GUIDE TO COOLANT ANALYSIS AND COOLING SYSTEM MAINTENANCE

COOLANT FORMULATIONS & RECOMMENDED TEST PACKAGES

Conventional Coolant

- Automotive, Light Duty & Heavy Duty engines
- Ethylene glycol, propylene glycol or glycerin base
- Inorganic inhibitor package for metal corrosion and cavitation pitting protection

Components

Typical Color: Green/Yellow, Pink, Blue, Purple
Ethylene/Propylene Glycol or Glycerin based
- Freeze point suppression
- Boil point elevation

Borate
- Iron protection
- pH buffer

Nitrate
- Aluminum and solder corrosion protection

Nitrite
- Cast iron and steel corrosion protection

Phosphate
- Iron protection
- pH control

Silicate
- Aluminum corrosion protection

Azoles (Mercaptobenzothiazole - MBT, Tolytriazole – TTZ or Benzothiazole - BZT)
- Yellow metal protection (copper & brass)

Silicon & Block Polymers
- Defoamant
- Scale and deposit control

SCA & Water
- Marine engines, Locomotives, Cooling towers
- Inorganic inhibitor package for metal corrosion and cavitation pitting protection
- General use in India, China, Brazil, Mexico, etc.
- General recommendation is to not use where there is a chance of freezing

Recommendations
- Sample high hour/mileage or high asset engines quarterly
- Sample engines less critical to production semi-annually
- Monitor glycol, nitrite, molybdenum and pH levels at every PM
  - High glycol could indicate an air leak that is allowing the water in the coolant to evaporate due to excessive under-hood heat
  - Submit samples with a significant drop in SCA for laboratory testing to determine cause

Test Package

Standard Conventional Coolant
- Visuals (color, foam, oil, fuel, magnetic precipitate, non-magnetic precipitate, & odor)
- pH
- Glycol %
- Freeze Point
- Nitrite
- SCA Number
- Total Hardness
- Specific Conductance
- Corrosion Metals & Inhibitors by ICP (Iron, Copper, Aluminum, Lead, Tin, Zinc, Silver, Calcium, Magnesium, Borate, Silicon, Molybdenum, Phosphorus, Potassium, Sodium)

Premium Conventional Coolant

Standard Conventional Coolant test package plus:
- Contaminant and Inhibitor Anions by IC (Fluoride, Chloride, Sulfate, Nitrite, Nitrate, Phosphate, Glycolate, Formate, Acetate, Oxalate)

Extended Life Coolant

(1st Generation)
(OAT, NOAT & HOAT)

Organic Acid Technology (OAT)
- Typical color: Orange
- Automotive and Light Duty
- Controls corrosion

Nitrite Organic Acid Technology (NOAT)
- Typical color: Red/Orange
- Heavy Duty engines
- Nitrite added for cavitation corrosion protection

Hybrid Organic Acid Technology (HOAT)
- Typical color: Fluorescent Yellow
- Automotive and Diesel engines
- Combination of conventional and OAT technologies
- Not restricted to any particular type of additive
- Low-Silicate and Phosphate free

Components

Ethylene Glycol
- Freeze Point Suppression
- Boil Point Elevation

Potassium Soap of Dibasic Carboxylic Acid
- Iron, Solder and Aluminum Protection

Potassium Soap of Monobasic Carboxylic Acid
- Aluminum and Iron (w/sebacate) Protection

Nitrite
- Cast Iron and Steel Protection

Molybdenum
- Iron Corrosion Protection (w/nitrite)

Azoles (Mercaptobenzothiazole - MBT, Tolytriazole – TTZ or Benzothiazole - BZT)

Modified Silicone Defoamant
- Inhibit foaming tendencies

Recommendations
- Sample high hour/mileage or high asset engines quarterly
- Sample engines less critical to production semi-annually
- Monitor glycol, nitrite and pH levels at every PM
- When changing from a conventional to an extended life coolant, first flush the system thoroughly unless using a conversion fluid - mixing the two degrades the benefit of using an ELC

NOTE: Components listed above do not reflect all components used in all ELCs manufactured

Test Package

Standard Extended Life Coolant
- Visuals (color, foam, oil, fuel, magnetic precipitate, non-magnetic precipitate, & odor)
- pH
- Glycol %
- Freeze Point
- Nitrite
- SCA Number
- Specific Conductance
- Carboxylic Acid Pass/Fail
- Total Hardness
- Corrosion Metals & Inhibitors by ICP (Iron, Copper, Aluminum, Lead, Tin, Zinc, Silver, Calcium, Magnesium, Borate, Silicon, Molybdenum, Phosphorus, Potassium, Sodium)

Premium Extended Life Coolant

Standard ELC Coolant test package plus:
- Contaminant and Inhibitor Anions by IC (Fluoride, Chloride, Sulfate, Nitrite, Nitrate, Phosphate, Glycolate, Formate, Acetate, Oxalate)
- Organic Acid and Azoles by HPLC(Benzoate, 2-Ethylhexanoic Acid, Sebacic Acid, Octanoic Acid, p-Toluic Acid, Mercaptobenzothiazole, Tolytriazole, Benzothiazole)

Extended Life Coolant

(2nd Generation)
(NAP-Free or NAPS-Free & P-OAT)

North American & European Formulated Coolants
- Typical color: Red
- Heavy- and light-duty diesel, natural gas, and gasoline engines
- Nitrite, Amine, Phosphate Free
- Combination of organic acids as inhibitor package
- Requires a different glycol curve than traditional coolant

P-OAT (Asian Formulated Coolants)
- Typical color Red/Orange or Blue
- Heavy- and light-duty diesel, natural gas, and gasoline engines
- Nitrite, Amine, Borate & Silicate Free
- Includes Phosphates
- Combination of organic acids as inhibitor package
- Requires a different glycol curve than traditional coolant

Components

Ethylene Glycol
- Freeze Point Suppression
- Boil Point Elevation

Carboxylic Acids – Standard
- Benzoate, 2-Ethylhexanoic, Sebacic, Octanoic, p-toluic, Adipic or Dodecanedioic acid
- Iron, Solder and Aluminum Protection

Azoles (Mercaptobenzothiazole - MBT, Tolytriazole – TTZ or Benzothiazole - BZT)

Phosphate
- Iron protection
- pH control

Modified Silicone Defoamant
- Inhibit foaming tendencies

Recommendations
- Sample high hour/mileage or high asset engines quarterly
- Sample engines less critical to production semi-annually
- Monitor glycol and pH levels at every PM
- Test organic acids by High Pressure Liquid Chromatography (HPLC) or test strip is necessary to determine suitability for continued use

— Mixing ELC coolant formulations with conventional coolant will degrade ELC benefits.

— If changing from a conventional to an ELC product flush the system thoroughly first unless conversion fluid is used.

— Coolant components listed above do not reflect all components utilized in all 2nd generation ELC coolants manufactured.

Test Package

Standard Extended Life Coolant
- Visuals (color, foam, oil, fuel, magnetic precipitate, non-magnetic precipitate, & odor)
- pH
- Glycol %
- Freeze Point
- Nitrite
- SCA Number
- Specific Conductance
- Carboxylic Acid Pass/Fail
- Total Hardness
- Corrosion Metals & Inhibitors by ICP (Iron, Copper, Aluminum, Lead, Tin, Zinc, Silver, Calcium, Magnesium, Borate, Silicon, Molybdenum, Phosphorus, Potassium, Sodium)

Premium Extended Life Coolant

Standard ELC Coolant test package plus:
- Contaminant and Inhibitor Anions by IC (Fluoride, Chloride, Sulfate, Nitrite, Nitrate, Phosphate, Glycolate, Formate, Acetate, Oxalate)
- Organic Acid and Azoles by HPLC(Benzoate, 2-Ethylhexanoic Acid, Sebacic Acid, Octanoic Acid, p-Toluic Acid, Mercaptobenzothiazole, Tolytriazole, Benzothiazole)

NOTE: Test package selection should be based on application, OEM coolant formulation and program goals.

COOLANT MAINTENANCE

Visual Appearance

	PROBABLE CAUSE	POTENTIAL DAMAGE
Color • should be clear and bright • Should match the color of original coolant used	Coolant mixing, glycol degradation, outside contaminants, precipitation	
Oil in Coolant • free from oil or petroleum products (can cause seal and hose failures)	oil cooler rubber seal or core leaks; combustion gas blow-by into the coolant	loss of heat transfer, liner, hose and water pump seal damage, block head water passage seal damage
Non-Magnetic/Magnetic Precipitate • free from precipitate, flocculent, algae, bacteria, and/or sludge (outside contaminants entering the system or coolant chemical dropout); magnetic precipitate should be a trace or less	improper coolant use, over-inhibiting, defective electrical grounds	water pump seal abrasion, scores soft metal surfaces (copper & aluminum), liner pitting around lower seals

NOTE: *Sample appearance alone does not determine whether a potentially harmful problem exists within the cooling system.*

Antifreeze/Glycol %

SPECIFICATIONS		PROBABLE CAUSE	POTENTIAL DAMAGE
• Antifreeze level will vary by OEM specifications, application and elevation at which the system operates • Engines operating at 195º or above must be at 50% for boil point control	Too Low	• Improper mixing of bulk coolant • Topping off with water only	• Internal boiling • Frozen and cracked block • Cavitation and pitting
• Engines operating at 10,000 ft. and above should maintain a 55-60% antifreeze level to prevent coolant boiling • Marine applications should maintain 30-60% antifreeze if the system operates above 195º	Too High	• Improper mixing of bulk coolant • Topping off with glycol concentrate • Evaporation of water	• Loss of heat transfer • Cavitation • Pitted liners • Seals may fail

pH

SPECIFICATIONS		PROBABLE CAUSE	POTENTIAL DAMAGE
• Conventional Coolant: 8.0 to 11 • ELC Formulation: typically 7.0 to 9.5; if pH is above 9.5, possible ELC and conventional coolant mixing • Correct cause of drop in pH	Too Low	• Coolant is water only • Source water does not meet engine manufacturer specifications • Ethylene glycol is beginning to degrade or coolant is burnt • Combustion gas blow-by from cracked head, head gasket failure, perforated hole in cylinder liner, etc… • Acid type cleaner used and not flushed thoroughly	• Corrosion on iron components as well as other metals in the system • Electrolysis pitting through liners • Corrosive attack on engine block • Possible corrosion protection chemicals precipitate out of solution
	Too High	• Coolant mixing of different formulations • Severe aluminum corrosion; aluminum is an alkaline metal • Overtreating the system with SCAs • Outside contaminant entering the system	• Severe aluminum corrosion • Inhibitor precipitation

Castrol LABCHECK NEXTGENERATION

COOLANT FORMULATIONS & RECOMMENDED TEST PACKAGES (continued)

Specific Conductance

SPECIFICATIONS		PROBABLE CAUSE	POTENTIAL DAMAGE
• Normally this level will be between 1000 and 6500 micromhos • Less than 10,000 micromhos • When level is excessive, find cause and correct	Too High	• Improper source water • Combustion gas leak • Antifreeze level too high • Inhibitor level too high • Inhibitor being added too many times over an extended period of time • Coolant mixing	• The inability of the coolant to resist carrying an electrical current between the dissimilar metals of an engine's cooling system • Engine becomes a wet cell battery

Total Corrosion Metals

(NOTE: Limits below are guidelines only. Type, make, model, service time, maintenance procedures and operating environment can affect machine severity level.)

SUGGESTED LIMITS BY SEVERITY (ppm)

Metals	A	B	C	D
Aluminum (Al)	0-4	5-9	10-14	>/=15
Copper (Cu)	0-4	5-9	10-14	>/=15
Iron (Fe)	0-14	15-24	25-34	>/=35
Lead (Pb)	0-14	15-24	25-34	>/=35
Tin (Sn)	0-14	15-24	25-34	>/=35
Zinc (Zn)	0-14	15-24	25-34	>/=35
Silver (Ag)	0-14	15-24	25-34	>/=35

PROBABLE CAUSE	POTENTIAL DAMAGE
• Air leaks • Combustion gas leaks • Localized over heating or hot spots • Electrical ground problems • Improper coolant maintenance • Improper source water being used	• Metal component corrosion • Copper or aluminum erosion • Liner pitting

Inhibitors and Additives

SPECIFICATIONS		PROBABLE CAUSE	POTENTIAL DAMAGE
• The SCA level refers to an additive in conventional coolant • Corrosion protection chemicals refer to nitrite or nitrite/molybdate in Extended Life Coolants or Extenders • Levels will vary depending on brand of coolant used: 780 ppm minimum for proper protection with nitrite no less than 300 ppm • Supplemental coolant additive/corrosion protection levels should be tested every PM in the field by strip and every quarter on high mileage engines or semi-annually on low mileage engines in the lab	Too Low	• Maintenance chemicals are not sufficient for metal protection and to prevent sludge from forming • Air leak into the cooling system • Combustion gas blow-by from cracked head, head gasket failure, perforated hole in cylinder liner, etc. • Localized overheating or hot spots • Stray electrical current going to ground through the coolant	• Corrosion protection chemicals insufficient for proper metal protection • Liner pitting and cavitation • Loss of heat transfer due to foaming • Coolant becomes acidic under heat
	Too High	• Addition of chemicals excessive for engine application • Adding inhibitor without checking present level • Coolant mixing of different formulations	• Silicate and/or phosphate can form deposits • Silicate and/or phosphate can precipitate to cause plugging and cavitation due to restriction of flow. • Coolants can form sludge over time

Organic Acids

	SPECIFICATIONS	PROBABLE CAUSE	POTENTIAL DAMAGE
	• Coolant manufacturer specific	• Coolant mixing of different formulations causing dilution of organic acids	• Corrosion protection chemicals insufficient for proper metal protection

SCALING POTENTIAL

Total Hardness

	SPECIFICATIONS	PROBABLE CAUSE	POTENTIAL DAMAGE
(calcium and magnesium as CaCo3)	• Conventional coolant: less than 85 ppm • ELC coolant: less than 85 ppm • Have source water analyzed	• Improper source water • Venting problem • Sea water contamination	• Scale formation that can be hard and insulating • Lack of heat transfer that can lead to cracked heads, head gasket failure, burnt valves, ring and bearing wear, etc

Silicon

	SPECIFICATIONS	PROBABLE CAUSE	POTENTIAL DAMAGE
(corrosion inhibitor for aluminum and seal protection; also found in some source water)	• Depends on coolant formulation; ASTM specification is not to exceed 250 ppm silicon in a conventional coolant for heavy-duty diesel engines • ELC coolants normally have lower levels • OAT, NOAT, NAPS-Free and P-OAT coolants do not have silicon • Automotive coolants have higher levels due to more aluminum in system	• Improper source water • Poor coolant maintenance practices • Mixing coolant formulations • Leaching from hoses	• Loss of lubrication • Increased ring bearing wear • Hot spots • Loss of heat transfer • Burnt valves • Silica gelation (green goo)

Phosphate

	SPECIFICATIONS	PROBABLE CAUSE	POTENTIAL DAMAGE
(corrosion inhibitor for iron protection)	• Best not exceed 10,000 ppm	• Over treatment of SCA • Over treatment of glycol • Excessive phosphate in antifreeze formulation • Mixing coolant formulations	• Inability for the coolant to maintain the phosphate in a soluble state • Scale formation due to phosphate combining with calcium or magnesium • Plugging of radiator and coolers

ACID PITTING POTENTIAL

Sulfate

	SPECIFICATIONS	PROBABLE CAUSE	POTENTIAL DAMAGE
	• Lower the better • Less than 300 ppm	• Improper source water • Combustion gas leaks • Sulfuric acid cleaner left in system	• Can form sulfuric acid • Combine with calcium to form scale • Severe metal corrosion and component damage

Glycolate

	SPECIFICATIONS	PROBABLE CAUSE	POTENTIAL DAMAGE
	• Less than 1000 ppm • Less than 2500 ppm Total Degradation Acids	• Localized overheating • Air leak • Combustion gas leak	• Ethylene glycol continuing to break down to form acids such as formic, acetic, oxalic • Coolant will be burnt and produce a foul solvent odor as well as take on a varnish characteristic • Severe metal corrosion and damage to components

Chloride

	SPECIFICATIONS	PROBABLE CAUSE	POTENTIAL DAMAGE
	• Less than 110 ppm	• Improper source water • Defective pressure relief valve or cap • Aging coolant • Presence of hydrochloric acid cleaner • Improper venting • Sea water leak	• Severe metal corrosion • Decarbonize iron • Hydrochloric acid formation • Localized aluminum corrosion

PREVENTIVE MAINTENANCE CHECKLIST

- ☑ Inspect belt tension & condition, hoses, radiator, fan, fan clutch
- ☑ Check for leaks, stains or streaks around hose clamps or cylinder block and wet areas around the radiator and on the ground
- ☑ Check radiator for damaged fins, dirt or debris
- ☑ Inspect pressure cap – check pressure
- ☑ Check fan operation, clutch activation
- ☑ Check temperature variances with infrared heat gun
- ☑ Check coolant level
- ☑ Perform appropriate PM field testing
- ☑ Pull sample for scheduled laboratory testing

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