Heavy-Duty Truck Cooling System

Coolant Technology Maintenance

Course Objectives

- Basic Overview Of Cooling System Operation And Components
- Discuss Common Cooling System Component Problems
- Review Antifreeze/Coolant Technologies
- Discuss Industry Standards For Aftermarket Antifreeze/Coolants
- Understand Prestone Command™ Antifreeze/Coolants
- Review Testing Methodology and Coolant Analysis Program
- Discuss Water Quality And Importance of Using Quality Water
- Explain Levels of Unwanted Cooling System Compounds with Potential Damaging Effects
- Understand Electrolysis And The Effects On The Cooling System
- Review Testing Methodologies For Electrolysis In The Cooling System

History of Prestone

Prestone History

1927: Prestone Antifreeze /Coolant was “born”
as pure Ethylene Glycol in cans

1930: Development and marketing of 1st Prestone
inhibitor package for even more protection

Over our 85+ years Prestone has developed antifreeze/coolants and inhibitor packages to protect current and future cooling system materials and holds over 100 patents

1972: Prestone Antifreeze is reformulated to incorporate
greater inhibitor effectiveness for aluminum cooling systems

1981: Prestone Antifreeze is reformulated to provide
even more corrosion protection

2001: Prestone Antifreeze is reformulated with a patented
formulation to provide corrosion protection for today’s
and future cooling systems

Prestone releases 50/50 pre-mixed AF/C – Ready to Use AF/C

Prestone Today

2002: GM Global Supplier Of Antifreeze/Coolant

2002: Release Of “All Makes All Models” Antifreeze/Coolant

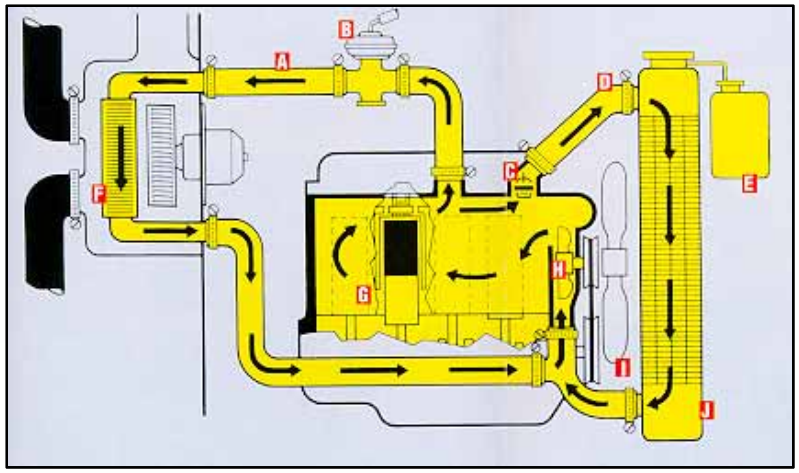
2010: Ford Motor Company Antifreeze/Coolant Supplier

2011: Navistar Approved YA956 OAT Antifreeze/Coolant Formulation

2013: Release of Prestone Command™ HD Antifreeze/Coolants

Cooling System 101

Heat Dissipation From The Engine



A- Heater Hose
B- Heater Control Valve
C- Thermostat
D- Radiator Hose
E- Overflow Reservoir
F- Heater Core
G- Engine
H- Coolant Pump
I- Fan
J- Radiator

- One-third transferred to the cooling system
- One-third transferred out the exhaust system
- One-third transferred to mechanical energy to operate vehicle

Cooling System Components

- Radiator
- Heater Core
- Coolant Pump
- Block
- Cylinder Head
- Thermostat
- Hoses
- Oil Cooler
- Air Charge Cooler
- Sensors
- Turbo Chargers

Cooling System Metals

- Cast Iron
- Steel
- Cast Aluminum
- Aluminum Alloys
- Brass
- Copper
- Solder (Sn30a, L50113)
- Magnesium Alloys

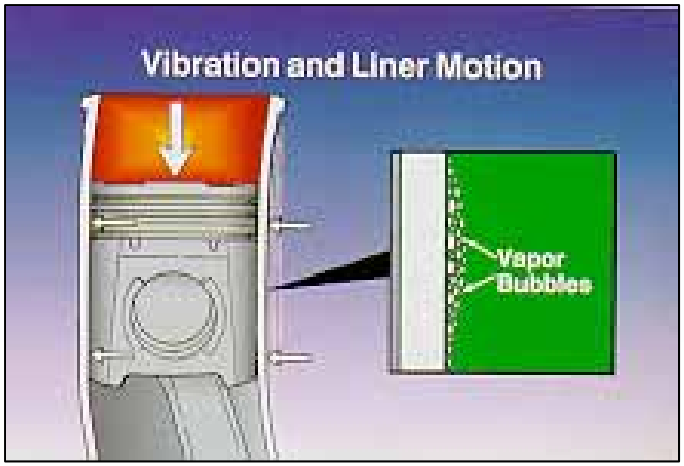
Cooling System Problems

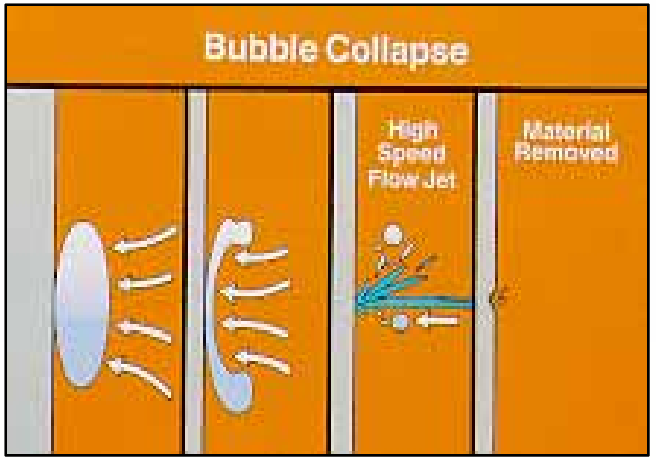
• Blocks	Rusting/ general corrosion
• Cylinder Heads	Cavitation pitting (aluminum), rusting, crevice corrosion under seals, leakage
• Cylinder Liners	Cavitation pitting, solids deposition
• Radiators and heater cores	Solder bloom, solids deposition, pitting (aluminum), blockage, transport-deposition
• Pumps	Seal leakage, bellows failure, cavitation pitting
• Thermostats	Sticking, corrosion/erosion
• Radiator Caps Pressurized Reservoir Caps	Gasket failure, Poor fluid exchange, air in cooling system, cavitation, overheating, collapsed radiator hoses
• Hose Necks	Crevice attack under hose and cavitation

General Surface Corrosion- Blocks

Cast iron surfaces in a corrosive coolant will form rust

Cavitation Pitting Corrosion/Erosion





Cooling System. Heavy Duty Coolant/SCA Maintenance, ProMotional Professional, Cummins, LT 15050

- Liner pitting is caused by vapor bubbles formed when the piston strikes the liner during heavy duty engine operation

Cavitation Pitting Corrosion-erosion

In an improperly protected cooling system cavitation corrosion-erosion can result in liner perforation

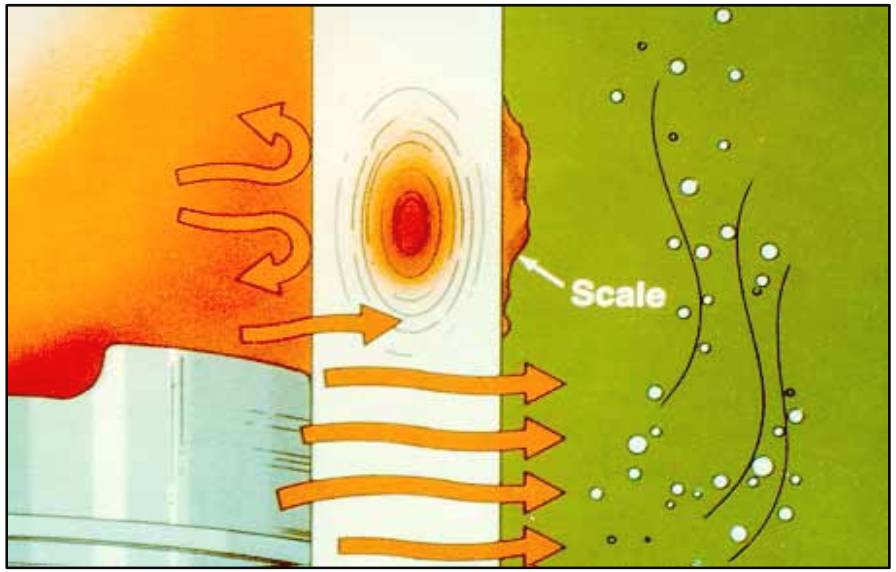
When coolant enters the combustion chamber, it will destroy an engine within minutes

Liner pitting is controlled by using the proper and fully formulated antifreeze/coolant

Cooling System Liner/Water Pump Pitting, TF-158, Nalco

Scale Corrosion/Erosion

Hard water scale
Phosphate dropout
Silica fallout
SCA dropout



Cooling System. Heavy Duty Coolant/SCA Maintenance, ProMotional Professional, Cummins, LT 15050

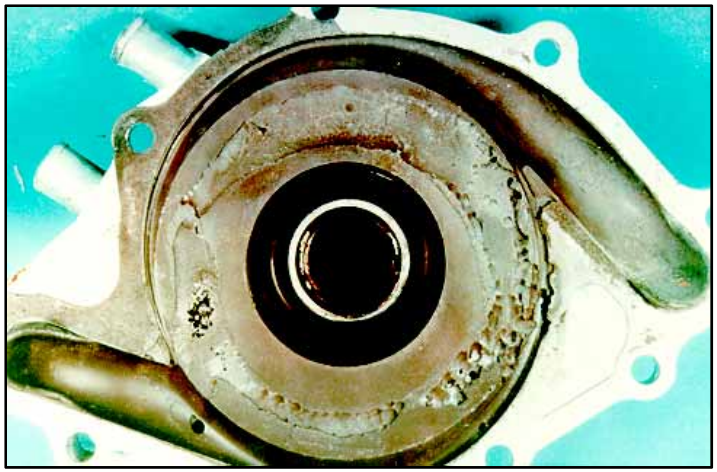
Scale

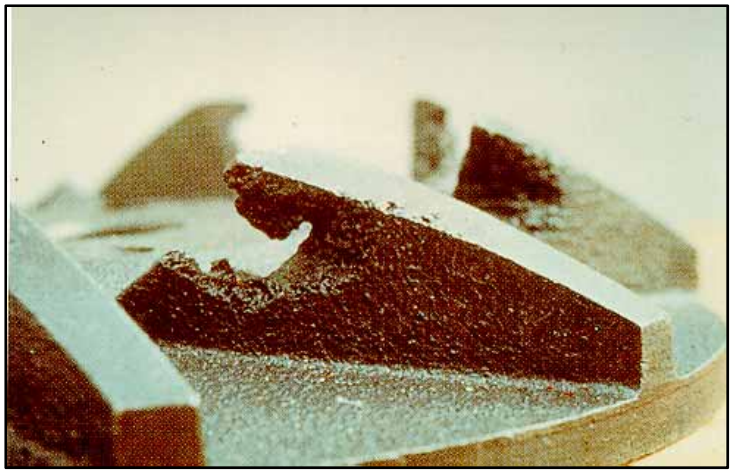
Polaris Labs, Cooling System Maintenance


From: Penray Technifax Bulletin TF-159

- Decreases flow
- Under deposit corrosion reduces part life
- Contributes to erosion corrosion
  - Poor heat transfer
  - Higher coolant temperatures
  - Higher oil & head temperatures
- Gelation and Contamination
  - Decreases flow and heat transfer

Cavitation Erosion Corrosion





- Damages Water Pump
  - Cavitation erosion corrosion
  - Aluminum Water Pump Cavitation
- Reduces Part Life

Erosion Damage Removes Metal

Heavy Deposits on Water Pump Seal Faces

- Water pump seal shown contains deposition of calcium phosphate. This deposition (formed by a hard water salt combining with phosphate, which is found in antifreeze and some additive packages) often causes seal failure and a lost water pump
- These deposits can destroy the flatness of a seal face, preventing the water pump seal from sealing properly. The end result can be coolant entering the air side of the water pump, resulting in destruction of pump bearing

From: Penray Technifax Bulletin TF-158

Thermostats and Temperature Sensors

Thermostats

Scale prevented the fan sensors from sensing coolant temperature. Cooling system fans never turned “ON” and the cooling system eventually boiled over

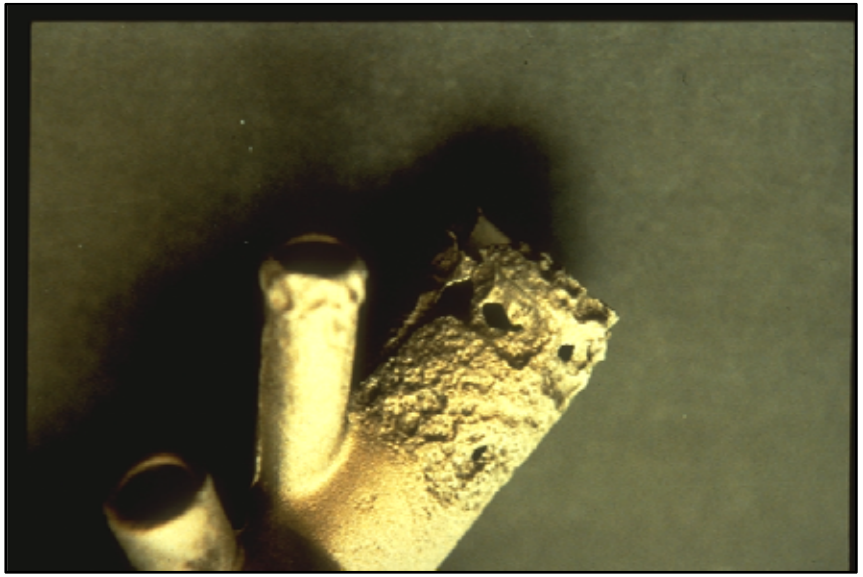
Radiator Caps

- Inspect pressure cap gasket
- Test pressure cap to rated pressure using a proper tester

Improper cooling system pressure can cause localized overheating and lead to component damage and oil degradation

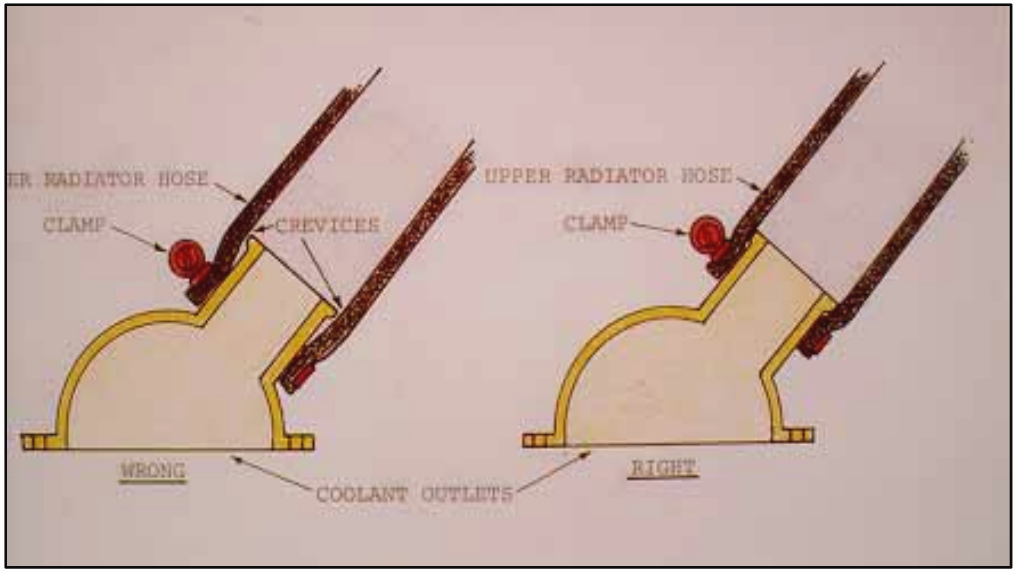
Drop out of silicates in a conventional coolant can occur from air leaks, drop in pressure, significant drop in pH, contaminates introduced into the system

Hose Necks



Severe crevice attack of coolant outlet

Hose Necks and Rubber Coolant Lines



The right and wrong way to position a hose clamp on a coolant inlet and/or outlet hose neck

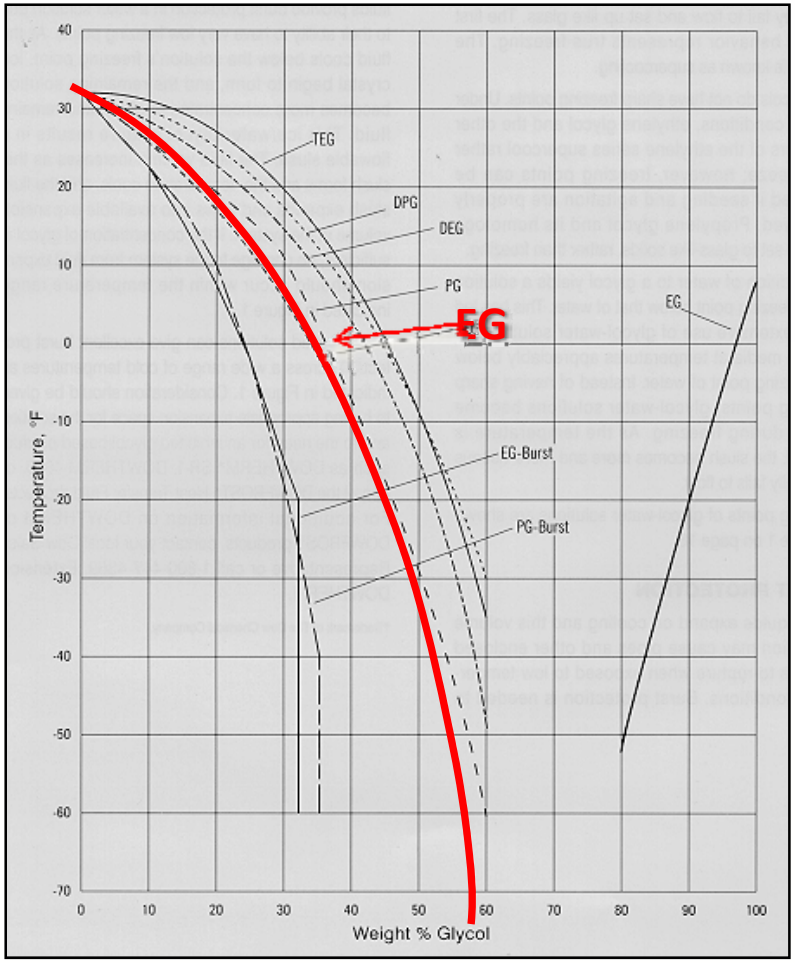
Antifreeze/Coolants 101

Composition Of Engine Coolants

	Wt%
• Glycol	95
• Inhibitors (inorganic / organic)	1.5 – 4.0
• Water	1.0 - 3.5
• Antifoam	10 – 1000 ppm
• Dye	trace

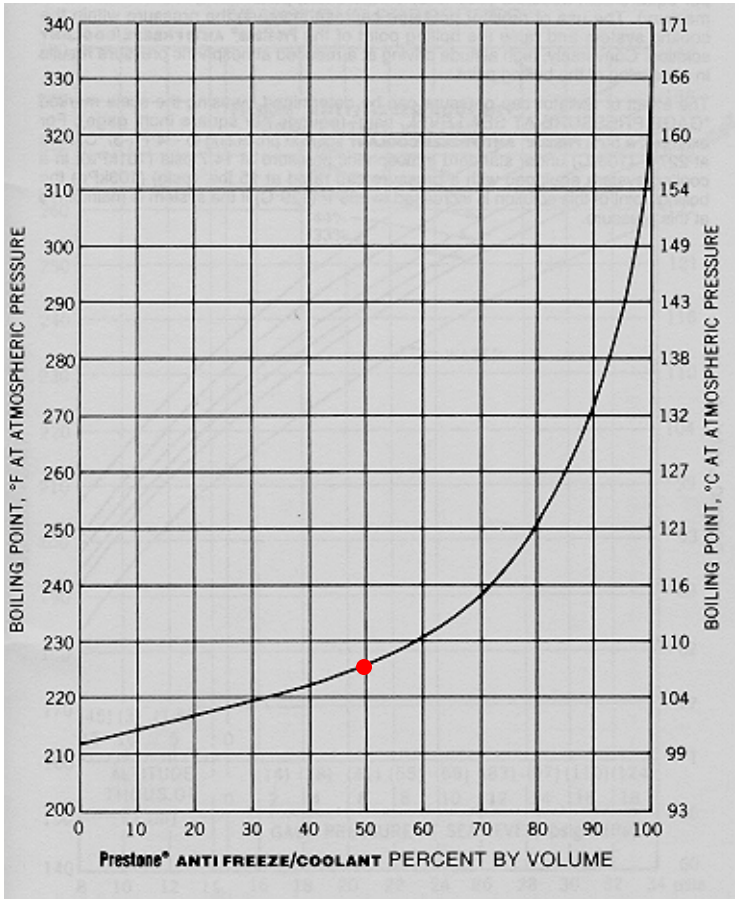
These values are approximate and do not reflect all antifreeze/coolant formulas

Freeze Point Of Aqueous Antifreeze/Coolant Solutions

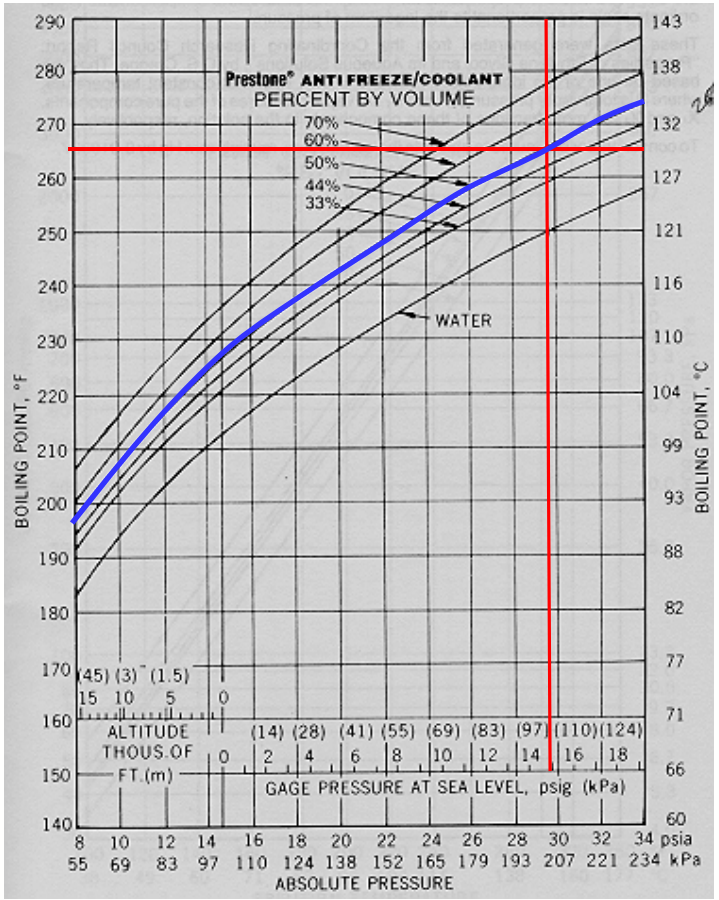


Accurate freezing points have been obtained for Antifreeze/Coolant solutions giving freezing protection down to -60 F (-51C)

Boiling Point Of Aqueous Antifreeze/Coolant Solutions



Boiling point at atmospheric pressure



Boiling point at various pressure

Antifreeze/Coolants --What Are the Differences?

- Inorganic Additive Technology (IAT)
- Nitrite Organic Acid Technology (NOAT)
- Organic Acid Technology (OAT)

The Role Of Inhibitors In Engine Coolants

• Borate	pH Buffering, cast iron
• Phosphate	pH Buffering, cast iron, aluminum
• Silicate	Aluminum, cast iron
• Silicone	Stabilize silicate
• Nitrite	Cast iron, prevents cavitation of cylinder liners
• Molybdate	Cast iron, prevents cavitation of cylinder liners
• Nitrate	Aluminum, Prevents pitting and crevice attack
• Azoles	Brass, copper, solder

The Role Of Inhibitors In Engine Coolants

• Sebacate	Cast iron, buffering
• Ethyl hexanate	Cast iron, buffering
• Neo Decanoate	Cast iron, buffering
• Benzoate	Buffering, cast iron, steel
• Organic Acid (Mono and/or Di)	Aluminum, Cast Iron, Solder
• Phosphate Esters and Polymers	Scale and deposit control, defoamant

Proper Combinations of Inhibitors-- Key to Performance!

Antifreeze/Coolant - What is the Difference?

HD Conventional

- Low Silicate Antifreeze/Coolant
  - Not used in factory fill
  - Phosphate and/or Borate, Nitrate, Nitrite, Azoles
  - Color: Green, yellow, other colors used as well
  - SCA's must be added at initial fill and monitored and recharged when necessary for proper protection to hours or mileage
  - Optimum change interval- one year
    - Protects up to 3000 hours or 100-150K, based on OE and manufacturer

Antifreeze/Coolant - What is the Difference?

HD Extended Service Interval

- Used factory fill in some HD cooling systems
  - Low Silicate Antifreeze/Coolant
  - Phosphate and/or Borate, Nitrate, Nitrite, Azoles
  - SCA Pre-charged (initial fill)
  - Color: Purple (recommended by TMC), other colors used as well
  - SCA's must be monitored and recharged when necessary for proper protection; check coolant level routinely and top-off only with ESI type product to minimize SCA addition
  - Coolant analysis is recommended at least once per year to monitor condition of Ethylene Glycol and also pH, metals, etc…

HD cooling systems on average, generally, leak at a rate of one gallon per month. It is very important to routinely check cooling system level and top-off with the proper antifreeze/coolant product and dilution.

Antifreeze/Coolant - What is the Difference?

Nitrite Organic Acid Technology (NOAT)

- Used factory fill in some HD cooling systems
  - More common place in today's HD cooling systems
  - Nitrite and/or Molybdate with Organic acids
  - Borate, Silicate, and Phosphate Free
  - Color: Red, Blue, Pink
    - Many other colors used as well
  - Protects up to 12,000 hours or 600,000 miles
    - Protection up to miles and hours with use of an Extender at 6000 hours or 300,000 miles

Antifreeze/Coolant - What is the Difference?

Organic Acid Technology (OAT)

- Used in factory fill in some light-duty and medium-duty gas and diesel engine cooling systems for factory fill
  - Used in full cast block diesel engines (without Wet Sleeves)
  - Organic acids
  - Borate, Silicate, Nitrite and Phosphate Free
  - Color: Orange, Red
    - Other colors used as well
  - Protects up to 5 years or 150,000 miles

Antifreeze/Coolant Products

Prestone COMMAND

ANYWHERE. ANYTIME. ANY ENGINE.™

Coolant Technology

- World class technology from world class scientists
- Partner with fleet owners and OE's
- Prestone® knows HD engine concerns
- Prepared for present and future technology
- Reduce maintenance and downtime

Prestone COMMAND

ANYWHERE. ANYTIME. ANY ENGINE.™

Extended Service Interval Coolant Technology

- Prestone Command™ Heavy Duty Antifreeze/Coolant is formulated with advanced corrosion protection technology.
- This provides an exceptional SCA pre-charged Extended Service Interval (ESI) Technology product which is compatible with any conventional heavy duty coolants and need-release filter technologies.
- Prestone Command™ Heavy Duty Antifreeze/Coolant is designed for use with ANY antifreeze/coolant in ANY Heavy Duty Engines used in normal to severe duty cycles and extreme temperature conditions.
- This product will provide complete protection against freezing, overheating, cavitation erosion, corrosion, scale and foaming without the need of SCA's in the initial fill.
- Concentration levels should not fall below 40% or exceed 65% by volume.

Pre-diluted & Full Concentrated Available

Available in Gallons, 55 Gallons, & Totes

Prestone COMMAND

ANYWHERE. ANYTIME. ANY ENGINE.™

Extended Life Coolant Technology

- Prestone Command™ Heavy Duty Extended Life Antifreeze/Coolant (ELC) is intended for use and compatible with ANY heavy duty antifreeze/coolant in ANY diesel powered commercial vehicle engine or stationary engine with aluminum or other engine metals.
- It's patented technologically advanced formulation is based upon a concentrated blend of premium long-lasting inhibitors designed to provide up to 600,000 miles / 12,000 hours* of protection against temperature extremes, rust, corrosion, scale and premature water pump failure.
- When used as directed, Prestone Command™ Heavy Duty ELC may be added to the antifreeze/coolant of any heavy duty commercial or stationary engine.
- Provides a silicate, phosphate and borate-free formulation for long lasting inhibition and corrosion protection.

Pre-diluted & Full Concentrated Available

Available in Gallons, 55 Gallons, & Totes

*One time use of the ELC Extender at 300,000 miles or 6,000 hours is required

Prestone COMMAND

ANYWHERE. ANYTIME. ANY ENGINE.™

Extended Life Prestone® DEX-COOL® Antifreeze/Coolant

- Formulated for use in all vehicles requiring DEX-COOL® antifreeze/coolant
- Patented formula has concentrated blend of premium long-lasting inhibitors for extended performance
- Protects against temperature extremes, ravages of rust and corrosion
- Protects 5 years or 150,000 miles with complete flush and fill

The pre-mixed formula contains
50% demineralized water
for heat transfer protection

GM, Ford, & Navistar Approved Formula

DEX-Cool® is a registered trademark of General Motors Corp.

Prestone COMMAND™ ANYWHERE. ANYTIME. ANY ENGINE.™

Prestone® LowTox® Antifreeze/Coolant

- Provides performance durability and protection against corrosion of all cooling system metals
- Propylene Glycol formula provides added margin of safety for pets and wildlife
- Can be used for light- duty, medium-duty and HD truck applications
- Label carries Ani-Med® logo

Physical Properties Of Glycols

	Degrees F	Degrees C
• Ethylene Glycol @ 15psi	265	129
• Propylene Glycol @ 15psi	259	126
• Ethylene Glycol	-34	-36
• Propylene Glycol	-30	- 34

50 VOL. % GLYCOL-WATER SOLUTIONS

Who is ASTM International?

- Originally known as: American Society for Testing and Materials
- Established in 1898
- Trusted and largest voluntary standards development organization in the world
- Leadership role in addressing the standardization needs of the global marketplace
- www.ASTM.org

OEM Specifications, in general, are Mirrored in the Industry Standard ASTM and SAE Specifications

Current Industry Practice

- Based on ASTM D3306
  - Standard Specification for Glycol Based Engine Coolants for Automobile and Light-Duty Service
- This specification covers the requirements for Aftermarket ethylene glycol based engine coolants (antifreeze) used in all automobiles and light-duty service:
- Ensure heat transfer properties
  - Protection against boil-over
  - Protection against freeze-up
  - Protection against corrosion

All Aftermarket Fluids For Cars And Light Duty Trucks Must Meet ASTM D3306

Current Industry Practice

- Based on ASTM D4985
  - Standard Specification for low silicate ethylene glycol base engine coolants for cooling systems of heavy-duty engines
- This specification covers the requirements for low silicate ethylene glycol base engine coolants (antifreeze) for cooling systems of heavy-duty engines
- Ensure heat transfer properties
  - Protection against boil-over
  - Protection against freeze-up
  - Protection against corrosion

Current Industry Practice

- Based on ASTM D6210
  - specification covers the requirements for fully-formulated glycol base coolants for cooling systems of heavy-duty engines
- When concentrates are used at 40 to 60% glycol concentration by volume in water of suitable quality, or when prediluted glycol base engine coolants (50% volume minimum) are used without further dilution, they will function effectively during both winter and summer
- Coolants meeting this specification do not require any addition of SCA
- This specification does not caver extended life service interval coolants
- To provide protection against:
  - Corrosion
  - Cavitation
  - Freezing
  - Boiling

Testing Methodologies

PRESTONE® Antifreeze/Coolant Tester

PRESTONE® Antifreeze/Coolant **Tester** is a professional type tester that easily tests for **EG** freeze and anti-boil protection

- Allows visual inspection for rust, oil contamination, and sediment

Float Hydrometer Coolant Testers

Coolant drawn into the tube
Depends on the number of floating balls
Limited accuracy and discrimination
Not recommended for use
For Ethylene glycol only

Test Strip Measures:

*Glycol (freeze point)

Nitrite Level

Molybdate Level

pH Level

Organic Inhibitor Levels

*Some are Compatible with Conventional and Extended Life Antifreeze/Coolants

Prestone COMMAND

ANYWHERE. ANYTIME. ANY ENGINE.™

Antifreeze/Coolant Hand Held Refractometer

Refractometer can be used for measuring the concentration and freezing temperature of **ethylene glycol** and **propylene glycol** which are used as antifreeze mixture for automobiles and truck applications. The refractometer can also be used to check the condition of electrolytes in a vehicle battery

- Easy use, friendly and portable
- Wide measurement range
- Easy to clean
- Indoor and outdoor usage
- Designed with a dual scale
- Temperature compensation

Field Test Methods

Measuring Glycol Concentration in Engine Coolant

Method	Accuracy @50% Glycol	Ethylene Glycol (EG)	Propylene Glycol (PG)
Hydrometer	+/- 10 to 20%	Yes	No
Test Strip	+/- 10%	Yes	Yes
Refractometer	+/- 3%	Yes	Yes if PG scale

Fluid Analysis Program

Coolant Analysis Testing
Tests
Visuals (color, oil, fuel, magnetic precipitate, non-Magnetic precipitate, odor & foam)
17 Metals by ICP
pH
Glycol % (Ethylene or Propylene Glycol)
Freeze Point
Boil Point
Nitrite
SCA Number
Total Dissolved Solids
Specific Conductance
Total Hardness

Sampling

- Be consistent
  - Same intervals
  - Same sampling method
  - Same sample location
- Use a clean bottle
- Fill out sample label completely

Hours/Miles on *coolant & unit* are crucial for interpretation of results

Sampling Methods

- Vacuum Pump
  - Turn engine off and allow to cool for approximately 15 minutes
  - Remove radiator pressure cap
  - Insert clean plastic tubing about six inches into coolant
  - Attach a sample bottle to the pump and tighten firmly
  - Activate the pump handle and fill sample jar 3/4 full

Vacuum Pump

Additional Sampling Methods

- Sampling from drain
- Rubber squeeze bulb

COOLANT ANALYSIS REPORT - 877-458-3312	
COMMENTS	Copper is at a SEVERE level, copper can attack the other metals in the cooling system; Zinc corrosion is at a minor level; The glycol level is too low for freeze and boil point control; SCA IS UNDERCONCENTRATED. Total Hardness is at a SEVERE level; Suggest cleaning this system with a cleaner designed to remove deposits from a cooling system then flush 3-5 times with water, install new recommended coolant; Resample in 60 days;

	CORROSION METALS - PPM							SCALE POTENTIAL PPM		CORROSION INHIBITORS - PPM				PPM/10		VISUALS SEE COOLANT REFERENCE TABLE						
SAMPLE #	IRON	ALUMINUM	COPPER	LEAD	TIN	SILVER	ZINC	CALCIUM	MAGNESIUM	SILICON	PHOSPHATE	BORON	MOLYBDENUM	SODIUM	POTASSIUM	FOAM	COLOR	OIL	FUEL	MAGNETIC PPT	NONMAGNET PPT	ODOR
1	0	0	4	0			0	1	4	114	3137	330	427	210	351							
2	0	0	6	0			1	1	6	148	2609	244	334	167	365	NONE	CRGN	NONE	NONE	NONE	NONE	NONE
3	0	0	2	0			0	1	2	98	2554	199	339	127	310	NONE	CLGB	MNOT	NONE	MNFL	NONE	NONE
4	0	0	1	0			0	0	0	147	3351	235	357	122	417	NONE	CRBL	NONE	NONE	MNFL	NONE	NONE
5	1	0	3	0			3	1	7	91	1230	96	149	60	0	NONE	VCGB	NONE	NONE	MNFL	MNFC	NONE
6	4	3	24	3			19	2	39	168	1030	83	141	56	140	NONE	VCDG	NONE	NONE	NONE	NONE	NONE

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"**Highlighted**" numbers denote test results the analyst has **flagged** because they exceed pre-set warning parameters and warrant closer examination or require action.

Samples are listed by **Date Received** in the lab – oldest first. They are also assigned a **Lab Number** for easy internal tracking. Important to also note is whether or not the **Coolant** has been **Changed** since the last sample was taken

Adequate **Glycol** levels must be maintained to ensure proper freezepoint protection. High glycol can cause additive drop out and decrease coolant life. A glycol range of 40% to 60% is recommended

Providing your lab with a New Coolant sample allows the analyst to verify product integrity and establishes a guideline for analyzing subsequent samples. It will appear first on all reports for the unit

SAMPLE #	DATE SAMPLED / DATE RECEIVED	UNIT LUBE	LUBE CHG	FILTER CHG	FREEZE POINT °F	BOIL POINT °F	ANTIFREEZE ppm	pH	HARDNESS ppm	TDS ppm	SPECIFIC CONDUCT µS	SCA NUMBER	CARBOXYLIC ACID pass/fail	NITRITES ppm	NITRATES ppm	CHLORIDES ppm	SULFATES ppm	GLYCOLATES ppm	FORMATES ppm	ACETATES ppm	OXALATES ppm
1	01/16/05 02/07/05		U	U	-41		53	8.9		2349		3.3		1819							
2	08/02/05 08/12/05		U	U	-7	220	38	8.8	23	2460	4640	3.0		1929							
3	01/13/06 02/13/06		U	U	-7	220	38	9.3	0	2230	4220	2.1		995							
4	06/28/06 07/10/06		U	U	-26	223	47	10.4	0	2000	3780	2.4		1204							
5	12/14/06 12/21/06		U	U	17	215	19	9.0	27	1953	3680	1.1		618							
6	05/30/07 06/05/07		U	U	20	214	16	8.9	140	1797	3390	0.8		359							

Excessive **Nitrite** levels can lead to solder corrosion. The **maximum** acceptable is 3333 ppm (parts per million).

Adequate **pH** range is vital to corrosion inhibition and should remain between 7.5 and 11.0

Gradual buildup of **Total Dissolve Solids (TDS)** such as inhibitor chemicals, silicates, contaminants and water hardness compounds can lead to water pump leakage. TDS levels should not exceed 4%. Should leakage occur, drain coolant and flush pump with tap water

An **SCA (Supplement Coolant Additive) Level** of 1.2 is the **minimum** required for adequate liner pitting protection. A level of 2.5 is ideal for extending coolant life.

Poor Maintenance

Leads To Costly Repairs

Properties Of Aqueous Antifreeze/Coolant Solutions

- Antifreeze(Ethylene Glycol Base) and water are mixed at a 50/50 ratio to lower the freeze point of the cooling system to -34 F and raise the boiling point of the system to 228 F.

Cooling System. Heavy Duty Coolant/SCA Maintenance, ProMotional Professional, Cummins, LT 15050

Above 5000 ft elevation antifreeze/coolant concentration should be maintained at a 55-60% antifreeze/coolant to water mixture to reduce the chance of boil over. Refer to OEM specifications

Boiling point increases 2.7^0 F for each 1 psi increase in pressure below 5000 ft
Boiling Point decreases 3^0 F for every 1000 ft above 5000 ft

Problems Caused by Poor Antifreeze Concentration Control

<30 Percent

- Raised freezing point
- Lowered boiling point
- Metal corrosion
- Increased incidence of liner pitting for heavy duty diesels

>70 Percent

- Slushing of Coolant
- Additive precipitation
- Water pump leakage
- Poor heat transfer and overheating
- Raised freezing and lower boiling points
- Higher metal temperature

Importance of Quality of Water

- Deionized Water
  - Deionization process
  - Purified of ions, such as:
    - Sodium, calcium, iron, copper, chloride and bromide
- Distilled Water
  - Distillation process
  - Virtually all of the impurities removed
- Soft Water
  - Naturally occurring or man-made
  - Contains few or no calcium or magnesium ions

Importance of Quality of Water

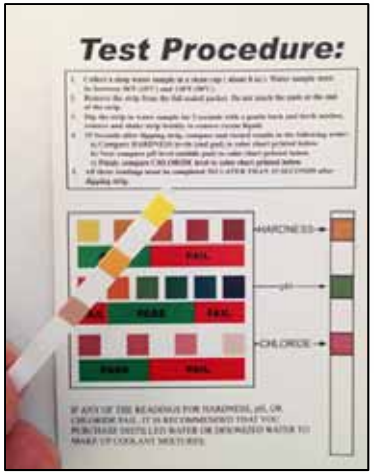
- Calcium and Magnesium
  - Salts of Calcium and magnesium carbonates adhere to metal compounds in hot heat exchangers causing scale build-up
- Chloride and/or Chlorine
  - Municipal water contains chloride and/or chlorine
    - These are corrosive to cooling system components, especially aluminum
- Sulfate
  - Municipal water can contain sulfates
  - Sulfates can contribute to general corrosion and/or scaling

It is <u>not</u> recommended to use hard water in a cooling system.
Hard water can lead to scaling on metal components.

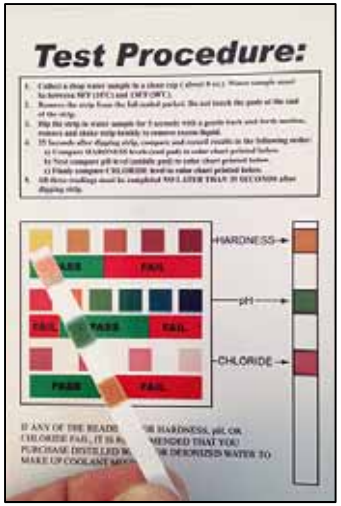
Scaling Property Levels

- Total Hardness < 170 ppm (ASTM)
- Iron < 0.5 ppm
- Silica < 30 ppm
- Sulfate < 100 ppm (ASTM)
- Total Dissolved Solids ≤ 340 ppm

Water Test Strips



Actual water test



Testing:
Hardness
pH
Chloride

pH – Measurement of water acidity or alkalinity – Base 7.0

Higher *pH* Level (Alkaline) Aluminum & Copper corrosion will result

Lower *pH* Level (Acidic) Higher temperature increases acidity causing pitting

Water source should be tested at least once a month

ANTIFREEZE/COOLANT MAINTENANCE

COOLANT MAINTENANCE

Visual Appearance

- Color-- should be clear, bright, and free of contamination

Oil in Coolant

- free from oil or petroleum products

- Probable Cause
  - oil cooler rubber seal or core leaks; combustion gas blow-by into the coolant
- Potential Damage
  - loss of heat transfer, liner 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

- Probable Cause
  - improper coolant use, air leaks,
  - defective electrical grounds
- Potential Damage
  - water pump seal abrasion, increased soft metal corrosion (copper & aluminum), liner pitting around lower seals

Testing appearance alone does not determine whether a potential problem exists within the cooling system

COOLANT MAINTENANCE

Antifreeze/Glycol %

Low

- Probable cause
  - Improper mixing of bulk coolant
  - Topping off with water only
- Potential damage
  - Coolant may boil or the block may freeze
  - Can cause cavitation and/or corrosion damage

COOLANT MAINTENANCE

Antifreeze/Glycol %

High

- Recommendations
  - Engines operating at 5000 ft. and above should maintain a 55-60% antifreeze/water mixture to prevent coolant from boiling
  - Marine applications must maintain 50-60% antifreeze/water mixture if the system operates above 195° F
- Probable cause
  - Improper mixing of bulk coolant
  - Topping up with full concentrate antifreeze
- Potential damage
  - Loss of heat transfer, cavitation, liner pitting, seals may fail

COOLANT MAINTENANCE

pH

Low pH

- Recommendations
  - Conventional coolant: 8.5 to 11
  - ELC formulation: typically 7.0 to 9.0
    - If pH is above 9.0 possible ELC and conventional coolant mixing
- Probable cause
  - Cooling system filled with water
  - Source of water does not meet engine manufacturer specifications
  - Ethylene glycol is beginning to decompose
  - Combustion gas leak
  - Acid type cleaner used and not flushed out properly

COOLANT MAINTENANCE

pH

Low pH

- Potential damage
  - Corrosion on iron components and other metals
  - Electrolysis pitting through liners
  - Corrosive attack on engine block
  - Precipitation of corrosion protection additives

COOLANT MAINTENANCE

Specific Conductance

- Recommendations
  - Normally between 1000 and 6500 microseimens
    - When level is excess find cause and correct
- Probable cause
  - Water source
  - Combustion gas leak
  - Antifreeze level two high
  - Inhibitor level to high
    - Inhibitor added too often over an extended period of time
- Potential damage
  - Coolant carrying an electrical current between dissimilar metals of an engine's cooling system
    - Engine becomes a wet cell battery
  - Erosion of cooling system metals

COOLANT MAINTENANCE

Total Metals

All Measurements ppm

Metal	Borderline	Concern	Problem
Iron	15	25	35
Copper	5	10	15
Aluminum	5	10	15
Lead	15	25	35
Zinc	15	25	35
Tin	15	25	35

COOLANT MAINTENANCE

Total Metals

- Probable cause
  - Air leaks
  - Electrical ground problems
  - Combustion gas leaks
  - Localized over heating
  - Improper coolant maintenance
  - Improper source water
- Potential damage
  - Metal corrosion
  - Liner pitting
  - Corrosion/erosion of any iron components

COOLANT MAINTENANCE

Supplemental Coolant Additives

Too Low

- Recommendations
  - Combined nitrite and molybdate at 1000 PPM is sufficient for proper protection
    - Levels will vary depending on brand of coolant used
- Probable cause
    - Electrical ground problem(s)
    - Poor maintenance practice
- Potential damage
    - Sludge can form over an extended period of time
    - Insufficient corrosion protection chemicals leading to metal corrosion/erosion

COOLANT MAINTENANCE

Supplemental Coolant Additives

Too High

- Recommendations
  - SCA or corrosion protection levels should be tested every 500 hours in the field by strip or every 1000 hours/six months utilizing lab analysis
  - Follow OEM recommended PM schedule for testing
- Probable cause
  - Not following specifications for engine application
  - Addition of SCA's without checking present level
- Potential damage
  - Silicate and/or phosphate precipitation forming scale
    - Can plug radiator cores and after coolers

SCALING POTENTIAL

Total Hardness

Salts of Calcium and Magnesium

- Recommendations
  - Conventional coolant: less than 880 PPM
  - ELC coolant: less than 660 PPM
  - Test source water
- Probable cause
  - Water source
  - Coolant maintenance practice
- Potential damage
  - Formation of scale - hard and insulating
  - Lack of heat transfer

Corrosion Inhibitor for aluminum protection; also found in some source of water

SCALING POTENTIAL Silicon

- Recommendations
  - 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
- Probable cause
  - Water source
  - Coolant maintenance practice
- Potential damage
  - Loss of lubrication
  - Ring bearing wear increase
  - Hot spots due to loss of heat transfer
  - Burnt valves

Corrosion inhibitor for iron & aluminum protection

SCALING POTENTIAL Phosphate

- Recommendations
  - Should not exceed 10,000 PPM
- Probable cause
  - Over addition of SCA
  - Improper mixture
- Potential damage
  - Coolant's inability to maintain phosphate in a soluble state
  - Phosphate forming Heavy precipitates (scaling)
  - Plugging of radiator and/or oil coolers
  - Water Pump seal damage

ACID PITTING POTENTIAL

Sulfate

- Recommendations
  - ASTM Specification: less than 100 PPM
- Probable cause
  - Water source
  - Combustion gas leaks
  - Sulfuric acid cleaner used and not properly flushed
- Potential damage
  - Sulfate can form sulfuric acid
  - Combine with calcium to form scale

ACID PITTING POTENTIAL

Glycolate

- Recommendations
  - Less than 1000 PPM
  - Correct the localized overheating or air leak
- Probable cause
  - Overheating
  - Air leak(s)
- Potential damage
  - Ethylene glycol breaking down forming acids such as oxalic
  - Metal pitting
- Burnt coolant with a foul solvent odor

ACID PITTING POTENTIAL

Chloride

- Recommendations
  - For antifreeze/coolant only 25 ppm max
  - Correct the source of chloride
- Probable cause
  - Water source
  - Radiator cap or pressure relief valve
  - Coolant aging
  - Hydrochloric acid cleaner used and not properly flushed
  - Improper venting
  - Marine - Sea water leak
- Potential damage
  - Extremely corrosive to engine components
  - Decarbonizes iron
  - Can form hydrochloric acid

APPLICATION RECOMMENDATIONS

Dry Land and Marine

- Use only water which meets specifications
  - preferred distilled or deionized water
- Maintained proper levels
  - antifreeze and supplemental coolant additives
- Coolant preventative maintenance
  - per engine manufacturer's specifications
- Inspect cooling system
  - All cooling system components
  - Air tight and holds proper pressure
  - Clean condenser and radiator fins
  - Electrical grounds are clean and secure
  - Electrical system functioning properly
  - Cooling system electrolysis
    - 500 mV will destroy an engine in a very short period of time
- Have coolant analyzed every 1000 hours or every 6 months, which ever comes first

Electrolysis

?

Electrolysis

- Electrolysis in the cooling system can have adverse effects on cooling system components, such as heater cores, radiators, Cylinder Liners, etc…
- Cause changes to the antifreeze/coolant affecting the additives that protect the cooling system components
- Merriam-Webster's dictionary defines "Electrolysis" as: "the producing of chemical changes by passing an electrical current through an electrolyte."

Testing For Electrolysis

This following test does not have to be performed on a regular bases.

Testing is only performed when there is a problem and diagnosing the cause is necessary.

Why Check For DC & AC Voltage

- DC voltage greater than 400mV in cooling system
  - Antifreeze/coolant additive depletion
  - Battery cable(s) need to be inspected and cleaned
    - Replace if necessary
  - Missing, loose, corroded, or undersized engine ground
  - Missing, loose, or corroded chassis ground(s)
  - Added customer accessories overloading ground strap(s)

- Electrolysis in cooling system
  - Lead to heater core and/or radiator failure
  - Antifreeze/coolant inhibitor precipitation
  - Lead to Cylinder liner pitting

Why Check For DC & AC Voltage

- AC voltage greater than 400mV in cooling system
  - Problem in alternator; faulty diode(s)
  - Faulty engine block heater
    - If equipped from OE or add-on
  - Customer added accessories
    - Ground straps overloaded

- Electrolysis in cooling system
  - Lead to heater core and/or radiator failure
  - Antifreeze/coolant inhibitor precipitation
  - Lead to Cylinder liner pitting

Testing Electrolysis in Cooling System

- Insert positive lead of DVM in coolant
  - Do not allow positive lead to touch any metal surface
- Both AC & DC voltages must be checked
- Do not add new coolant to original coolant before the test
- Do not remove radiator or pressurized coolant reservoir cap if system is pressurized
  - Wait until cooling system has cooled before removing cooling system pressure cap

Testing DC Voltage in a Cooling System

Pressurized coolant reservoir bottle is completely tied into cooling system allowing testing at coolant reservoir

Sealed radiator

Testing DC Voltage in a Cooling System

- Engine OFF- Key OFF
- Disconnect positive & negative battery cables from battery
- DC voltage check
  - Positive lead of DVM in coolant
  - Negative lead of DVM connected to engine ground
- Greater than 400mV flush system and replace coolant
- Retest

Testing DC Voltage – Poor, Loose or Missing Grounds

- Engine OFF- Key ON
  - Battery cables connected to battery
  - Accessories OFF
- DC voltage check
  - Positive lead of DVM in coolant
  - Negative lead of DVM connected to battery negative terminal
- Greater than 400mV inspect & clean battery cables, flush system and replace coolant
  - Replace battery cable(s) if corrosion is in cable(s) under insulation
- Retest

If vehicle is equipped with an engine block heater plug in heater and test for greater than 400mV

Testing DC Voltage – Poor, Loose or Missing Grounds

- Engine OFF- Key ON
  - Accessories OFF
- DC voltage check
  - Positive lead of DVM in coolant
  - Negative lead of DVM connected to an engine ground
- Greater than 400mV inspect & clean engine grounds or replace missing grounds
- Flush system and replace coolant
- Retest

If vehicle is equipped with an engine block heater plug in heater and test for greater than 400mV

Testing DC Voltage – Poor, Loose or Missing Grounds

- Engine OFF- Key ON
  - Accessories OFF
- DC voltage check
  - Positive lead of DVM in coolant
  - Negative lead of DVM connected to a chassis ground
- Greater than 400mV inspect & clean chassis ground(s)
- Flush system and replace coolant
- Retest

If vehicle is equipped with an engine block heater plug in heater and test for greater than 400mV

Testing DC & AC Voltage in Cooling System

- Also test with engine running at 2000 RPM and ALL accessories turned ON
  - If equipped; Electric engine cooling fan(s) should be running during this test
- Test for DC & AC voltages
- If voltage is greater than 400mV turn-off one accessory at a time (including fans)
  - If voltage drops below 400mV inspect and repair ground to the accessory
  - If voltage drops gradually and is less than 400mV it could be the ground straps are overloaded with non OEM installed accessories
    - Install heavier gauge ground strap(s)
  - Flush system and replace coolant
  - Retest

Testing AC Voltage in Cooling System

- If AC voltage is still present after turning OFF all devices
  - Turn OFF ignition
  - Remove the B+ from the alternator
    - Tape the B+ connection
  - Retest for AC voltage in the cooling system

Crank Test

- Also test for voltage in cooling system by cranking engine but do not start:
  - Check DC voltage while cranking engine
  - Voltage greater than 400mV
  - Check starter ground or repair starter
  - Flush cooling system and refill Antifreeze/Coolant
  - Retest

Electrolysis in a Cooling System

NEVER Ground The Heater Core

- Grounding the heater core would:
  - provide a path through the coolant for current to flow to ground
  - cause the heater core to develop into an anode advancing electrolysis
  - allows stray voltage to utilize the coolant as a ground path

Thank You For Your Business

And For Attending This Training Session