Marine Piston Damage

By Tom Benton, Marine Surveyor

In the last several years I have noticed an increase in the number of outboard motors which have sustained piston damage, and several cases in V-8 inboard & stern drive engines. Specifically pre-ignition/detonation damage. Quite frequently, this damage is reported to the insurance companies as either impact related, or from plastic sack induced water starvation. Why? Because if it were reported as a mechanical/fuel related problem, in most cases there would be no insurance coverage.

What is pre-ignition/detonation damage? It is piston failure resulting from abnormal burning or explosion of the fuel/air mixture in the cylinder. It is rarely found in more than one or two cylinders at a time, and is always caused by a customer controlled condition. Probably the most common cause is from excessive carbon build-up on the pistons and cylinder heads. It can also be caused by overly lean fuel/air ratios, and on a more rare occasion is caused by general overheating of the complete power head. When the last example is the cause, there will be several other indicators of what happened, including dulled cylinder block paint, melted plastic engine parts, blistered block decals, etc. Also in the last case, it usually is triggered by excessive carbon which creates a natural “hot spot” in the cylinder. The elevated cylinder block temperatures just provide an enhanced environment for the pre-ignition to occur.

Pre-ignition and detonation are actually two different phenomenon, but are many times found in conjunction with each other. Some technicians incorrectly use the two terms interchangeably.

Pre-ignition is abnormal fuel ignition, caused by combustion chamber hot spots. Control of the start of ignition is lost, as combustion pressure rises too early, causing power loss and rough running. The upward motion on the piston is opposed by the pressure rise. This can result in extensive damage to the internal parts from the high increase in combustion chamber temperature. The fuel/air mixture starts to ignite before the spark plug fires, hence the term “Pre-Ignition”.

This piston shows classic symptoms of pre-ignition. The outer edges of the piston dome are melted away, with the worst destruction on the exhaust (hottest) side of the piston. In this case, the piston material melted away past the top ring land, and pieces of ring broke off and beat the top of the piston as they bounced around in the cylinder.

This side view shows the missing section of ring, and the heavy scoring to the piston skirt. This failure was from a 200 hp outboard motor, it was a single cylinder failure, and the insured claimed that it was caused by an impact.

PRE-IGNITION CAUSES (As listed by Mercury Marine)

Pre-ignition occurs in both 2 cycle and 4 cycle engines. The causes are as follows.

1. Hot spots in the combustion chamber from glowing deposits (due in turn to the use of improper oils and/or fuels).

2. Overheated spark plug electrodes (improper heat range or defective plug).

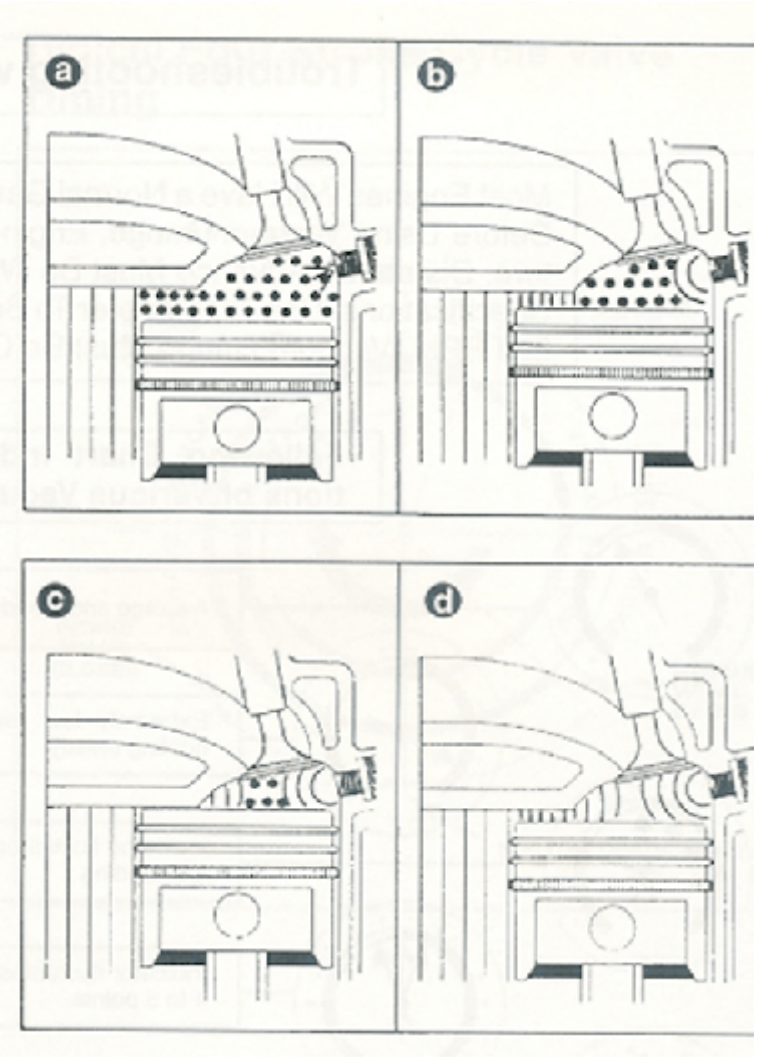
3. Any other protuberance in the combustion chamber, such as an overhanging piece of gasket, an improperly seated valve or any other inadequately cooled section of material which can serve as a source for pre-ignition problems.

By far the most common cause in outboard motors is poor quality oil & fuel leaving excessive carbon deposits in the combustion chamber. The second most common cause in outboards is a lean fuel/air mixture causing elevated temperatures in the combustion chamber. The most common cause in inboard or stern drive engines is a lean fuel mixture, and /or low octane.

DETONATION

Detonation is commonly called “fuel knock”, “spark knock”, or “carbon knock”. It is abnormal combustion of the fuel which causes the fuel to explode violently. The explosion in turn causes overheating or damage to the spark plugs, pistons, valves, and in severe cases, results in pre-ignition. This is why many technicians use the terms interchangeably, detonation can, and will, cause pre-ignition, and in advanced states, the pre-ignition is the most readily apparent evidence.

Detonation can be detected early by listening for “spark knock”. If detonation is not corrected, it will soon lead to serious damage to the cylinder. Detonation is the collision of two opposing flame fronts in the cylinder. It occurs after the spark plug has fired, as shown in the following diagrams.



“a” shows normal spark occurrence

“b” shows the beginning of combustion from the spark plug.

“c” shows combustion continuing, and the flame front from a hot spot on the other side of the cylinder.

“d” shows the collision of the two flame fronts, and the resulting detonation. This “explosion” can blow a hole in the piston top in severe cases.

Detonation Damage

This drawing shows severe detonation damage (hole in piston). Early stages of pre-ignition show around the piston edges, however the loss of compression from the hole prevented further pre-ignition from occurring.

DETONATION CAUSES (As listed by Mercury Marine)

A few of the most common causes of detonation in a marine application are as follows.

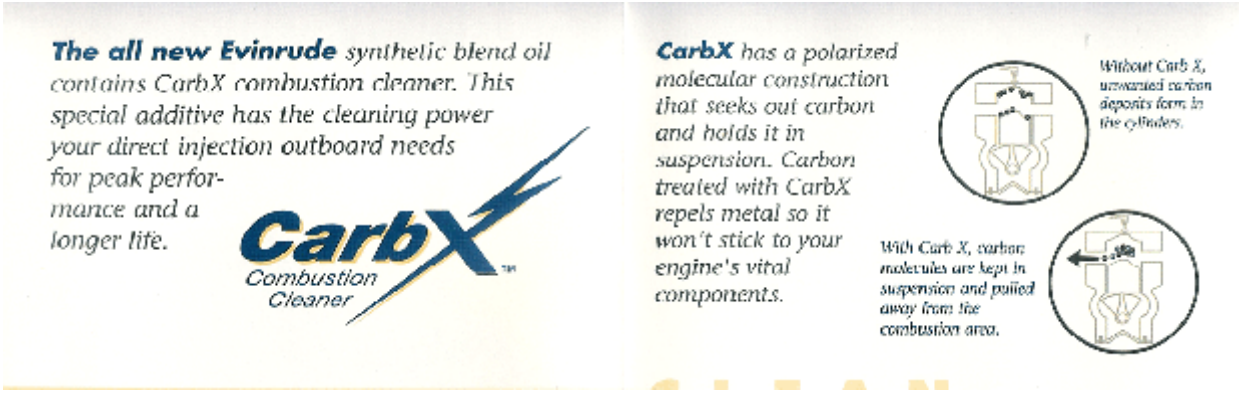
1. Over-advanced ignition timing
2. Use of low octane fuel (old fuel loses octane rapidly)
3. Propeller pitch too high (engine rpm below recommended maximum range)
4. Lean fuel mixture at or near wide-open-throttle.
5. Spark Plugs (heat range too hot - incorrect reach - cross-firing.
6. Inadequate engine cooling (deteriorated cooling system)
7. Combustion chamber/piston deposits (results in higher compression ratio)

WHAT ARE "CUSTOMER CONTROLLED CONDITIONS"?
It is the responsibility of the owner to perform normal required maintenance, and to use good quality lubricants and fuels. It is also the responsibility of the owner to make sure that the machinery is properly tuned up, and setup for optimal operation. This includes correctly sized propellers.

Oil

In the 2 cycle marine engine, the oil is designed to burn with the fuel, after it has provided necessary lubrication to the moving parts. The industry sets "minimum" specifications for 2 cycle oil composition. It is currently listed as "TC-W3" specification. All 2 cycle oil is not created equally, and some of the lower grades will contribute to excessive carbon build-up in the cylinders. These cheaper oils do not have the clean burn agents that help to breakup the carbon deposits and keep the cylinders in good working order. I suggest that it is best to buy your 2 cycle oil from the engine manufacturer. Who else would know what was best for their product?

The customer controls the oil that is used.



OMC Advertisement for Evinrude Oil

Mercury sells Quicksilver oils
Yamaha sells Yama-lube oils
Every engine manufacturer sells a 2 cycle oil that they believe is best for their engines.

Competitive brand oils may not have the clean burn agents, even though the meet the "TC-W3" requirements, and many times leave unwanted carbon deposits in the cylinders.

De-Carbonization

Routine maintenance should include periodic tuneup, and de-carbonization. Every major engine manufacturer sells a product designed to dissolve cylinder carbon, and to clean the combustion chambers.

The customer controls the engine maintenance and tuneup schedules.

PROPELLERS

The propeller acts as a governor on the marine engine. Too little pitch will cause the engine to over-rev, and too much pitch will cause the engine to labor, also called "lugging". A engine that has the wrong propeller with too much pitch will cause excessive loads on the power head, and can lead to spark knock and detonation. It is similar to climbing a hill in high gear in your car all the time.

Correct propeller selection is a customer controlled condition.

FUEL

Premium Gasoline:

Mercury Marine is discontinuing their recommendation of using premium unleaded gasoline because many are blended with components (oxygenates, ethers, butane, etc.) which primarily raise the research octane number only. Force, Mariner, and Mercury outboards respond most favorably to a higher motor octane number. Pump octane (pump posted) is determined by adding the research octane and the motor octane and then divide by 2 (R + M + 2). If the outboard is used in severe service or hard working conditions (skiing, large boats, heavy loads, etc.) or if detonation is suspected to be caused by poor grade gasolines, use mid-grade (89 - 91 pump octane) unleaded gasoline supplied by a major name brand company. If detonation persists, check for improper cooling, a lean fuel mixture and/or incorrect ignition timing.

Carbon Deposits:

Today's gasolines can leave significant amounts of carbon deposits when used in two cycle outboard engines. Carbon deposits can cause piston ring sticking and/or piston ring "jacking" and may contribute to powerhead failure. Encourage the use of gasoline that has fuel injector cleaner added at the factory to control carbon deposits which results in a cleaner and more efficient engine. Caution your customers on the use of fuel injector cleaners that are manually added to the gasoline as the mixture ratio is critical to controlling carbon deposits. Also, if too much cleaner is added, engine damage may result due to the removal of some of the lubricating properties of the oil.

POOR QUALITY FUEL

Is poor quality fuel to blame? I believe that it is partially responsible, and studies have shown that fuel left to age in the boat, or fuel purchased from a low volume dealer (most marinas sell last falls fuel in the early spring), are low on "motor octane". Motor octane is different from "pump octane". The ratings at the pump have little to do with the "anti-knock" capability of fuel in the marine engine.

Octane

The octane quality of a gasoline is its ability to resist detonation, a form of abnormal combustion. Detonation occurs when the air-fuel mixture reaches a temperature and/or pressure at which it can no longer keep from self igniting. Two types of abnormal combustion are common: the first is detonation as previously mentioned and the other is pre-ignition.

Detonation occurs after the spark plug has ignited the air-fuel mixture and the flame front is moving smoothly across the combustion chamber. If, during this burning process, the unburned air-fuel mixture reaches a temperature and/or pressure at which it is no longer stable, it burns very rapidly causing a new flame front to collide with the one that originated at the spark plug. Maximum pressure in the cylinder occurs before the piston reaches top dead center (TDC) and that pressure tries to push the piston down before it is ready to go down. Piston burning and rod bearing damage are the result.

Pre-ignition is the other bad actor and is usually started by a hot spot in the combustion chamber which causes the mixture to ignite before the plug fires. Under wide open throttle conditions, pre-ignition will destroy pistons in a relatively short period of time.

Fuel selection is a customer controlled condition.

From Mercury Service Training Notebook
Gasoline Storage:

Use a major name brand of gasoline from an outlet that sells a large amount of fuel.
Fuel stored longer than 15 days may have lost some of the desired properties (dependent on temperature and storage conditions). Always keep the vent closed on portable fuel tanks when not in use to prevent air exchange and water absorption. Use Quicksilver Fuel System Treatment and Stabilizer PIN 92- 78383A 12 and Gasoline Stabilizer PIN 92-817529A 12 to prevent unused gasoline from losing desired properties during periods of non-use (15 days or more). Mercury Marine reserves the right to refuse warranty on parts which are damaged when using improper gasoline and or lubricants.

Mercury Marine appears to suggest that fuel has started the deterioration process in as little as 15 days! Fuel stabilizers help, but there is no substitute for fresh (octane enhanced) fuel.

CONCLUSION:

Did the damaged pistons occur as the result of an impact, or from a plastic sack covering the water intake? **Not likely!** The plastic sack theory is the subject of a whole other discussion. Nearly always, particularly in 2 cycle motors, piston damage is caused by a combination of the above discussed oil/fuel/carbon problems.

Credit is given to Mercury Marine for information obtained from Service Training Publications.
Credit is given to OMC for information obtained from Evinrude Oil brochure.