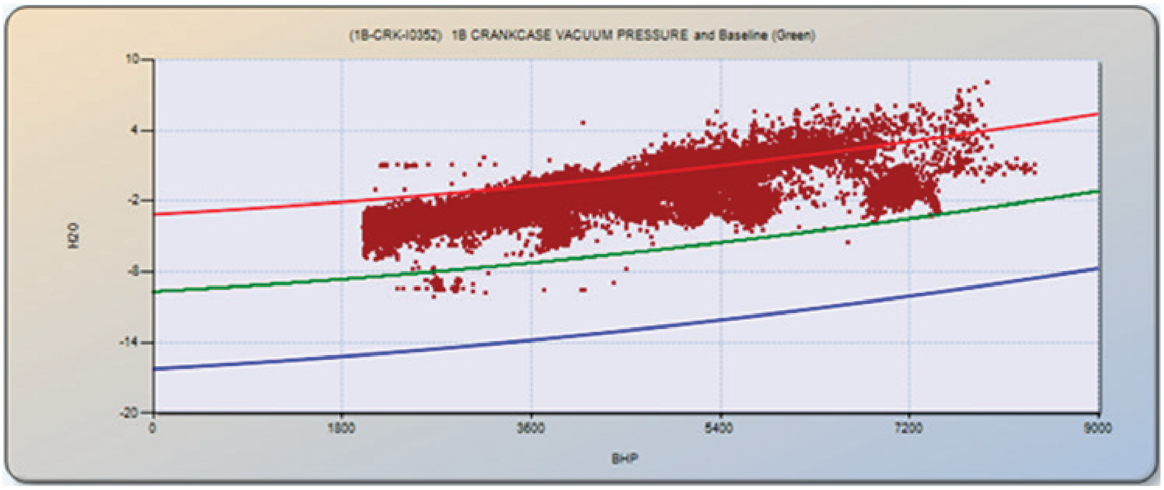


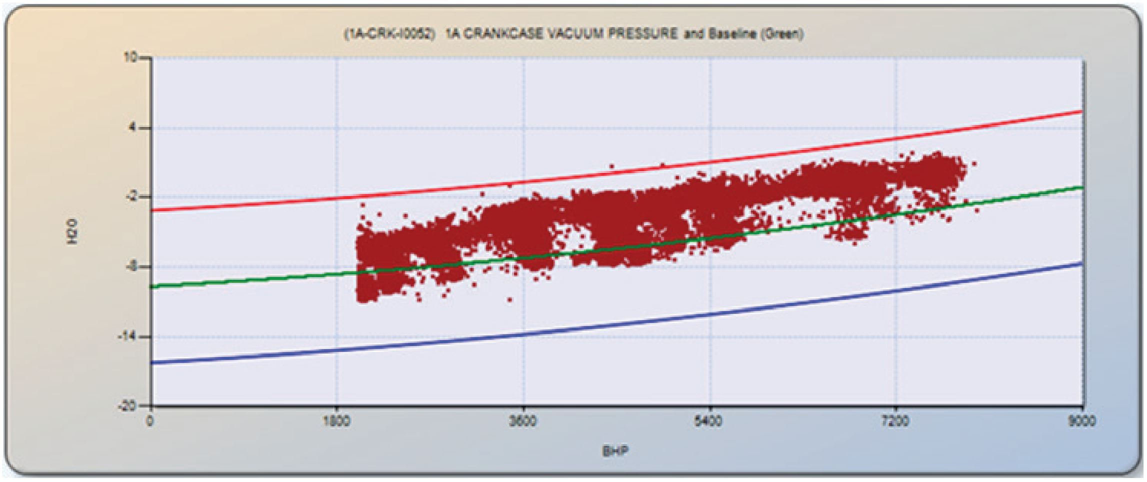
Figure 2 – Developing Risk Conditions for Crankcase Explosion

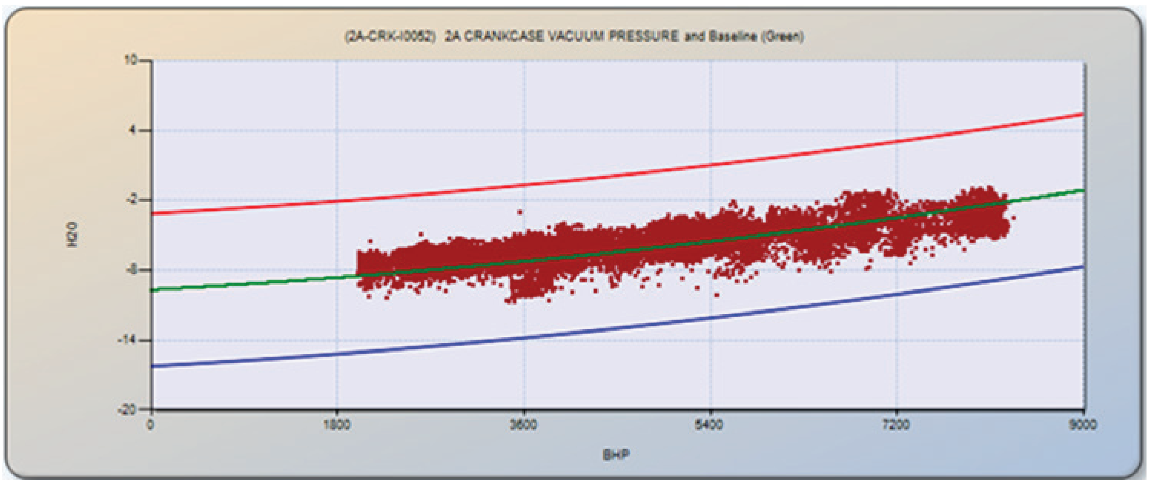
Figure 3 shows similar crankcase pressure behaviors for the other three diesel engines on this particular vessel, all of which appear to be normal

Crankcase Explosion Avoidance

Crankcase explosions can result in loss of life, shipboard fires, loss of power, and expensive ship repairs. All available measures should be taken to ensure that the engines are operating within the prescribed safety limits, using devices such as oil mist detectors or by diligently monitoring key performance data, such as crankcase pressure.

DEXTER is a real-time, on-board diagnostic and prognostic system designed to provide early warning alerts when equipment problems start to occur. Abnormal engine conditions and degrading performance trends are automatically identified, allowing plant operators to pinpoint and correct problems before catastrophic failures can occur. By attending to DEXTER's alert warnings, expensive repairs and life-threatening failures can be avoided. DEXTER will also help ensure that engines continue to operate at top health and efficiency.





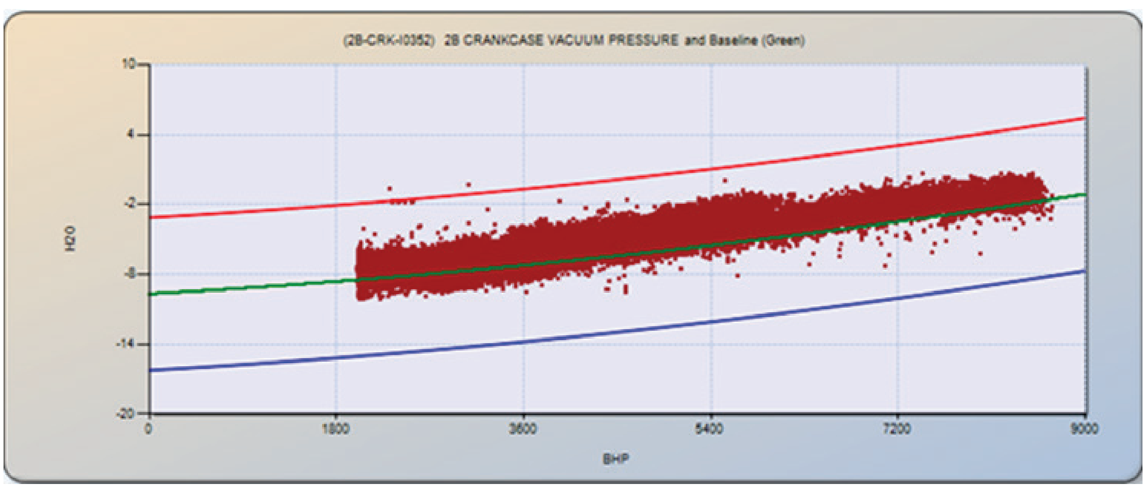


Figure 3 – Engines with Normal Crankcase Pressures