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1st Edition

Basics of Coolant Analysis

It's better to know.

INTRODUCTION

The Birth of an Industry

By the late 1950s, massive interstate highway construction was underway across the United States. Higher demand for a smaller supply of petroleum products led to the energy crisis of the 70s. As a result, there was demand among fleet owners and operators for engines designed for more power, reliability and durability, yet still economical and affordable. Manufacturers answered with significant changes in engine designs that have continued at a phenomenal rate. Granted, these changes have increased horsepower and doubled engine life, but at the same time, operating temperatures have risen by as much as 30-40°F (1.1 - 4.4°C).

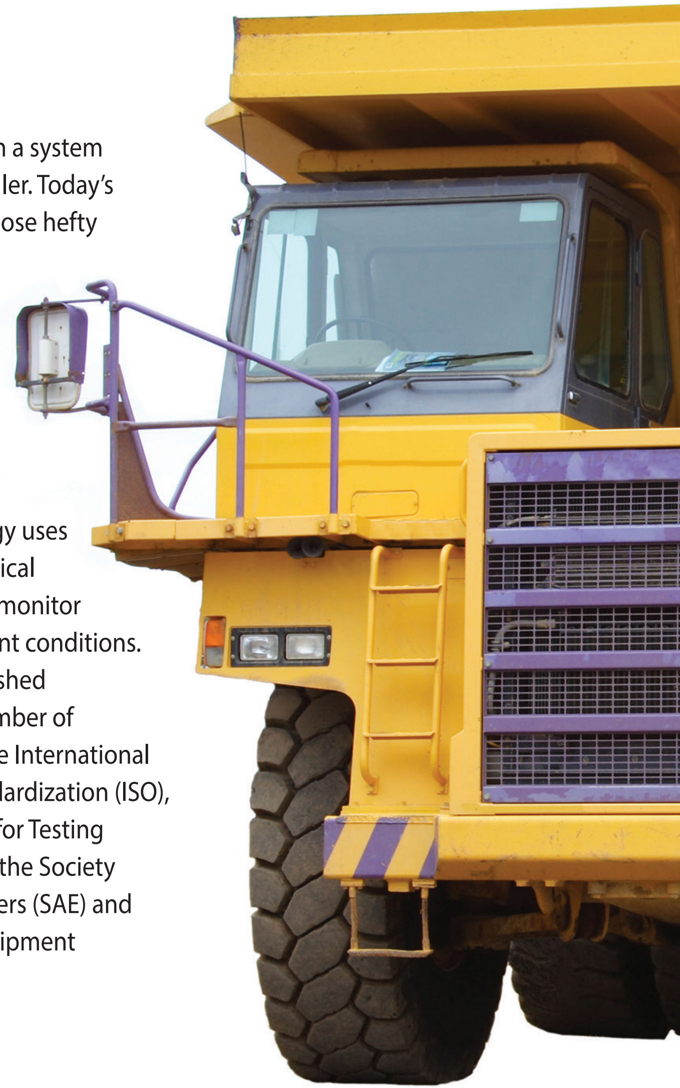
The need for better performance under stricter emissions standards has required cooling systems to operate at much higher temperatures under greater pressure and increased flow rates. This has, in effect, turned the cooling system into a "boiler," increasing combustion chamber efficiency and decreasing engine wear by as much as 40%.

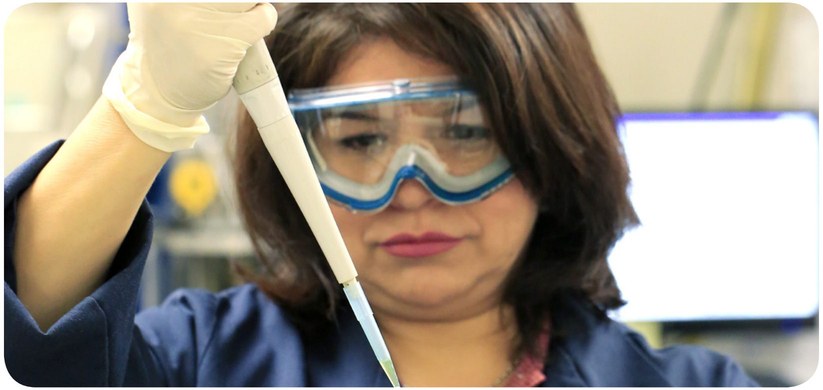
In 2000, the EPA moved forward with its initiative to require heavy-duty trucks and buses to run cleaner and finalized the Highway Diesel Rule (the "2007 Highway Rule"), in 2001. Beginning with the 2007 model year, NOx from heavy-duty highway vehicles was to be reduced by more than 90%.

The Modern Era

Engine OEMs responded with EGR (Exhaust Gas Recirculation) and ACERT (Advanced Combustion Emission Reduction Technology) designs. These engine designs are larger and contain additional components necessary for meeting the Tier 4 standards. Significantly more heat is generated requiring even more cooling efficiency from a system that is now much smaller. Today's engine technologies pose hefty challenges for their cooling system counterparts, making coolant and cooling system monitoring more important than ever.

Present-day technology uses a combination of physical and chemical tests to monitor coolant and component conditions. These tests are established and reviewed by a number of agencies, including the International Organization for Standardization (ISO), the American Society for Testing and Materials (ASTM), the Society of Automotive Engineers (SAE) and the Association of Equipment Manufacturers (AEM).





A Laboratory Partner

Cooling system problems can potentially reduce the life of components within all systems: engines, transmissions and hydraulics. Proper cooling system maintenance is essential to achieving optimum engine performance, reliability and longevity.

To meet the demands of this ever-changing system, Castrol Labcheck, has developed one of the most comprehensive coolant analysis programs in the industry. The Castrol Labcheck coolant analysis program can optimize coolant change intervals. Testing tells you when the fluid's inhibitor and pH levels are no longer providing adequate metal protection and should be drained and replaced. Routine coolant analysis can also identify mechanical issues occurring within the system that can lead to premature engine and component failure.

Customer Commitment

Castrol Labcheck has designed The Basics of Coolant Analysis as an easy reference for understanding the fundamental concepts of a coolant analysis program. It is our hope that all practitioners, whether novice or expert, can gain practical information from this book for improving or implementing a coolant analysis program.

REQUIREMENTS FOR AN EFFECTIVE COOLANT ANALYSIS PROGRAM

1. Determine your primary objectives.

Coolant analysis can be applied to equipment and lubricant utilization, maintenance and management.

Utilization

- Decrease unscheduled downtime
- Increase overall component lifespan
- Control coolant consumption and disposal costs
- Assist in product selection, comparison and verification

Maintenance

- Identify, measure coolant contamination, component wear – target corrective action
- Reduce in-service failures and field repairs
- Establish proper coolant service intervals

Management

- Improve reliability, product quality and productivity
- Improve cost control for equipment, labor and materials
- Eliminate needless inspections or repairs
- Control spare parts inventory and replacement costs

2. Examine Example Reports for Reliable Recommendations and an Easy-to-Read Format.

Clearly stated results and recommendations are vital to the success of your coolant analysis program. Castrol Labcheck reports are concise and informative. Our recommendations are specific, complete and easy to understand. The recommendations reflect a real knowledge of the operating and wear characteristics of the component sampled. Test results indicating the need for a major inspection are double-checked and verified prior to reporting to you. Our staff of data analysts and chemists are members of professional and technical societies and our established position in the commercial coolant analysis field ensures ready access to coolant and component manufacturers' data.

Expect Rapid Turnaround of Analysis Reports.

Castrol Labcheck provides an average turnaround time of one day or less for routine samples. Over 80% of the samples received are completed the same day. We notify you immediately if critical conditions are detected and make your reports available online instantly after completion.

> *A sample's transit time from sampler to lab is always the largest part of the actual turnaround of a sample.*

Look for Specialized Summary Reports.

To help you manage your coolant sampling program, we provide a series of specially-designed program management and summary reports. These reports consolidate sampling activity such as Critical Condition (Units), Condition Analysis Statistics, Summarized Sampling Activity and Summarized Sample Conditions.

Look for a Full Range of Information Management Tools.

Castrol Labcheck maintains a comprehensive website at **www.labcheckresources.com** where users can find informative videos, guides and how-tos on numerous fluid analysis topics. Users can also login to Labcheck Next Generation – our online Lube Oil Analysis Management System – which was developed in response to today's proactive reliability management needs. Through Labcheck Next Generation, your entire fluid analysis program can be managed in the cloud. From program setup to program administration, Labcheck Next Generation provides the user with easy-to-use features, such as report retrieval, equipment management, label printing, graphing and user management.

3. Build the Foundation for Your Program.

Frequently, there is an assumption that a coolant analysis program can be hurriedly established simply by taking a few samples and sending them to the nearest, cheapest laboratory. Nothing could be further from the truth.

Conduct a Sampling Point Survey.

Before you begin sampling, a necessary first step is to identify the systems you want to sample and collect relevant technical reference information on those systems. Begin by considering a unit's criticality to production – the impact of downtime and repair on your business process – and any historical operating issues or wear problems.

Select Testing That Meets Your Program Goals.

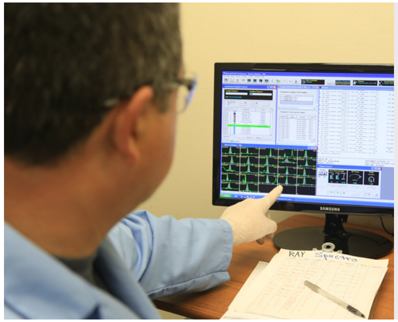
Different combinations of physical and Atomic Emission Spectroscopy (AES) tests are used to measure the properties of the coolant and determine levels of contaminants and chemical elements suspended in the coolant. The application and goals of the coolant analysis program help determine the number and type of tests that should be performed.

The **physical analysis** concentrates on measuring certain characteristics of the coolant, including contaminants, inhibitors, chemical reactions and coolant degradation acid by-products, as well as their general effect on coolant properties. The **AES** analysis identifies and measures selected metallic elements present in the coolant as microscopic particles. Test results are reported in parts per million (ppm) by weight. The relative concentrations of these elements are used to monitor corrosion rates, detect contaminants and determine additive levels.

Castrol Labcheck has developed standardized "packages" which are combinations of routinely performed tests. These packages are designed to cover the general testing needs of broad industry classifications such as power generation, construction, mining, marine and over-the-road trucking. While these packages meet most program's needs and objectives, you can develop your own custom test slates to meet your programs goals. Castrol Labcheck will assist you in selecting the proper combination of tests prior to beginning your sampling program.

Determine Appropriate Sampling Intervals.

When beginning a routine coolant analysis program, the usual practice is to sample the entire group of units/components as part of the criticality assessment to establish initial baseline data and quickly spot any components with serious problems. Once this process is complete, the client and laboratory then agree on an initial routine sampling interval. This interval is based on the results of the preliminary work, component manufacturer guidelines, client maintenance procedures and service scheduling and Castrol Labcheck's experience with similar components and applications. Once the program is fully established, the routine sampling interval may be adjusted.



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Organization and planning help in building a strong foundation for a successful coolant sampling and analysis program.

"

Obtain Representative Samples.

Obtaining a representative sample is one of the most important parts of a scheduled coolant analysis program. If a sample does not represent the true condition of the coolant and component at the time of sampling, the reliability of both the test results and their interpretation is affected. Once determined, routine sampling intervals should remain as constant as possible.

Sampling a component while it is running or within 30 minutes after shutdown gives the most representative sample. This ensures that corrosion products and contaminants are thoroughly mixed with the coolant and that the heavier corrosion particles have not settled out.

Areas where coolant flow is restricted or where contaminants and coolant products tend to settle or collect should be avoided as sampling points.

Castrol Labcheck recommends the following sampling points in order of preference:

1. A petcock valve or other sampling access installed prior to the coolant filter using a QSS® or similar valve
2. Top of the radiator tank using a vacuum pump
3. Bottom of the radiator drain

A sample taken from the radiator drain may contain settled debris. If this is the only way to take a sample, allow approximately a half-gallon of fluid drain in a clean catch container, then pull the sample at mid-stream. Place the coolant drained prior to sampling back into the system.

The bottom of the radiator or overflow tank is often the easiest sampling point, but it is so prone to sampling error and evaporation issues that we discourage it.

In special cases, samples may be taken from coolant filters. The lab should be advised prior to testing if this occurs.

Once a proper sampling point and method are chosen, coolant samples from that component should always be taken from the same point using the same method.

4. Establish a Consistent Baseline of Coolant and Component Information.

In a busy operations and maintenance schedule, no one wants extra paperwork and recordkeeping. But, if a fluid analysis program is to furnish anything more than test data, the user must provide supporting information on the machine's components and fluids in service.

Initial equipment registration can be easily accomplished by furnishing the laboratory with a consolidated equipment list based on your sampling point survey, or by completing an individual registration form for each sampled system. In either case, the sampling point ID and current operating data is sent with each sample.

In completing our coolant analysis forms and sample container labels, the following brief definitions are helpful:

Unit ID Number

The Unit ID Number is a unique reference number for an entire functional unit. Examples include a company asset or inventory identification or a vehicle serial number.

Engine Type/Manufacturer/Model

It is extremely important to record the engine type, manufacturer and model as each OEM has their own cooling system and coolant specifications. Metals and alloys used in manufacturing can also be different as can wear patterns and other engine-specific operating issues making it important to also indicate type of engine, i.e., diesel, gasoline, NG or other.

Coolant Type

Coolant formulation type is extremely important. For example, the freeze curve is different for ethylene glycol and propylene glycol which could mean the difference between not having enough glycol for freeze and boil point control or having too much for proper heat transfer.

In addition to engine manufacturer and model specifications, our report recommendations are based on coolant formulations and their inhibitor packages. Not knowing the type of coolant tested greatly affects these recommendations as Extended Life Coolant (ELC) inhibitor packages are completely different than conventional or hybrid coolant formulations.

> "*Recording operating time on coolant is absolutely essential to time-based trending—the most accurate way to pinpoint abnormal wear conditions.*"

Time Since New or Since Last Overhaul

This is the number of operating hours or miles since the unit was first put into service, or since the last overhaul or rebuild was performed. Since normal wear rates change over the lifetime of a component and break-in may resemble abnormal wear, this information is needed as an ongoing reference for interpretation. This data may be obtained directly from an equipment or component service meter or from general operating records.

Time Since Coolant Change

This is the number of operating hours or miles between the time the coolant was last changed and the time the sample was taken. This information is essential to time-based trending.

Coolant Consumption or Makeup Coolant

This is the amount of coolant added to maintain a correct coolant-fill level in the sampled component. Complete coolant changes should not be reported as makeup coolant or identified as "new coolant."

Cooling System Information

The cooling system's capacity is important knowledge for properly calculating the amount of fluid that needs to be drained from or added to a system to adjust glycol or inhibitor levels.

Antifreeze Brand Name

Most coolant manufacturers have more than one formulation on the market so just knowing the brand does not tell the laboratory what formulation the coolant is or what inhibitor package should be present. Recording the complete coolant brand and product name ensures that proper recommendations can be made for that particular coolant. This becomes extremely important in determining if coolant mixing has occurred or when recommending adjustments in the fluid.

SCA/DCA Brand Name

Concentration levels of SCA or DCA are different for each inhibitor manufacturer. To ensure proper recommendations are given when an adjustment needs to be made, it is extremely important to record the SCA/DCA brand name.

Antifreeze/Water Ratio

Typically, a 50/50 solution of antifreeze to water ratio is recommended but in some locations the ratio is 40/60 and in other locations a 60/40 is best. Certain equipment does not require more than a 30% solution of antifreeze. For the laboratory to make the proper recommendations for your equipment and operating environment this information is extremely important. Without this knowledge the default recommended level will be a 50/50 solution.

Type of Filter in Service

There are different types of coolant filters on the market. Some filters only have the paper medium to filter out dirt and debris where other filters are pre-charged with an inhibitor package to maintain the SCA level. If the SCA level is low, having this information is helpful to the laboratory in making correct recommendations for maintaining the coolant inhibitor properties. Having this information can also be indicative of using a conventional SCA pre-charged type filter with an ELC, which is not recommended.

Reference Sample

When beginning a new cooling system predictive maintenance program, it is always recommended to sample your bulk coolant so that all used coolant test data can be compared to the new product. This measure is also a safeguard for the customer and ensures that bulk deliveries are compatible with their engines' cooling systems. A new reference sample only needs to be sent in once a year or if you change coolant products. The Premium Conventional or ELC test packages are recommended for reference samples. Certain tests that are in engine OEM and ASTM specifications are only available within the Premium testing level.

Disadvantages of Inaccurate or Incomplete Sample Data

A sample may not be processed immediately if the client name, unit and component identification, or sample date are not provided. If you have sampled a particular machine before and do not ensure that the unit and component identifications match what you originally provided, testing may be delayed while the needed information is established, or the results may not be filed correctly with other samples from that machine.

In addition to this must-provide data for each sample, you should report any recent maintenance, changes in performance or unusual operating conditions. If you sample at the same time that you perform other routine maintenance and servicing activities, you should also record that information and submit it with the sample.

Specific individuals should be assigned long-term responsibility for this portion of the program. If this is not feasible, then a particular department should be designated for involvement. Once this responsibility is established, a system of recordkeeping and correct sample identification should then be developed and initiated.

5. Use Laboratory Data Interpretation Properly.

Our laboratory interpretation typically separates the overall component and fluid condition – relative to severity of contamination and wear – into four main classifications:

A

Physical properties of the fluid are within acceptable limits and no signs of excessive contamination or wear are present.

B

Specific test results are outside acceptable ranges, but are not yet serious enough to confirm abnormal conditions or justify diagnostic action. Caution is advised. The initial stages of an abnormality often show the same pattern of results as temporary conditions, such as extended usage or overloading. Adjustments to glycol or inhibitor levels may be needed.

C

Coolant physical properties, contamination, and/or component wear are clearly unsatisfactory, but not critical. A confirming re-sample should be submitted. Additional diagnostic procedures may be needed to confirm each condition. Corrective actions are necessary to prevent reduction of service life or overall loss of performance.

D

Coolant physical properties, contamination and/or corrosion are clearly serious enough to require immediate diagnostic and corrective action to prevent major long-term loss of performance or component failure. Increases in operating hazards are likely. Short-term loss of performance may already be present. Large scale repairs may be required. You may be advised to remove the unit/component from service until a confirming re-sample is tested and other diagnostics confirm that repairs are necessary.

NOTE: These four assessment conditions are relative and are assigned using both trend analysis and condemning limits.

When **trend analysis** is used – primarily in monitoring corrosion elements – threshold values are developed to identify the boundary areas between normal and abnormal results. For corrosion metals, these threshold values are usually specific and consistent for each individual model of a given application. The values do not provide sharp lines of "normal/abnormal" interpretations; instead, they indicate ranges of increased likelihood that a problem has developed to a particular point.

Generally, the coolant and component condition can be considered "normal" as long as the corrosion, contamination and coolant deterioration levels remain within the established "normal" ranges. Regardless of the threshold values, any sharp increase in corrosion metals or major shift in physical properties can signal the beginning of problems. Therefore, the threshold values can't be used as "go/no-go" criteria. A great deal of caution, judgment, experience and client technical input must be used in applying threshold values properly.

Clients are contacted immediately by phone on all samples where our interpretation detects a critical condition. Further, email copies of all critical or abnormal samples are dispatched upon completion of our evaluation. On these reports, the laboratory will recommend specific maintenance actions designed to correct not only the indicated problems but also the causes of these problems.

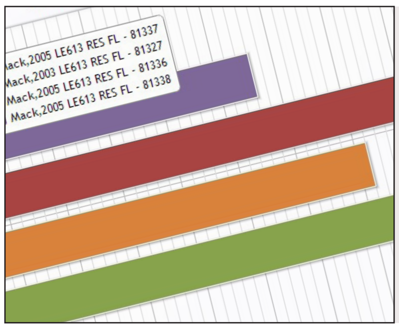
Each report should be reviewed as soon as possible for action items. Analysis copies should be attached to work orders or instructions. Access to electronic versions of the report(s) should be given to appropriate personnel.

6. Provide the Laboratory with Proper Feedback.

The interpretation guidelines' accuracy is verified by comparing the laboratory's maintenance recommendations with actual conditions confirmed by inspection. In this way, the test interpretations are continually refined by practical experience. Feedback from the client can include:

- Abnormal coolant or component conditions that you suspect are present
- The findings of any inspection performed as a result of coolant analysis program recommendations
- Abnormal machine conditions discovered that were not previously indicated by coolant analysis
- Notification of servicing and/or maintenance performed
- Information concerning operating environment or equipment application changes

These items may be noted on the sample information form or recorded in Labcheck Online. If the feedback is sent separately, please provide the component reference number (upper right corner of report).



> "*One simple way of measuring program effectiveness is to trend the number and type of abnormal or critical conditions in your machines over time.*"

7. Measure Cost Effectiveness.

The goal of an effective coolant analysis program is to reduce operating expenses and increase profit margins. Routine testing through the Castrol Labcheck coolant analysis program helps maintenance professionals achieve substantial savings in maintenance and repair costs.The program operates much like a medical checkup; if problems are detected, they can be corrected before they develop into serious and hazardous conditions that are costly to repair. When samples are reported normal, then the immediate value of coolant analysis is a personal "peace of mind" rather than an economic return. As the number of sampled pieces of equipment increases, the financial benefit of coolant analysis also increases. Greater equipment availability and reliability means more production, less downtime and increased profits.

> "*Coolant analysis is both proactive and predictive and is one of the most cost-effective maintenance techniques available*"

The importance of tracking the savings generated by your coolant analysis program cannot be over-emphasized. Manpower, parts and tool expenses will all be affected. However, because a well-run coolant analysis program is deeply integrated into a client's overall maintenance program, management must establish a strong platform of results measurement and documentation to see the unique contribution coolant analysis can make to profitability.

Since many of the benefits of coolant analysis may not show clearly on the "bottom line" because they represent conditions that were prevented, many of the economic savings from coolant analysis can be calculated by documenting:

- Parts and labor expenses for component repair, overhaul or replacement
- Loss of revenue during downtime
- Reduction in consumable items – coolants, lubricants or fuels
- Increase in productivity

Five Keys To Successful Coolant Analysis

As with any diagnostic method, the user must share in the responsibility for success when using this well-established and widely accepted proactive maintenance tool. To achieve overall success for your coolant analysis program, use these proven keys:

1. **Clearly defined client goals and program requirements** ensure that the tests performed fit the application and that the service is being fully utilized on an ongoing basis.

2. **Representative samples** ensure that the true condition of the coolant and component can be determined by reliable, accurate testing.

3. **Frequent lab/client contact** promotes accurate interpretation and leads to increased client confidence and interest in maintaining an active coolant analysis program.

4. **Complete sample information** speeds processing and increases the laboratory's ability to fully interpret the test results.

5. **Prompt report review** ensures that abnormal or critical conditions are recognized and acted on in time to prevent damage or a loss in production.

TESTS AND THEIR SIGNIFICANCE

Without a working knowledge of coolant analysis tests and their significance, the user may be uncertain about the value of the service and how each test interrelates with the others to provide a useful, accurate picture of internal component and fluid conditions. The following information is provided as a general orientation to what Castrol Labcheck considers the most important coolant analysis tests for industrial and non-industrial applications.

Spectrochemical Analysis

Spectrochemical Analysis identifies dissolved or dispersed elements in the fluid by Atomic Emission Spectroscopy (AES) and reports the results in parts per million (ppm) by weight. AES is a method of chemical analysis that uses the intensity of light emitted from a flame, plasma, arc or spark at a particular wavelength to determine the quantity of an element in a sample. The wavelength of the atomic spectral line gives the identity of the element while the intensity of the emitted light is proportional to the number of atoms of the element. The analyzed elements are grouped into three main categories:

Corrosion Metals

Corrosion is a chemical reaction between an imbalanced coolant and the metals present. Common types of corrosion in the coolant system and causes are:

Uniform Corrosion

Also called general corrosion, uniform corrosion is caused by a chemical or electrochemical reaction that results in the deterioration of the entire exposed surface of a metal. The end result will be deterioration of the metal to the point of failure. Uniform corrosion can be caused from acid formation within the cooling system, combustion gas leaks, excessive flow velocities, aeration, excessive cavitation (chemical or mechanical), external contaminants, glycol degradation, low pH, poor coolant maintenance or use of source water that does not meet specifications.

Localized Corrosion

Corrosion specific to one area of the metal structure and classified as one of two forms:

Pitting and Cavitation

This is the sudden formation and collapse of low-pressure bubbles in liquids by means of mechanical forces or restriction of flow. The result will be the formation of a small hole or cavity in the metal that is typically the result of depassivation of a small area. The deterioration of this small area penetrates the metal and can lead to failure. Pitting and cavitation can be caused from cylinder wall vibration, cooling system pressure lower than design specs, cooling system temperature lower than design specs, block-to-cylinder wall coolant passages too narrow or imbalanced coolant composition.

Crevice Corrosion

This type of corrosion occurs at a specific location and is often associated with a stagnant micro-environment such as areas under gaskets, washers and clamps. Acidic conditions or a depletion of oxygen can lead to crevice corrosion.

Galvanic Corrosion

Also known as dissimilar metal corrosion, galvanic corrosion occurs when two different metals are located together in a corrosive electrolyte. A galvanic couple forms between the two metals, where one metal becomes the anode and the other the cathode. The anode, or sacrificial metal, corrodes and deteriorates faster than it would alone, while the cathode deteriorates more slowly than it would otherwise. Galvanic corrosion is due to incorrect design, incorrect material selection or imbalanced coolant.

Erosion/Cavitation Corrosion

This is the wearing away of surface materials and soft metals. Erosion can be caused by coolant carrying abrasive particulates, incorrect design or materials or poor coolant.

Electrolysis

Electrolysis occurs when a stray electrical current grounds through the coolant due to dirty, loose or broken ground straps or the system being grounded improperly. Coolant is a conductor and the stray current will take the path of least resistance to the ground. Many times this is right through the cooling system. As the softest metal on the electrolytic scale, aluminum is more susceptible to electrolysis issues and destruction but other metals in the cooling system are vulnerable as well.

Corrosive Metals

IRON alloying element or cast metal	Sources may be corrosion from cylinder liners, engine block, cylinder head
COPPER alloying metal	Sources may be corrosion or erosion from radiators, heat exchangers, oil coolers, air coolers, thermostat, brass (tubes, headers, side-plates)
ALUMINUM alloying element or cast metal	Sources may be corrosion or erosion of the radiator, heat exchangers, oil coolers, air coolers, thermostat
LEAD used in tube-header joints of copper/brass components	Sources may be from the corrosion of tube-to-header joint corrosion (solder bloom) in the radiator, heat exchanger, oil coolers. Solder bloom is a corrosion mode of the radiators internal solder joints. The term bloom is used to describe a flowering appearance of corrosion by-products. Solder bloom leads to blockage of the radiator tube passages and results in engine overheating issues.
TIN	Used to give strength to lead in solder. Sources may be from corrosion of the solder in the radiator, heat exchanger, oil cooler
SILVER	Silver solder is often used in heavy-duty radiator repair for its structural strength. Sources may indicate corrosion of silver solder used in the radiator or heat exchanger.
ZINC	Used as an anode or sacrificial metal especially in marine applications. Also used with copper to form a yellow metal brass. Sources may indicate corrosion in the radiator, heat exchanger, oil cooler

Contaminants

The contaminant elements detected by Spectrochemical Analysis in coolants are calcium and/or magnesium hard water salts. Specifications are on total hardness which is the sum of calcium and magnesium hardness in mg/L as $CaCO_3$. Typically, calcium is double that of magnesium. Higher magnesium levels than calcium may be due to outside contaminants such as magnesium chloride winter road de-icer or, in agricultural applications, fertilizer entering the system from an air leak or, in marine applications, an ingression of sea water.

Hard water salts will cause the formation of scale on hot metal surfaces and impede heat transfer. The greatest amount of scale will form where the most heat transfer is needed. Hard water salts can react with silicate, sulfate or the formation of carbonates. A calcium/silicate scale has the same insulating capacity as 3 – 4 inches of cast iron. Failures can include clogged radiators and oil coolers, burnt valves, cracked heads or head gasket failure.

CALCIUM	General: Combines in engine coolant to form scale on hot heat exchange surfaces. Scale is an efficient insulator and the result is localized engine overheating that can cause component failure.
MAGNESIUM	General: Can form scale to create localized overheating. Measured with calcium to determine total hardness.

Additives and Inhibitors

Heavy duty antifreeze formulations differ from one another by virtue of the additive package blended into the base glycol. Additive and inhibitor packages all have the same job – to inhibit cavitation, scale, rust and acid formation. Additive packages among various antifreeze formulations have fundamentally different chemical fingerprints. Spectrochemical Analysis of additives and inhibitors helps in determining the formulation present and if the levels are adequate for proper protection.

SILICON	General: Aluminum corrosion inhibitor, antifoam and elastomer compatibility in Cummins engines. Can be used in conventional and hybrid coolant formulations.
PHOSPHATE	General: Iron corrosion protection and pH control. Can be used in conventional, hybrid and P-OAT coolants.
BORON	General: Iron corrosion protection and pH control. Can be used in conventional and hybrid coolant formulations.
MOLYBDENUM	General: Iron, aluminum and solder protection. Can be used in Conventional, hybrid, NOAT, NAP-Free and P-OAT coolants formulations.
SODIUM	General: Carrier metal for inorganics
POTASSUM	General: Carrier metal for inorganics

Visual Analysis

Visual Analysis may seem unimportant but visual observation of contaminants can highlight or confirm issues taking place in other areas of the engine. The following visual observations should always be checked at every scheduled analysis:

Foam

The foam test checks the coolant's foam break time. Foam can hinder heat transfer in a cooling system. Defoaming agents are used in coolants but this type of inhibitor can deplete in harsh operating environments. Foam can result from increased operating temperatures, increased flow rates, increased detergents and soaps in oils, a cracked inlet on a water pump, air or improper coolant maintenance.

Color

Samples are held over an artist's true color light to determine if the coolant is becoming darker, which can indicate a breakdown of the glycol or be a sign of outside contamination. The true color light is also used if the coolant's color does not match coolant manufacturer and product name specifications.

Oil & Fuel

Samples are visually inspected for hydrocarbon contaminants such as engine oil, hydraulic fluid, gear oil or fuel. Hydrocarbons can cause EPDM rubber hoses and seals to swell, deteriorate and eventually fail. The presence of oil or fuel can also be an indication of a more serious issue with the engine's lubrication system, such as an oil cooler or fuel injector failure.

Magnetic Precipitate

Magnetic particulate can be an indication of component wear due to cavitation, air leaks, flow velocities, etc. Magnetic precipitate is abrasive and can scratch softer copper and aluminum surfaces and damage seals.

Non-Magnetic Precipitate

Samples are visually inspected for non-magnetic precipitate that can cause plugging of the cooling system passages which can lead to cavitation from restriction of flow and superheating. Non-magnetic precipitate can be inhibitors falling out of solution due to overtreatment, air contamination or an unstable pH. Non-magnetic precipitate can also indicate that environmental particulates are being drawn into the system through an external air leak.

Odor

Samples are checked for any abnormal odors such as ammonia, burnt, fuel, gear, solvent or any other abnormality. Odor can help confirm maintenance or mechanical issues taking place internally that could cause catastrophic premature failure.

Physical Analysis

Physical Analysis encompasses the bench testing portion of coolant analysis. These tests are checking the maintenance of the glycol and inhibitor levels as well as the acidity and alkalinity of the coolant. Tests include:

Freeze Point

The point at which the coolant will freeze or solidify. If the coolant freezes, it will expand and can result in a cracked engine block.

Glycol %

Ethylene Glycol % by Volume	°F (°C)	Propylene Glycol % by Volume	°F (°C)
0	32 (0)	0	32 (0)
10	23 (-5)	10	25 (-4)
20	16 (-9)	20	19 (-7)
30	4 (-15)	30	10 (-12)
40	-12 (-24)	40	-6 (-21)
50	-34 (-37)	50	-27 (-34)
60	-62 (-52)	60	-56 (-49)
70	-78 (-61)	70	-65 (-54)

Nitrite

In fully formulated heavy duty engine coolants, nitrite is an inorganic inhibitor for prime cast iron, steel and cavitation pitting protection. Nitrite forms a cavitation-resistant film on wet sleeve liners. Cavitation is the pitting of the liner's surface by vapor bubbles that violently implode against the liner as it vibrates with the engine's combustion cycle.

SCA

Supplemental Coolant Additives enable the coolant to provide adequate protection against cylinder liner pitting and scaling in heavy duty engines plus general corrosion protection when water only is used as a coolant. SCA number is a calculation of nitrite or nitrite and molybdenum to determine the number of units per gallon present.

Carboxylic Acid Pass/Fail

This test measures the purity/contamination level of an extended life coolant by testing the carboxylic acid level. If dilution is more than 25%, the sample fails as there is insufficient carboxylic acids present to provide adequate protection of metal components.

pH

This test measures the acidity (below 7.0) or alkalinity (above 7.0) of the coolant. Acceptable pH ranges are contingent upon the formulation. A conventional coolant's pH range is 8.0 – 11.0 whereas an Extended Life or Hybrid coolant's pH range is 7.0 – 9.5. A pH level below 7.0 is acidic and can cause serious damage to metal components, hoses and seal material. A pH above 11.0 can cause aluminum corrosion or precipitation of certain inhibitors.

Reserve Alkalinity

This test indicates a coolant's capacity to neutralize acids formed in (glycol oxidation products) or entering (exhaust gas blow-by) the cooling system. The rate at which reserve alkalinity decreases, along with the amount of inhibitor added, will help predict when the coolant will become too acidic to protect the cooling system from corrosion.

Conductivity

Conductivity is the measurement of electrically charged ions that will either be positive (cationic) or negative (anionic). The greater the number of ions present, the greater the levels of contamination and the higher the conductivity, therefore making it easier for it to conduct electricity. The fewer the number of ions there are the more resistivity to conducting electricity there will be. Measurement is reported in microsiemens (µS).

Total Hardness

Total Hardness is the sum of calcium and magnesium hardness in mg/L as $CaCO_3$. ASTM and OEMs have set specifications on the amount of total hardness that can be present in water used to dilute a coolant 50/50. Hardness will cause the formation of scale on hot metal surfaces and impede heat transfer.

PREMIUM TESTING

Ion Chromatography (IC)

Increasing emissions control and demands for higher horsepower and improved fuel efficiency are largely responsible for the changes in both engine and cooling system design over the past decade. As a result, system operating temperatures have increased dramatically, requiring better heat transfer capability, the use of higher performance coolant formulations and improved cooling system maintenance practices.

Ion chromatography can monitor coolant formulations and significantly reduce premature engine and component failure. The IC detects contaminants, inhibitors and degradation acids that can develop as a result of air leaks, combustion gas leaks, hot spots or localized overheating or electrolysis issues. If glycol is breaking down due to excessive heat, glycolic acid (glycolate) forms. If left untreated, glycol will continue to breakdown forming acetic acid (acetate), formic acid (formate) and oxalic acid (oxalate). These acid formations can cause severe corrosion of cooling system metals and components and eventually lead to premature engine failure.

IC testing can also determine if the quality of the glycol in a new coolant reference is adequate for use in the system. Recycled coolants that are not properly scrubbed can leave behind contaminants and acids that can severely damage engines and cooling system components. IC testing is most frequently used in coolant analysis to monitor:

Sulfate

Sulfate is a contaminant that may be present from source water, a combustion gas leak or sulfuric acid cleaner left in the cooling system. In an acidic condition, sulfate can form sulfuric acid which promotes cavitation and the pitting of cast iron surfaces as well as ferrous corrosion or red rust. In an alkaline condition, sulfate can combine with calcium to form scale on hot metal surfaces and impede heat transfer.

Chloride

Chloride is a contaminant from source water or air leaking into the cooling system. Chloride promotes metal corrosion and localized aluminum corrosion.

Nitrate

Nitrate is an inorganic inhibitor added to some coolant formulations for aluminum and solder protection. Nitrate can be present in conventional, hybrid, NAP-Free or P-OAT coolants or if nitrite (NO_2) is converting to nitrate (NO_3) due to electrolysis or other chemical reaction.

Degradation Acids

The chemical breakdown of ethylene or propylene glycol due to heat will form degradation acids – first glycolic, then formic, acetic and oxalic. This results in a decrease in the coolant's pH which can accelerate the corrosion of metal components. As heat transfer issues continue, the glycol will continue to degrade forming the remaining acids. Degradation acid by-products can also be present which can take on the form of a varnish-like, hydrocarbon contaminant or combine with heavy metals to form abrasive particulate.

Azoles

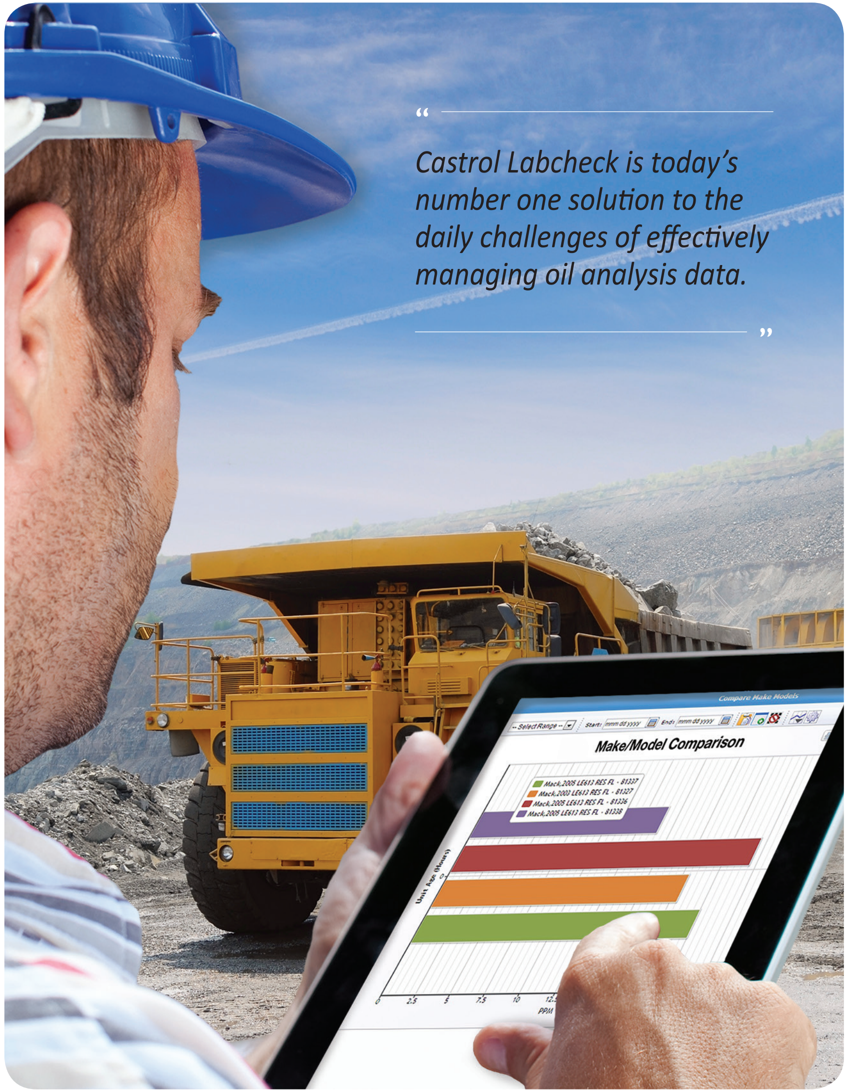
Mercaptobenzothiazole (MBT), Benzothiazole (BZT) and Tolytriazole (TTZ) are inhibitors added to fully formulated coolants for yellow metal (brass) protection. Most coolants today contain TTZ and azoles can be present in all coolant formulations on the market.

High Pressure Liquid Chromatography (HPLC)

Castrol Labcheck uses High Pressure Liquid Chromatography – or HPLC – to monitor the organic acid inhibitor and azole levels for yellow metal protection (copper and brass). Conventional coolants do not contain organic acid inhibitors and will not benefit from HPLC testing, unless azole levels are a concern.

Organic Acids

Organic Acid Technology (OAT) neutralizes the acids in the soap family. They do not lay a protective film on the metal surfaces but rather interact with the metal surface providing excellent long-term protection for aluminum and cast iron. An OAT, NOAT, HOAT, NAP-Free or P-OAT Extended Life Coolant may include one or more of the following organic acids: benzoic acid, sebacate, 2-ethylhexanoic (2-EHA), p-toluic and octanoic as well as other organic acids for iron, aluminum and solder corrosion protection.



> *Castrol Labcheck is today's number one solution to the daily challenges of effectively managing oil analysis data.*

CASTROL LABCHECK – A Full Range of Information Management Tools

Look For a Full Range of Information Management Tools

Castrol Labcheck coolant analysis was developed in response to today's proactive maintenance and reliability needs. It is a free, online data management system that can:

- monitor equipment condition
- print sample jar labels
- graph test results
- quickly retrieve sample data and efficiently communicate it to others

Castrol Labcheck provides easy-to-use tools for complete fluid analysis program management:

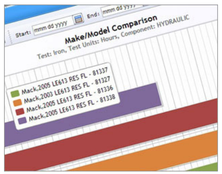
Equipment Management Should Be Easy

- Keep equipment lists clean and sampling histories intact with the power to add, delete, update, merge and move units between locations
- Maintain scheduled sampling intervals, print barcoded jar labels and register trackable sample information online prior to the sample's arrival at the laboratory

Sample Report Management

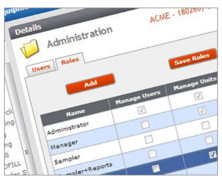
- Create filters to search sample data by multiple equipment parameters
- Save filters to quickly locate commonly viewed test results and download, print or email to others

Graphing



- Track trends in abnormal test results for individual pieces of equipment using multiple test parameters
- Overlay test results by make or model to compare equipment performance between individual units or across populations of units
- Chart sample condition for specific components to view performance compared to similar models or families of component types

System Configuration & Administration



- Designate roles, permissions and preferences to determine how data is received, displayed and communicated to others

Communications and Distributions

- Utilize filters to automate email distributions of sample reports and management reports specific to other Castrol Labcheck users and non-users

Technical Support

- Help icons on each menu tab explain the tab's functionality
- Quick Links give users access to detailed training videos, quick start guides and Frequently Asked Questions
- The Coolant Technical Support Desk is available to demonstrate Castrol Labcheck features or answer user questions at 1-800-655-4473.