



To: All X-1R distributors

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Cc:

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Subject: Engineering Bulletin - Formation of sludge in the engine

Thousands of car owners in recent months have been hit with an expensive engine repair, one that can cost \$5,000 or more.

Numerous late-model piston engines from many manufacturers have suffered from failures due to oil sludge contamination. These problems happen when fine engine oil passages become clogged with sludge, and often result in catastrophic failure of the engine.

3.3 million **Toyota** engines were affected, as were 426,000 from **Volkswagen** and an unknown number from **Chrysler & Dodge** (estimated to be in hundreds of thousands) and most recently **SAAB** also admitted engine problems with sludge on 430,000 vehicles worldwide.

Fixes include changing to synthetic oil, engine flushes, more frequent oil change intervals and even engine replacement.

What is "sludge" ?

There are different "types" of sludge, they are of different appearance ranging from light brown to opaque black, they range from semi-liquid to solid, and they can be formed by different chemical reactions.

Since any sludge is formed primarily from the engine oil, the oil itself appears to be at fault. Actually the oil is the victim of mechanical and chemical attack.

The formation of sludge is a very complex interaction of components which include mechanical and thermal stress and multitude of chemical reactions.

Although there are thousands of documented engine failures in the field, not a single research chemist has to date succeeded to create a "synthetic" sludge under controlled laboratory conditions. The real life conditions are therefore so complex as to be virtually impossible to duplicate in laboratory, yet hundreds of engines all over the world fail daily due to sludge formation.

While some engine types are more prone to sludge formation, the fact is that only very small proportion of the "affected" engines actually fail in service.

For example out of the over 3.3 million **Toyota** engines that are "affected" only about 7,000 of them have had serious failures. That is 0.2% or about two failures in 1,000 engines.

Sludge in *gasoline* engines is usually black emulsion of water and other *combustion* by-products, and oil formed primarily during low-temperature engine operation. Sludge is typically soft, but can polymerize to very hard substance. It plugs oil lines and screens, and accelerates wear of engine parts. Sludge deposits can be controlled with a dispersant additive that keeps the sludge constituents finely suspended in the oil.

"*Black Sludge*" is defined as thick to solid material with low water content, of dark color, light oil insolubles, and typically found in rocker cover, cylinder head, timing chain cover, oil sump, oil pump screen, and oil rings in variable quantities.

Sludge in *diesel* engines, is soot combined with other *combustion* by-products which can thicken the oil to gel like sludge. This sludge is typically soft, but can also polymerize to very hard substance. It plugs oil filters, oil lines and screens, and accelerates wear of engine parts.



Picture of typical engine sludge

What causes "sludge" ?

Sludge formation is the result of one or more of these factors:

- severe service driving with improper drain intervals
- mechanical malfunctions
- inadequate engine maintenance

Severe Service Driving:

The term "severe service" refers to:

1.) Short Trips

- Engine Coolant and Engine Oil never reach the "normal" operating temperatures (170° F to 190° F for coolant and over 212° F for motor oil)

2.) Stop & Go Driving

- Slow driving and long idling periods lead to high under hood temperatures due to limited flow
- The "average" miles per hour run time is low and engines accumulate many engine run hours for the relatively low number of miles driven, thus typically exceeding the safe number of hours for which particular motor oil was designed to operate (Typically service life of premium motor oils is not more than 212 hours)

3.) Extended Idling

- sitting in traffic
- delivery truck operation
- The "average" miles per hour run time is low and engines accumulate many engine run hours for the relatively low number of miles driven, thus typically exceeding the safe number of hours for which particular motor oil was designed to operate (Typically service life of premium motor oils is not more than 212 hours)

4.) High temperature operation

- driving at high ambient temperatures
- towing
- driving at maximum engine power output (high speeds or up hill)

5.) Extreme Cold

- starting engine below 0° F
- Engine Coolant and Engine Oil never reach "normal" operating temperatures (170° F to 190° F for coolant and over 212° F for motor oil)

6.) Heavy Loads

- operating in hilly regions
- trailer Towing
- oxidation rate of conventional motor oils doubles for every increase of 15° F to 18° F, therefore motor oil that is fine for thousands of miles at "normal" operating temperature can fail in just few hours if it is overheated to over 300 F.
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Severe conditions are not all that uncommon. It is estimated that we operate our vehicles 80% of the time under one of above "severe service" conditions !

Mechanical Malfunctions:

A flat tire, engine knock or an electrical problem is easily identified. However, a small, subtle malfunction, like a leak from your cooling system into your crankcase, can create big problems for your engine. The resulting oil and coolant mixture reacts to form harmful deposits. An improperly operating cooling system will cause problems, too. If your thermostat sticks and does not allow coolant flow when needed, your engine will run either too cold or too hot. You might not even notice the difference on your temp gauge (if you have one). Constant elevated temperatures promote oil thickening after thousands of miles. This can create sludge. While engine that operates too cold will form a "black sludge".

A clogged or defective PCV valve can contribute to sludge formation. If this valve does not operate properly, harmful exhaust gases remain in the crankcase. These gases, which contain water, acids, soot, etc., promote sludge.

Excessive amount of fuel due to leaky fuel injectors, malfunctioning choke mechanism or failed oxygen sensor can also contribute to sludge formation.

Sludge contributors:

Although the oil appears to be at fault, it is actually the victim of mechanical and chemical attack. The formation of sludge is a complex interaction of components. Each of the following factors deserves attention.

These are the enemies of your engine oil:

- Soot
- Heat
- Fuel
- Water
- Acid
- Dirt
- Blow-by
- Engine Coolant

SOOT:

Soot is fine powder that is a product of incomplete combustion. This carbon substance enters the crankcase with exhaust blow-by gases that escape past the piston rings. Since soot is a very fine powder, it thickens oil by a process called "soot loading." It gels the oil like a cake mix thickens milk. If your motor oil becomes excessively thick, there will be less oil circulated through the engine. Also, the oil will leave a thicker oil film on the engine parts, which prevents proper heat transfer. By remaining on the hot parts, the oil will burn and form deposits. Diesel Engines especially ones with EGR are more prone to soot formation.

HEAT:

Engine heat, a natural result of internal combustion, takes its toll on your motor oil. In the presence of air, oil undergoes a process called oxidation, which becomes more severe as the temperature increases. Oxidation thickens the oil and produces corrosive acids. Left unchecked, your oil would degrade into a tar-like mess.

While you want your engine temperature above 212° F to evaporate unwanted contaminants, above 250° F the oil is more prone to oxidation. At temperatures of 300° F, this process occurs rapidly. Oil companies have some additives that contain powerful oxidation inhibitors. These additives break down the oxidation cycle.

As long as these inhibitors are present, no significant oxidation will occur. However, these additives are consumed with time. After their depletion, oil oxidation proceeds rapidly. Regular oil changes are needed to remove the unwanted products of combustion and to replenish the supply of oxidation inhibitors.

Typical oxidation rate doubles for every 15° F to 18° F increase in oil operating temperature.

Therefore motor oil that is just fine for 6,000 miles at 220° F (normal operating temperature for most modern engines) will be only suitable for less than 100 miles at 310° F ! It is not uncommon to have motor oil temperature reach over 320° F when towing heavy trailer up hill in Summer heat, for example.

FUEL:

Fuel enters your crankcase with exhaust blow-by gases in unburned and partially burned forms. It is chemically unstable; therefore, it reacts with itself and the oil to form gums, varnishes and asphaltic-type compounds. These resinous substances are also unstable and react further to cause even more oil thickening.

WATER:

Water gets into your crankcase typically through condensation or in exhaust gases that escape past the piston rings. It's your engine's job to get rid of this moisture by operating at sufficiently high temperatures (motor oil temperature above boiling point of water 212° F is ideal).

However, all engines operate periodically at low temps and experience some water contamination. When this occurs, water becomes emulsified. That is, it is absorbed by the oil, which thickens the lubricant. As a result, the oil does not flow or cool well. The increased viscosity can cause the oil to burn, creating engine deposits. Unfortunately, there is not much that engine oil can do to reduce the harmful effects of water.

ACIDS:

When fuel burns, some products of combustion react with moisture in the system to form acids. These include sulfuric, hydrochloric and organic acids. Sulfur-based acids are undesirable because they attack the oil, reducing its detergency. Organic acids react with unburned fuel to promote sludge and varnish. In addition, acids can cause additive settling, or dropout.

DIRT:

People associate dirt with engine wear. It can also play a role in sludge formation. Wear of piston rings and cylinder walls causes an increase in piston blow-by.

However frequently more "dirt" is introduced into engine during an oil change than during the operation in between the oil changes.

BLOW-BY:

Since exhaust gases contain harmful by-products, their presence in the crankcase should be minimized. Some of these compounds will escape past the rings.

A clogged or defective PCV valve can contribute to sludge formation. If this valve does not operate properly, harmful exhaust gases remain in the crankcase. These gases, which contain water, acids, soot, etc., promote sludge formation.

ENGINE COOLANT (Antifreeze):

Coolant is your engine oil's number one enemy. Engine sludge is inevitable when oil meets engine coolant. Contamination of your oil with coolant promotes sludge by two means. First, it introduces water into the oil. This presents problems that we've previously discussed. Second, it brings into contact oil and coolant, which are incompatible fluids.

Oil and coolant react to form deposits as they experience temperature changes in your engine. Some are gooey or gel-like. Others are hard, brittle deposits that plug oil passageways, reducing oil flow. These two types of deposits guarantee a shortened life for your engine.

No oil additives available will help solve this problem. The only solution is to drain the oil and locate the source of contamination. Then, have the mechanical problem repaired.

Most common cause of sludge problem

As complex as the issue of sludge formation is, the most common cause of the sludge problem is the oil itself.

More exactly it is the use of either substandard oil like API SA or just using even the top quality oil for just too long.

As "obvious" as this may be, it is not surprising that general motoring public is not aware of either of these two problems..

Even if your "Owner's Manual" recommends top API or ILSAC quality motor oil, there is not any assurance that the local cut rate "quick oil change" outlet actually will use it in your vehicle, more often than not they will use deeply discounted "surplus" bulk oil whose quality is either substandard or as bad as API SA !

The second most common reason is just running way too long on the motor oil for the given type of service.

As indicated in the "HEAT" example you can ruin perfectly good motor oil (or gear oil or ATF) in just few hours by overheating it.

Another not too often disclosed fact is that during the ILSAC or API engine tests on motor oils, the oil life is measured in HOURS, and yet only very few vehicles sold anywhere in the world have ENGINE HOUR RUN meters.

The normal motor oil recommended service frequency is specified in miles or kilometers, but the motor oil life is in hours of service.

Sure you can approximate how many miles you on average drive in how many hours, but if in your particular car you are stuck daily in stop and go traffic, you can easily average twice or even three times MORE hours of engine run time for the SAME distance travelled !

Most people in the USA spend about 500 hours in their vehicles annually while driving from 9,000 to 15,000 miles. That is an average speed of only 18 to 30 MPH !

Yet automobile industry still today equates "normal" driving with 45 MPH average, something that is almost unattainable in modern traffic unless you only drive on highways.

The longest and most severe engine oil test: "**Sequence VG engine test**" runs for 216 hours, and if motor oil passes this test it is suitable to be licensed under the latest **API** and **ILSAC** quality classification (**API SM** or **ILSAC GF-4**) - yet that represents MAXIMUM SAFE service interval of only 3,888 miles for someone that averages 18 MPH in typical city traffic !

But what if your MPH average is only 12 MPH ? That is ONLY 2,592 miles !

You SHOULD change your oil that often ! Even if it is of the latest **API SM** classifications.

But what if you "accidentally" or "inadvertently" install API SA motor oil and you subject the car to the same operating regime ? Such oil is safe ONLY for about 20 to 50 hours - or ONLY 240 to 600 miles of operation BEFORE it should be changed. It will FAIL (engine will have mechanical damage) in 144 hours - or as little as 1,728 miles of stop and go traffic at 12 MPH - you will have serious engine problems !!!

During laboratory **Sequence VG engine test** of **API SA** oil, intermediate inspections of the valve decks, rocker arm covers and camshaft baffles with the API SA oil showed sludge deposits at 144 hours, and at 168 hours the kinematic viscosity had increased as well, to a point where the test had to be aborted to prevent certain engine failure.

Just ONLY ONE fill with poor quality oil not just can, but WILL ruin your engine ... given enough time ! (about 200+ hours)