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GUIDE TO HEAVY DUTY PRODUCTS AND SERVICES

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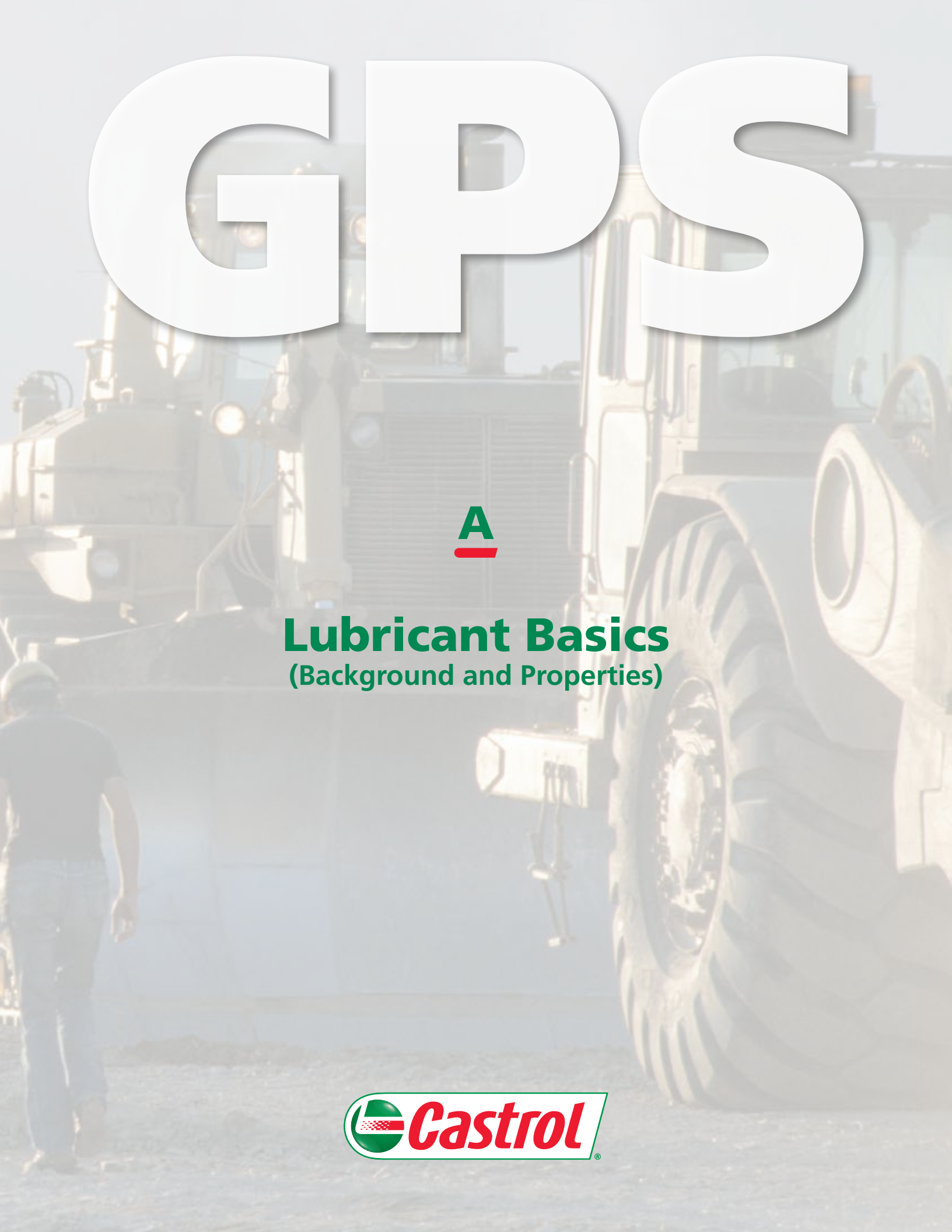
A

Lubricant Basics
(Background and Properties)



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Lubricant Basics

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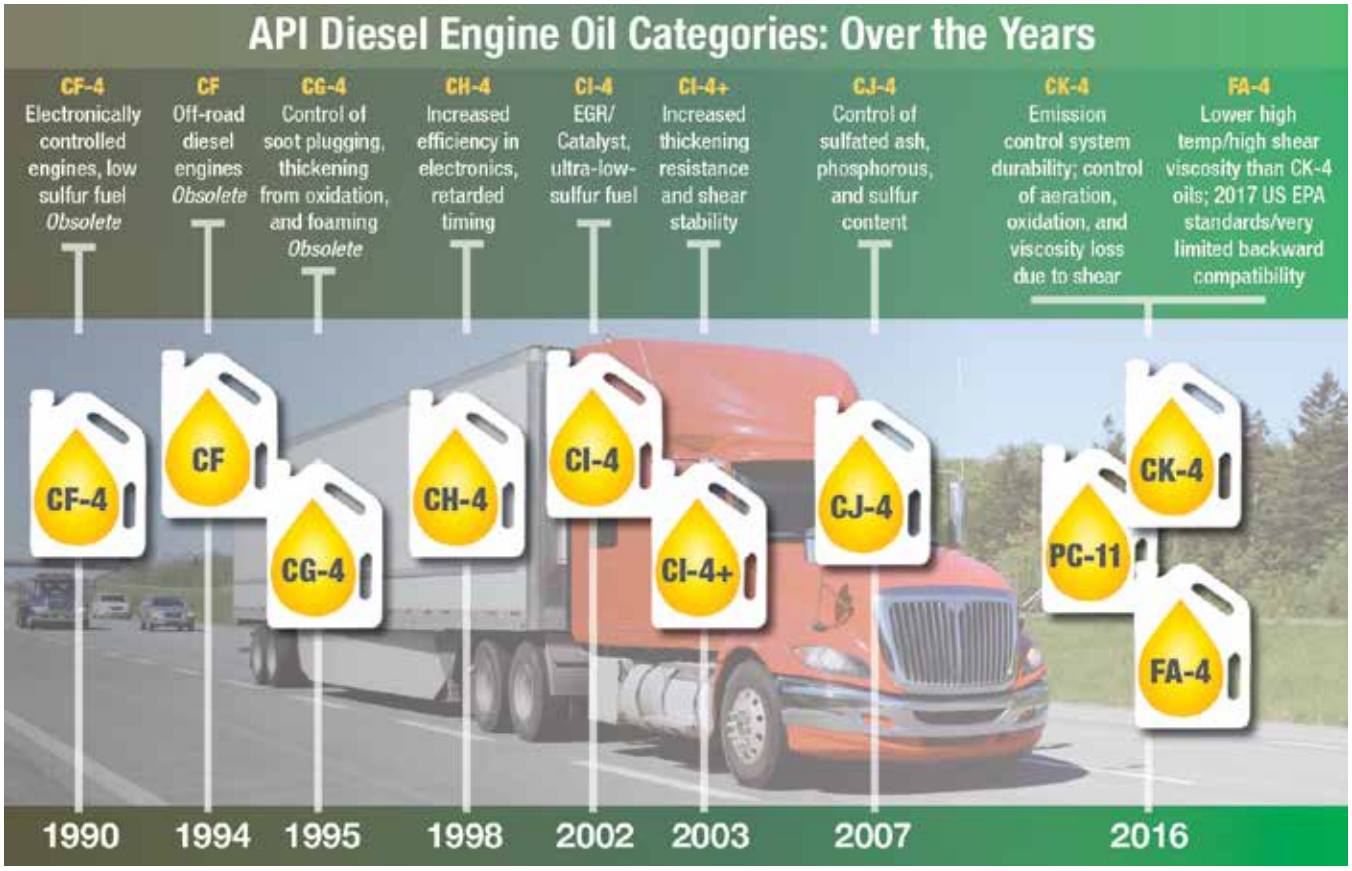
Castrol®

Industry Specifications

History

Over the years, the drivers for change in diesel engine oils have been based upon the U.S. Environmental Protection Agency (EPA) regulations for exhaust gas emissions. These changes occur every few years. To be able to meet ever-tightening limits, engine manufacturers must change engine designs; these design changes almost always put additional stresses on the oil, therefore calling for new engine oil service categories. With particulate matter (PM) and nitrogen oxide gases (NOx) already at very low levels, the newer exhaust emission regulations address the reduction of greenhouse gases (GHG), especially carbon dioxide (CO_2). The CO_2 limit has led to the development of the next generation heavy duty (HD) engine oil for low GHG engines. The first licensing of the new American Petroleum Institute (API) specifications, CK-4 and FA-4, began on December 1, 2016.



Industry Specifications

API CK-4

The current engine oil specification, API CK-4, was released into the marketplace on December 1, 2016, replacing the previous API CJ-4 engine oils specification. API CK-4 is backward compatible with most applications where engine manufacturers recommended CJ-4.

CK-4 was developed to better protect new *and* older engines, improve engine oil performance, and help engine manufacturers meet 2017 U.S. government emissions standards. The new CK-4 oils provide a number of improvements over CJ-4 standards such as improved shear stability and aeration control; they also offer enhanced protection against oil oxidation and engine wear, catalyst contamination, particulate filter blocking, piston deposits, soot-related viscosity increase, and degradation of low- and high-temperature properties.

The CK-4 category addresses diesel engine changes that have occurred since the 2006 introduction of CJ-4, thus meeting the needs of today's more fuel-efficient engines with their increased power and use of such hardware as high pressure, common-rail injection systems and advanced turbocharger technology. CK-4 is the result of EPA and National Highway Traffic Safety Administration (NHTSA) emission legislation for diesel-powered commercial transport vehicles. It requires significant improvements in fuel consumption to help reduce carbon dioxide emissions. CK-4 is specified for high-speed four-stroke cycle diesel engines designed to meet the 2017 model year on-highway and Tier 4 non-road exhaust emission standards, and for use in all applications with diesel fuels ranging in sulfur content up to 500 ppm.

CK-4 exceeds performance criteria of API CJ-4, CI-4 PLUS, CI-4, and CH-4. While this category was under development, it was referred to as American Society for Testing and Materials' (ASTM) Proposed Category (PC) 11A. The API CK-4 Donut looks the same as the previous CJ-4 Donut.

API FA-4

Like CK-4, API FA-4 also launched on December 1, 2016. API FA-4 oils provide similar improvements over CJ-4 oils, but are intended for use *only* in newer on-highway diesel engines. FA-4 oils have **limited or no backward compatibility** with on- and off-highway diesel engines where engine manufacturers recommended CJ-4. However, FA-4 oils are expected to play an important role in some current and new diesel engines by protecting those engines while also helping them meet more stringent emissions requirements.

FA-4 was created for *certain* XW-30 oils that are specifically formulated for use in select high-speed four-stroke cycle diesel engines designed to meet 2017 model year on-highway GHG emission standards and on-highway applications with diesel fuel sulfur content up to 15 ppm. FA-4 offers enhanced protection against oil oxidation, viscosity loss due to shear, and oil aeration as well as protection against catalyst poisoning, particulate filter blocking, engine wear, piston deposits, degradation of low- and high-temperature properties, and soot related viscosity increase.

FA-4 is not interchangeable or backward compatible with API CK-4, CJ-4, CI-4 PLUS, CI-4, and CH-4 oils, nor is it recommended for use with fuels having greater than 15 ppm sulfur. While FA-4 was under development, it was referred to as the ASTM Proposed Category (PC) 11B. The API FA-4 Donut features a *shaded section* to differentiate API FA-4 oils from CK-4 oils.

CK-4 and FA-4 oils are designed for different applications, making it important that technicians consult a vehicle's owner's manual or the engine manufacturer to determine whether CK-4 or FA-4 is recommended.

Industry Specifications

API CJ-4: *The Previous Spec*

The previous API CJ-4 engine oil specification was released into the marketplace on October 15, 2006 as a result of the EPA's mandate to further control exhaust emissions from on-road truck diesel engines. This previous regulation, known as US EPA 07, required that all 2007 model year vehicles emit lower levels of NOx and PM. Changes in engine design alone were not sufficient to reduce emissions to the EPA 07 required levels. Therefore, original equipment manufacturers (OEMs) had to use supplementary technologies such as Exhaust Gas Recirculation (EGR) and Diesel Particulate Filters (DPFs), often known as exhaust aftertreatment. EGR has been used on many diesel engines since EPA 02 and often had the effect of introducing more soot into the oil, decreasing engine efficiency, and increasing fuel consumption.

At that time, DPFs were new to the diesel engine; they work by trapping the soot particles from the exhaust and were sensitive to certain performance-enhancing additives in API CI-4 oils. The combination of these two extra demands upon the lubricant led to the introduction of the API CJ-4 lubricant performance category. New technology was employed when developing CJ-4 lubricants because 2007 and newer engine components were sensitive to sulfated ash, phosphorus and sulfur (SAPS). API CJ-4 lubricants had to be low SAPS engine oils, while still delivering the same or in many aspects, better performance than their predecessors. CJ-4 lubricants could be used in place of CI-4 Plus, CI-4, CH-4, CG-4, and CF-4 lubricants.

Wear Protection in the Presence of Soot

Maintaining wear protection and engine durability in the presence of heavily sooted engine oil is a primary performance criterion for API CK-4 oils. Mack had had long-standing interest in proper control of soot, with tests in each category since CF-4. Other OEMs joined in, starting with the Cummins M-11 in CH-4, M-11 EGR in CI-4, and the ISM and ISB in CJ-4. All major OEMs share the concern of soot-related wear and corrosion that can result from high percentages of EGR, promoting an environment in which acids are created.

API CK-4 Engine Tests

Caterpillar C-13 ASTM D7549

Scope:

The test method defines a heavy-duty diesel engine test procedure conducted under high output conditions to evaluate engine oil performance with regard to piston deposit formation, piston ring sticking and oil consumption control in a combustion environment designed to minimize exhaust emissions. This test method uses a Caterpillar production C-13 diesel engine. Test operation includes a 60-minute warm-up and break-in, followed by a 4-hour cool down and a valve lash adjustment. Following the valve lash adjustment and any other needed adjustments, a 500-hour test is begun. The engine is operated under steady-state, rated power conditions known to generate excessive piston deposits and/or oil consumption.

Test Conditions:

Engine speed: 1800 rpm
Test length: 500 hours

API CK-4 Pass/Fail Criteria:

1000 merits

Industry Specifications

Caterpillar 1N ASTM D6750

Scope:

The 1N test is run in the Caterpillar 1Y5400 SCOTE (Single Cylinder Oil Test Engine) utilizing a one-piece aluminum piston and 0.05 wt. percent sulfur fuel. This test was originally developed to replace the 1K test as part of the upgrade requirements to move from API CF- 4 to API CG-4. The Caterpillar 1N uses the exact same hardware and test conditions as the 1K, but with low sulfur diesel fuel. It was added to API CI-4 Plus as an adjunct to the Caterpillar 1R test to insure that oils developed for this new category also protect engines that use one-piece aluminum pistons. The Caterpillar 1N is designed to determine the ability of an oil to provide minimal piston deposits; ring sticking; low oil consumption; and piston, ring and liner scuffing resistance. The test is intended to simulate on-highway, heavy-duty diesel service prior to 1998 with low sulfur fuel.

Test Conditions:

Engine speed:	2100 rpm
Fuel flow rate:	8000 BTU/min
Test length:	252 hours
Approximate power output:	70 HP

API CK-4 Pass/Fail Criteria:

Top Groove Fill: 20% max

Top Land Heavy Carbon: 3% max

Weighted Demerits: 286.2 max

Avg. Oil Consumption, gm/Kw-hr: 0.15

Ring/Liner Scuffing: none

Caterpillar Oil Aeration Test (COAT) ASTM D8047

Scope:

The COAT utilizes a Caterpillar C-13 6-cylinder engine to measure entrained gas or foam. A micro-motion meter measures oil density to calculate % aeration. Air is entrained in the lubricant during the test and reaches a maximum value toward the end of the test.

Test Conditions:

Fuel flow rate:	1.5 L/min
Test length:	50 hours

API CK-4 Pass/Fail Criteria:

11.5% max amount of air in oil in last 10 hours of the test

Industry Specifications

Mack T-11 ASTM D7156

Scope:
The Mack T-11 is a procedure that evaluates the soot handling performance, as measured by viscosity increase, of lubricating oils operating in diesel engines equipped with cooled exhaust gas recirculation. The Mack T-11 evaluation procedure simulates stop-and-go operation and high-soot loading. It is run on a Mack E-TECH V-MAC III engine.

Test Conditions:
Oil samples are taken every 12 hours and analyzed for soot content and viscosity. Test duration is 180 hours.

API CK-4 Pass/Fail Criteria:
The main parameter is the kinematic viscosity increase limit within soot "windows":

3.5% minimum soot for 4 cSt viscosity increase
6.0% minimum soot for 12 cSt viscosity increase
6.7% minimum soot for 15 cSt viscosity increase

Mack T-12 ASTM D7422

Scope:
The Mack T-12 test involves the use of a Mack E-TECH V-MAC III diesel engine with Exhaust Gas Recirculation (EGR). This test method was developed to evaluate the wear performance of engine oils in turbocharged and intercooled four-cycle diesel engines equipped with EGR and running on ultra-low sulfur diesel fuel (ULSD).

Test Conditions:
A warm-up and a 1-hour break-in are followed by a two phase test consisting of 100 hours at 1800 r/min and 200 hours at 1200 r/min, both at constant speed and load conditions.

API CK-4 Pass/Fail Criteria:
Total Merits: 1000

Mack T-13 ASTM D8048

Scope:
Mack T13 uses a 2010 Volvo/Mack D13 6-cylinder diesel engine with electronically controlled fuel injection, six electronic unit injectors, VGT (variable geometry turbocharger), and cooled EGR (exhaust gas recirculation). The test measures Kinematic viscosity increase at 40°C (300-360 hours), % max. Oil filter adapter is a modified 2007 housing.

Test Conditions:
The 360-hour test is conducted at 1500 RPM steady state conditions at a given fuel flow to evaluate the oxidation stability performance of engine oils at an elevated oil temperature. ULSD fuel is used.

API CK-4 Pass/Fail Criteria:
75% max. from 300 - 360 hours

Industry Specifications

Cummins ISM ASTM D7468

Scope:

Cummins ISM is a replacement for Cummins M-11 EGR. It is used to evaluate a lubricant's effectiveness at reducing soot-related wear of overhead components, sludge and oil filter plugging. High-load, heavy-duty field conditions with high soot and EGR flow rates using a 2004 emission-compliant engine are simulated.

Test Conditions:

This 200-hour procedure uses a Cummins ISM engine equipped with EGR and is intended as a replacement procedure for the M-11 EGR, using newer hardware. The Cummins ISM procedure uses ultra low sulfur diesel fuel.

API CK-4 Pass/Fail Criteria:

Total Merits: 1000

Cummins ISB ASTM D7484

Scope:

The Cummins ISB test method is a 350-hour test developed to evaluate the durability and reliability of the camshaft and tappet interface when run with different lubricating oils. Oil performance is determined by assessing crosshead wear, tappet weight loss, and cam profile wear at 3.25% soot.

Test Conditions:

The test method uses a 2007 EPA emission compliant Cummins 5.9L ISB diesel engine. Test duration is 350 hours in two stages. During the 100-hour stage A, the engine is operated with retarded fuel injection timing to generate excess soot. During the 250-hour stage B, the engine is operated at cyclic conditions to induce valve train wear.

API CK-4 Pass/Fail Criteria:

Average cam wear, microns: 55 max
Average tappet wear, mg: 100 max

Sequence IIIF ASTM D6984

Scope:

This test evaluates high temperature oil thickening characteristics, sludge and varnish deposits and overall engine wear in unleaded gasoline engines. The test engine is a six-cylinder, four stroke, 3.8 liter 1996 Buick. The test was designed to simulate high speed driving conditions during high ambient temperatures found typically in the Southern regions of the United States. *Note: Criteria for this test is based upon the CJ-4 specification.*

Test Conditions:

The test is operated on a four-hour break-in schedule after which the oil is sampled. The engine is then run for 80 hours under conditions of high speed, load and temperature.

API CJ-4 Pass/Fail Criteria:

Viscosity Increase @ 80 hour: % max 275

Industry Specifications

Sequence IIIG (alternative to IIIF) ASTM D7320

Scope:

The objective of this test is to measure oil thickening and piston deposits under high temperature conditions and to provide information about valve train wear. At the end of the test, all six pistons are inspected for deposits and varnish; cam lobes and lifters are measured for wear and oil screen plugging is evaluated. *Note: Criteria for this test is based upon the CJ-4 specification.*

Test Conditions:

A 1996/1997 231 C.I.D. (3800 CC) Series II General Motors (GM) V-6 fuel-injected gasoline engine is used. Using unleaded gasoline, the engine runs a 10-minute initial oil leveling procedure followed by a 15-minute slow ramp up to speed and load conditions. It then operates at 125 bhp, 3600 rpm, and 150°C oil temperature for 100 hours, interrupted at 20-hour intervals for oil level checks.

API CJ-4 Pass/Fail Criteria:

Viscosity Increase: 150%

GM 6.5 Roller Follower Wear Test (RFWT) ASTM D5966

Scope:

The RFWT or GM 6.5L measures an oil's ability to prevent wear of the pin in an engine equipped with needle bearings in the roller cam followers.

Test Conditions:

Engine speed: 1000 rpm
Fuel flow rate: 9.0 kg/hour
Test length: 50 hours
Approximate power output: 30-34 kW

API CK-4 Pass/Fail Criteria:

Average Pin Wear, microns max: 7.6

API CK-4 Bench Tests

A bench test differs from an engine test in that it is performed in a laboratory, not on a full engine. Bench tests are less expensive to run and help round out the performance measurement for the API CK-4 category.

Noack or Volatility Bench Test ASTM D5800

Scope:

The Noack test measures oil volatility at high temperatures. As temperatures rise, any fluid, even engine oil, has a tendency to evaporate. This test ensures that API CK-4 oils will experience only minimal evaporation due to temperature.

Industry Specifications

During the Noack Volatility Test, a sample of oil is placed in the test machine and held at elevated temperatures with a slight vacuum for one hour. The oil sample's weight is noted at the beginning and end of the bench test. The Noack Volatility Test measures oil volume to assure that the oil experiences only minimal evaporation at high temperatures.

Test Conditions:

The test oil is heated for one hour at 250° C. The sample is under vacuum with resulting oil vapors drawn off by an air stream. The amount of vapor indicates volatility of oil and oil consumption.

API CK-4 Pass/Fail Criteria:

Loss @ 250°C, percent max volatility: 13.0%

Kinematic Viscosity/SAE J300 ASTM D445

Scope:

This simple test describes the viscosity of the oil at various temperatures.

Test Conditions:

The flow of the oil against gravity is measured using a calibrated glass tube immersed in a heated bath.

API CK-4 Pass/Fail Criteria:

@ 100° C: 9.5 to <12.5 cSt for XW-30
12.5 to <16.3 cSt for 15W-40

High Temperature Corrosion Bench Test (HTCBT) ASTM D6594

Scope:

HTCBT was first used by API for CG-4. This test measures a diesel engine oil's tendency to corrode various metals, specifically alloys of lead and copper, which are commonly used in cam followers and bearings.

Test Conditions:

Four metal specimens of copper, lead, tin and phosphor bronze are immersed in a measured amount of engine oil. The oil, at an elevated temperature, is blown with air for a period of time.

When the test is completed, the copper specimen and the stressed oil are examined to detect corrosion and corrosion products, respectively. The corrosion process under investigation is believed to be induced primarily by inappropriate lubricant chemistry rather than lubricant degradation or contamination.

API CK-4 Pass/Fail Criteria:

Copper (Cu)	20 mg, Max
Lead (Pb)	120 mg, Max
Tin (Sn)	50 mg, Max
Copper Discoloration	3 Max

Industry Specifications

Kurt Orbahn Shear Stability Test ASTM D7109

Scope:

The Kurt Orbahn test was first used by API for API CH-4. This test method covers the evaluation of the shear stability of polymer-containing fluids (e.g., multi-viscosity engine oil). It measures the percent viscosity loss at 100° C when evaluated by a diesel fuel injector apparatus procedure. The viscosity loss reflects permanent shear loss (chain breakage). Shear stability is a critical test for hydraulic/electronic unit injector (HEUI) equipped engines. Engine oils that shear down from their original viscosity cause injection pressures to drop, which decreases overall engine efficiency. Wear protection is also diminished as an oil shears.

Test Conditions:

Test procedure: 90 passes for both CJ-4 and CK-4

Test temperature: 100° C

Test oil is sent through the test apparatus either 30 or 90 times at pressures of 1,900 to 2,600 psi, as defined by instrument calibration. The final viscosity is measured and the percent loss from the beginning viscosity is recorded.

API CK-4 Pass/Fail Criteria:

Kinematic Viscosity after 90 passes: 9.3 cSt min for XW30
12.5 cSt min for 0W40
12.8 cSt min for other XW-40 grades

High Temperature High Shear (HTHS) Viscosity Test ASTM D4683

Scope:

The HTHS test gives an indication of temporary shear stability of the viscosity index improver used in multi-grade oils.

Test Conditions:

Unlike Kinematic Viscosity, HTHS viscosity is measured under conditions similar to those of an operating engine. The test is conducted at 150° C under shear stress conditions similar to those found in very thin film lubrication areas. An example is the piston ring-to-cylinder wall interface. The value obtained from this test provides an indication of the ability of the oil to maintain fluid film strength in an engine.

API CK-4 Pass/Fail Criteria:

Non-Critical Limit: 3.5 cP min

API FA-4 Pass/Fail Criteria:

Non-Critical Limit: 2.9 - 3.2 cSt

Industry Specifications

Foaming ASTM D892

This test is the standard test method for foaming characteristics of lubricating oils.

Scope:

The tendency of oils to foam can be a serious problem in systems such as high-speed gearing, high-volume pumping, and splash lubrication. Inadequate lubrication and cavitation can lead to component failure. This test method is used in the evaluation of oils for such operating conditions.

Test Conditions:

The sample, maintained at a temperature of 24° C (75° F), is blown with air at a constant rate for 5 minutes and then allowed to settle for 10 minutes. The volume of foam is measured at the end of both periods. The test is repeated on a second sample at 93.5° C (200° F), and then, after collapsing the foam, at 24° C (75° F).

API CK-4 Pass/Fail Criteria:

Sequence I: 10 minutes/ 0 max

Sequence II: 20 minutes/ 0 max

Sequence III: 10 minutes/ 0 max

Sooted Oil Mini-Rotary Viscometer (MRV) ASTM D6896

Scope:

This test utilizes an MRV that consists of one or more viscometric cells in a temperature-controlled aluminum block. Each cell contains a calibrated rotor-stator set. The rotation is achieved by applied load acting through a specified pulley mechanism.

Test Conditions:

A used engine oil sample is heated at 80° C and then vigorously agitated. The sample is then cooled at a programmed cooling rate to a final test temperature. A low torque is applied to the rotor shaft to measure yield stress and a high torque is applied to determine apparent viscosity of the oil.

API CK-4 Pass/Fail Criteria:

180-hour sample from Mack T-11 or T-11A

Viscosity @ -20° C, max: 25,000 mPA-S

Yield Stress: <35 Pa

Elastomer Compatibility Test ASTM D7216

Scope:

This seal compatibility test method evaluates the compatibility of API CK-4 oils with typical elastomeric compounds used in heavy-duty engines. These include nitrile, silicone, polyacrylic, and fluoroelastomers.

Test Conditions:

Test procedure: Variation of gear lube test

Test length:	20 days (336 hours)
Test temperature:	100° C for Nitrile Seals
	150° C for Silicone, Polyacrylic, and Fluoroelastomer seals
Seal measurements:	Volume swell
	Hardness change
	Tensile strength change
	Elongation change

API CJ-4 Pass/Fail Criteria:

	Volume	Hardness	Tensile Strength	Elongation
Nitrile	+5/-3	+7/-5	+10/-R	+10/-R
Polyacrylate	+5/-3	+8/-5	+18/-15	+10/-35
Fluoroelastomer	+5/-2	+7/-5	+10/-R	+10/-R
Silicone	+R/-3	+5/-R	+10/-45	+20/-30

R = TMC 1006

Other OEM Specifications

Often, API performance categories do not meet the additional performance requirements sought by every engine manufacturer. For this reason and others, OEMs may elect to issue their own engine oil classifications. These classifications typically apply to specified engine models and/or operating conditions. Over the years, these classifications have included the following:

Cummins CES 20086

The Cummins specifications for CK-4 tend to have the CJ-4 test criteria, but with some tighter limits.

Cummins 20087

These specifications for FA-4 tend to have the CJ-4 test criteria, but with some tighter limits.

Cummins CES 20081

This specification was similar to API CJ-4 but with some tighter test limits. Designed for Cummins 2007-compliant engines equipped with diesel particulate filters (DPFs), it can be used with diesel fuel containing up to 500 ppm of sulphur.

Cummins CES 20078

On 12/04/01, Cummins issued Cummins Engineering Standard 20078 (CES 20078). The intent of CES 20078 was to ensure that high quality engine oils, suitable for Cummins EGR-equipped engines, would be available by the 2nd quarter of 2002. API CI-4 Plus wasn't officially required until August 2002; however, Cummins was planning to sell EGR engines by April. This specification made sure that these engines would be lubricated with approved oil.

This specification is very similar to API CI-4 Plus but has a few test limits that are more severe.

Industry Specifications

Detroit Diesel Power Guard 93K222

This specification for CK-4 tends to have the CJ-4 test criteria as 93K218 (below), but with some tighter limits.

Detroit Diesel Power Guard 93K223

This specification for FA-4 tends to have the CJ-4 test criteria, but with some tighter limits.

Detroit Diesel Power Guard 93K218

This specification is intended for all four-stroke cycle series engines with an aftertreatment system, EPA 07 and older (including legacy engines), operating on ULSD fuel. These oils are similar to API CJ-4.

Detroit Diesel Power Guard 93K214

This specification is for engine oils used in the Detroit Diesel engines model year 2002 and newer Series 50 and 60 and Mercedes Benz MBE 400 and MBE 900 engines. This specification was needed to address the rapidly changing requirements for emission-controlled engines. API CI-4 Plus tests formed the core of the category with additional tests to assure lubricant performance for newer emission-controlled engines, particularly those using cooled EGR. Another key purpose behind this specification is to extend drain intervals up to 50 percent in some engines.

Mack VDS 4.5

This specification for CK-4 tends to have the CJ-4 test criteria, but with some tighter limits.

Mack EO-O Premium Plus ‘07

This specification exceeded API CJ-4 with tighter pass limits in the Mack T-12, Cummins ISM and Cummins ISB engine tests plus the addition of the Volvo D12D test. It can be used with diesel fuel containing up to 500 ppm of sulphur.

Mack EO-N Premium Plus

In 2002, EO-N Premium Plus oil performance specification was made mandatory for usage in ASET™ AI and AC engine models and was recommended for all MACK engine models (E-Tech™, E7, E6, etc.) regardless of vintage. EO-N Premium Plus engine oil promotes longer engine life and reduced component wear, providing a higher oil film thickness, better wear performance and improved oxidation control at higher oil temperatures.

Cat ECF-3

Recommended for Caterpillar 2007 engines, this specification is the same as API CJ-4.

Cat ECF-1

Engine Crankcase Fluid Specification 1 (ECF-1) was issued in response to Caterpillar’s concern regarding the potentially negative side effects of industry standard API CI-4 oil formulations. CI-4 oils with high sulfated ash had demonstrated unacceptably high piston and ring groove deposits in Caterpillar engines.

The API Service Symbol

The API Service Symbol "Donut" is divided into three parts:

- The top half describes the oil's performance level.
- The center identifies the oil's viscosity.
- The bottom half tells whether the oil has demonstrated energy-conserving properties in a standard test in comparison to a reference oil.

Performance Levels

The top of the Donut shows the oil's performance level for gasoline and/or diesel engines. The letter "S" followed by another letter (for example, SM) refers to oil suitable for certain gasoline engines. The letter "C" followed by another letter and/or number (for example, CK-4) refers to oil suitable for certain diesel engines. These letters officially stand for "Service" and "Commercial."

SAE Viscosity Grade

The center of the Donut shows the oil's SAE viscosity grade. Viscosity is a measure of an oil's flow characteristics, or thickness, at certain temperatures.

A multi-grade oil (for example, SAE 5W-30) provides good flow capability for cold weather but still retains thickness for high-temperature lubrication.

A single grade oil (a single number in the center of the Donut) is recommended for use under a much narrower set of temperature conditions than multi-grade oils.

SAE Engine Oil Viscosity Grades

Physical Requirements

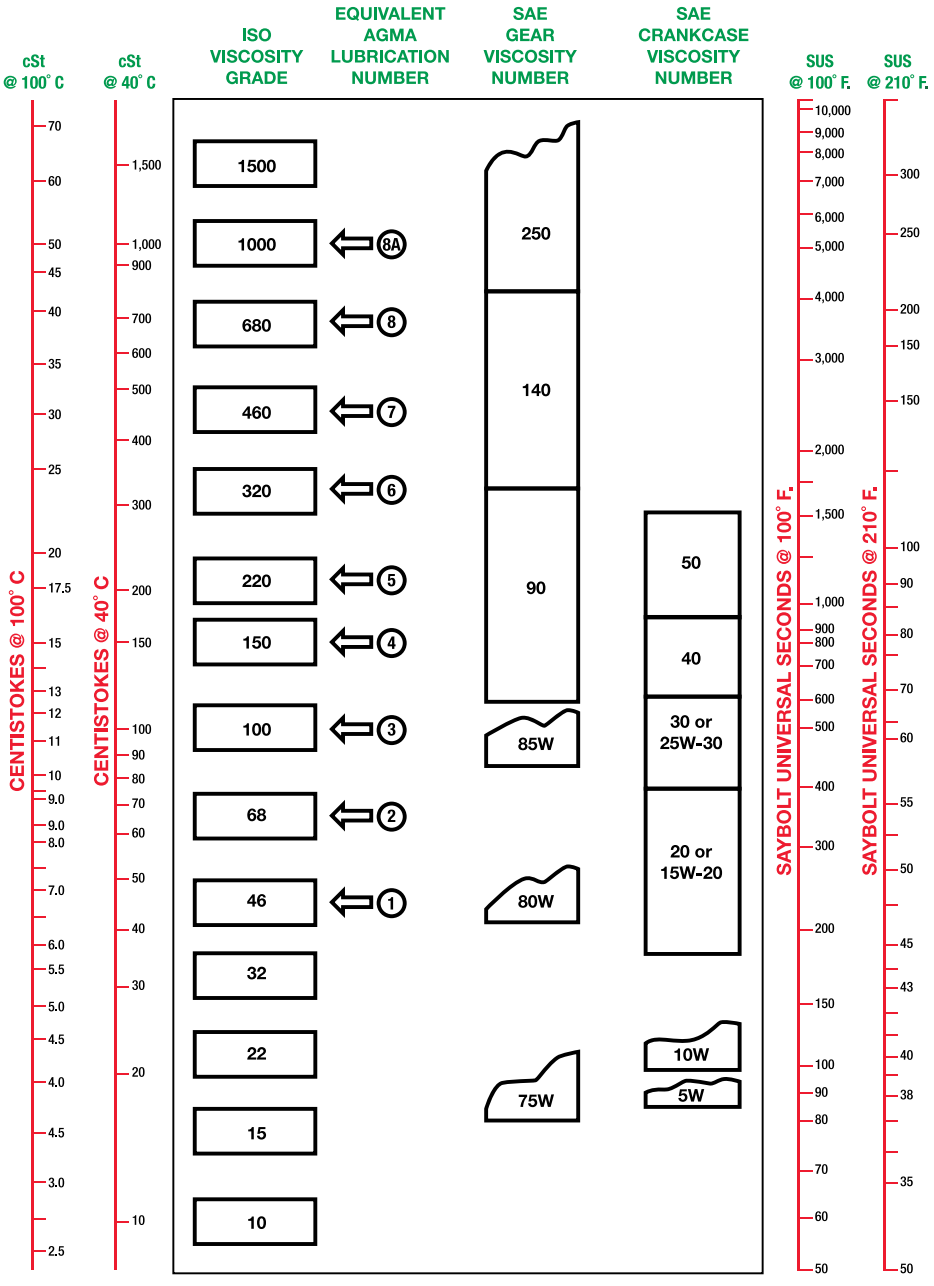
The following chart contains the physical requirements for SAE viscosity grades as described in SAE J300*. Additional requirements are imposed by the U.S. military.

Low-Temperature Viscosity				High-Temperature Viscosity		
SAE Grade	Cranking (cP) max. at °C	Pumping (cP) max. with no yield stress at °C		Low Shear Rate Kinematic (cSt) min.	max. at 100°C max.	High Shear Rate (cP) at 150°C min.
0W	6200 at -35	60,000 at -40		3.8	----	----
5W	6200 at -30	60,000 at -35		3.8	----	----
10W	7000 at -25	60,000 at -30		4.1	----	----
15W	7000 at -20	60,000 at -35		5.6	----	----
20W	9500 at -15	60,000 at -20		5.6	----	----
25W	13,000 at -10	60,000 at -15		9.3	----	----
20	----	----		5.6	<9.3	2.6
30	----	----		9.3	<12.5	2.9
40	----	----		12.5	<16.3	2.9 (0W-40, 5W-40, 10W-40)
40	----	----		12.5	<16.3	3.7 (15W-40, 20W-40, 25W-40, 40 grades)
50	----	----		16.3	<21.9	3.7
60	----	----		21.9	<26.1	3.7

* All values are critical specifications as defined by ASTM D 3244 b ASTM D 5293 c ASTM D 4684 The presence of any yield stress detectable by this method constitutes a failure regardless of viscosity. d ASTM D 455 e STM D 4683, ASTM D 4741, CEC-L-36-A-90 or ASTM D 5481 See SAE J300 for full formulation.

SAE Engine Oil Viscosity Grades

Comparative Viscosity Classifications



VISCOSITIES AT VARIOUS TEMPERATURES ASSUME 95 VI OILS

NOTE: Viscosities at various temperatures are related horizontally.
SAE gear and crankcase specifications are at 100° C only.
Multigrade oil viscosities are not representaive at other temperatures.

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Important Engine Oil Properties

Role of Engine Oil

A high quality engine oil is formulated to perform a number of roles within an engine:

- **Reduce frictional resistance**
- **Protect against corrosion and wear**
- **Assist in sealing**
- **Contribute to cooling the engine**
- **Facilitate the suspension of harmful combustion by-products**

The key to choosing an engine oil that can effectively accomplish the above tasks is to choose a fluid with good base stocks and properly blended, premium additives. Below is a quick reference of base stock characteristics and how each can influence the finished engine oil:

Key Base Stock Property	Engine Oil Performance Criteria
Viscosity and Viscosity Index	High Temp Viscosity
Viscosity, Viscosity Index, Pour Point, and Amount of Wax	Low Temp Viscosity
Amount of Saturates and Sulfur	Oxidation Control
Amount of Saturates	Seal Swell Control and Additive Compatibility
Volatility* and Viscosity Index	Oil Consumption Control

In addition to meeting or exceeding industry specifications and accomplishing the duties described above, there are several desirable engine oil properties that can impact the performance of today's equipment. Typically, these properties can be enhanced when an engine oil is blended with high quality base stocks and a premium additive package using cutting-edge technology. Some oil properties and their importance are shown on the following pages.

**Low volatility is especially important in engine oils because the high operating temperatures in today's diesel engines can lead to excessive oil consumption.*

Total Base Number or TBN

Modern diesel engine oils have a characteristic referred to as alkalinity (or Reserve Alkalinity) as part of their formulation. This alkalinity — commonly called detergency, or "TBN" — describes an oil's ability to neutralize acids as they are formed in the crankcase. These acids are a normal by-product of the combustion process when diesel fuel is burned because the fuel *itself* contains sulfur compounds. TBN levels in North American CK-4 engine oils typically range from 8 to as high as 11.

Research suggests that TBN should never be the sole indicator for calculating drain intervals. Factors such as the lubricant's viscosity, soot content, and low temperature flow are critical factors in evaluating its drain limit.

Important Engine Oil Properties

High Temperature/High Shear (HT/HS)

An oil's resistance to permanent viscosity loss due to shear is called *shear stability*. Forces inside an engine — such as high temperature, heavy loads and outside contaminants — can cause an oil to shear down, or thin. Oil thinning can cause increased oil consumption and reduced oil film strength. Once the oil film strength is compromised, engine components are exposed to wear and premature failure is possible. Increased oil consumption can also elevate maintenance costs.

Oils that are shear stable maintain their oil film thickness, protecting critical moving parts like rings, bearings, and other engine components while extending engine life. Temporary viscosity loss in high-speed, heavy-load applications can result in metal-to-metal contact, which causes premature engine wear. Oils that offer excellent high temperature/high shear protection give users an increased margin of protection against viscosity loss.

Viscosity Index (VI)

Viscosity index is a measure of an oil's change in viscosity based on changes in operating temperatures. Oils with a high viscosity index (over 100) experience relatively little change in viscosity as a result of temperature changes. High VI oils do not experience thinning at high temperatures *or* thickenening at low temperatures. Viscosity index is a performance benefit that is a result of high-quality base oils and premium additives.

Base Oil

Building a Lubricant from the Base Up

Base oil comprises 80 to 98 percent of finished lubricants used in engines, transmissions, hydraulics, and gear housings. Base oil contributes to a number of properties in a finished lubricant; these properties can be further enhanced with additives. A lubricant manufacturer's goal is to accentuate the base oil's positive properties while decreasing or removing any unwanted characteristics. Some of the most important properties influenced by a base oil are listed and defined below:

Viscosity and Viscosity Index (VI)

Viscosity is a measure of a fluid's resistance to flow; viscosity index (VI) is the relationship of a fluid's viscosity to temperature. High VI fluids experience less change in viscosity relative to temperature than low VI fluids do. Base oils have natural tendencies toward high, medium or low VIs, but VI can be enhanced through refining techniques and with additives in the blending process.

Volatility

Volatility refers to how readily a base oil and resulting finished lubricant will evaporate as temperatures rise. Volatility is especially important in engine oils where compartment temperatures are extremely high; high volatility can result in increased oil consumption.

Important Engine Oil Properties

Pour Point

Pour point is the temperature at which an oil "gels." Pour point directly influences a finished lubricant's ability to flow to critical components during low ambient temperatures. In a base oil, the amount of wax in the fluid can make pour points higher, but refining techniques can *remove* the wax so that the pour point is lowered. It is recommended that a finished lubricant's pour point be approximately 15 degrees below the expected ambient temperature.

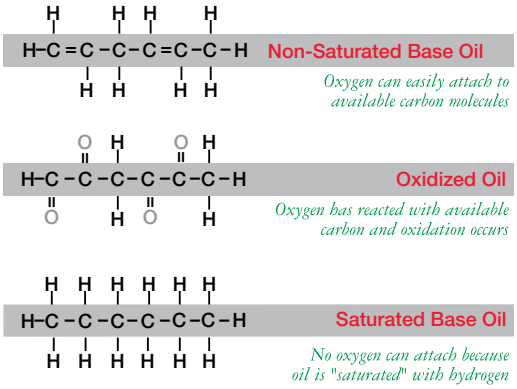
Pour point is a relatively crude measure of cold temperature performance and should not be used as the sole indicator of a fluid's cold temperature properties. It should be viewed in conjunction with more precise testing methods such as pumpability via TP-1 coding, D-4684 and end Brookfield viscosity measurements.

Demulsibility

The ability of an oil to separate from water that has contaminated a system is called "demulsification." A lubricant's ability to separate from water is a necessity for applications where water can attack metal parts or even cause additives to drop out of the finished lubricant. Demulsibility is especially important in hydraulic fluids.

Oxidation

Chemically, oxidation occurs when hydrocarbon molecules react with oxygen molecules at elevated temperatures. An oxidized oil thickens excessively, jeopardizing pumpability to critical parts, and can become acidic and eventually corrode metal surfaces. Good oxidation performance in a base oil relates directly to how "saturated" the base oil is. Saturation refers to the amount of base oil molecules that have no chemically active double bonds. This creates a situation where there is less chance for oxygen to bond with any molecules, which would eventually lead to oxidation. Mineral base oils treated during refining with hydrogen are more saturated, and therefore have better oxidation stability than mineral base oils not treated with hydrogen.



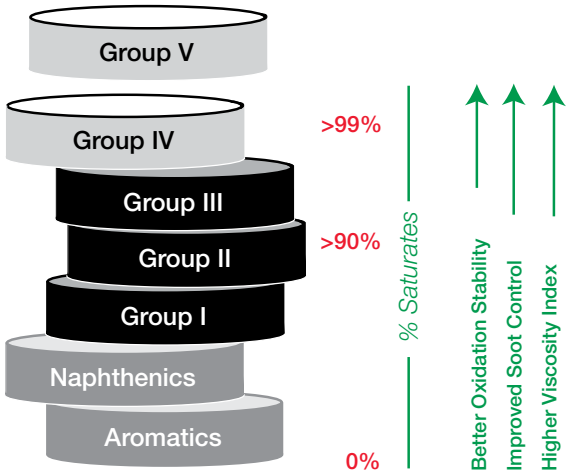
Thermal Stability

Base oils that can withstand high temperatures for long time periods without oxidizing are termed "thermally stable." In applications that experience high operating temperatures for extended lengths of time, thermal stability cannot be compromised. Thermal stability is achieved by good base stocks and additives.

Important Engine Oil Properties

Base Oil Groups

There are several major types of base oil groupings. Each base oil group has specific characteristics that relate to the application of the finished lubricant. As illustrated, progressing from aromatics up to synthetic base oils increases the oxidative stability, viscosity index and amount of saturation typically found in the base oil. It is important to note that these base stocks are not always interchangeable. Additive packages that produce approval with Group I base stocks in finished lubricants may not replicate that approval in a Group II finished lubricant. Additives can react differently with each category of base oil.



API Base Oil Groups

Three easily discernible characteristics in base stocks are sulfur content, saturation, and viscosity index. The measurement of these features gives insight into ultimate finished product benefits.

Sulfur Content

Sulfur content relates directly to many performance characteristics of the base stock. Sulfur negatively impacts catalysts in aftertreatment systems and can impact seal compatibility, oxidation, and deposit performance. Total sulfur in CK-4 oils Is limited to 4000 ppm max. Advanced refining and finishing processes remove nearly all of the sulfur in a base oil.

Saturation

Saturation refers to the amount of base oil molecules that have no chemically active double bonds. This is an important characteristic in a base oil because these double bonds can be easily broken to allow hydrocarbon molecules to react with one another or oxygen or nitro-oxidized molecules. The result is oxidation in the base oil, which leads to oil thickening, deposits, and breakdown in finished lubricants.

Highly saturated base oils, like Group II stocks, have been treated with hydrogen gas during refining. This process forces hydrogen through the oil and causes it to react with the double bonds. This saturates the molecule with hydrogen, thus eliminating opportunities for oxygen to attach and making the base oil more oxidation resistant.

Important Engine Oil Properties

Viscosity index

Viscosity index (VI) may be one of the single most important performance measures in both a base oil and finished lubricant. VI is the measure of a change in viscosity relative to a change in temperature. Base oils with high VIs (over 100) experience less change in viscosity due to temperature. High VI finished lubricants, such as multi-viscosity engine oils, offer improved protection, pumpability, efficiency, and oil consumption benefits over lower VI lubricants.

Base Oil Groups: Characteristics

Currently, the media, the industry, and oil marketers are playing up the benefits of Group II and higher base stocks. Here is a review of the characteristics of each base oil group:

- Group I base oils have VIs of 80 to 120 and were the original, traditional engine oil base stock, but are not common in modern engine lubricants. Group I base oils have more sulfur and less saturates than Group II, III, or IV fluids. The performance of finished lubricants blended with Group I base oils is largely dependent upon the quality of the additive package.
- Group II base oils are known for their excellent deposit control and high level of saturates, which makes them more oxidation resistant. They typically have VIs of 95 up to 120 and rely heavily on additives to enhance finished lubricant characteristics. Different refining techniques work to remove unwanted characteristics and improve upon desired ones, like viscosity index and oxidation control. Most of Castrol's finished lubricants are blended with Group II base oils and a premium-performing additive package.
- Two other categories of fluids are common—synthetics or Group III/Group IV and specialized fluids, or Group V. For engine oils, synthetic fluids fall into two categories: *refined* and *polyalphaolephins*.
- Refined Group III base oils are petroleum fluids that undergo extreme refining techniques, producing a base fluid with characteristics of a man-made synthetic. Group III refined base oils are typically found in partial to full synthetic finished lubricants, since they have greater than 90% saturates (usually 99%+) and VIs over 120. They have low pour points, good oxidation resistance, and low volatility.
- Group IV base oils are known as polyalphaolefins (PAO). PAOs, the most widely used of the engineered base stocks, consist of all saturated hydrocarbon structures and contain no unwanted sulfur or other metals. Free of wax, PAOs have very low pour points and typically have VIs of 140. PAOs have good thermal stability, but are sometimes difficult to blend with additives. Despite their noted performance features, PAOs are sometimes cost-prohibitive for users.
- Group V base fluids consist of other fluids that are not typically derived from oil refining or PAO synthesis, predominately esters and polyolesters. There are also aromatic and naphthenic base oils that are not suitable for use in heavy-duty engine lubricants due to their poor oxidation stability and low VIs. Aromatics contain elevated levels of sulfur (which lead to deposit formation) and sometimes nitrogen (which contributes to oxidation and deposit formation). Aromatics are typically used as solvents, cleaners, and process oils, and in further chemical reactions for industrial products.
- Naphthenic fluids, typically, have low to medium VIs of up to 60. They exhibit very low pour points, high solubility, and excellent cold flow in long term storage. Naphthenics are commonly used in refrigeration lubricants, metalworking oils, greases, and as extreme cold temperature fluids, such as snowplow oils.

Important Engine Oil Properties

Refining Techniques

Group I and II mineral-based fluids are all refined from crude oil, and the way that crude oil is refined determines its place in the base oil groupings.

Solvent refining is older technology that is often used to create Group I base stocks. A solvent refined crude oil is dissolved in solvent, then chilled and filtered to remove wax. The resulting base fluid will still have poor low temperature fluidity and a typical VI of 90 to 100. To further influence a base oil's performance characteristics, additional refining using hydrogen may be performed. There are basically three types of hydrogen refining, each more potent than its predecessor:

Hydrofinishing forces pressurized hydrogen into a solvent extracted base oil. The hydrogen molecule fills some of the active double bonds in the hydrocarbon molecule so these molecules cannot react with oxygen molecules to begin the process of oxidation. Hydrofinishing also removes some of the sulfur, nitrogen, oxygen, and color impurities present in the solvent-refined base oil.

A more severe process called **hydrotreating** forces hydrogen gas through the base oil, at higher pressures than hydrofinishing, which further saturates the oil with hydrogen molecules. Hydrotreating boosts oxidation stability, increases pour point, and removes even more sulfur and nitrogen from the base oil. A finished lubricant that has been hydrotreated has lower carbon-forming tendencies than hydrofinished or solvent-refined fluids.

Hydrocracking, or **hydrorefining**, is another severe form of hydrogen processing whereby larger, waxy molecules are cut into smaller, lighter weight ones. Hydro de-waxing reduces the wax content and increases pour point. Group II Hydrocracked base stocks contain over 90 percent saturated molecules and typically have VIs of 95 to 115. They exhibit strong oxidation stability and excellent demulsibility. Castrol uses hydrocracked, Group II base fluids in most of their engine, transmission, hydraulic, and gear oils. Group III base stocks are generally hydro-isomerized during the hydrorefining process, improving the VI to 120 or higher by rearranging the branching of basestock molecules. Group III base stocks also exhibit other improved qualities compared to Group II oils such as reduced volatility and improved oxidation and deposit resistance.

A properly balanced additive package is the critical link to bringing out the best performance in a high quality base oil and, ultimately, in the user's equipment. Castrol has been one of the largest users of Group II base stocks for many years. Castrol also focuses on balancing premium-performing additives with base oil for lubricants that exceed manufacturers' recommendations and customer expectations.

Important Engine Oil Properties

Additives

In today's marketplace, there is very little conventional oil that does not contain additives. Especially prevalent in the heavy-duty industry, diesel engines with high rates of soot and contamination demand a top performing additive package in an engine oil. Generally, additives are used to perform one or more of the following functions within a finished lubricant:

- Protect metal surfaces
- Extend range of lubricant applicability
- Extend lubricant life

The different types of additives on the market can be categorized according to functionality as surface protectors, performance oriented, and protection based. A brief overview of the additives within each of these categories gives insight into the benefits of lubricants containing such additives.

Surface Protecting Additives

Although grouped together under surface protectors, each of the additives below has a very specific job within the finished lubricant. The largest group of additives, surface protectors, can be found in almost every type of lubricant on the market today.

- Considered a cleaning agent, **detergents** prevent deposit formation by either combining with solid combustion debris or changing combustion and oxidation acids into inactive, neutral salts. Total Base Number, or TBN, is a measure of the detergent's ability to neutralize acid. The stronger the TBN, the better an oil's acid neutralizing effects. For more information on TBN, see page A-15.
- **Dispersants,** another cleaning agent, control sludge and varnish by keeping particulates from grouping together to form larger deposits, which become sludge and varnish over time. A lack of dispersants can increase oil viscosity due to the agglomeration of soot and combustion by-products.
- **Anti-wear agents** prevent metal-to-metal contact by adhering to metal surfaces and forming a protective film. Anti-wear agents must be selected carefully because they can affect hydrolytic and frictional stability, as well as become corrosive to yellow metals.
- **Rust and corrosion inhibitors** protect metal surfaces from water-related wear. Improper rust protection can result in significant corrosion in transmission or final drive gear. Rust and corrosion inhibitors protect components by forming a protective layer on the component or by neutralizing harmful acids.
- Found primarily in heavy-duty transmission fluids, greases, and gear lubricants, **extreme pressure (EP) agents** are a special type of anti-wear agent in that they protect against metal-to-metal contact but under extreme loads and temperatures. EP agents must be monitored carefully because they may have compatibility issues with other active chemicals in the lubricant and with yellow metals, such as copper and bronze. Other trade-offs include hydrolytic stability and frictional characteristics.
- **Friction modifiers** work to improve the overall efficiency of a lubricant by decreasing friction, preventing scoring, and reducing wear and noise while adding some fuel economy.

Important Engine Oil Properties

Performance Additives

Specific to temperature performance, these additives are essential in lubricants whose applications are subject to wide temperature ranges. Lubricants with improper tolerance for temperature, both environmental and operational, can cause a host of problems with pumpability, cold starts, and wear.

- **Viscosity modifiers** boost a base oil's natural viscosity index (VI) as well as extend lubricant performance over varying temperatures. Viscosity modifiers work through a unique method of selective oil thickening. High temperatures result in more thickening, which reduces the likelihood of wear; and low temperatures result in less thickening so a lubricant can maintain pumpability.
- **Pour point depressants** are targeted specifically toward enhancing low temperature flow characteristics. Oils tend to form wax crystals during low temperatures. A pour point depressant prevents oil molecules from "sticking" to wax crystals, which would inhibit flow. Some viscosity modifiers also function as pour point depressants and vice versa.

Protective Additives

Different from surface protecting additives, protective additives focus on preventing breakdown from foam, oxygen, or water. Due to the severe duty endured by most diesel applications, protective additive packages are a distinguishing factor among finished lubricants.

- **Anti-oxidants** protect against oil breakdown due to oxidation. Under conditions of high temperature and severe service, oxygen can mix with the churning lubricant at high temperatures and oxidation occurs. Anti-oxidants or oxidation inhibitors act like a sponge to extract oxygen from the oil and slow the oxidation process. Anti-oxidants are used in almost every heavy-duty and automotive lubricant.
- Foam is the result of air getting trapped in the oil. **Anti-foam agents** repress foaming by lowering surface tension and allowing trapped air to escape. Excessive foam can lead to a breakdown in an oil's film strength and eventually causes extensive wear. Like anti-oxidants, anti-foam agents are found in almost every commercial lubricant.
- **Metal deactivators** are actually a class of oxidation inhibitors. Primarily used in transmission fluids, metal deactivators protect metal surfaces from additives that may be corrosive.
- **Emulsifiers and demulsifiers** are engineered to handle water contamination in a lubricant sump. Emulsifiers eliminate any free-circulating water by enabling oil and water to mix. Demulsifiers separate water from oil. If maintenance practices call for water removal, then demulsifiers are the additive of choice. When there is no opportunity to remove water, emulsifiers are added to the lubricant.

Viscosity Index (VI) – A Measure of Performance

Viscosity is one of the single most important characteristics of an engine oil. By definition, viscosity is the measure of a lubricant's resistance to flow. Flow characteristics and temperature are directly related. For example, the higher the temperature, the more freely an oil flows; the lower the temperature, the more flow is inhibited. This relationship results in oil thinning as temperature increases and oil thickening as temperature decreases.

GPS

B

Engine Oils

Castrol®

B

Engine Oils

Product Data

Castrol® Vecton® 10W-30 FA-4

Castrol Vecton 10W-30 FA-4 with unique System Pro Technology™ is a part-synthetic diesel engine oil that represents the latest technology heavy-duty engine oil engineered specifically for **fuel economy** in select 2017 and beyond model year diesel engines. It is targeted *exclusively* at today's low emission, low fuel consumption trucks and buses where API FA-4 is required.

Fuel Savings and Increased Productivity

Pumping oil around the engine creates drag, which saps engine power and increases the consumption of diesel fuel. Castrol Vecton 10W-30 FA-4 delivers a **1.5% Fuel Saving*** **and extended drain intervals of up to 96,000 kilometers or 770 hours**.**

In addition, Castrol Vecton 10W-30 FA-4 has lower viscosity under high temperature and high shear forces. These characteristics reduce drag and save fuel, thus improving the productivity of the engine.

Adapting to Lower Emissions

New technology developments in diesel engines have led to lower emissions in heavy-duty vehicles. In turn, these advances in technology also result in increasing levels of torque within the engine, which leads to higher pressures and temperatures.

Castrol Vecton 10W-30 FA-4 with unique System Pro Technology™ **adapts to increased pressure and temperature with proven shear stability and oxidation performance**.

Features/Benefits

Castrol Vecton 10W-30 FA-4 offers the following benefits in support of modern diesel engine technology:

- **Excels under high pressure.** Engine combustion pressures are increasing, which puts increased pressure on key engine parts. Castrol Vecton 10W-30 FA-4 with unique System Pro Technology™ is formulated to **hold its viscosity** under high shear contacts to extend oil life.
- **Performs at high temperature.** In modern engines, engine oil is subjected to areas of very high temperature; this causes oxidation and oil thickening. Castrol Vecton 10W-30 FA-4 is formulated to **fight oxidation** to extend oil life.

Industry Approvals and OEM Specifications

- API FA-4
- Cummins CES 20087
- DDC DFS 93K223

* In independent testing versus SAE 15W-40 CJ-4 oil using SAE J1321 test method for class 8 trucks

In combination with and following a proper used oil analysis program like **Castrol Labcheck®

Castrol® Vecton® 10W-30 FA-4

Typical Properties

Name	Method	Units	Vecton 10W-30 FA-4
Appearance	Visual	-	Clear & Bright
Viscosity, Kinematic 100C	ASTM D874	% wt	1.0
Viscosity, Kinematic 40C	ASTM D2896	mg KOH/g	10
Viscosity Index	ASTM D97	°C	-42
Sulfated Ash Content	ASTM D445	cSt	67
Total Base Number	ASTM D445	cSt	10.2
Pour Point	ASTM D2270		137

Castrol® Vecton® Long Drain

Castrol Vecton Long Drain 10W-30 CK-4 with unique System Pro Technology™ is an advanced part-synthetic heavy-duty diesel engine oil that conforms to the requirements of PC-11 engine oil technology. Specifically engineered to deliver longer oil life and enable longer service intervals even under severe operating conditions, Castrol Vecton Long Drain 10W-30 CK-4 can be used in diesel engines where API CK-4 or CJ-4 and previous diesel engine oil categories are required.

Extended Oil Life *and* Extended Drain Intervals

New technology developments in diesel engines have led to *lower emissions* in heavy-duty vehicles. In turn, these advances in technology also result in *increasing levels of torque* within the engine, which leads to higher pressures and temperatures.

Castrol Vecton Long Drain 10W-30 CK-4 with unique System Pro Technology™ adapts to increased pressure and temperature with its proven shear stability and oxidation performance, extending useful life of the oil for longer service intervals and higher productivity.

In addition, Castrol Vecton Long Drain 10W-30 CK-4 **delivers extended drain intervals of up to 113,000 kilometerss or 900 hours**.*

Features/Benefits

Castrol Vecton Long Drain 10W-30 CK-4 offers the following benefits in support of modern diesel engine technology:

- **Excels under high pressure.** Engine combustion pressures are increasing, which puts increased pressure on key engine parts. Castrol Vecton Long Drain 10W-30 CK-4 with unique System Pro Technology™ is formulated to **hold its viscosity** under high shear contacts to extend oil life.
- **Performs at high temperature.** In modern engines, engine oil is subjected to areas of very high temperature; this causes oxidation and oil thickening. Castrol Vecton Long Drain 10W-30 CK-4 is formulated to **fight oxidation** to extend oil life.
- **Neutralizes harmful acids and combustion by-products that cause bearing corrosion.** Castrol Vecton Long Drain 10W-30 CK-4 maintains outstanding TBN level even while operating at maximum drain intervals.

Industry Approvals and OEM Specifications

- API CK-4, CJ-4, CI-4 Plus
- CAT ECF-3

*In combination with and following a proper used oil analysis program like **Castrol Labcheck©**

Castrol® Vecton® Long Drain

Typical Properties

Name	Method	Units	Vecton Long Drain 10W-30 CK-4
Appearance	Visual	-	Clear & Bright
Viscosity, Kinematic 100C	ASTM D445	cSt	12.16
Viscosity, Kinematic 40C	ASTM D445	cSt	83.74
Viscosity Index	ASTM D2270		143
Ash, Sulphated	ASTM D874	% wt	0.95
Total Base Number, TBN	ASTM D2896	mg KOH/g	10.69
Pour Point	ASTM D97	°C	-39

Castrol® Vecton® 15W-40 CK-4

Castrol Vecton 15W-40 CK-4 with unique System Pro Technology™ is an advanced part-synthetic heavy-duty diesel engine oil that conforms to the requirements of PC-11 engine oil technology. Castrol Vecton 15W-40 CK-4 can be used in diesel engines where API CK-4 *or* CJ-4 and below is required.

Castrol Vecton 15W-40 CK-4 is engineered specifically to deliver longer oil life, thus enabling longer service intervals even under severe operating conditions. In fact, it **delivers extended drain intervals of up to 97,000 kilometers or 770 hours***.

Adapting to Lower Emissions

New technology developments in diesel engines have led to *lower emissions* in heavy-duty vehicles. In turn, these advances in technology also result in *increasing levels of torque* within the engine, which leads to higher pressures and temperatures.

Castrol Vecton 15W-40 CK-4 **adapts to increased pressure and temperature** with proven shear stability and oxidation performance, extending useful life of the oil for longer service intervals and higher productivity.

Features/Benefits

Castrol Vecton 15W-40 CK-4 offers the following benefits in support of modern diesel engine technology:

- **Excels under high pressure.** Engine combustion pressures are increasing, which puts increased pressure on key engine parts. Castrol Vecton 15W-40 CK-4 with unique System Pro Technology™ is formulated to **hold its viscosity** under high shear contacts to extend oil life.
- **Performs at high temperature.** In modern engines, engine oil is subjected to areas of very high temperature; this causes oxidation and oil thickening. Castrol Vecton 15W-40 CK-4 is formulated to **fight oxidation** to extend oil life.

Industry Approvals and OEM Specifications

- API CK-4, CJ-4, CI-4 Plus
- CAT ECF-3
- Mack EOS-4.5
- Volvo VDS-4.5
- DDC DFS 93K222
- Cummins CES 20086
- RVI RLD-4

*In combination with and following a proper used oil analysis program like **Castrol Labcheck®**

Castrol® Vecton® 15W-40 CK-4

Typical Properties

Name	Method	Units	Vecton 15W-40 CK-4
Appearance	Visual	-	Clear & Bright
Viscosity, Kinematic 100C	ASTM D445	cSt	15.5
Viscosity, Kinematic 40C	ASTM D445	cSt	116
Viscosity Index	ASTM D2270		140
Ash, Sulphated	ASTM D874	% wt	0.99
Total Base Number, TBN	ASTM D2896	mg KOH/g	10
Pour Point	ASTM D97	°C	-42

Castrol® CRB® Multi 15W-40

Castrol CRB Multi 15W-40 CK-4 is a multi-purpose, heavy-duty engine oil designed to provide superior protection to diesel engines. It is engineered to promote long and healthy engine life, offering protection to diesel engines in a variety of applications and duty cycles. Castrol CRB Multi 15W-40 CK-4 conforms to the strict requirements of PC-11 engine oil technology and can be used in diesel engines where API CK-4, CJ-4 and below is required.

Versatility for Heavy Duty and Commercial Vehicles

Castrol CRB Multi 15W-40 CK-4 can be used in a wide range of heavy duty and commercial vehicles; this versatility makes it ideal for use in mixed fleets. **Its special formulation helps to keep diesel engines cleaner and gives more reliable engine protection**. This, in turn, prolongs engine life to various vehicles fleet-wide.

Features/Benefits

Castrol CRB Multi 15W-40 CK-4 offers the following benefits:

- **Protection against oil thickening and deposit build-up** in critical engine parts
- **Protection from wear and deposits**
- **Protection against viscosity loss** for reliable engine protection
- **Better shear stability**

Castrol CRB Multi 15W-40 CK-4's versatility makes it a highly practical solution for workshops and mixed fleets.

Industry Approvals and OEM Specifications:

- API CK-4, CJ-4, CI-4 Plus
- CAT ECF-3

Typical Properties

Name	Method	Units	CRB Multi 15W-40
Appearance	Visual	-	Clear & Bright
Total Base Number	ASTM D2896	mg/g KOH	10
Sulfated Ash Content	ASTM D874	% wt.	1.0
Pour Point	ASTM D97	C	-42
Viscosity, Kinematic 100C	ASTM D445	mm^2/s	15.5
Viscosity, Kinematic 40C	ASTM D445	mm^2/s	116
Viscosity Index	ASTM D2270	None	140

Castrol® Elixion® 5W-30 CJ-4

Castrol Elixion, a revolutionary SAE 5W-30 synthetic engine oil, is formulated with high quality synthetic base fluids.

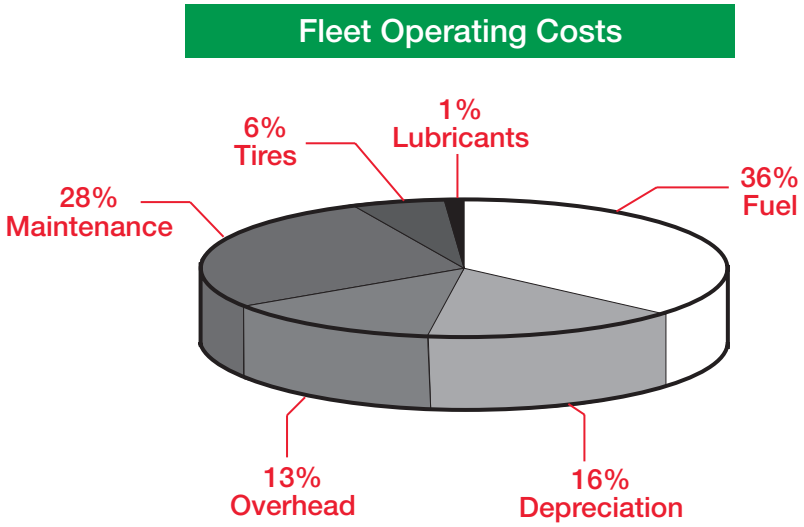
- Synthetic based fluids are known for their extremely low pour points and high viscosity indexes of 140 or better.
- A high viscosity index gives the finished lubricant outstanding viscosity over a range of temperatures, as well as wear protection during extreme high and low temperatures.

Castrol Elixion is a technologically advanced fully synthetic diesel engine oil engineered to reduce operating costs while providing outstanding engine protection. Castrol Elixion offers the fuel economy benefits of a 5W-30 engine oil and combines it with certified API CJ-4 performance. It is formulated with synthetic base oils, which allow for easy cold-weather starting and provide added protection against the intense heat of today's newest diesel engines. Castrol Elixion utilizes a high performance additive package that provides excellent protection against wear, oxidation, soot and deposits to deliver outstanding engine life.

Castrol Elixion has been engineered to provide users with the following benefits:

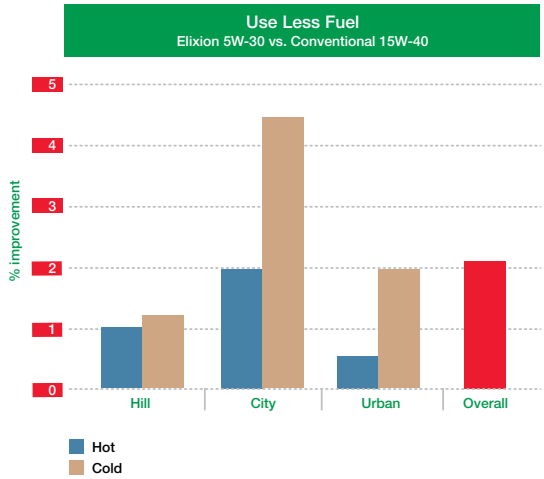
Operational Cost Savings

Castrol Elixion has been specially designed to give fuel economy savings while protecting the engine and allowing extended service intervals. Reviewing the total operating costs of a fleet, it is easy to see where most dollars are spent. Fuel is the biggest variable operating cost for truck fleets today. The combined cost of lubricants, maintenance and tires does not equal the cost to fuel a fleet's vehicles.



Castrol® Elixion® 5W-30 CJ-4

Castrol Elixion is proven to give fleet fuel economy savings of up to 4% over conventional 15W-40 oils.

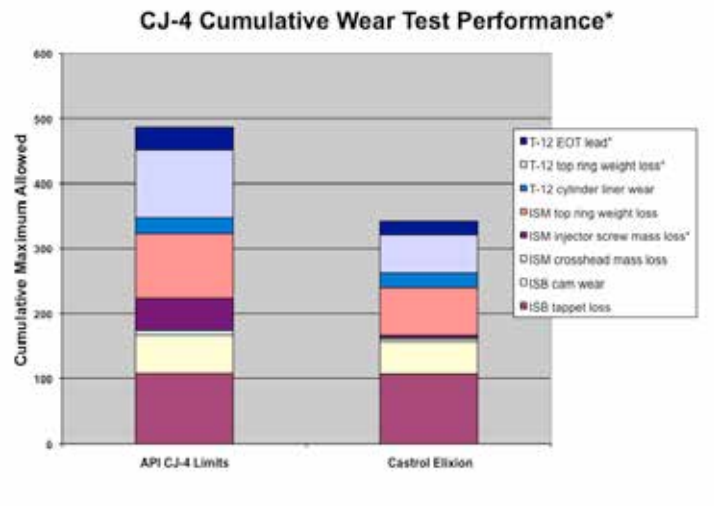


* the data reflects Castrol testing from either field tests or engine dynamometer testing, whichever is pertinent to this data.

By using Castrol Elixion, a fleet can lower fuel bills by reducing fuel consumption.

Enhanced Engine Durability

Castrol Elixion was the first SAE 5W-30 engine oil to meet the latest industry specification, API CJ-4. In fact, it exceeds API CJ-4 limits with outstanding wear protection as evidenced by the wear chart below. In the industry's toughest wear tests, Castrol Elixion falls well below API CJ-4 limits, proving that this 5W-30 engine oil can control soot and deposits in heavy-duty engines and promote long engine life.



* the parameters asterisked are statistically better than the CJ-4 limit at 95% confidence. Results on other parameters are not statistically better than the respective CJ-4 limits.

Castrol® Elixion® 5W-30 CJ-4

All-Temperature Engine Protection

Castrol Elixion offers all-temperature protection for engines. Its base oils have very low pour points and excellent pumpability for cold temperature flow and wear protection, while safeguarding the engine against excessive oil thinning or thickening during very high operating temperatures and pressures.

Proven Reduced Emissions

Using Castrol Elixion, your engine will emit less carbon dioxide (CO^2) as a result of decreased fuel consumption. For example, running a fleet of 100 trucks with Castrol Elixion and gaining just a 2% improvement in fuel economy can reduce CO^2 emissions by up to 342 tons per year as compared to using a conventional 15W-40 engine oil.** Furthermore, Castrol Elixion has been proven to produce significantly less ash forming deposits. This ensures that Diesel Particulate Filters (DPFs) remain cleaner and more efficient, which can help lengthen regeneration cycles and prevent early and costly replacement.

**Based on a fleet of 100 trucks, each covering 100,000 miles a year with average fuel consumption of 6.5 mpg and 2% fuel savings

Features/Benefits:

- Up to 4% fuel economy improvement vs. a 15W-40 oil.
- Highly advanced chemistry provides extra protection against wear, soot, oxidation and deposits.
- Synthetic base oils help enable extended drain capability beyond that of conventional mineral-based engine oils.
- Low volatility minimizes oil consumption.
- Helps maintain protection for the diesel particulate filters on newer engines.

Industry Specifications and OEM Approvals:

- API CJ-4, CI-4 Plus, CI-4, CH-4
- CAT ECF-3
- Cummins CES 20081
- Volvo VDS-4
- Mack EO-O Premium Plus
- MB Sheet 228.31

Castrol® Elixion® 5W-30 CJ-4

Typical Properties

Test	Method	Typical
Viscosity @40°C, cSt	ASTM D445	68.0
Viscosity @100°C, cSt	ASTM D445	11.4
Viscosity Index	ASTM D2270	161
Specific Gravity @60°F	ASTM D1298	0.853
Pour Point, °C(°F)	ASTM D97	-42 (-44)
Flash Point, °C (°F)	ASTM D92	207 (404)
Low Temp Pumping Viscosity @-35°C	ASTM D4684	17,800
Noack Volatility, %loss	ASTM D5800	10.3
Sulfated Ash Content, %wt.	ASTM D874	1.0
Total Base Number	ASTM D2896	11

Due to continual product research and development, the information contained herein is based on products purchased in the U.S. and subject to change without notification. Typical properties may vary slightly.

Castrol® Assuron™

Castrol Assuron (SAE 10W, 30, 40, and 50) are high performance, heavy-duty engine oils that couple selected base stocks with a carefully balanced additive package. Castrol Assuron has proven performance in various on- and off-highway heavy-duty diesel engines, particularly in applications requiring API CF-2.

Castrol Assuron (SAE 10W, 30, 40, and 50) are extremely resistant to the formation of high temperature deposits. The higher dispersant package also works to keep the cooler areas of the engine from sludge and other harmful deposits.

Features/Benefits

- Enhances engine performance
- Protects engine parts for extended life
- Reduces maintenance costs

Industry Specifications and OEM Approvals by Grade:

Castrol Assuron (10W, 30, 40, and 50) exceeds the requirements of the following API categories:

- SAE 10W (CF)
- 30 (CF-2, CF)
- 40 (CF-2, CF)

Typical Properties

SAE Grade		10W	30	40	50
Viscosity 40° C, cSt	ASTM D-445	43.9	92.2	150.1	208
100° C, cSt	ASTM D-445	7	11	14.8	19.3
210° F, SUS	ASTM D-2161	48.9	63	79	94.9
Viscosity Index	ASTM D-2270	108	104	98	99
Sulfated Ash % wt	ASTM D-874	0.95	0.95	0.95	0.95
Total Base Number mg KOH/g	ASTM D-2896	7.5	7.4	7.4	7.5
Pour Point °C	ASTM D-97	-30	-30	-27	-24
Specific Gravity @60F g/ml	ASTM D-1298	0.874	0.8854	0.8911	0.895
Pounds per gallon		7.28	7.38	7.42	7.46

Due to continual product research and development, the information contained herein is based on products purchased in the U.S. and subject to change without notification. Typical properties may vary slightly.

Castrol® Duratec™ ES 15W-40

Low Ash Synthetic Natural Gas Engine Oil (NGEO) for On Road Trucks

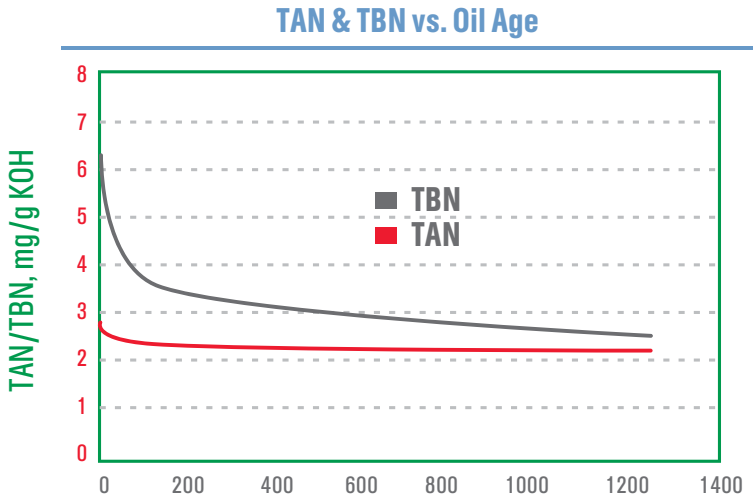
Castrol Duratec ES 15W-40 is a synthetic lubricant formulated for use in natural gas fueled engines where minimal thermal degradation and good deposit control is expected. Castrol Duratec ES 15W-40 provides outstanding resistance to nitration and oxidation compared to mineral on road NGEO and meets the performance requirements of many of today's mobile natural gas fueled engines. Castrol Duratec ES 15W-40 provides improved cold temperature engine starting and reduced oil consumption relative to single grade natural gas fueled engine oils.

Real World Testing

Castrol Duratec ES 15W-40 has been formulated to provide extended performance in on-road natural gas fleets to maximize uptime and optimize operational efficiency. After thousands of hours of field trials, Duratec ES 15W-40 has delivered extreme drain intervals up to 1,200 hours (with used oil analysis).

Advanced Acid Neutralization for Extreme Extended Drain

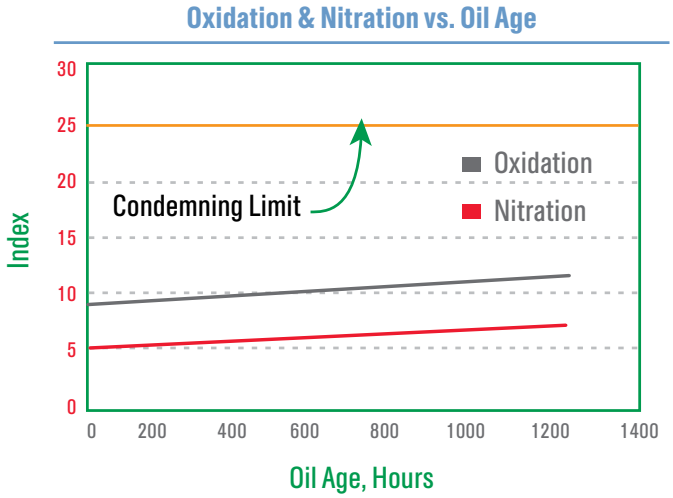
Castrol Duratec ES 15W-40 has outstanding combustion acid neutralization capability throughout extended drain intervals, preventing damage to engine surfaces from corrosive wear.



Castrol® Duratec™ ES 15W-40

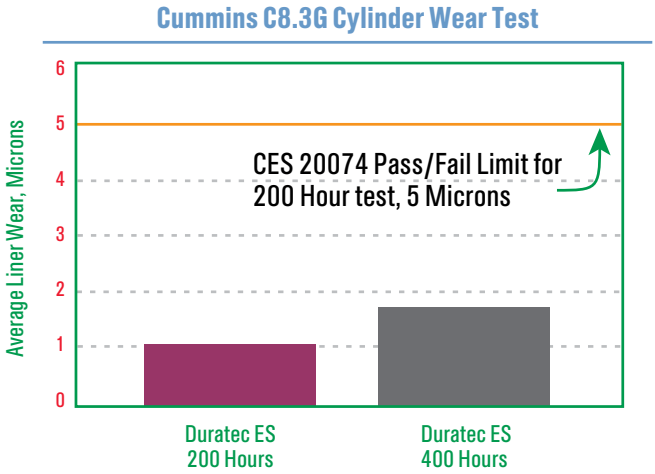
Exceptional Performance Against Oxidation and Nitration

Natural gas engines have higher combustion temperatures than their diesel counterparts, which leads to increased oxidation and nitrogen oxide formation. Duratec ES 15W-40 suppresses and controls oxidation and nitration throughout extended drain intervals, preventing sludge, varnish, plugged filters and deposits.



Outstanding Wear Control

In natural gas engines, ash deposits (rather than soot, as in diesel engines) are a primary contributor to wear on key metal surfaces like cams and cylinders. Castrol Duratec ES provides excellent ash wear protection across extended drain intervals. Cummins C8.3G test results show that not only does the additive chemistry in Duratec ES easily pass the test at the standard 200 hours; it also has outstanding performance when extended to 400 hours. This cutting edge technology is the key to extended drain performance.



Castrol® Duratec™ ES 15W-40

Features/Benefits

Castrol Duratec ES 15W-40 enables "extreme" extended drain intervals while maintaining outstanding protection and delivers an advanced detergent/dispersant system that has been designed to reduce deposit formation and improve oxidation characteristics while offering excellent corrosion control, TBN retention and outstanding wear control. User benefits include:

- Exceptional nitration and oxidation control compared to conventional on road NGEO
- Specially designed for on road trucks
- Exceptional anti-wear and extreme pressure protection
- Reduces deposits & maintains engine cleanliness
- Wide range of operating temperatures

Castrol Duratec ES 15W-40 is designed for use in a wide range of natural gas equipment including Cummins, Mack, Volvo, and other on road engines requiring a low ash natural gas engine oil.

Typical Properties

SAE Grade	Method	Units	Typical
Kinematic Viscosity @100°C, cSt	ASTM D445	mm^2/s	15
Kinematic Viscosity @40°C, cSt	ASTM D445	mm^2/s	106
Viscosity Index	ASTM D2270	--	146
Sulfated Ash, %wt	ASTM D874	% wt.	0.82
Total Base Number, Mg KOH/g	ASTM D2896	mg/g KOH	5.5
Pour Point, °C	ASTM D97	°C	-33
Appearance	Visual		Clear and Bright

Due to continual product research and development, the information contained herein is based on products purchased in the U.S. and subject to change without notification. Typical properties may vary slightly.

Castrol® Duratec™ NG 15W-40

Low Ash Natural Gas Engine Oil for On-Road Trucks

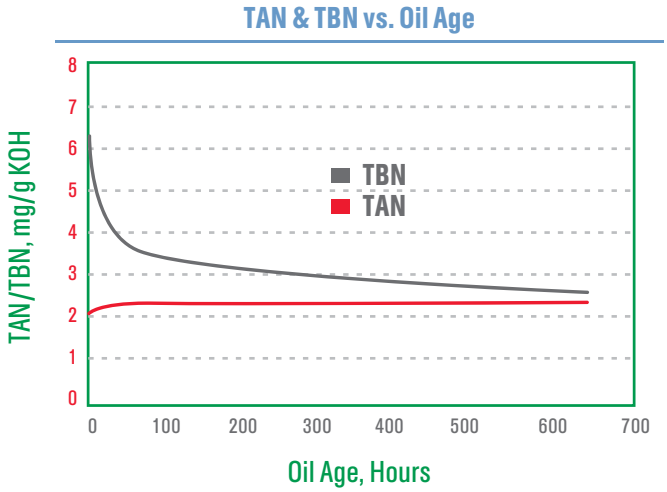
Castrol Duratec NG 15W-40 is formulated for use in natural gas fueled engines where minimal thermal degradation and good deposit control is expected. Castrol Duratec NG 15W-40 provides outstanding resistance to nitration and oxidation and meets the performance requirements of many of today's mobile natural gas fueled engines. Castrol Duratec NG 15W-40 provides improved cold temperature engine starting and reduced oil consumption relative to single grade natural gas fueled engine oils.

Real World Testing

Castrol Duratec NG 15W-40 was developed to deliver real world results in on-road fleets looking to safely extend service and improve operational efficiency. With countless hours of field experience, Duratec NG 15W-40 has been proven to extended drain intervals up to 600 hours (with used oil analysis).

Outstanding Acid Neutralization

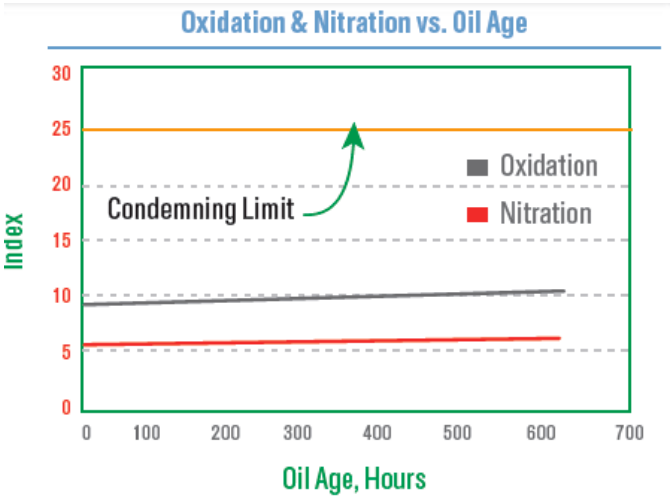
Castrol Duratec NG 15W-40 protects engine surfaces from corrosive wear with advanced combustion acid neutralization capability throughout extended drain intervals.



Castrol® Duratec™ NG 15W-40

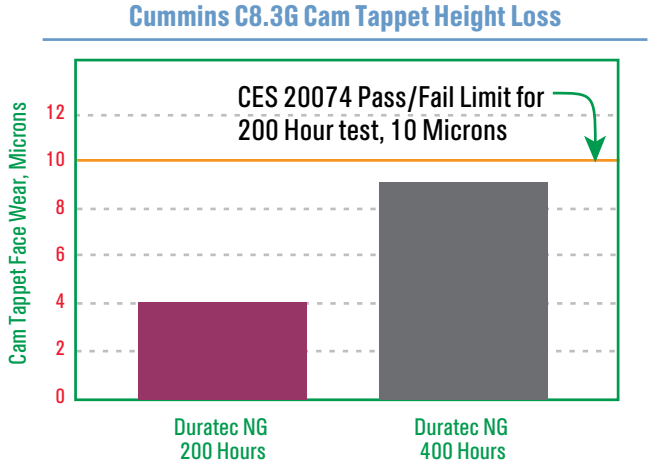
Excellent Oxidation and Nitration Protection

Castrol Duratec NG 15W-40 prevents sludge, varnish, plugged filters and deposits that occur in natural gas engines as a result of oxidation and nitration.



Outstanding Wear Control

Duratec NG 15W-40 prevents cylinder liner and cam tappet wear by providing excellent protection against ash deposits over an extended drain interval. Duratec NG easily passes the Cummins C8.3G test at the standard 200 hours, and also passes when extended out to 400 hours.



Castrol® Duratec™ NG 15W-40

Features/Benefits

Castrol Duratec NG 15W-40 delivers an advanced detergent/dispersant system that has been designed to reduce deposit formation and improve oxidation characteristics while offering excellent corrosion control, TBN retention and outstanding wear control. User benefits include:

- Formulation exhibits excellent thermal and oxidative stability
- Provides excellent resistance to acid corrosion
- Specially designed for on-road trucks
- Exceptional anti-wear and extreme pressure protection
- Reduces deposits & maintains engine cleanliness
- Wide range of operating temperatures

Castrol Duratec NG 15W-40 is designed for use in a wide range of natural gas equipment including Cummins, Mack, Volvo, and other on road engines requiring a low ash natural gas engine oil.

Industry Approvals and OEM Specifications by Grade

- Cummins CES 20074

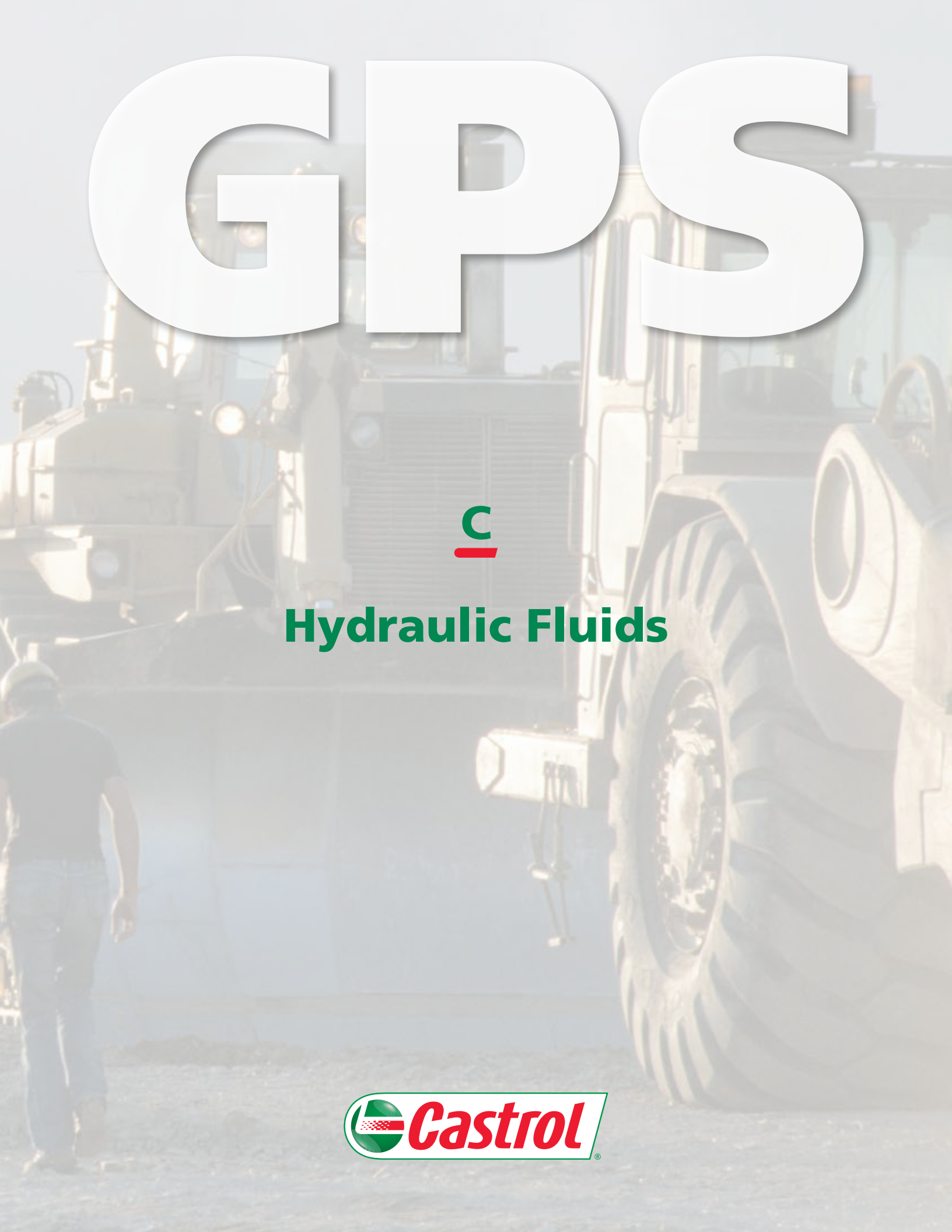
Typical Properties

SAE Grade	Method	15W-40
Kinematic Viscosity @100°C, cSt	ASTM D445	15
Kinematic Viscosity @40°C, cSt	ASTM D445	115
Viscosity Index	ASTM D2270	134
Sulfated Ash, %wt	ASTM D874	0.82
Total Base Number, Mg KOH/g	ASTM D2896	5.5
Pour Point, °C	ASTM D97	-18
Appearance	Visual	Clear and Bright

Due to continual product research and development, the information contained herein is based on products purchased in the U.S. and subject to change without notification. Typical properties may vary slightly.

GPS

Hydraulic Fluids



Hydraulic Fluids

Background & Properties

Product Data

Industry Specifications

Performance standards for anti-wear hydraulic fluids are set primarily by original equipment manufacturers. Unlike engine oils, anti-wear hydraulic oils do not have an industry licensing procedure. Therefore, anti-wear hydraulic fluid users must seek out information on test results from the oil manufacturer itself. Without a standard industry licensing program, it is worthwhile for users to research hydraulic fluid choices carefully.

Castrol's Liquid Engineers have developed a range of hydraulic flueds to meet performance standards required by Original Equipment Manufacturers (OEMs). These include products that meet recent changes in hydraulic fluid formulation, driven by industry trends and OEMs:

- Improved oxidation stability to accommodate higher operating temperatures.
- Improved air release, foam control and water separation to handle smaller reservoirs and reduced cycle times.
- Improved dry/wet filterability due to reduced filter pore size and tolerance to water contamination.
- Better hydrolytic stability to handle water contamination.
- Extended pump life to meet Denison T6HZOC pump performance.
- Increased drain intervals requiring the lubricants to retain original performance longer.

Importance of Oxidation Tests

When selecting a hydraulic fluid, resistance to oxidation is a key component of performance. The ability to protect against oxidation in the oil prevents premature oil thickening, sludging and other critical lubrication failures. Good oxidation protection comes from the combination of base oil selection and quality of the additives.

Types of oxidation tests include:

Turbine Oil Oxidation Test (ASTM D 943)

This test measures the oil's ability to prevent oxidation and the formation of destructive acids. To pass HF-O, the oil's acidity level must not exceed 2.0 mgKOH/g after 1500 hours.

Test Criteria

Time to 2.0 TAN, hours 1,500 min

Rotary Pressure Vessel Oxidation (ASTM D 2272)

This test utilities an oxygen pressurized vessel to evaluate oxidation stability of lubricants in the presence of water and copper @150°C.

Test Criteria

Time to 25-psi loss in minutes HF-O, HF-2 1500

Industry Specifications

Thermal Stability: Cincinnati Milacron

This test evaluates whether an oil will cause a reaction to steel and copper components. Run for 168 hours at 275°F.

Test Criteria	P-68, P-69 and P-70	HF-O
Viscosity change, (%), max	5	
Neutralization number, (%), max	±50	
Sludge (mg/100 ml), max	25	100
Copper wt loss (mg), max		10
Copper rod appearance	5	Report
Iron rod appearance	No discoloration	

1000-h Sludge (ASTM D 4310)

This test measures the build-up of sludge and increase of iron and copper particulate in the oil.

Test Criteria	Denison HF-O	HF-1	HF-2
TAN (mg KOH), max	1.0	.2	1.0
Insoluble Sludge, mg max	100	100	400
Total Cooper, mg max	200	-	200
Total Iron, mg max	50	-	100

TAN (ASTM D 974-07)

Standard Test Method for Acid and Base Number by Color-Indicator Titration

Importance of Wear and Load Tests

Load performance and wear protection are crucial components when selecting a hydraulic fluid. Hydraulic fluids are designed to handle important shock loads and other various types of loads during operation. The ability to prevent metal to metal contact also results in lowering component wear, such as in hydraulic pumps. Proper viscosities and excellent anti-wear additives play a pivotal in protecting against wear.

Types of Wear and Load Tests include:

Vickers 35VQ-25 Vane Pump Test

This test measures wear to the cam ring and the vane pump. It is run for three, 50-hour segments at 200°F, 3,000 psi and 2400 rpm.

Test Criteria

Ring	75-mg max
Vane	15 mg max
Total	90 mg max

Industry Specifications

Denison T6H2OC Hybrid Pump Test

Denison's more stringent pump test is known as the T6H2OC. This incorporated both vane and piston pump in a single housing, thereby replacing the need to run separate T6 and P46 pump tests, as previously required by HF-O. The test contains both wet and dry hydraulic phases. When testing multigrade oils, this test is known to provide a high level of shear and is able to effectively discriminate between different types of viscosity modifiers.

Test Criteria

less than or equal to 300 mg piston valve wear
less than or equal to 15 mg vane and pin wear

Denison T-6C Vane Pump Test

This test measures the oil's ability to prevent wear on cam ring, side plate and vanes. It is run for 60 hours at 160°F and 40 hours at 210°F both at 2400 rpm and 2500 psi.

Test Criteria

Vane Contour Increase

Denison P-46 Piston Pump Test

This evaluates the oil's ability to withstand high pressures and temperatures in piston pumps. This test is the same as the Denison T-5D Vane Pump Test, except it is performed on a piston pump.

Test Criteria

Piston Shoe Wear Plate, Port Plate Appearance

Denison T5D42

Vane pump test used to evaluate hydraulic fluids for wear in vane pumps.

Denison T6-C

Vane pump test used to evaluate hydraulic fluids for wear in vane pumps.

Denison T6H20C

Hybrid pump test used to evaluate oils for antiwear and working in presence of water contamination, part of HF-O qualification.

Sundstrand Pump Test

Old test used to evaluate ability of fluid to continue to function in presence of water contamination.

Industry Specifications

Hydrolytic Stability and Anti-wear Additives

Whether the customer uses a hydraulic fluid that emulsifies or demulsifies, the fluid must still be hydrolytically stable. Hydrolytic stability refers to the oil's ability to maintain performance during water contamination. Unstable wet hydraulic oils under high operating temperatures can cause anti-wear compounds to break down. Once this occurs, the zinc compound is no longer providing anti-wear protection and other chemicals can cause wear to hydraulic components. As a result, component life can be decreased by 50% or more.

Hydrolytic Stability (ASTM D 2619)

This test measures the oil's ability to protect against wear in the presence of water. It is run at 2030 psi for 250 hours at 1440 RPM.

Test Criteria:

Copper Weight Loss, mg maximum	0.2
Acidity of Water, mg KOH, maximum	4.0

Load Test FZG (DIN 51354, Part 2)

This test evaluates a hydraulic fluid's ability to withstand heavy shock loads.

Test Criteria	Damage Load Stage, min
US Steel 136	10
DIN 51524 Part 2	10
GM (LS-2) LH, 03, 04, 06	10
HF-O	Report

Hydraulic fluids containing extreme pressure additives are better equipped to handle heavy shock loads.

4-Ball Wear (ASTM D 2266)

This test measures an oil's anti-wear and anti-weld properties. It is run for 1 hour at 54°C, 1800 rpm and 20 kg.

Test Criteria	Scar Diameter, mm max
US Steel 127	0.5 (40 kg)
US Steel 136	0.5 (20 kg)

4-Ball EP (ASTM D 2783)

This test evaluates extreme pressure and anti-weld properties of the oil.

Test Criteria	US Steel 136
Weld Load (kg), min	150
LWI (kg), (min)	30

Industry Specifications

Cold Start (Up ASTM D2983)

Used to evalute ability of oil to be pumped or flow in cold temperatures.

KRL Shear Test (20 hours)

Bench test method that compares the permanent shear loss of multigrade hydraulic oils. Recent tests have shown that the 20-hour test provides excellent correlation to actual field and pump test performance. During this test, the lubricant is tested in a tapered bearing fitted to a four-ball EP test machine.

Test Criteria

% viscosity loss @100°C	15% max

Filterability, Demulsibility and Foam Tests

Water Tolerance: Demulsify or Emulsify?

Two major concerns for maintenance managers are keeping water out of a hydraulic system, and then dealing with it once it inevitably enters the system. Water can enter a hydraulic system in a number of ways: loose fill caps, poor seals, loose tolerances on the suction side of components, use of a pressure washer, condensation in the sump and even by contaminated top-off fluid that has been compromised during storage or delivery. Once in the system, water is to blame for problems like wear, power fluctuations, rust and the overall destruction of sensitive components. Knowing how a hydraulic fluid handles water can inevitably save your customer time and money in maintenance.

Separating Water from Oil

The best way to handle water contamination is with proper maintenance practices and an excellent hydraulic oil. AW hydraulic oils demulsify, or separate water from oil. This allows for the water to be drained from the sump, preferably at the beginning of each work shift. There should be a clear delineation between the water and oil. A white, creamy cuff between the water and oil or cloudy hydraulic fluid means the oil is not properly demulsifying and additive dropout may be occurring.

Mixing Oil with Water

If maintenance practices or system design do not allow for the daily removal of water, a fluid that emulsifies is the next best choice. Fluids that emulsify oil and water are ones that mix with the water to create an emulsion, fully enveloping the water. This eliminates free-circulating water, but must be weighed against possible tradeoffs like wear protection and proper viscosity grade selection.

How a hydraulic fluid deals with water contamination is one of the vital questions that needs to be answered when determining the hydraulic fluid for a customer. At the same time, internal maintenance practices need to be evaluated to assure that system maintenance coincides with the fluid's handleability to water (emulsify or demulsify).

Industry Specifications

Importance of Filterability, Demulsibility and Foam Tests

In hydraulic systems, air can be treated as a contaminant and lead to failures in the hydraulic pumps, including cavitation and air bubbles. The ability to demulsify air and disperse foam improves filterability, leading to longer component life.

Types of Filterability, Demulsibility, and Foam Tests include:

Filterability (Denison TP 02100)

This test measures how quickly an oil will filter when dry and how quickly it will filter when contaminated with 2% water.

Test Criteria

A. Dry	600 seconds maximum to 75 ml
B. Wet (2%)	2xA seconds maximum to 75 ml

Demulsibility (ASTM D 1401)

This test measures the oil:water cuff and the time it takes for the oil and water to separate. Equal amounts of oil and water are agitated at 130°F and left to separate over a timed interval. It is run at 130°F with ISO VG 32/46.

Test Criteria

Oil-water-cuff (ml)	40-37-3
Separation time (min)	30

This test is very important to hydraulic fluid users. A good AW hydraulic fluid must separate oil and water effectively and leave no creamy white cuff between the two fluids.

Foam (ASTM D 892)

This test measures an oil's ability to prevent excessive foaming in the presence of entrained air.

Test Criteria

No foam allowed after 10 minutes

Air Separation (DIN 51381)

Test Criteria

Separation Time, min	ISO VG 46/68	ISOVG 32
DIN 51524 Part 2	10 max	5 max
GM (LS-2) LH,03, 04, 06)	10 max	5 max
Denison HF-O	7/10	NR

Industry Specifications

Environmental Tests

OECD 301B

Biodegradability test that measures how long it takes for a substance to totally biodegrade into carbon dioxide gas and water. More severe than CEC L-33 T 82.

CEC L-33-T-82

Biodegradability test that measures only the first step in the biodegradation process. Is an alternative to OECD 301B.

Importance of Corrosion and Rust Tests

Keeping hydraulic systems clean is important to an efficient operation. Corrosion and rust can occur from the presence of oxygen or water. Hydraulic fluids need to protect against these contaminants with rust and corrosion inhibitors formulated in the fluid, and protect metallic surfaces. Rust and corrosion will affect pump performance and can lead to hydraulic pump failures.

Types of Corrosion and Rust Tests include:

Rust Prevention (D665 -06 A & B)

Standard test method for rust-preventing characteristics of lubricants in the presence of water. Method A uses distilled water, Method B uses salt water, so method B is more severe.

Steel Corrosion (ASTM D 665)

This test is performed with distilled water and synthetic seawater. It measures the hydraulic fluid's ability to protect against rust and corrosion when contaminated with water.

Test Criteria

Distilled Water	Pass/Fail
Synthetic Sea Water	Pass/Fail

Once again, this is a very important test for hydraulic fluids that must protect equipment in the presence of water. Some additives in lesser quality hydraulic fluids may become corrosive when exposed to water.

Copper Strip (ASTM D 130)

Test Criteria

DIN 51524 Part 2	2 max
GM (LS-2) LH, 03, 04, 06	1b max

Important Anti-wear Hydraulic Fluid Properties

By definition, any fluid whose pressure and flow is used to produce work is considered a hydraulic fluid. For this and reasons of convenience, a multitude of different lubricants have found their way into the hydraulic sump. Without a formal industry specification, it can be difficult to decide on the best fluid for hydraulic equipment.

A hydraulic fluid must be able to perform the following tasks:

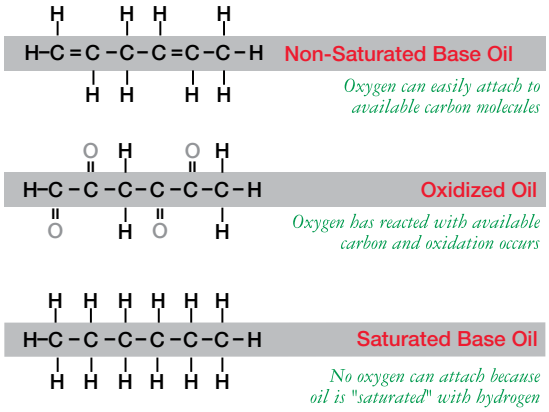
- Transmit power;
- Provide a viscous seal;
- Maintain system pressure;
- Transfer heat to cool the system;
- Prevent rust and corrosion;
- Guard against foaming;
- Separate water from oil for easy removal;
- Be thermally and hydrolytically stable;
- Lubricate components; and
- Maintain long service life.

Selecting a hydraulic fluid that can meet the above criteria centers on determining the following fluid properties:

What is the base stock used in the fluid?
Does the oil separate from or combine with water?
How does the oil deal with water contamination?
How does the anti-wear additive react with water?
What is the viscosity index of the fluid?

Base Fluid

Base fluid selection and its inherent performance characteristics are important to the formulation of a premium-performing AW hydraulic fluid. Although base oil must be enhanced with additives of varying treat rates, they are expensive. It can be tempting for oil marketers to choose lower cost base stocks and standard treat levels to create a lower priced fluid. Consequently, decreased performance will result from these choices.



Important Anti-wear Hydraulic Fluid Properties

Viscosity Index

Viscosity Index, or VI, is one of the single most important performance indicators in both a base stock and finished hydraulic fluid. Viscosity is a measure of a fluid's resistance to flow. Flow characteristics and temperature are related: oil thins at higher temperatures, making it flow more freely; oil thickens at lower temperatures, inhibiting flow. Viscosity Index is a quick way to tell whether an oil can withstand extreme high and low temperatures. VI is a measure of change in an oil's viscosity relative to a change in temperature. Oils with higher VIs experience less change in viscosity due to temperature. Higher VI oils guard against wear at high temperatures and maintain pumpability at lower temperatures. This offers customers a more reliable hydraulic fluid during all temperature ranges.

Base oils that exhibit natural VIs over 95 experience less change in flow characteristics as the temperature fluctuates. In a hydraulic system, where pressure and power are partly reliant on the hydraulic fluid's viscosity, oil that is too thin or too thick will ultimately shorten component life.

Saturation Levels

A base oil's saturation level can also impact finished product performance. When a base fluid is highly saturated, there are less chemical opportunities for oxygen to bond with hydrocarbon molecules—a process that results in oxidation or oil breakdown. Refining techniques, such as hydrocracking and hydrotreatment, can boost the base stock's saturation levels by forcing hydrogen through the oil, saturating oil molecules with hydrogen and eliminating the oxygen molecule's ability to bond with those molecules. In essence, the base oil is now more oxidation resistant. In addition, hydrotreated base oils have a longer working life and can endure higher sump temperatures than non-treated stocks.

Key Base Stock Property	Hydraulic Oil Performance Criteria
Viscosity Index	High Temp Viscosity Control
Viscosity Index and Pour Point	Low Temperature Fluidity
Volatility	Oil Consumption Control
Amount of Saturates	Oxidation Stability, Seal Swell and Additive Compatibility

A note on base stocks: Hydrocracked Group II base stocks provide higher VIs and higher saturation levels than Group I or napthenetic base stocks.

Important Anti-wear Hydraulic Fluid Properties

Base Oil Types

Mineral Group I and II

Group I base oils have VIs of 80 to 120 and were the original, traditional hydraulic fluids base stock. Group I base oils have more sulfur and less saturates than Group II, III or IV fluids. The performance of finished lubricants blended with Group I base oils is largely dependent upon the quality of the additive package.

Group II base oils are known for their excellent deposit control and high level of saturates, which makes them more oxidation resistant. They typically have VIs of 105 up to 120 and rely heavily on additives to enhance finished lubricant characteristics. Different refining techniques work to remove unwanted characteristics and improve upon desired ones, like viscosity index and oxidation control. Most of Castrol's hydraulic fluids are blended with Group II base oils and a premium-performing additive package.

Synthetic Group III

Refined Group III base oils are petroleum fluids that undergo extreme refining techniques that produce a base fluid with characteristics similar to a man-made synthetic. Group III refined base oils are typically found in partial to full synthetic finished lubricants since they have greater than 90% saturates (usually 99%+) and VIs over 120. They have low pour points, good oxidation resistance and can solubilize additive systems better than their man-made counterparts.

Synthetic PAO Group IV

Group IV base oils are known as polyalphaolefins (PAO). PAOs, the most widely used of the engineered base stocks, consist of all saturated hydrocarbon structures and contain no unwanted sulfur or other metals. Free of wax, PAOs enjoy very low pour points and have VIs typically of 140. PAOs have good thermal stability but are sometimes difficult to blend with additives. Despite their noted performance features, PAOs are sometimes cost prohibitive for users.

Group V: All Others

Group V base fluids consist of "all others," predominately esters and polyolesters, along with aromatic and naphthenic.

- Aromatic base oils are not suitable for use in heavy-duty lubricants due to their poor oxidation stability and low VIs of 0 to 45. Aromatics also contain elevated levels of sulfur (which leads to deposit formation) and sometimes nitrogen (which contributes to oxidation and deposit formation). Aromatics are typically used as solvents, cleaners and process oils, and in further chemical reactions for industrial products.

- Naphthenic fluids have low to medium VIs of up to 60 typically and they exhibit very low pour points, high solubility and excellent cold flow in long term storage.

Important Anti-wear Hydraulic Fluid Properties

Group V base fluids are commonly used in refrigeration lubricants, metalworking oils, greases and as extreme cold temperature fluids, such as snowplow oils. These include:

Vegetable Oils

Vegetable oils are derived from plants with the most common being canola oil. Vegetable oils are esters of fatty (long chain) acids and are about as stable as group I mineral oils. The most desirable property of these oils is that they are environmentally friendly in three ways:

1. The process to create the oil is growing a plant.
2. The oils themselves are non-toxic and, in some cases, edible (canola oil's biggest use is salad oil), but including additives to make a suitable lubricant increases the toxicity.
3. Vegetable oils are 100% biodegradable. (However, the oil plus additives are less than 100% as most of the additives will not readily biodegrade.)

Ester base fluids

Ester base fluids are synthetic base fluids containing oxygen in the molecule instead of just carbon and hydrogen like typical mineral oils. Most esters are readily (highly) biodegradable, and some have a high degree of oxidative stability as well. Thus, one can create an ester, which has the desirable combination of being highly biodegradable and oxidative stable. Their disadvantage is being significantly more expensive than mineral oils.

PolyAlkaline Glycols

PolyAlkaline glycols are used as synthetic lubricants in many diverse applications where petroleum oil-based products do not provide the desired performance – and because they are fire-resistant and will not harm workers or the environment. Other benefits of using PAG lubricants over petroleum, animal and vegetable oils is reduced energy usage, reduced machine wear and overall operational efficiency.

Common Hydraulic Fluid Choices

The following are the most common fluid choices for hydraulic equipment and some of the performance features of each:

Anti-Wear (AW) Hydraulic Fluid

Still the number one recommended fluid by pump manufacturers, a premium-performing AW hydraulic fluid should demulsify or clearly separate water from oil, protect against wear in the presence of water, maintain fluid viscosity and guard against oxidation. Fluids with a natural VI of 100 or more are better equipped to handle the extreme temperatures and pressures found in a hydraulic system. Properly formulated AW fluids usually provide excellent protection for hydraulic systems.

It is important to note that hydraulic fluids with anti-wear additives that are not hydrolytically stable can become aggressive to yellow metal and cause premature failure in piston pumps. Excess water not removed from a hydraulic system will also accelerate vane and piston pump wear.

Important Anti-wear Hydraulic Fluid Properties

Engine Oil

Convenience has sometimes dictated the use of motor oils in the hydraulic sump. Motor oils emulsify or combine with water that has contaminated the system and may provide some protection from rust in wet, undrained systems. But, the anti-wear additives in motor oil are typically NOT hydrolytically stable when exposed to water. This can cause additive dropout in wet motor oil that can result in viscosity gain, pumpability problems and poor wear protection.

Motor oil is designed for use in engine compartments where minor amounts of water are boiled off each day. A hydraulic system's operating temperature does not normally get high enough to boil off the water and the zinc compounds in the anti-wear additives can cause corrosive wear.

Automatic Transmission Fluid (ATF)

Like motor oils, ATFs emulsify or combine with water but are less aggressive when wet than motor oils. As a rule, the friction modifiers used in ATFs are not sensitive to water and tend to be thermally stable. In the past, ATFs have been a better hydraulic fluid choice than motor oil because of their oxidation resistance and solid wear protection. But, the latet passenger car specification, ATF Dexron®-VI, must meet performance specifications for extremely low temperature flow, which results in viscosities that are far too low for use in heavy-duty applications.

Tractor Hydraulic Fluid (THF)

When formulated to meet OEM specifications, THFs are designed to operate in the presence of water. Good hydraulic pump and wear protection result from a GL-4 level of gear wear protection. OEMs do not monitor THFs and low-cost marginal base oils and incomplete additive systems can sometimes show up in low-priced fluids. THF's viscosity grades may be too high for some hydraulic applications but are the best choice for consistently water-contaminated systems.

Biodegradable Fluids

Biodegradability simply means a chemical breakdown of the material by living organisms in the environment. The biodegradable portions of the fluid biodegrade to carbon dioxide and water.

The definitions in the oil industry are:

Inherently biodegradable: An oil that degrades >20% in an extended period of time. (By that definition, all oil products are inherently biodegradable.)

Readily biodegradable: >60% of the oil is converted/biodegraded in 28 days.

N.B. No oil fluids will completely break down and return to nature within one year.

Non Toxic Fluids

Fluids which have a low level of toxicity to living organisms. White mineral oil and vegetable oil would be common examples.

R & O Fluids

Lubricant where the only additives are antioxidants and corrosion inhibitors (most rust inhibitors). There are no anti-wear or EP additives present. Such a lubricant is appropriate for air compressors, non anti-wear hydraulic and circulating systems, as well as non-EP gear oil applications.

Castrol® Dual Range HV™

Stay-in-Grade Performance

The shear stable polymers in Castrol Dual Range HV keep the fluid's viscosity consistent over a wide range of temperatures. High operating temperatures, which may break down other hydraulic oils leading to damage to metal parts and increased oxidation, are easily managed by Castrol Dual Range HV.

Also contributing to Castrol Dual Range HV's excellent viscosity performance is its extra high viscosity index. The high viscosity index of Castrol Dual Range HV (at least 140) indicates that as the temperature dramatically rises or falls, Castrol Dual Range HV will not excessively thin or thicken. This protects your customer's equipment from premature wear or oil breakdown and leads to decreased maintenance costs.

Water Tolerance

In environments with high risk of water contamination, Castrol Dual Range HV delivers excellent demulsibility and hydrolytic stability. When water penetrates a hydraulic system, Castrol Dual Range HV protects sensitive hydraulic components from damaging rust and corrosion. At the end of the day, Castrol Dual Range HV easily separates water from the oil for removal at the beginning of the next work shift. The creamy cuff that sometimes forms between the water and other hydraulic oils shows that the hydraulic oil is not completely demulsifying and that cuff can encourage oil thickening and foam. Castrol Dual Range HV separates from water cleanly and consistently protecting equipment from damaging foam and thickened oil.

Filterability is another major concern for hydraulic equipment once water has entered the system. In tests where uncontaminated oils were compared with water-contaminated Castrol Dual Range HV in the Denision TP 02100 test, oil filtration time was quicker than the allowable limit. Because of this filtration, Castrol Dual Range HV provides better lubrication protection for pumps and cylinders and helps to avoid dramatic pressure surges that could blow seals or split hoses.

Thermal Stability

Thermal stability refers to an oil's ability to withstand breakdown during periods of high operating temperatures. Oils that are not thermally stable experience breakdown, which leads to damaged metal parts and oxidation of the oil. Castrol Dual Range HV maintains its chemical stability during high temperatures and protects critical hydraulic parts from wear.

Oxidation Control

Oxidation is a degenerative process that is accelerated by a combination of air, catalyzing metals and heat that culminates in excessive oil thickening which leads to the formation of sludge and corrosive acids. The by-products of oxidation cause pumpability problems, compromised wear protection and eventual downtime. Castrol Dual Range HV easily surpasses industry test limits for oxidation control in the Turbine Oil Oxidation Test (D 943). Exceeding limits in this test proves that Castrol Dual Range HV resists the formation of sludge and protects against wear on iron and copper components.

Castrol® Dual Range HV™

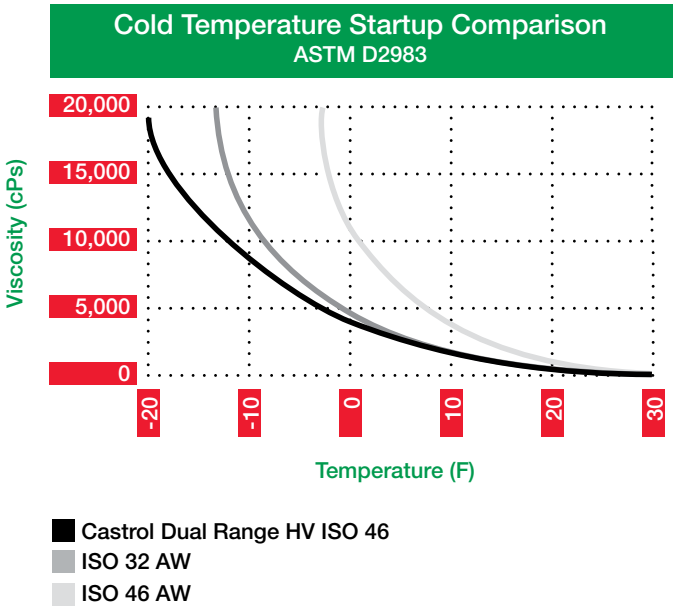
Performance in Industry Test Results

ASTM D 2983 Cold Temperature Startup

In ASTM D 2983, Castrol Dual Range HV exhibited better cold temperature performance than an ISO 32 and ISO 46 fluid. Castrol Dual Range HV flows even in colder temperatures, allowing it to reach critical components before hazardous startup wear can occur.

Load-carrying Ability

Castrol Dual Range HV is recommended for heavily loaded applications like hydrostatic transmissions and high speed/ high pressure hydraulic circuits. It surpasses the load-carrying ability of economy and premium-performing hydraulic fluids.



Leak Detection

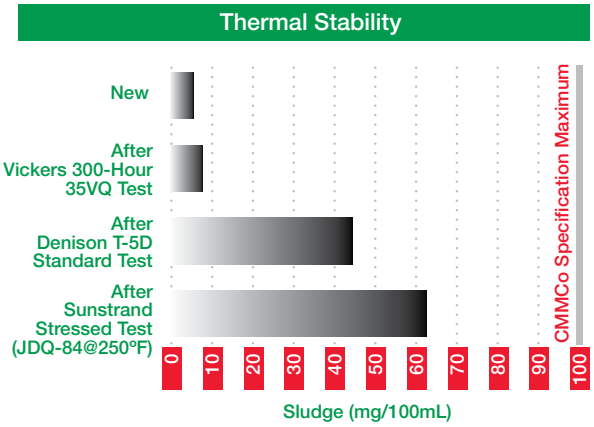
Castrol Dual Range HV is dyed to facilitate leak detection.

Castrol® Dual Range HV™

Thermal Stability

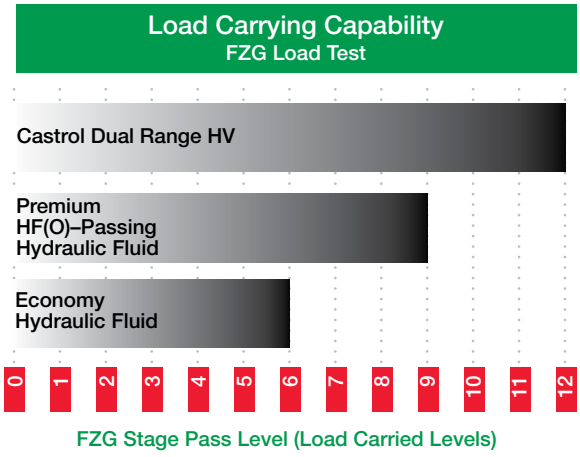
Cincinnati Milacron Thermal Stability

Castrol Dual Range HV far exceeds the acceptable limits for sludge in the Cincinnati Milacron Thermal Stability test. Castrol took the thermal stability test one step further. Even after being run through 3 vigorous industry tests, Castrol Dual Range HV still far exceeded sludge limits, proving its use for severe service applications.



FZG Load Carrying Test

Castrol Dual Range HV passes the rigorous FZG Load Carrying Test at Stage 12, easily surpassing a premium HF-O hydraulic fluid and an economy hydraulic fluid. The Stage 12 pass represents the exceptional load carrying ability of Castrol Dual Range HV. Your customers can be assured of extra protection during high loads, especially with hydrostatic transmissions and high speed/high pressure hydraulic circuits.



Castrol® Dual Range HV™

KRL Shear

In the severe 20 hour test, Castrol Dual Range HV easily exceeds the major OEM requirements with the ISO 32 grade having over 50% viscosity reserve.

Castrol Dual Range HV 32, % viscosity loss is 7.3% (limit 15%)

Castrol Dual Range HV 46, % viscosity loss is 9.0% (limit 15%)

Demulsibility Test (ASTM D 1401)

After the Turbine Oil Demulsibility Test, Castrol Dual Range HV separated all the oil from water and left no creamy white cuff.

This line includes exceptional multi-viscosity hydraulic fluids that provide proven anti-wear protection coupled with very shear-stable polymers and anti-foam additives for a balanced package. An extreme load carrying capability is indicated where Castrol Dual Range HV Hydraulic Fluids pass the FZG Load carrying test at Stage 12. This outstanding performance provides the extra measure of protection required in high load applications such as hydrostatic transmissions and high speed/high pressure hydraulic circuits.

Castrol Dual Range HV Hydraulic Fluids' high viscosity indexes and their low pour points ensure extra pump protection and efficiency in cold weather starts and provide needed viscosity protection at higher operating temperatures. The products are dyed purple to facilitate leak detection.

Features	Advantages	Benefits
Very shear stable polymers.	Universal applications under a wide range of ambient conditions. Excellent viscosity at operating temperatures (particularly under extreme conditions).	Less wear. Longer equipment life. Better productivity through outstanding hydraulic system efficiency.
Excellent vane and piston pump performance.	Meets major hydraulic pump manufacturers' requirements.	Less failure of hydraulic circuits. Less equipment repair. Long term trouble-free service.
Outstanding hydrolytic stability.	Additional protection against corrosion in the presence of water.	Systems operate more efficiently. Less maintenance costs.

Castrol® Dual Range HV™

Industry Specifications and OEM Approvals by Grade

- Denison HF-O, HF-1, HF-2 Approved
- Vickers 35VQ25A - meets performance requirements
- Vickers M-2950-S Mobile Hydraulic Systems and I-286-S Industrial Hydraulic Systems
- Cincinnati Machine P-68 (ISO 32), P-70 (ISO 46) and P-69 (ISO 68) approved
- Meets Racine S106
- Meets Joy Mining Machinery HO-T (AW 46), HO-S (AW 68)
- Meets DIN 51524 Requirements

Typical Analysis

ISO Grade	Method	32	46	68	100
Viscosity @40°C, cSt	ASTM D445	32.6	46.5	68	100.3
Viscosity @100°C, cSt	ASTM D445	6.2	7.9	10.6	13.9
Viscosity @100°F, SUS	ASTM D2161	153	216	314	459.0
Viscosity @210°F, SUS	ASTM D2161	47	52	61	73
Viscosity Index (Min.)	ASTM D2270	141	143	146	141
Dielectric Breakdown	ASTM 877	--	--	--	--
Voltage, kV/0.1 inch		--	35	--	--
Flash Point, °C	ASTM D92	210	232	240	251
(°F.)		(410)	(450)	(464)	(484)
Pour Point, °C	ASTM D97	-51	-45	-39	-36
(°F.)		(-60)	(-49)	(-38)	(-33)
Gravity, API	ASTM 287	31.3	34	30	29
Pounds per Gallon		7.24	7.12	7.3	7.34
Specific Gravity @60 °F, g/ml	ASTM D1298	0.869	0.859	0.874	0.88

(1) At the point of manufacture.

Castrol® Blue Hydraulic Plus™

Castrol Blue Hydraulic Plus meets the most severe industry requirements including the new "hybrid" test from Denison (T6H2OC), which incorporates both vane and piston pumps under wet and dry conditions over 600 hours. Formulated with up to 50% more performance additive than some competitors, Castrol Blue Hydraulic Plus gives a larger margin of safety in key areas of corrosion, oxidation and wear protection.

Water Tolerance

Castrol Blue Hydraulic Plus deals with water contamination in a number of ways. First, when water enters the system, Castrol Blue Hydraulic Plus' hydrolytic stability keeps the water from causing damaging rust and corrosion to sensitive hydraulic components. Second, after hydraulic equipment has been shut down for the day, Castrol Blue Hydraulic Plus will effectively demulsify or separate the water and oil. Water can then be drained from the system before the start of the workday. And third, Castrol Blue Hydraulic Plus is able to remain filterable even after water invasion. Water contamination
tends to slow down the filter time of a hydraulic oil. Castrol Blue Hydraulic Plus exhibits
excellent filterability after 2% water has been introduced into the oil.

In recent years, many original equipment manufacturers have reported that some commercial hydraulic fluids have caused field failures when contaminated with water. It is important to note that these fluids had previously met the severe performance standards of many pump manufacturers. Castrol Blue Hydraulic Plus Lubricants, which had outstanding performance in many severe OEM pump tests, was subsequently run in modified tests contaminated with 1% water. Results: Still a pass against the standard pass fail criteria.

Thermal Stability Oxidation and Control

Extended high operating temperatures, commonly encountered in hydraulic equipment, can create corrosive acids, allow sludge and varnish to form and excessively thicken oil until its breakdown is inevitable. Castrol Blue Hydraulic Plus has an outstanding additive package that boosts its oxidation resistance. Castrol Blue Hydraulic Plus prevents the formation of harmful deposits and guards against thermal breakdown due to high operating temperatures. As a result, hydraulic equipment runs longer, more efficiently and with less downtime.

Safe for Vane, Gear and Piston Pumps

Castrol Blue Hydraulic Plus is formulated to meet or exceed the industry standards for vane, gear and piston pumps. Castrol Blue Hydraulic Plus is specially suited for use in mobile hydraulic equipment, like excavators, bulldozers and drilling equipment, that have various types of pumps and a common sump in the same hydraulic circuit.

Castrol® Blue Hydraulic Plus™

Industry Test Results

All test results are for Castrol Blue Hydraulic Plus ISO 32.

Denison T6H2OC Pump Test

Castrol Blue Hydraulic Plus passed under Denison HF-O requirements.

Denison T6-C Pump Test

Castrol Blue Hydraulic Plus passed under Denison HF-O requirements.

Denison T5D42 Vane Pump Test

Castrol Blue Hydraulic Plus passed under Denison HF-O requirements.

Denison P-46 Piston Pump Test

Castrol Blue Hydraulic Plus passed under Denison HF-O requirements.

Vickers 35VQ25 Vane Pump Test

With an allowable total weight loss for ring and vane at 90 Mg, Castrol Blue Hydraulic Plus exceeded the test limits with total weight loss of 23.3 Mg.

Turbine Oil Rust Prevention Test (ASTM D 665)

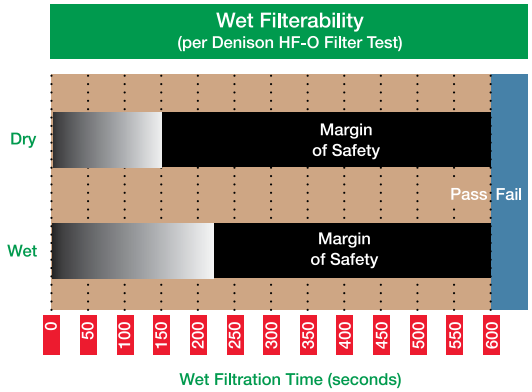
Using distilled water (D 665A), Castrol Blue Hydraulic Plus passed this test under both Cincinnati Milacron and Denison HF-O requirements. Using synthetic sea water (D 665B), Castrol Blue Hydraulic Plus passed under Denison HF-O requirements. There is no requirement for Cincinnati Milacron.

Foam Inhibition (ASTM D892)

Castrol Blue Hydraulic Plus left no foam after this 10 minute test.

Filterability (Denison TP 02100)

Castrol Blue Hydraulic Plus filtered in 150 seconds when dry and only 220 when contaminated with 2% water. The limit was 600 seconds dry and 2 times the dry figure when wet.



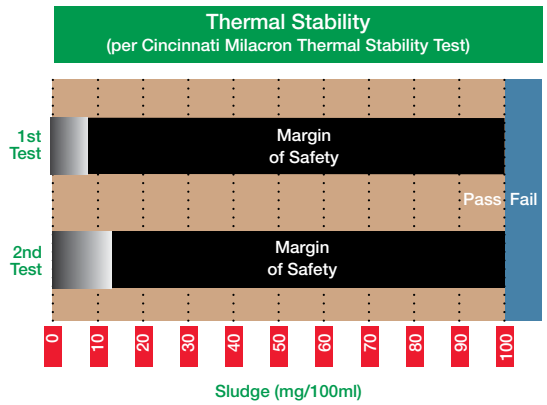
Castrol® Blue Hydraulic Plus™

Hydrolytic Stability (ASTM D 2619)

Castrol Blue Hydraulic Plus performed exceptionally well in ASTM D 2619. With an allowable copper weight loss of .2 mg maximum, Castrol Blue Hydraulic Plus 46 had only .09 mg copper weight loss. For water acidity, Castrol Blue Hydraulic Plus had an acidic reading of 0, mg KOH while the test limit was 4.0 maximum.

Cincinnati Milacron Thermal Stability

Castrol Blue Hydraulic Plus received a copper rod rating of 1.5, a steel rod rating of 1 and a sludge rating of 7.2 mg per 100 ml.



FZG

Castrol Blue Hydraulic Plus 46 passes load stage 12 in the FZG test, where as many Dension HF-O grades only meet FZG levels of 10. This ensures that Castrol Blue Hydraulic Plus protects equipment under the most rigorous conditions.

Castrol Blue Hydraulic Plus

Castrol Blue Hydraulic Plus provides excellent pump life and trouble free service in construction and mining mobile hydraulic applications. Castrol Blue Hydraulic Plus possesses proven anti-wear protection, a high viscosity index to enhance performance over a wide temperature range, and excellent water separation properties.

Castrol Blue Hydraulic Plus is formulated with carefully selected premium base oils, coupled with rust, oxidation and foam inhibitors. Castrol Blue Hydraulic Plus meets or exceeds the equipment manufacturers' requirements for Vane, Gear and Piston Pumps. The fluid has been dyed a medium blue to facilitate leak detection by the equipment user.

Castrol Blue Hydraulic Plus is approved or recommended for the Cincinnati Lamb P-68 and P-70 specifications. In today's mobile hydraulic equipment, such as excavators, bulldozers and drilling equipment, pumps of different types have been incorporated into the same hydraulic circuit in order to achieve outstanding cost effectiveness and efficiency.

Castrol Blue Hydraulic Plus will meet the challenge where a common fluid has to be used, which allows vane, gear and piston pumps to work at their maximum rated output.

Castrol® Blue Hydraulic Plus™

Performance Summary

Grades	Cincinnati Lamb Requirements 32	Denison Requirements HF-0 46	Castrol Blue Hydraulic Plus Oil ISO 32 68
Cincinnati Lamb P- 70 Pump Test	Pass	-	Pass
Denison T5D42 Vane Pump Test	NR	Pass	Pass
Denison P-46 Series Piston Pump Test	NR	Pass	Pass
Vickers 35VQ25 Vane Pump Test (Total Wt. Loss 90 Mg. Max.)	NR		23.3 Mg.
Rust Prevention, ASTM D665			
D665A	Pass	Pass	Pass
(Distilled water)	Pass	Pass	Pass
D665B (Synthetic sea water)	NR	Pass	Pass
Foam Inhibition, ASTM D892 Volume of Foam after 10 min.	NR	None	None
Denison Filterability (HF-O)			
A. Dry (sec. to 75 ml)	NR	600 Max.	51
B. Wet (sec. to 75 ml)	NR	2xA	63
Hydrolytic Stability, D2619			
Copper Wt. Loss, mg/cm2	NR	0.2 Max.	0.09
Acidity of Water, mg KOH	NR	4.0 Max.	0.27
1000 Hours Sludge (D-4310)			
Insoluble sludge, mg	NR	200 Max.	15.8
TAN, mg KOH	NR	2.0 Max.	0.09
Copper Appearance			1B
Oxidation Life, ASTM D943			
Hours to TAN 2.0	NR	1500 Min.	6000+
Cincinnati Milacron Thermal Stability			
Sludge, mg per 100 ml	25.0 Max.		19.6
Copper Rod Rating	5 Max.		2
Steel Rod Rating	1 Max.		1
Cincinnati Milacron Assessment			Approved

Castrol® Blue Hydraulic Plus™

Special Performance Summery

Sundstrand Pump Test (Double Length Stress Test)

A. Conditions: Test run for 450 hours at 180° F. with water (Standard test is run for 225 hours at 180° F.)

B. E.O.T. Inspection:

1-Bearing plate - Good Condition
2-Thrust plate - Good Condition
3-Piston Shoes - Good Condition
4-Distress on other parts - None

C. Assessment: Pass double length stress test.

Industry Specifications and OEM Approvals by Grade:

- Denison HF-O, HF-1, HF-2 approved
- Vickers 35VQ25A meets performance requirements
- Vickers M-2950-S Mobile Hydraulic Systems and I-286-S Industrial Hydraulic Systems
- Cincinnati Machine P-68 (ISO 32), P-70 (ISO 46) and P-69 (ISO 68) approved
- Meets Racine S106
- Meets Joy Mining Machinery HO-T (AW 46), HO-S (AW 68)
- Meets DIN 51524 Requirements

Typical Analysis

ISO Grade Former Grade	Method	32 (Light)	46 (10)	68 (20)	100 (30)
Viscosity @40°C, cSt	ASTM D445	33.8	45.3	68.2	105.7
Viscosity @100°C, cSt	ASTM D445	5.5	6.6	8.7	11.7
Viscosity @100° F, SUS	ASTM D2161	160	215	319	551
Viscosity @210° F, SUS	ASTM D2161	44	48	54	65
Viscosity Index	ASTM D2270	103	103	105	102
Flash Point, °C (°F)	ASTM D92	210 (411)	215 (420)	226 (440)	226 (440)
Pour Point, °C (°F)	ASTM D97	-32 (-26)	-26 (-15)	-26 (-15)	-15 (+5)
Oxidation Life, (Hours to TAN 2.0)	ASTM D943	6000+	5000+	5000+	4000+
Gravity, API	ASTM D287	34	32	29.5	28
Pounds per Gallon	ASTM D287	7.12	7.21	7.32	7.39
Specific Gravity @60F g/ml	ASTM D-1298	0.857	0.863	0.879	0.88

Castrol® Paradene™ AW

Castrol Paradene AW is a premium industrial anti-wear hydraulic oil line suitable for hydraulically activated equipment that utilizes high-performance pumps. The fluids contain very effective anti-wear additives that allow them to meet or exceed industry OEM vane, gear and piston pump specifications. These fluids are highly dependable, peak efficiency oils that meet the lubricant demands of precision industrial equipment. Castrol Paradene AW will remain very stable and clean in today's machine tool equipment where increasingly sophisticated control systems are used.

Features	Advantages	Benefits
Effective antiwear performance.	Minimizes wear in industrial pump applications.	Long, dependable equipment life.
Special non-silicone anti-foam additive.	Rapid release of entrained air.	System response is dependable for consistent work yield.
Careful selection of base stock coupled with outstanding additive selection.	Hydraulic components yield excellent performance.	Long fluid life and equipment life savings.

Industry Specifications and OEM Approvals by Grade

- Denison HF-O, HF-1, HF-2 Approved
- Vickers 35VQ25A - meets performance requirements
- Vickers M-2950-S Mobile Hydraulic Systems and I-286-S Industrial Hydraulic Systems
- Cincinnati Machine P-68 (ISO 32), P-70 (ISO 46) and P-69 (ISO 68) approved
- Meets Racine S106
- Meets Joy Mining Machinery HO-T (AW 46), HO-S (AW 68)
- Meets DIN 51524 Requirements

Castrol® Paradene™ AW

Typical Analysis

ISO Grade	Method	22AW	32AW	46AW
Viscosity @40°C, cSt	ASTM D445	22	33.2	46
Viscosity @100°C, cSt	ASTM D445	4.3	5.5	6.7
Viscosity @100°F, SUS	ASTM D2161	114	143	214
Viscosity @210°F, SUS	ASTM D2162	40	44	47
Viscosity Index	ASTM D2270	102	100	98
Flash Point, °C	ASTM D92	205	211	215
(°F)		(401)	(412)	(419)
Pour Point, °C	ASTM D97	-32	-32	-27
(°F)		(-26)	(-26)	(-17)
Gravity, °API	ASTM D287	33.5	32.9	30
Spec. Gravity, API @60°F	ASTM D1298	0.8591	0.861	0.877
Pounds per Gallon	ASTM D287	7.14	7.17	7.3
Oxidation Life, (Hours to TAN 2.0)	ASTM D943	--	4000	3500

ISO Grade	68AW	100AW	150AW	320AW
Viscosity @40°C, cSt	68.5	100	150	321
Viscosity @100°C, cSt	8.8	11.1	13.9	24.8
Viscosity @100°F, SUS	315	480	708	1489.0
Viscosity @210°F, SUS	55	62	73	120
Viscosity Index	101	96	88	99
Flash Point, °C	226	226	232	245
(°F)	(429)	(439)	(450)	(473)
Pour Point, °C	-26	-15	-15	-10
(°F)	(-15)	(+5)	(+5)	(+14)
Gravity, °API	28.8	27.5	27.3	25.5
Spec. Gravity, API @60°F	0.884	0.89	0.8912	0.9015
Pounds per Gallon	7.35	7.4	7.45	7.5
Oxidation Life, (Hours to TAN 2.0)	3000	--	--	--

Castrol® Anvol® SWX 46 [PREVIOUSLY Castrol Anvol SWX FM]

Fire Resistant Hydraulic Fluids

Castrol Anvol SWX 46 products are HFDU Polyolester type hydraulic fluids as defined by ISO 6743/4 and ISO 12922[(1)]. They meet the requirements for Factory Mutual Category 1 Classification. Castrol Anvol SWX 46 products are outstanding in their category in providing a safe working environment, improved system reliability and ready biodegradability.

Formulated to work in high-pressure hydraulic systems up to 7500 psi, Castrol Anvol SWX 46 provides gear, vane and piston pumps with protection against wear equivalent to that of mineral oils.

Castrol Anvol SWX 46 is designed to combine fire resistance with outstanding system reliability and a reduced tendency to form varnish or sludge in valves, pipes and reservoirs. It also provides greater resistance to water by offering high levels of corrosion protection and ease of separation.

Even in the harshest steel mill environment, Castrol Anvol SWX 46 provides safety, protection and reliability. This has the added value of reducing failures and minimizing unscheduled downtime.

Application

Castrol Anvol SWX 46 is used in areas of the manufacturing industry where there is high risk of fire such as hot strip mills, coil handling facilities, pipe mills and continuous casters. The risk is minimized by Castrol Anvol SWX 46's high fire point and a low heat of combustion.

Performance Benefits

- **Greater fire protection**
  With a high fire point and shear stability, Castrol Anvol SWX 46 provides excellent fire suppression characteristics, thereby creating a safer working environment and greater equipment protection.
- **System protection from water**
  Castrol Anvol SWX 46 is designed to separate water to allow it to be removed from the system. Advanced corrosion inhibition protects ferrous components from any residual water. This reduces rust and leads to extended equipment life and a reduction in downtime.
- **Stability in harsh operating environments**
  – Resistance to oxidation and thermal degradation and improved filter tolerance.
  – Reduces sludge/varnish formation and the potential for valve sticking/failure.
  – Ensures that product life is extended with greater drain intervals.
  – Maintains fire protection characteristics with use.

[(1)] per ISO 6743 / 4 and ISO 12922:1999 / Corrigendum 1:2001 (E), these are classified as synthetic fluids free of water, but of other composition than HFDR (Phosphate Ester)].

Castrol® Anvol® SWX 46 [PREVIOUSLY Castrol Anvol SWX FM]

- **Readily biodegradable**
  – Conforms to highest standards of biodegradability and has low toxicity.
  – Environmentally friendly hydraulic fluids providing pump performance that is equivalent to mineral oil.
  – Well suited for applications where inadvertent environmental contamination might occur due to leakage.
  – Easily exceeds the 60% bioconversion of CH2/CH3 to CO2 within 28 days as per OECD 301 B.
- **Outstanding equipment performance**
  – Extended pump and component life and reduction in replacement/maintenance costs.
  – Longer life.

Compatibility with Seal Materials

Castrol Anvol SWX fluids are compatible with Acrylonitrile-butadiene rubbers (NBR), hydrogenated NBR and fluoro-carbon rubbers (FKM). The Seal Compatibility Index (IP278) for Castrol Anvol SWX 46 is comparable to mineral oils.

System Changeover

Mineral Oil or Polyolester-based Fluids

Castrol Anvol SWX 46 fluids are miscible and compatible with nearly all mineral oil and polyolester type hydraulic fluids. To convert a system using these types of fluids, simply drain and recharge with Castrol Anvol SWX 46. For proper fire resistance, at least 95% of the mineral oil-based fluid should be removed. See "Topping Up an Existing System" (below) for more detailed changeover information.

Water Glycol and Emulsions

Castrol Anvol SWX 46 fluids are not miscible or compatible with water-containing fluids and these fluids must be removed from the system. Remove most of the fluid by draining the reservoir and lines. Remove residual fluid by circulating Castrol Anvol SWX 46 and draining. Refill with fresh fluid. Repeat until residual fluid is less than 1% of the system volume. The lower the residual the better, as water can cause hydrolysis and acid increase/breakdown of the ester in Castrol Anvol SWX 46.

Phosphate Ester

Some but not all phosphate esters are compatible with Castrol Anvol SWX 46. Testing prior to conversion is recommended. Please contact Castrol for testing and conversion recommendations.

Topping Up an Existing System

If the two products to be mixed have been compatibility checked and are deemed compatible, then simply add fresh Castrol Anvol SWX 46 on top of the existing system. If, however, you are required by Factory Mutual to completely change out the system, we suggest the following:

1. Heat hydraulic system to operating temperature.
2. Drain the warm oil.
3. Change existing filters.
4. Flush with new fluid. Run all cylinders, if possible, to remove old fluid. Check the Castrol Anvol SWX 46 content of the system. If greater than 95%, go no further with flushing.
5. If Castrol Anvol SWX 46 is present at less then 95%, then drain the system again and fill with fresh Castrol Anvol SWX 46.

Castrol® Anvol® SWX 46 [PREVIOUSLY Castrol Anvol SWX FM]

6. Take a sample after one hour of running, if necessary, to check for Castrol Anvol SWX 46 levels. A fire point may need to be done to confirm Factory Mutual rating.

Property	Method	Units	Anvol SWX 46
Appearance	Visual		Clear & Bright
Kinematic Viscosity at 40°C	ASTM D445	mmÇ/s	48.4
Kinematic Viscosity at 100°C	ASTM D445	mmÇ/s	9.56
Viscosity Index	ASTM D2270		180
Pour Point	ASTM D97	°C	-36
Relative Density at 15°C	ASTM D4052	g/ml	0.89
Flash Point, COC	ASTM D92	°C	280
Fire Point, COC	ASTM D92	°C	360
Autoignition Temperature	ASTM E659	°C	430
Total Acid Number (Potentiometric)	ASTM D664	mg KOH/g	1.3
Foam Sequence I, Tendency	ASTM D892	ml	10
Foam Sequence I, Stability	ASTM D892	ml	0
Copper Corrosion, 3hrs at 100°C	ASTM D130		1A
Rust Test, Procedure B	ASTM D665B		Pass
RPVOT	ASTM D2272	mins	230
FZG Gear Failure Load Stage (A/8.3/90)	DIN 51354		>12
Air Release to 0.2%volume at 50°C	IP 313	mins	2

Health and Safety

Castrol Anvol SWX 46 is classified as non-hazardous and presents no significant risks to operators. However, it is good safety procedure to minimize skin contact and inhalation of oil mist.

Storage

To ensure that your product reaches your hydraulic system in excellent condition, it is important to store your drums of product correctly. Where practical, place drums under cover out of direct contact with sunlight and weather. Store the drums on their side or use a drum cover to prevent water contacting the drum bung. When decanting product from the drum, ensure that the bung area is cleaned with a lint free cloth before transfer.

All reasonable care has been taken to ensure that this information is accurate as of the date of printing. Nevertheless, such information may be affected by changes in the blend formulation occurring subsequent to the date of printing. Material Safety Data Sheets are available for all Castrol products. The MSDS must be consulted for appropriate information regarding storage, safe handling and disposal of product.

Castrol® Performance™ Bio HE [PREVIOUSLY Castrol Carelube HTG]

Castrol Performance Bio HE is formulated from vegetable oils to be more environmentally acceptable than traditional mineral-based hydraulic fluids. Since hydraulic systems are prone to leakage due to high pressures, Castrol Performance Bio HE is an excellent hydraulic fluid in applications where leakage could cause water or soil contamination.

Biodegradability

Formulated from natural vegetable oils, Castrol Performance Bio HE is more than 95% biodegradable as measured in the CEC L-33-T-82 tests. Tests indicate that it is capable of being decomposed by biological agents within 120 hours, unlike mineral oil, which may remain intact for much longer, polluting water and soil. Castrol Performance Bio HE is recommended for outdoor applications where leakage could result in soil or ground water contamination and substantial fines or claims for damage on the responsible operator. (Spills, however, must be handled the same as for mineral-based fluids.)

Low Toxicity

In addition to its biodegradability, Castrol Performance Bio HE has a very low toxicity before, during and after breakdown. This reduces the threat to bacteria, fish and humans coming in contact with contaminated water.

Stay-in-Grade Performance

Castrol Performance Bio HE has a very high viscosity index (VI) of 200. Standard mineral hydraulic oils have VIs of around 100. This extra-high VI means that Castrol Performance Bio HE experiences little change in viscosity during its recommended operating range of 0°F to 175°F. Castrol Performance Bio HE is also very shear stable, which means that it resists breakdown during high shear applications.

Anti-wear Performance and High Lubricity

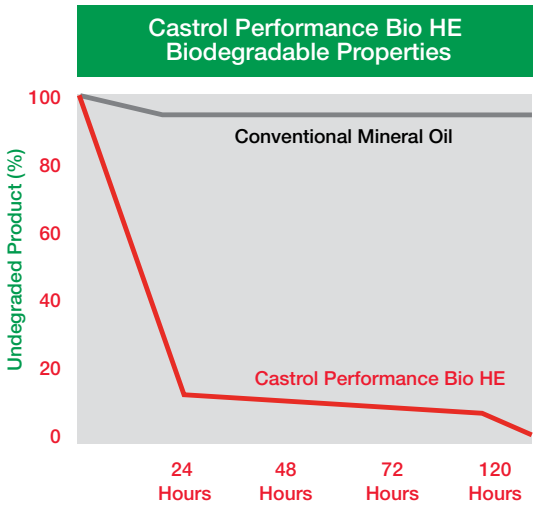
Due to its special formulation, Castrol Performance Bio HE is inherently a better lubricant than its standard mineral-based counterparts. This high lubricity accounts for reduced wear and less fuel consumption due to more efficient operations. Castrol Performance Bio HE also contains an anti-wear package that increases its load-carrying abilities.

Castrol® Performance™ Bio HE [PREVIOUSLY Castrol Carelube HTG]

Industry Test Results

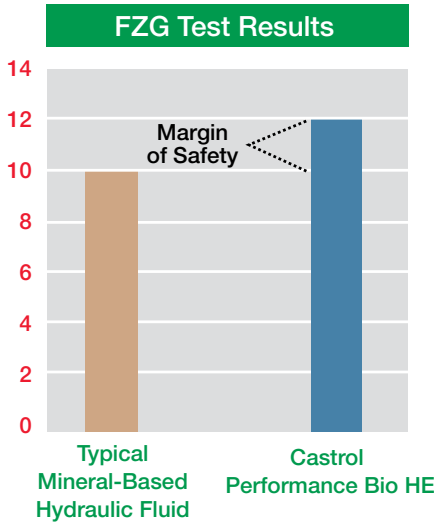
CEC L-33-T-82

This test measures the biodegradability of a fluid over a period of 120 hours. Castrol Performance Bio HE is more than 95% biodegradable during the allotted time frame.



FZG Gear Test

The FZG gear tests rates the load-carrying ability of gear oils. Castrol Performance Bio HE out-performed its mineral-based counterparts, which testifies to its excellent anti-wear performance.



Castrol® Performance™ Bio HE [PREVIOUSLY Castrol Carelube HTG]

Important Information about Castrol Performance Bio HE

Storage and Handling

Castrol Performance Bio HE should be stored and handled as if it were a conventional mineral oil. It is recommended that Castrol Performance Bio HE be stored indoors at temperatures above freezing to avoid any appearance of clouding during extended storage periods. This clouding tendency is in the nature of vegetable oils but does not affect their performance. The cloudiness will disappear when the chilled oil warms to 50-60°F.

It is also very important that Castrol Performance Bio HE be stored in a manner that prevents water contamination. While Castrol Performance Bio HE rejects water just like mineral-based fluids do, as a regular gross contaminant, water has greater potential for shortening service life of a vegetable oil as compared to a mineral oil. Traces of water present under normal conditions do not present a problem.

Converting to Castrol Performance Bio HE

Drain the system while hot as completely as possible from all drain points. Small quantities of oil left in the system are not significant. Replace the filter and clean the filter housing. Refill system with Castrol Performance Bio HE. After start-up, change the filter after 50 and 100 hours of operation. Consult OEM for recommended drain schedule for biodegradable, vegetable-based hydraulic oils and use routine used oil analysis to help determine drains.

Spills, Clean-Up and Disposal

Although biodegradable, Castrol Performance Bio HE must still be cleaned up when spilled. Spill prevention and clean up efforts are the same for Castrol Performance Bio HE as for other mineral hydraulic fluids. All oil spills are reportable to the National Response Center and/or state and local government agencies.

From a disposal standpoint, it is advisable to segregate waste Castrol Performance Bio HE from other waste oils, which, if mixed with Castrol Performance Bio HE, could render it hazardous and eliminate less costly disposal options.

Castrol Carelube HTG

Castrol Performance Bio HE is a biodegradable hydraulic fluid that is formulated using a natural renewable fluid. The environmentally acceptable hydraulic fluid is based on a natural fatty oil, which has a special affinity to metal surfaces affording exceptional boundary lubrication. Castrol Performance Bio HE has also been carefully formulated to provide excellent anti-wear and anti-corrosion properties.

Castrol Performance Bio HE is based on a specially selected natural vegetable oil that is much friendlier to the environment than conventional mineral based hydraulic oils. (The 200 VI [viscosity index] is a property of the vegetable oil, which means the fluid will experience very little viscosity change with temperature.)

Castrol Performance Bio HE is designed for use in applications where the risk of environmental damage through leakage/spillage from hydraulic equipment is high: agriculture, construction, mining, forestry and marine industries. Castrol Performance Bio HE offers a wide range of performance features similar to mineral oil based formulations.

Castrol® Performance™ Bio HE [PREVIOUSLY Castrol Carelube HTG]

Typical Analysis

Product Appearance	Clear Green Fluid
Odor	Bland
Application	Environmentally friendly hydraulic fluid with similar mineral oil level performance.

Performance Profile Test	Method	Units	Typical Results
Viscosity @40°C	ASTM D445	cSt	37
Viscosity @100°C	ASTM D445	cSt	8.5
Viscosity Index	ASTM D2270		200
Pour Point	ASTM D97	°F	-25 (-13)
Flash Point	ASTM D92	°C (°F)	285°C (545 °F)
Demulsification	ASTM D1401	mins	20
Rust Test	ASTM D665A		No Rust
Rust Test	ASTM D665B		No Rust
Copper Corrosion, 3 hrs at 100°C	ASTM D130		1b
FZG Gear Test, Pass Stage	Din 51354		11
4-Ball Wear Test, 1 hr, 30kg, 1460 rpm	MWSD mm		0.4
Vickers Vane, weight loss	ASTM D2882		< 5 mg
Biodegradability	CEC-L-33-T-82	%	95

Castrol® Aerial Lift Fluid

Castrol Aerial Lift Fluid is a specially formulated multi-viscosity high performance hydraulic fluid. It is designed to provide outstanding performance in mobile lift applications where ambient temperatures vary widely and system operation, reliability and protection are mandatory.

Features	Advantages	Benefits
Very shear stable polymers.	Universal applications under severe ambient conditions. Excellent viscosity at operating temperatures (particularly under extreme conditions). Pour Point of -46° C (-50° F.)	Less wear/longer equipment life. Better productivity through excellent hydraulic system efficiency. Reduces equipment wear and repair.
Thermally stable Zinc Dialkyldithio-phosphate (ZDDP).	Good thermal stability.	Less failure of hydraulic circuits. Less equipment repair. Long term trouble-free service.
Excellent vane and piston pump performance.	Meets all hydraulic pump manufacturers' requirements.	Reduced inventory.
Outstanding hydrolytic stability.	Additional protection against corrosion in the presence of water.	Longer pump life. Less wear.

Castrol® Aerial Lift Fluid

Typical Physical Characteristics

Test	Method	Typical Results
Viscosity at 40°C, cSt	ASTM D445	24.5
Viscosity at 100°C, cSt	ASTM D445	5.9
Viscosity Index	ASTM D2270	196
Viscosity @ 100° F., SUS	ASTM D2161	127.1
Viscosity @ 210° F., SUS	ASTM D2161	45.8
Appearance	Visual	Red
Brookfield Viscosity at -18°C (0°F), cP	ASTM D2983	660
Brookfield Viscosity at -23°C (-10°F), cP	ASTM D2983	1,290
Brookfield Viscosity at -35°C (-31°F), cP	ASTM D2983	7,560
Brookfield Viscosity at -40°C (-40°F), cP	ASTM D2983	22,350
Pour Point, °C (°F)	ASTM D97	-46 (-50)
Flash Point, °C (°F)	ASTM D92	165 (330)
API Gravity	ASTM D287	30.1
Specific Gravity, 60°F	ASTM D1298	0.858
Pounds per Gallon	ASTM D287	7.291
Aniline Point, °C (°F)	ASTM D611	92 (198)
Turbine Oil Oxidation (D-943), Hrs to 2.0 TAN	ASTM D943	2800
Dielectric Breakdown, voltage KV/0.1 inch	ASTM D287	30

GPS

D

Transmission Fluids

Castrol®

D

Transmission Fluids

Background & Properties

Product Data

Castrol®

Important Transmission Fluid Properties

Getting power from the engine to the drive track or wheels is the job of the transmission. The key to effective power transmission performance and long component life is proper transmission fluid selection. An understanding of transmission types, transmission fluids and OEM recommendations is important for maximizing transmission performance.

Transmissions can be grouped into the following types: automatic, powershift, hydrostatic and manual. Each transmission requires uniqiue lubricant properties.

Transmission Fluids and Friction

Each type of transmission fluid has specialized formulations to create frictional properties that ensure proper operation of the automatic, powershift or hydrostatic transmission it is protecting. In some instances, friction modifying additives are added to a base stock to make a lubricant more slippery. Of these fluids, the most friction-modified fluid is engine oil. As the evolution of transmission and transmission fluids progresses, some transmissions lubricated by engine oils may result in relatively poor transmission performance and holding capabilities, as well as increased wear.

With automatic transmission fluids, TO-4 fluids and tractor hydraulic fluids, there is both dynamic and static friction measurements. Static friction refers to how well the transmission fluid will hold once lock-up has been achieved. Dynamic friction refers to the amount of slippage a transmission fluid allows before lock-up occurs.

A balanced base oil and additive package for a transmission fluid is dependent upon the role the finished lubricant must play in the transmission.

A typical transmission fluid must perform several critical functions:

- Lubricate gears, bushings and bearings;
- Provide anti-wear performance;
- Displace heat efficiently;
- Ensure seal performance; and
- Modify frictional characteristics in transmission clutches and wet brake systems.

Formulating a premium transmission fluid begins with a high quality base oil. The base oils must provide oxidative resistance and high and low temperature performance in order to ensure transmission fluid performance. The measure of a base oil's ability to resist oxidation or breakdown due to high temperature and severe service is related to the amount of saturated hydrocarbon molecules it contains.

Group II and Group III base oils are treated with hydrogen to saturate the molecules and eliminate opportunities for oxygen to attack and break down these molecules. This process fills spaces in the hydrocarbon molecule that might otherwise fill with oxygen, with hydrogen atoms. This makes the base oil oxidation resistant, which is important to transmission fluid performance.

Important Transmission Fluid Properties

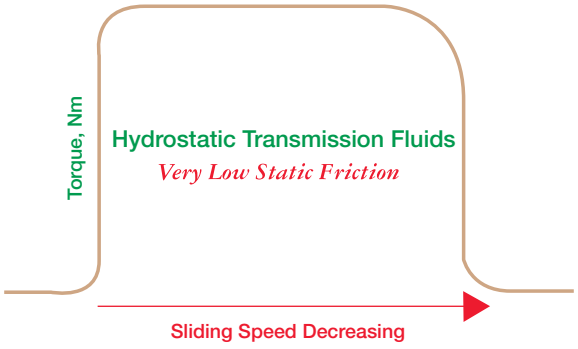
Viscosity index (VI), or the measure of change in an oil's viscosity relative to a change in temperature, is another critical factor in base oil and finished lubricant performance. Transmission fluids undergo fluctuations in temperature and are responsible for removing heat from the system. Base oils with high VIs (over 100) experience less change in viscosity related to temperature. In addition to stay-in-grade performance, high VI base oils offer excellent pumpability and lower oil consumption.

An exceptional additive package is just as important as a high quality base oil. Differing friction characteristics of transmission clutch surfaces require a delicate balance of friction modifiers and other additives. Additives typically found in a premium-performing transmission fluid are:

- Dispersants for sludge and varnish control;
- Anti-oxidants to control oil thickening and breakdown;
- Anti-wear agents to protect planetary gears, bushings, thrust washers, sprags and pumps;
- Seal swell agents to control swelling, hardness and tensile strength of elastomers;
- Corrosion inhibitors to prevent corrosion of bushings and thrust washers;
- VI improvers to minimize viscosity change due to temperature and control sludge and varnish; and
- Friction modifiers to help clutch plate/band friction engage properly and promote smooth shifts.

Hydrostatic Transmission Fluids (HTFs)

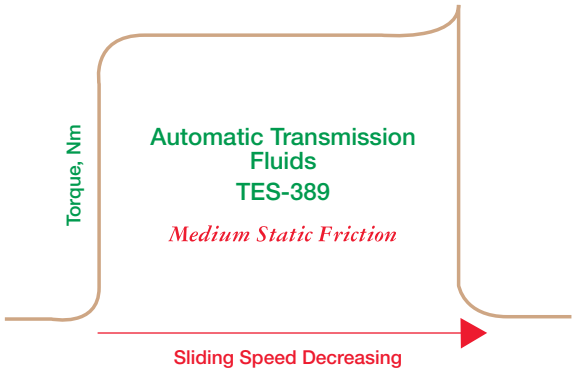
HTFs are charged with protecting not only the transmission and final drives but the wet brake system as well. On the transmission side, HTFs have a higher coefficient of friction to handle heavy loads, but some friction modifier has been added to the fluid to prevent squawk and shudder in the wet brake systems. HTFs have a low static coefficient of friction because the fluids must have some slippery characteristics in order to protect the wet brake system. The chart illustrates this fact.



Important Transmission Fluid Properties

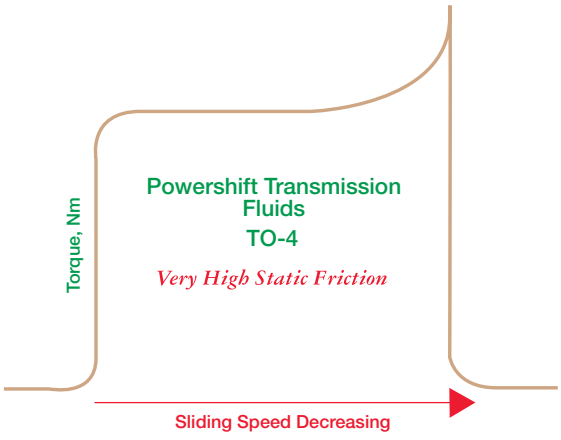
Automatic Transmission Fluids (ATFs)

ATFs must be able to hold loads and encourage smooth shifts. Therefore, ATFs have a high dynamic coefficient of friction with a moderate static coefficient of friction. ATFs do contain friction modifiers, which translate to moderate static friction to avoid harsh shifts.



TO-4 Fluids

The most dramatic friction characteristics are found in the TO-4 fluids for powershift transmissions. TO-4 fluids have the highest static coefficient of friction for fast lock-up and outstanding holding capacity. The chart depicts this fact with its sharp upward point illustrating a tight, firm lock-up.



Important Transmission Fluid Properties

Reviewing the different friction characteristics of transmission fluids makes it clear how the incorrect fluid choice could be a serious detriment to equipment and its operation. Proper transmission fluids are a wise investment that provide return in the long run.

TRANSMISSION FLUIDS: A CHARACTERISTIC COMPARISON			
FLUID FEATURES	**TO-4 FLUID**	**THF**	**Dexron III HD/ TES-389**
Friction	Grabby	Most Slippery	Slippery
EP/AW	Very Good	Best	Good
Oxidation	Good	Good	Best
Low Temperature	Poor	Good	Best
Water Sensitivity	Wet Anti-foam Test	Very Good	Not Tested
Color	Dyed (some)	___	Dyed
Viscosity Grade Kv at 100 degrees C	Various (6-26)	10W-30 (9.5-10.5)	0W-20 (7.0-7.5)

Types of Transmissions and Diagnosing Problems

Automatic Transmissions

An automatic transmission uses electronically- or hydraulically-controlled friction clutches to select gears. Although easier to operate, automatic transmissions sometimes require more maintenance. Automatic transmissions typically require an automatic transmission fluid.

Premium automatic transmission fluids (ATFs) are designed to:

- Prevent metal-to-metal contact and wear;
- Promote efficiency in vane pumps, planetary gear sets and bushings;
- Maximize fuel economy;
- Allow low temperature operation;
- Control oxidation to guard against oil thickening;
- Provide correct frictional properties for shifting clutches;
- Be compatible with seals; and
- Protect against thermal degradation.

Diagnosing Automatic Transmission Problems

Problems associated with automatic transmissions can sometimes be traced back to the fluid. Using a TO-4 fluid in an automatic transmission will result in harsh shifts, poor low temperature performance, mediocre transmission response, sludge and deposit formation and copper and bronze corrosion. Using a tractor fluid in an automatic transmission will often cause burnt shifting clutches, elongated shifts, inadequate holding capabilities and sludge and deposit formation. An automatic transmission operating with an improper fluid will increase the likelihood of shortened component life, unscheduled downtime and elevated maintenance costs.

Fluid choices for automatic transmissions should take into account severity of service, ambient and operating temperatures, which will influence viscosity grade selection, and any OEM-required approvals. For example, Allison prefers a TES-295 fluid for severe or extended service automatic transmissions, a TES-353 fluid for its more severe, off-highway automatic transmissions and a TES-389 fluid for its lighter duty and standard service, on-highway automatic transmissions. Once the fluid type and grade is established, choosing a quality ATF will enhance transmission performance and component life while decreasing costly downtime.

Powershift Transmissions

The powershift transmission has some internal components similar to that of the automatic transmission, but with some key additions. The control of the powershift transmission is manual and allows for a wide range of speed ratios with an almost instant shift from forward to reverse.

Most powershift transmission fluids have evolved from motor oil and multi-viscosity recommendations to straight weight TO-4 transmission fluids. This fundamental shift in fluid type was prompted by the design of the powershift transmission itself. Today's powershift transmissions have highly sensitive friction-based components that require a "grabby," not slippery, fluid to achieve a tight lock-up.

Types of Transmissions and Diagnosing Problems

A premium TO-4 powershift transmission fluid should:

- Provide control over the 7 different frictional elements, both metallic and non-metallic, commonly found in a powershift transmission;
- Eliminate brake noise;
- Reduce wear of elastomeric material;
- Prevent slippage;
- Encourage stable performance over the life of the fluid;
- Inhibit metal-to-metal contact while protecting vane pumps, planetary gear sets, final drive gears and bearings from premature wear;
- Offer foam protection to guard against fluid loss;
- Promote low temperature performance to reduce start-up wear;
- Control oxidation to prevent deposit formation that can restrict lubrication; and
- Maintain excellent shear stability to ensure consistant protection from wear.

Diagnosing TO-4 Type Powershift Transmission Problems

Improper use of an ATF or tractor fluid in most powershift transmissions will produce burnt and/or slipping clutches, inadequate holding capacity for both brakes and clutches and insufficient wear protection for gears.

Caterpillar pioneered the TO-4 specification for its off-highway powershift transmissions. Fluids meeting this specification have been factory fill on all CAT powershift transmissions since 1991, and there is little comparison between the TO-2 and TO-4 specifications. The TO-4 specification defines frictional capabilities in-depth and combined with the anti-wear properties and added gear protection, a premium TO-4 fluid maximizes powershift transmission life and operating efficiency.

Some agricultural equipment such as medium and large size tractors also employ powershift transmissions. The friction material of the shifting clutches in this application are selected to function properly with tractor hydraulic fluids, which have a low static coefficient of friction to prevent chatter or squawk in the wet brakes used in these machines.

Hydrostatic Transmissions

A hydrostatic transmission uses fluid to transfer power from the engine to the drivetrain through a hydraulic pump and motor. A transmission of this type consists of a pump connected to the engine generating fluid power to drive a hydraulic motor, which is connected to the axle and/or driving wheels. If the displacement of the pump and motor were fixed, the transmission would merely act as a gearbox to transmit power. Most hydrostatic transmissions use a variable displacement pump or motor in order to vary speed, torque or power and provide transmission function.

Therefore, the fluid used in a hydrostatic transmission only needs to function as a hydraulic fluid, as there are no clutches or gears to lubricate. Fluids commonly used in hydrostatic transmissions include hydraulic fluids, automatic transmission fluids and tractor hydraulic fluids. The owner's manual of the specific equipment should be consulted for the manufacturer's preferred fluid.

Types of Transmissions and Diagnosing Problems

A premium-performing hydrostatic transmission/hydraulic fluid must:

- Protect against metal-to-metal contact;
- Prevent wear in vane and piston pumps, transmission spur gears, final drive spur, and spiral bevel gears and axle and transmission bearings;
- Provide proper frictional characteristics for wet brakes and clutches;
- Have exceptional water tolerance to maintain function and prevent corrosion in the presence of 1-2% water, which may be found in these machines;
- Offer excellent extreme pressure protection for gears;
- Provide antiwear protection for hydraulic pumps; and
- Provide adequate lubrication over a wide range of temperatures.

Diagnosing Hydrostatic Transmission Problems

Improper fluid usage in a hydrostatic transmission typically causes brake squawk, harsh shifts, poor low temperature performance and inadequate water tolerance. An ATF used in some transmissions will result in brake squawk, inadequate water tolerance and insufficient film strength for gear protection.

Manual Transmissions

Unlike automatic, power shift and hydrostatic transmissions, manual transmissions do not use fluid to transfer power. Power from the engine is distributed through the transmission by engaging and disengaging gears through the clutch and collars. Gears will move freely unless engaged by a collar.

Premium manual transmission fluids are designed to:

- Prevent metal-to-metal contact and wear;
- Provide cold flow characteristics and maintain proper viscosity over a wide temperature range;
- Be compatible with seals;
- Maintain thermal stability throughout drain interval; and
- Control oxidation.

Diagnosing Manual Transmission Problems

The use of an inadequate fluid in most manual transmissions will produce burnt and/or slipping clutches, insufficient wear protection for gears, harsh shifts, premature thermal degradation, poor low temperature performance, mediocre transmission response, sludge and deposit formation and copper and bronze corrosion.

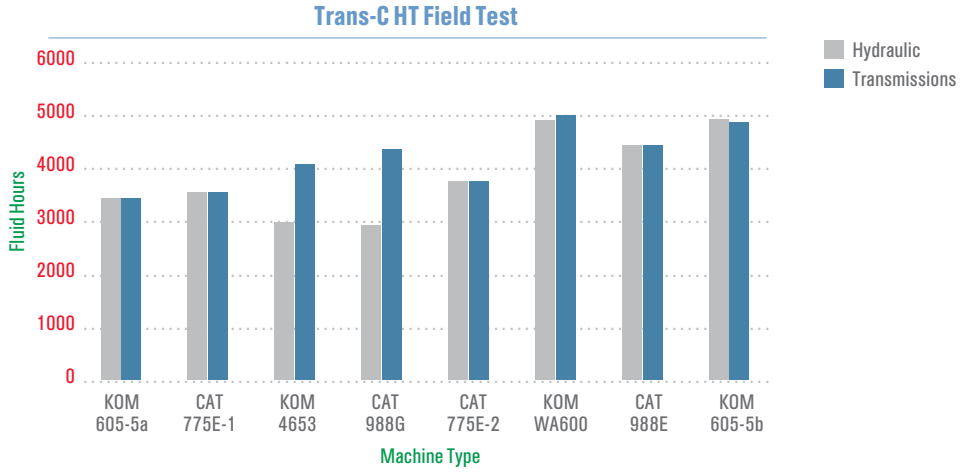
Friction Characteristics:
Similar to a gear oil, manual transmission fluids need to protect gears from metal to metal contact, disperse heat, and seal the component. Friction modifiers are utilized in manual transmissions and are needed for proper synchronizer friction. These friction modifiers utilize a low static coefficient of friction to allow smooth shifting between collar and gears. Typically, manual transmission fluids will require a 50 weight or a 75W-85 transmission fluid. Newer ones are moving toward lower viscosity.

Castrol® Trans-C™ HT

Castrol Trans-C HT is a full synthetic transmission/hydraulic fluid that balances high-temperature wear protection for gears and bearings with low temperature flow properties for positive shifting in transmissions. Its full synthetic formulation allows for extended drain intervals with regular used oil analysis. It is a multi-functional fluid that can be used for both hydraulic systems and transmissions, which helps business owners consolidate inventory and simplify maintenance practices.

Extends Service Intervals

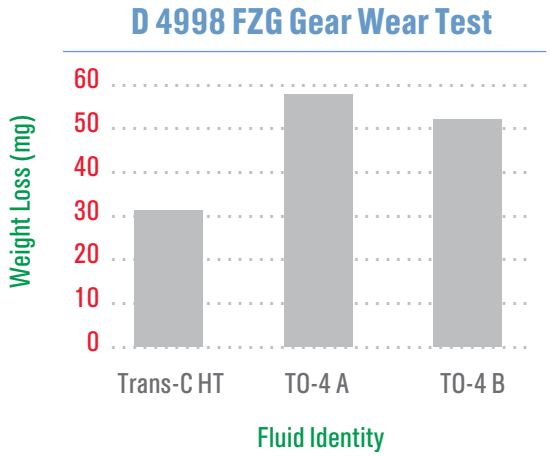
In field tests on various types of earthmoving equipment, Castrol Trans-C HT stretched service intervals to more than 5,000 hours in hydraulic systems and more than 2,500 hours in powershift transmissions without problems.



Exceptional Gear Wear Protection

The excellent gear protection offered by Castrol Trans-C HT is further demonstrated during a D 4998 gear wear test and FZG D 5132 Load Test. The FZG is a heavily loaded spur gear test commonly used to evaluate gear oil performance. The gear wear directly correlates to weight loss, with less weight loss being equal to less wear. Castrol Trans-C HT was tested versus other TO-4 type fluids and showed the least gear weight loss. Trans-C HT achieved a 11 load stage pass delivering wear protection at high loads.

Castrol® Trans-C™ HT



Excellent Pump Protection

The outstanding anti-wear hydraulic performance of Castrol Trans-C HT is illustrated in a Vickers D 2882 Modified Pump test. Castrol Trans-C HT showed only 9 milligrams weight loss on the parts, which is well below the passing limit. The pump part photos show them to be in excellent condition with very little evidence of wear on the rings and vanes.

Vickers D 2882

Vickers D 2882 Ring

OEM Specifications

- Meets or exceeds Caterpillar TO-4 requirements
- Vickers 35VQ25 Vane Pump Performance

Castrol® Trans-C™ HT

Typical Analysis

Test	Method	Results
Kinematic Viscosity @ 40° C, cSt	ASTM D445	84.6
100° C, cSt	ASTM D445	11.8
Viscosity Index	ASTM D-2270	134
Flash Point °C (°F)	ASTM D92	240(464)
Pour Point °C (°F)	ASTM D97	-36(-33)
Brookfield Viscosity -35°C, cP	ASTM D2983	138,000
20 Hours KRL (Shear Test)		
After Shear cSt @ 100°C	CEC-L45-20	11.63
% Viscosity Loss		-1.61
FZG Gear Scuffing - Pass Load Stage	ASTM D5182	11
FZG Gear Wear - mg wt. Loss	ASTM D4998	48
Gravity, API	ASTM D287	32
Pounds per Gallon	ASTM D287	7.21
Specific Gravity @60F, g/ml	ASTM D1298	0.8654

Castrol® Trans-C™

Low Temperature Fluidity

Castrol Trans-C provides excellent cold weather pumpability and decreases wear typically associated with cold weather starts. Less wear can mean longer transmission life.

Gear Protection

Castrol Trans-C passes the 35VQ25 Vickers pump test ensuring protection for high pressure hydraulic systems. Because of this added gear protection, customers can consolidate fluids in on- and off-highway equipment.

Castrol Trans-C Transmission Drive Train Oil meets the stringent Caterpillar TO-4 fluid requirements, particularly important where paper and elastomer disc materials are utilized and friction retention must be optimized for extended clutch life and slippage control under severe high load operations. While commercial engine oil technology excelled in the previous Caterpillar required CD/TO-2 specification where the bronze clutches prevailed, Castrol Trans-C provides field-tested technology to ensure durability under today's strenuous operating conditions and where significant clutch material changes have taken place.

Castrol Trans-C will also provide Detroit Diesel Allison C-4 performance. Castrol Trans-C excels in many on and off-highway hydraulic oil applications.

Castrol Heavy Duty's traditional quality approach prevails in Castrol Trans-C by having premium base oil selection (high viscosity indexes) coupled with select additives for noted oxidation stability, rust and corrosion protection, foaming inhibition, anti-wear protection, mild "EP" and assured excellent pumpability in the "SAE 10W" or ISO 32 grade.

Applications and Recommendations:

- Exceeds Caterpillar TO-4 specifications/requirements
- Approved Allison C-4
- Vickers 35VQ25 Vane Pump performance
- Many on and off-highway transmissions, drive trains and hydraulic systems

Typical Analysis

SAE Grade	Method	10W	30	50	60
Viscosity @40°C, cSt	ASTM D445	47	97	221	351
Viscosity @100°C, cSt	ASTM D445	7.19	11	19	25
Viscosity Index	ASTM D2270	113	99	96	91
Flash Point, °C (°F)	ASTM D92	203 (397)	220 (428)	228 (442)	229 (444)
Pour Point, °C (°F)	ASTM D97	-42 (-44)	-39 (-38)	-24 (11)	-24 (11)
FZG Gear Scuffing, Load Stage	ASTM D5182	10 pass	11 pass	11 pass	11 pass
Gravity, °API	ASTM D287	29.5	27.9	24.2	24.0
Specific Gravity @60°F	ASTM D1298	0.879	0.889	0.907	0.91
Pounds per Gallon	ASTM D287	7.32	7.4	7.56	7.58

Castrol® Syntrans™ 75W-85

Castrol Syntrans 75W-85 is a full synthetic transmission fluid recommended for most commercial vehicle manual transmissions (truck, bus, light commercial vehicle) where API GL-4 lubricants are required. These transmissions are generally larger and subjected to higher loads and temperatures than those in passenger cars; this product was developed for these particular requirements and is approved by a number of manufacturers.

Features and Benefits

- Excellent thermal and oxidative stability maintains transmission cleanliness and lubricant performance, allowing extended drain capability.
- Synthetic formulation provides a reduction in operating temperatures, giving longer component and lubricant life.
- Superb cold flow characteristics give smoother gear shifts at low temperatures.
- High shear stability maintains lubricant performance throughout the drain interval.
- Good wear and EP performance ensures component protection under high load conditions, reducing downtime and service costs.

Industry Specifications and OEM Approvals:

- API GL4
- MAN 341 E4
- MB approval 235.4
- Volvo 97307
- Eaton 500,000km drain Europe (service bulletin 2273)

Typical Properties*

Test	Method	Typical Results
Viscosity at 40°C, cSt	ASTM D445	64.6
Viscosity at 100°C, cSt	ASTM D445	11.9
Viscosity Index	ASTM D2270	185
Brookfield Viscosity at -40 C, cP	ASTM D2983	18,000
Pour Point, °C (°F)	ASTM D97	-60 (-76)
Flash Point, °C (°F)	ASTM D92	220 (428)
API Gravity	ASTM D287	37.5
Specific Gravity, 60°F	ASTM D1298	0.837
Pounds per Gallon	ASTM D287	6.97

** Due to continual product research and development, the information contained herein is based on components purchased in the U.S. and subject to change without notification. Typical properties may vary slightly.*

Castrol® UTF

Castrol UTF, Universal Tractor Fluid, is a premium hydraulic/ transmission fluid that exceeds the refill and service topup needs of farm and industrial tractor transmission, differentials and immersed disc brakes. Castrol UTF is compounded with anti-wear, extreme pressure, anti-oxidant and friction control additives and foam and corrosion inhibitors. Castrol UTF couples this superb additive package with highly refined base oils and a shear stable viscosity index improver for a balanced package.

Excellent Water Tolerance and Pump Life

Water contamination in off-highway equipment poses a threat to productivity and the health of the equipment. Castrol UTF was designed to operate in the presence of 1% water contamination. During the Gear Wear Test, Castrol UTF protected up to four times better than the competition against wear and corrosion with water contamination up to 1%.

Gear Wear Protection

In several OEM gear tests, Castrol UTF demonstrated its ability to withstand system pressures while showing no signs of pitting, ridging, scoring and corrosion. On a sensitive gear surface or tooth, the slightest amount of wear can cause maintenance problems.

Smooth Transmission Performance

Castrol UTF provides just the right balance of smooth engagement and minimum slippage, which is ideal for power transmission performance. Due to its smooth performance characteristics, Castrol UTF reduces heat-associated wear in power transmissions.

Thermally Stable

Castrol UTF's excellent thermal stability provides wear protection in high temperatures. Castrol UTF protects against the excessive deposit build-up that results from overheating, which can cause wear on clutch plates, control valves and pressure regulators.

Low Temperature Performance

Castrol UTF's extremely low pour point of -37°F gives it exceptional low temperature performance. Castrol UTF can maintain flow characteristics during a cold-start, which means the oil reaches pumps, cylinders and hydraulic components quickly, dramatically reducing start-up wear.

Compatibility

Castrol UTF maintains the size, hardness and strength of elastomers, seals and gaskets, which helps to reduce downtime and maintenance costs.

Friction Control

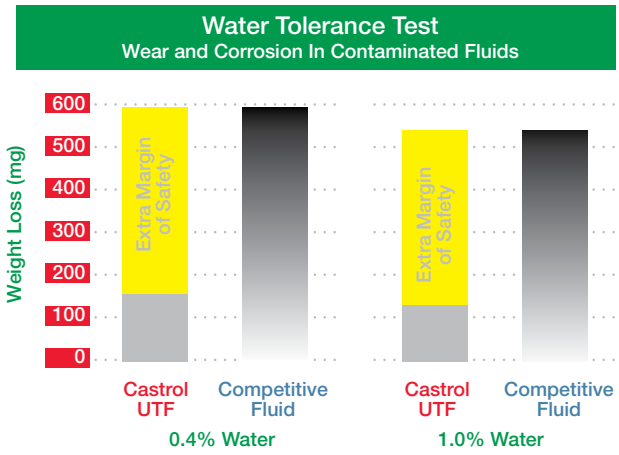
Castrol UTF uses friction modifying additives to ensure the smooth, quiet operation of multi-disc clutches and oil-immersed disc brakes. In industry tests, Castrol UTF consistently provided quiet brake operation with no loss in capacity.

Castrol® UTF

Industry Test Results

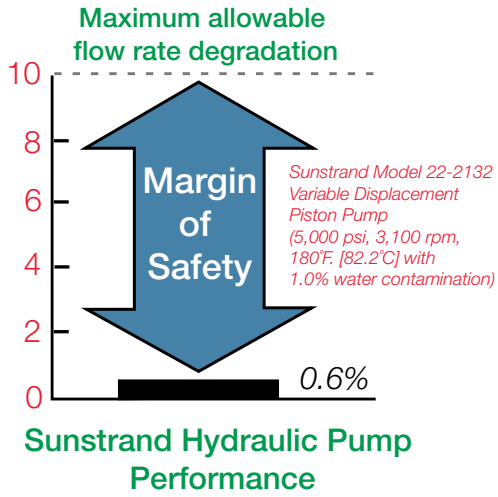
Water Tolerance Wear Test

The Water Tolerance Wear Test measures a fluid's ability to protect against corrosive wear when contaminated with water. Castrol UTF, pitted against a competitive fluid during 0.4% and 1.0% water contamination, showed that it guarded against wear four times better than the competitive fluid.



Sunstrand Hydraulic Pump Performance Test

During the Sunstrand Hydraulic Pump Performance Test, a fluid is contaminated with water and the flow of the fluid is then measured. The loss of flow from the pump is measured and reported in flow degradation and is an indicator of how well the fluid would flow and protect when contaminated with water. Castrol UTF showed only 0.6% flow rate degradation on a Sunstrand Piston Pump Model 22-2132. The maximum allowable flow rate degradation is 10%.



Castrol® UTF

Plessey-Sunstrand Ford M3C134-D Test

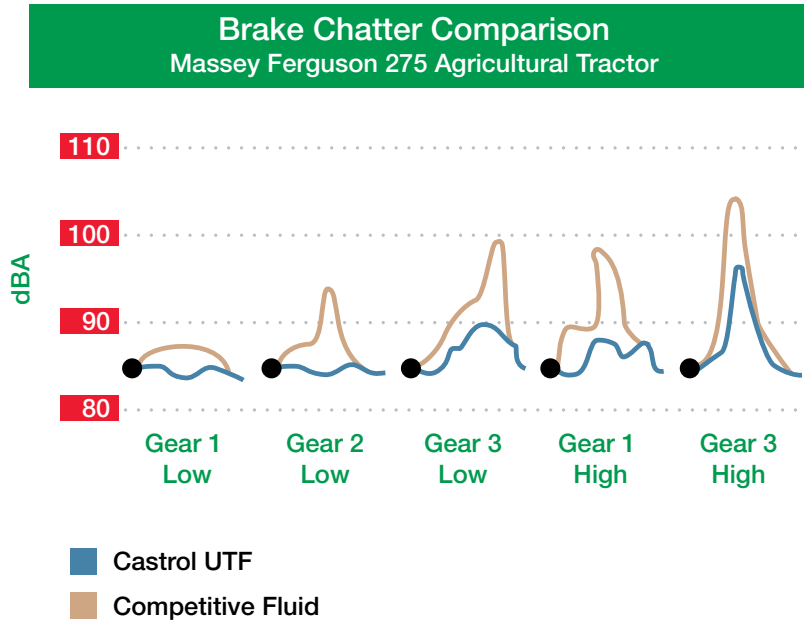
The Plessey-Sunstrand Ford M3C134-D Test also measures the flow characteristics of a fluid once it is contaminated with water. Castrol UTF showed no flow rate degradation during this test. The maximum allowable flow rate degradation is 5%.

Ford 3000 Axle Test

The Ford 3000 Axle Test subjects gear tooth surfaces to pressures of 400,000 psi for 100 hours at almost 200°F. During this test, gears protected with Castrol UTF showed practically no wear due to pitting, scoring, ridging or corrosion.

Brake Chatter Test

Castrol UTF was compared with a competitive fluid on a Massey Ferguson 275 Agricultural Tractor to measure brake chatter. In all gears, Castrol UTF provided consistently quieter brake performance than the competitor.



Castrol® UTF

Features	Advantages	Benefits
Additives that provide quality friction modifiers.	Assured proper and decisive functioning of multi-disc clutches used in power shift type transmissions and in oil-immersed disc brakes. Excellent control over brake chatter (shudder, squawk, etc.)	Chatter-free power transfer for wet brakes for longer equipment life.
Balanced chemistry to control water contamination.	Water tolerance with minimal loss of performance.	Better productivity and longer equipment life.
Seal swell and protection.	Maintain size, hardness and strength of elastomers, seals and gaskets.	Excellent system performance for better productivity.
Low pour point.	Mobility and prompt lubrication at low ambient temperatures.	Better productivity through year round operation. Less repair costs. Longer equipment life.
Excellent anti-wear package.	Prevent scoring and gear wear. Provides excellent load carrying capacity and wear protection under all load conditions.	Longer equipment life and less maintenance.
Shear stable viscosity index improver.	Minimal viscosity change in such applications as torque converts and hydrostatic drives under very high temperatures.	Longer equipment life. Less wear under severe conditions.
Balanced formulation.	Compatibility with all seal materials. Assured miscibility with other tractor fluids.	Less inventory for reduced costs.
Excellent rust and corrosion inhibitors, anti-foam additives and oxidation inhibitors.	Protects susceptible parts against rust. Excellent resistance to oil degradation due to oxidation at high temperatures.	Less maintenance costs.

Castrol® UTF

Applications & Approvals

Allis Chalmers	Power Fluid 821
Case/New Holland(IH)	MS-1207/Hy-Tran Plus, MS-1210/TCH, MS-1204/TFD Fluid, MS-1205/TFD-II Fluid, MS-1206/PTF Fluid, JIC-145, JIC-185, B-6/Hy-Tran, CNH MAT 3505 (MS-1209 Hy-Tran Ultra Fluid), Ambra Mastertrans Fluid CNH MAT 3525 (M2C134D), Multi G & Multi G 134, Nexplore Fluid
Caterpillar	TO-2
John Deere	J20A, J20C, JD303, J14B, J14C
Deutz-Allis	AC Power Fluid 821XL
Ford Tractor	M2C53A, M2C53C, M2C41A/B, M2C86B/C, M2C134A/B/C/D, M2C77A
Kubota	Universal Transdraulic Fluid, UDT Fluid
Massey Ferguson	M-1110, M-1127 A/B, M-1129-A, M-1135, M-1141 (Permatran III)
Oliver/White	Q-1766B, UHTF Type 55, Q-1722, 102082, Q-1826
Sperry Vickers	Pass on Pump Tests ASTM D-2882 and 35VQ25
Volvo	WB-101
ZF	03E, 05F

Typical Analysis

Test	Method	Results
Viscosity @40°C, cSt	ASTM D445	56
Viscosity @100°C, cSt	ASTM D445	9.7
Viscosity @100°F, SUS	ASTM D2161	285
Viscosity @210°F, SUS	ASTM D2162	58
Viscosity Index	ASTM D2270	160
Flash Point, °C(°F)	ASTM D92	215(419)
Pour Point, °C(°F)	ASTM D97	-37(-35)
Cold Crank Vis, -25C, cP	ASTM D5293	6272
Gravity, °API	ASTM D287	29
Specific Gravity @60°F	ASTM D1298	0.8834
Pounds per Gallon	ASTM D287	7.34

Castrol® Heavy Duty Multi-Purpose ATF

Castrol Heavy Duty Multi-Purpose Automatic Transmission Fluid (ATF) is a multipurpose power transmission fluid that is designed for most power transmission and hydraulic systems to include passenger car and truck automatic transmission, powershift transmissions in off-highway construction equipment, hydrostatic drives and industrial, agricultural, mining and marine hydraulics.

Castrol Heavy Duty Multi-Purpose ATF has excellent anti-wear, corrosion resistance, friction retention, and oxidation and thermal stability. In addition, it is inhibited against foaming, and the high viscosity index helps assure sufficient body for proper lubrication in severe hot weather service, without excessive thickening low temperatures.

Features	Advantages	Benefits
High viscosity index.	Maintains viscosity in severe hot weather service.	Longer transmission, torque converter, hydraulic system life.
Low pour point (low temperature fluidity).	Less wear in cold weather starts and operation.	Longer transmission, torque converter, hydraulic system life.
Controlled frictional properties. Maintains excellent frictional properties (smooth shifting) for the life of the fluid, a prime benefit of the Dexron®III specification.	Transmission of power is smooth and efficient and a noted long term retention of these properties.	Better productivity through efficient equipment performance.
Oxidation stability is excellent.	Resists chemical deterioration over long service periods.	Longer equipment life under severe service conditions.
Excellent anti-wear performance when the application demands the need for boundary lubrication.	Reduced metal-to-metal contact in such applications as torque converters, transmissions, vane pumps, etc.	Less maintenance. Keeps downtime to a minimum.
Compatibility with rubber and various friction materials, etc.	Not harmful to synthetic rubber seal materials, compatible with such material as sintered bronze and graphitic surfaces.	Longer life for vital components.
Minimal lock-up shudder.	Smooth, consistent shift feel.	Fewer operator complaints.

Castrol® Heavy Duty Multi-Purpose ATF

Warranty and Protection Requirements

- Meets or exceeds all truck and passenger car manufacturer's warranty requirements for vehicles, transmissions, transaxles, power steering systems or hydraulic systems where an Allison C4, Allison TES-389, Dexron-IIIH, Mercon or Vickers 35VQ25 fluid is specified.
- Meets or exceeds Allison transmission warranty requirements where an approved and licensed Allison TES-389 ATF is specified.

Industry Specifications and OEM Approvals

- Allison TES-389 approved and licensed (AA-32252007, AA-32362007)
- Allison C4 Approved
- Meets or Exceeds General Motors DEXRON®-IIIH Requirements
- Meets or Exceeds Ford MERCON® Requirements
- Meets or Exceeds the performance requirements of high pressure vane and piston pumps: Vickers (35VQ25, V-
- 104C) and Denison (T-6C, P-46)

Benefits

- Considerable savings through vastly reduced inventory.
- Minimal chance of costly application errors.

Typical Analysis

Test	Method	Results
Viscosity at 40°C, cSt	ASTM D445	34.0
Viscosity at 100°C, cSt	ASTM D445	7.7
Viscosity Index ASTM	D2270	210
Viscosity @ 100° F., SUS	ASTM D2161	171
Viscosity @ 210° F., SUS	ASTM D2161	51.8
Color, Typical	ASTM D1500	6.0 - 8.0
Appearance	Visual	Red
Brookfield Viscosity at -40 C, cP	ASTM D2983	12,100
Pour Point, °C (°F)	ASTM D97	-51 (-60)
Flash Point, °C (°F)	ASTM D92	185 (365)
API Gravity	ASTM D287	34
Specific Gravity, 60°F	ASTM D1298	0.865
Pounds per Gallon	ASTM D287	7.119

GPS

E

Gear Lubricants

Castrol®

Gear Lubricants

Background & Properties

Product Data

Types of Gears

Gears are the most common way to transmit power from one revolving shaft to another. Different combinations of gears are responsible for increasing speed, decreasing speed and changing the direction of the shaft. Gears are usually found in meshed pairs; the smaller gear is called the pinion and is responsible for speed reduction, and the larger gear is called the ring gear and is used to increase speed.

Due to varying needs and applications, there are several different types of gears. A basic knowledge of the most common types of gears, their components and method of operation is helpful in understanding which lubricants will enhance gear performance. Below are some of the types of gears encountered in today's equipment. Each gear is typically named for its general shape or by the arrangement of its teeth.

Spur Gears

A spur gear is a toothed wheel whose teeth run parallel to the gear shaft or axle. Spur gears are simple to manufacture, limited in their load-carrying ability and known for their noisy operation. A variation of the spur gear can be found in planetary gear sets.

Helical Gears

Helical gears transmit motion between non-intersecting parallel and nonparallel shafts. Similar in design to the spur gear, the teeth of the helical gear are angled or twisted to allow several teeth to be in mesh at the same time. Because the gear teeth engagement area is larger, helical gears can carry greater loads and tend to be much quieter and smoother in operation than spur gears.

Herringbone Gears

A double helical gear is commonly called a herringbone gear based on the opposing angles of the gear teeth. Herringbone gears can carry heavy loads at high speeds.

Bevel Gears

Bevel gears employ two intersecting shafts with meshing teeth cut straight across the face of a cone-shaped gear blank. Bevel gears are commonly used when a 90-degree change in direction of shaft power is required. A special grouping of bevel gears in automotive applications are known as differential gear sets. These gears are used to divide power between two variable speed shafts.

Spiral Bevel Gears

The teeth of an ordinary bevel gear can be twisted to form a spiral bevel gear. The "spiral" look results from cutting angled teeth into a cone-shaped gear. The angled teeth allow for a quiet, smooth transfer of power and a strong gear system. Spiral bevel gears are typically found in off-highway equipment.

Types of Gears

Hypoid Gears

A modification of the spiral bevel gear, hypoid gears transmit motion between non-intersecting shafts that cross at right angles. Hypoid gears have inherently strong teeth, excellent load-carrying ability and offer noiseless operation. The sliding motion of the hypoid gear requires lubricants with EP additives to maintain film strength. Hypoid gears can be used for the most severe applications.

Worm Gears

When shafts are intersecting at right angles and the driving gear is much smaller in diameter than the driven gear, this is called a worm gear. The two most common types of worm gears are throated and non-throated. The throated worm gear has angled teeth that increase the number of teeth in mesh at any given time. As with spiral bevel gears and helical gears, this feature increases load-carrying ability and quiets operation. On the contrary, the non-throated worm gear has only one tooth at a time in mesh, thus decreasing the gear's ability to carry loads. Due to the sliding nature of the worm gear, lubricants employing special additives are necessary. Worm gears are typically found where great velocity reductions are required.

Rack and Pinion Gears

A rack and pinion gear set is commonly found in automotive steering applications. Motion is transferred from the circular motion of the pinion gear to a linear gear alignment called the rack, or bar. Gear teeth are more tolerable, giving drivers a better feel while steering.

Gear System Lubrication Problems

The sensitive gears described above can experience problems for a number of reasons. Below are some of the more common ones:

- Inadequate lubrication or low gear oil level;
- Incorrect type of gear lubricant;
- Wrong lubricant viscosity;
- Poor-performing lubricant;
- Dirty/contaminated gear lubricant; and
- Misalignment of gear sets.

Any or several of the above factors can contribute to gear wear. The most common types of gear wear are micro-pitting, spalling, scoring and ridging. Basically, these different types of wear cause small pieces of metal to be removed from the system, which eventually causes tooth failure and severe system contamination.

Industry Specifications

Formulation of quality gear lubricants takes a delicate balance of additive chemistry. One of the best ways to determine lubricant quality is to review service specifications and mechanical test requirements with a fluid's results. Finding gear oils that meet, or more importantly exceed, the API test standards is the first step to choosing a quality gear oil.

The most widely used gear lubricants in North America are of API GL-4 (for manual transmission) and API GL-5 for axles. Since many equipment builders' specifications exceeded that of the above classifications, a new gear oil classification, API MT-1, was introduced. API MT-1 contains upgraded performance requirements for oils used in heavy-duty truck and bus nonsynchronized manual transmissions. This specification does not address oils for synchronized manual transmissions in passenger cars and heavy-duty vehicles.

Physical Requirements for Gear Lubricants Intended for Axle and Manual Transmission Applications			
SAE Viscosity Grade	Max Temperature for Viscosity of 150,000 cP (°C)[1,2]	Kinematics Viscosity at 100°C (cSt)[3] min[4]	max
70W	-55[5]	4.1	--
75W	-40	4.1	--
80W	-26	7.0	--
85W	-12	11.0	--
80	--	7.0	<11.0
85	--	11.0	<13.5
90	--	13.5	<18.5
110	--	18.5	<24.00
140	--	24.0	<32.5
190	--	32.5	<41.0
250	--	41.0	--

[1]Using ASTM D2983

[2]Additional low temperature viscosity requirements may be appropriate for fluids intended for use in light-duty synchronized manual transmissions.

[3]Using ASTM D 455

[4]Limit must also be met after testing in CEC L-45-T-99, Method C (20 hours).

[5]The precision of ASTM Method D 2983 has not been established for determinations made at temperatures below -40°C. This fact should be taken into consideration in any producer-consumer relationship.

Industry Specifications

API Gear Oil Classifications

Service Designations in Current Use:

Classification	Description	Uses
API GL-1	Straight Mineral Oil	Manual transmissions operating under mild conditions.
API GL-4	Equivalent to MIL-L-2105	Manual transmissions, axles with spiral bevel gears operating under moderate to severe conditions of speed or load, hypoid gears operating under moderate to severe speeds and loads and transaxle applications where API MT-1 lubricants are unsuitable.
API GL-5	Virtually equivalent to MIL-L-2105E	Gears, particularly hypoid gears, in axles operating under various combinations of high-speed shock loads and low speed, high-torque conditions.
API MT-1	Thermally stable and contains EP additives	Nonsynchronized manual transmissions used in buses and heavy-duty trucks.

Service Designations Not in Current Use:

Classification	Description	Uses
API GL-2	Usually contain fatty materials	Automotive worm gear axles.
API GL-3	Mild EP additives	Manual transmissions operating under moderate to severe conditions and spiral-bevel axles operating under mild to moderate conditions of speed and load.
API GL-6	Obsolete	Gears with very high pinion offsets.

Reprinted from Lubrizol's Ready Reference for Lubricant and Fuel Performance.

Due to obsolescence or inability to verify test requirements from unavailable equipment, this manual will not discuss API GL-1 through API GL-4 and API GL-6.

Industry Specifications

API GL-5

The mechanical tests required for API GL-5 gear lubricants are as follows:

Load Carrying (ASTM L-37)

This low speed/high torque test determines the load-carrying ability of the lubricant. Extreme pressure additives are needed to pass this test.

Test Limit
No tooth disturbance, such as pitting, ridging, rippling or severe wear

Corrosion Resistance (ASTM L-33-1)

Corrosion resistance in the presence of water is determined by this test. The gear lubricant must protect a surface against rust after 7 days of water exposure.

Test Limit
No rusting after 7 days on any working surface Max .5 in rust on cover plate
(1% of surface area)

High-Speed Shock Loads (ASTM L-42)

The ability to prevent scoring under high-speed shock load conditions is measured by ASTM L-42.

Test Limit
Gear/pinion scoring must be equal to or better than RGO-110

Thermal and Oxidative Stability (L-60-1)

L-60-1 measures base oil quality, additive component and thermal and oxidative stability.

Test Limit
100% max viscosity increase
3% max pentane insolubles
2% max toluene insolubles

Anti-foam Properties (ASTM D 892)

The oil's ability to resist foam is determined after 5 minutes of aeration during the ASTM D 892.

Test Limit
Sequence I 20 ml, max
Sequence II 50 ml, max
Sequence III 20 ml, max

Industry Specifications

Copper Corrosion (ASTM D 130)

Corrosion levels are taken on copper components after a specified time interval and under strict temperature conditions in ASTM D 130.

Test Limit
3 max after 3 h at 121.1°C

Oil Compatibility and Solubility (FTM 3430 & FTM 3440)

Evaluated by FTM 3430 and FTM 3440 respectively, an oil must show minimal separation of material and continue to maintain solubility after being mixed with different reference oils.

Test Limit
FTM 3430: 0.25% wt max or original nonpetroleum material in sample
FTM 3440: 0.50% wt max of original nonpetroleum material in sample

API MT-1

API MT-1 was designed as a specification for transmissions apart from API GL-4. It provides additional protection against thermal degradation, component wear and oil-seal deterioration versus API GL-4 and API GL-5 lubricants. The test requirements for API MT-1 lubricants are as follows:

Copper Compatibility (ASTM D 130)

Measured by ASTM D 130, API MT-1 lubricants have a stricter corrosion limit than API GL-5 lubricants.

Test Limits
2A max after 3 h at 121.1°C

Foam Resistance (ASTM D 892)

Same test and limits as API GL-5 lubricants.

Thermal and Oxidative Stability (L-60-1)

Same test and limits as API GL-5 but with added measurements for component cleanliness as shown by carbon and sludge deposits.

Test Limits
7.5 min carbon/varnish rating on large gear
9.4 min sludge rating on all gears

Industry Specifications

Oil Compatibility and Solubility (FTM 3430 and FTM 3440)

Same test and limits as API GL-5 gear lubricants.

Oil Seal Compatibility (Similar to ASTM D 471)

A test not required for API GL-5 gear lubricants. Measures the change in volume, hardness and elongation of oil seals for API MT-1 lubricants.

Test Limits

Polyacrylate	
Elongation change	-60 to 0%
Hardness change	-20 to +5 pts
Volume change	-5 to +30%
Fluoroelastomer	
Elongation change	-75 to 0%
Hardness change	-5 to +10 pts
Volume change	-5 to +15%

Anti-wear Characteristics (ASTM FZG D 5182)

Another test not performed on API GL-5 lubricants, ASTM FZG D-5182 determines a lubricant's anti-wear strength.

Test Limit
Min 10 stage pass

High Temperature Stability (Mack Transmission Test T2180)

Performed only on API MT-1 lubricants, the Mack Transmission Test T-2180 evaluates the oil's thermal stability during extreme high temperatures.

Test Limit
Equal to or better than reference oil

There is increasing concern from OEMs regarding the operating temperatures API GL-5 lubricants must consistently face. API MT-1 was the result of an update to the API GL-5 category as spurred by heavy-duty equipment builders.

Important Gear Lubricant Properties

Gear lubricants perform a number of duties within a gear set including preventing metal-to-metal contact, providing good shiftability in all temperatures, dissipating heat, preventing rust, removing wear debris and reducing friction. Specially formulated gear lubricants work to optimize performance and preserve the gear itself. When choosing a gear lubricant, several factors should help to determine final lubricant choice, including:

Extreme Pressure

Extreme pressure characteristics are especially important to gear lubricants. In some cases, EP additives account for up to 80% of a gear oil's additive package. EP additives work to protect the gear face from high temperatures and prevent metals from welding together and tearing apart.

Gear Type

Wear resistance is especially important with spur and bevel gear lubrication since only one tooth carries the entire load. With spiral bevel, helical and herringbone gears, the sliding action tends to wipe away the lubricant, which dictates the need for a slightly higher viscosity lubricant. The lubricant for these gears must provide good film protection but not excessive so that friction is increased.

Worm gears also employ sliding motion and therefore require a higher viscosity lubricant. Lubricants that are compounded are usually specified for these gears. Hypoid gears by design require lubricants with EP additives to combat the changing boundary and film conditions.

Gear Speed

Low viscosity oils can be used in higher speed gear operations because speed reduces the metal-to-metal contact and actually assists in forming fluid films. High viscosity oils are typically used in low speed gear assemblies because there is ample time for fluid films to deteriorate.

Reduction Ratio

The reduction ratio is a vital piece of information because it usually foretells of multiple reduction gears. Each reduction set operates at a different speed; the first set being the highest speed and the last set being the lowest. The inverse relationship between gear speed and oil viscosity holds true for multiple reduction sets. Two ways to lubricate multiple gear reducers are to use a dual viscosity oil system, or to try circulating the cool oil to low speed gears and then transferring it to the higher speed gears after its temperature is increased and viscosity decreased.

Operating Temperature

Ambient and operating temperatures affect an oil's viscosity and oxidation resistance and are therefore critical pieces of information in selecting a lubricant. To determine the operating temperature of a gear set, take the rise in operating temperature and add it to the ambient temperature. Choose the appropriate lubricant for the calculated temperature range.

Important Gear Lubricant Properties

Transmitted Power

Based on the type of gear and amount of power and load that it is expected to handle, lubricant choice should take into account the appropriate increase in temperature. Gear sets that transmit more power tend to run hotter than their smaller counterparts. This additional heat should not be a problem if the operating temperature was properly calculated and an adequate viscosity was chosen based on that temperature.

Surface Finish

The relative roughness of the gear surface is another determinate of gear lubricant viscosity. Rougher surfaces need heavier viscosities to maintain adequate film strength. It is sometimes recommended to choose a viscosity based on the average smoothing that can take place as the gear is operated.

Load Characteristics

Before choosing a gear lubricant, it is necessary to evaluate the type of loads the gear will be expected to handle. Excessive loading and/or shock loads require the use of extreme pressure lubricants. In cases of severe loading, as with automotive hypoid gears, metal-to-metal contact cannot be avoided and special extreme pressure lubricants are needed to prevent welding.

Drive Type

Engines that produce varying amounts of torque typically require a higher viscosity lubricant to assure film strength.

Application Method

How the lubricant comes in contact with the gear set affects the lubricant choice. Splash-lubricated units require a higher viscosity lubricant to help the oil stay in the gear and maintain film thickness. A pressure-applied lubricant tends to distribute the oil uniformly, removing more heat than a splash-applied lubricant. A heavier viscosity lubricant is not typically necessary in a pressure system.

Water Contamination

Steam, condensation or cooling effects can result in water contamination in an enclosed gear set. In cases where water contamination is probable, a lubricant with good demulsibility (the ability to separate water and oil) is required. It is of critical importance that the oil's demulsibility characteristics do not fade after the oil is in service or has become oxidized. Water in dirty oil that can no longer demulsify can cause excessive wear to gears and bearings. A lubricant with good rust and corrosion inhibitors is also necessary to prevent gear and bearing surfaces from rusting in the presence of water.

Other Qualities

In gears that experience heavy leakage, a special lubricant that resists leakage may be specified. Other desirable lubricant qualities include foam resistance and oxidation resistance. These qualities help to assure oil quality during periods of extreme service.

Castrol® Gear Lubricants

The demand for increased equipment and vehicle productivity requires more frequent and prolonged high-load operation. The thermal stress this creates in the gear box results in tough challenges in performance, fuel economy and durability for the lubricant. Castrol gear lubricants meet these real world challenges and exceed the highest industry standards. Castrol gear oils offer the following performance benefits:

Thermal Stability

Castrol gear oils are engineered to deliver high-temperature performance and protection from deposit buildup under the stress caused by hauling extra-heavy loads, driving on-highway at high speeds and operating on severe grades.

Wear Protection

The advanced extreme pressure performance of Castrol gear oils reduces wear under severe conditions and permits longer equipment life.

Seal Compatibility

Castrol gear oils reduce the loss of fluid due to leakage from seals that have become too soft, too brittle or damaged by deposits.

Hydrolytic Stability

Water contamination of gear lubricants can promote rust and reduce equipment performance. Castrol gear oils have excellent demulsibility to effectively separate water from oil for easy removal from the system. Residual water is not a problem, since Castrol gear lubricants maintain their performance in up to 1% water-contaminated oil. Further equipment safeguards are provided by excellent anti-rust protection.

Clean Parts

Particulate matter can also contaminate gear oils and cause accelerated wear or deposit buildup. The detergent/dispersant properties of Castrol gear lubricants keep parts cleaner by keeping particulates suspended in the fluid until they can be removed when the oil is changed. As a result, parts stay cleaner even during extended service intervals.

Castrol® Alpha® HC [PREVIOUSLY Castrol Isolube]

Castrol Alpha HC Lubricants are a series of ISO grade, technically advanced chemistries that exceed the performance levels historically attributed to the traditional synthetic products that are available today. Castrol Alpha HC Lubricants excel in applications requiring excellent oxidation control and thermal stability, consistent anti-wear performance, and low carbon forming tendencies, with chosen synthetic components that provide the potential for extended drain intervals and reduced maintenance costs. Castrol Alpha HC Lubricants have noted viscosity range properties for low temperature fluidity and controlled volatility. Other exceptional benefits of this innovative formulation include rust protection, consistent demulsibility and hydrolytic stability.

Castrol Alpha HC Lubricants excel in circulating oil and gear set applications, and pass a 12 stage minimum in the demanding FZG spur gear test, which provides an additional margin of safety in the noted applications. (Please note that the Castrol Alpha HC Lubricants series should not be used for heavily loaded gear sets and where the OEM requires an AGMA [American Gear Manufacturers Association] EP lubricant.)

Oxidation Control

Castrol Alpha HC has increased oxidation resistance as evidenced by field test results in the RBOT Oxidation Life Test. This test showed that even after 835 hours in use, Castrol Alpha HC's minutes to oxidation still exceeded that of new commercial mineral and synthetic fluids. This increased oxidation control contributes to outstanding deposit protection and extended compartment life. Castrol Alpha HC's oxidation resistance is also important for users who want to extend drain intervals in conjunction with a used oil analysis program.

Wear Protection

Castrol Alpha HC's anti-wear additives give it outstanding wear protection that ensures long component life and less maintenance and downtime.

Low Temperature Performance

Castrol Alpha HC's proven low temperature pumpability ensures that critical parts remain protected, even during extreme low temperatures. The added benefits of pumpability include more efficient operations and reduced energy consumption.

Seal Compatibility

Castrol Alpha HC is considered elastomer compatible and showed no damaging seal swell or increase in seal hardness.

Other Qualities

Castrol Alpha HC provides outstanding rust protection, consistent demulsibility and excellent hydrolytic stability.

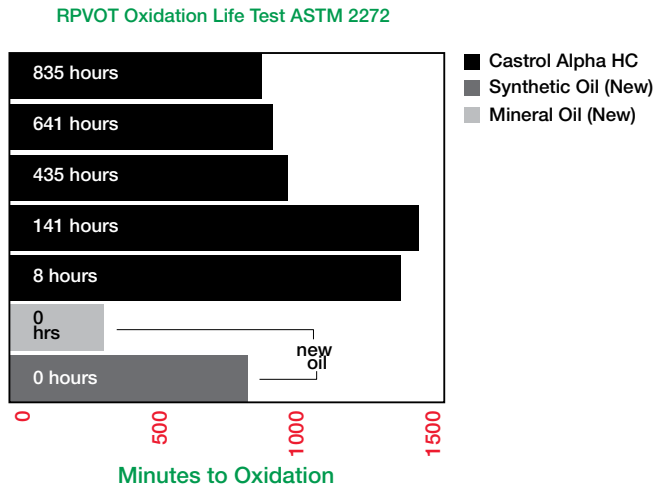
Field Test Results

Castrol Alpha HC was field tested at two national heavy-duty construction companies. The field test was designed to test the following criteria: oxidation resistance, wear protection, low temperature performance and seal compatibility. In compressor units at one of the sites, several candidate fluids were tested. Castrol Isolube was pitted against a commercial mineral fluid and a commercial synthetic (PAO) fluid in most of these tests. The results are as follows:

Castrol® Alpha® HC [PREVIOUSLY Castrol Isolube]

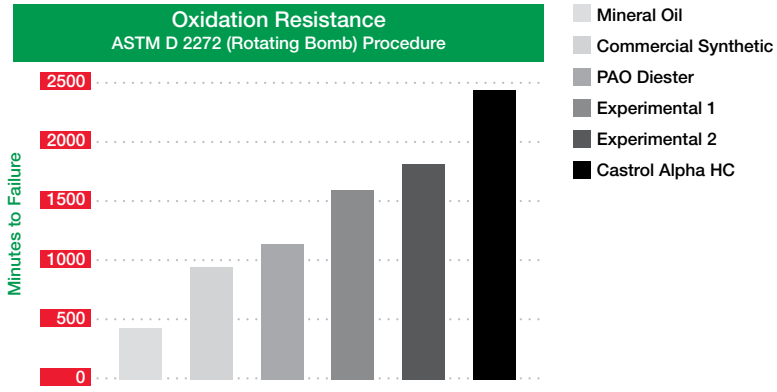
RPVOT Oxidation Life Test

In the RPVOT Oxidation Life Test, a fluid is heated in pure compressed oxygen to determine how long it would take for the fluid to fail. As shown in the chart below, Castrol Alpha HC was tested at field test intervals from 8 to 835 hours. Even after 835 hours of use, Castrol Alpha HC's minutes to oxidation still exceeded that of a new commercial mineral and synthetic fluid.



ASTM D 2272 (Rotating Bomb) Procedure

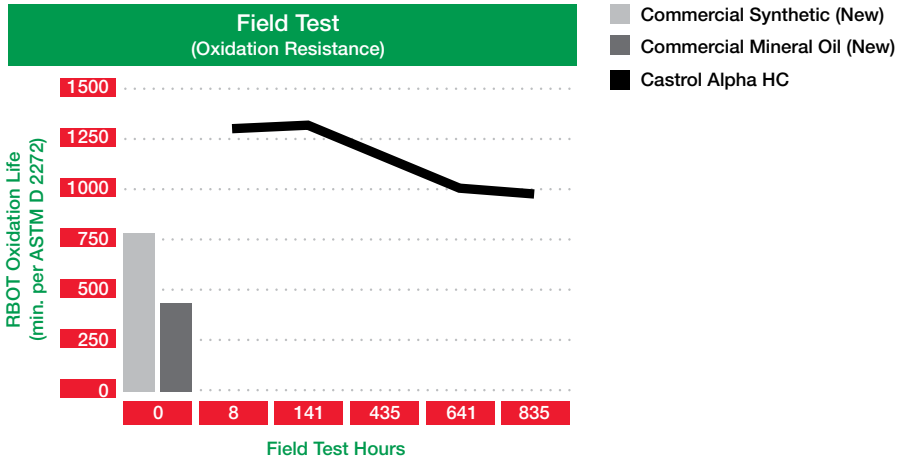
In another test for oxidation resistance, Castrol Alpha HC outperformed several test fluids, showing exceptionally long fluid life.



Castrol® Alpha® HC [PREVIOUSLY Castrol Isolube]

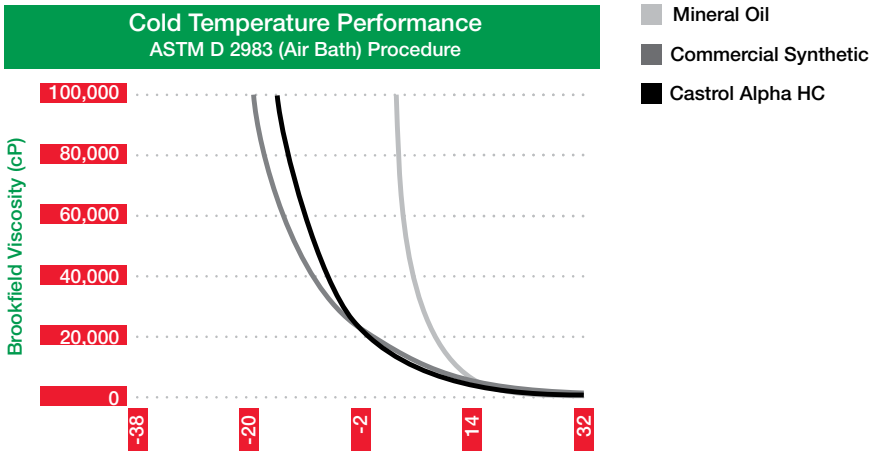
Wear Metals and Ferrographic Analysis

Castrol Alpha HC's outstanding anti-wear performance showed minimal wear in a field test compared to a commercial PAO-based alternative. Ferrographic analysis also showed only trace levels of normal wear, whereas the competitive PAO gear oil showed low to moderate levels of wear and a moderate level of dark oxides.



ASTM D 2983 Air Bath Procedure

Castrol Alpha HC displayed characteristics of outstanding low temperature performance in the ASTM D 2983 test for cold temperature performance.



Castrol® Alpha® HC [PREVIOUSLY Castrol Isolube]

ISO Grade	Method	Unit
Viscosity @40°C, cSt	ASTM D445	mm^2/s
Viscosity @100°C, cSt	ASTM D445	mm^2/s
Viscosity @100°F	ASTM D2161	SUS
Viscosity @210°F	ASTM D2161	SUS
Viscosity Index	ASTM D2270	--
FZG Gear Test, load stage	ASTM D5182	Stages
Pour Point	ASTM D97	°C (°F)
Flash Point, open cup method	ASTM D92	°C (°F)
API Gravity	ASTM D287	--
Specific Gravity @16°C/60°F	ASTM D1298	--
Pounds per Gallon	ASTM D287	--

	150	220
Viscosity @40°C, cSt	149.2	220.8
Viscosity @100°C, cSt	18.9	25.6
Viscosity @100°F, SUS	691	1,021
Viscosity @210°F, SUS	93.8	122.8
Viscosity Index	143	148
FZG Gear Test, load stage	>12	>12
Pour Point, °C (°F)	-45(-49)	-45(-49)
Flash Point, open cup method	227(441)	227(441)
APO Gravity	33.4	33.0
Specific Gravity @16°C/60°F	0.858	0.860
Pounds per Gallon	7.14	7.16

Castrol® Alpha® HC EP [PREVIOUSLY Castrol Isolube EP]

Castrol Alpha HC EP Lubricants are a series of ISO graded, technically advanced chemistries that exceed the performance levels historically attributed to the traditional synthetic products that are available today. Castrol Isolube EP Lubricants have been formulated with carefully chosen synthetic components for excellent performance in applications requiring AGMA (American Gear Manufacturers Association) EP gear oils. The product has coupled multiple components in a formulation that provides outstanding wear protection in industrial gear sets, off-highway construction, and mining applications where consistent performance is critical.

Castrol Alpha HC EP Lubricants provide exceptional oxidative and thermal stability in selected applications. Castrol Alpha HC EP Lubricants offer a unique approach to gear and system component lubrication through a focused formulation that will provide the end user with true confidence in the selected application.

Industry Specifications and OEM Approvals

- ANSI/AGMA Standard 9005-E02
- DIN 51517 Part 3
- AIST 224

Typical Analysis

Test	Method	Unit	68	150	220
Kinematic Viscosity @40°C/100°F	ASTM D445	mmÇ/s	67.8	149.2	220.8
Kinematic Viscosity @100°C / 210°F	ASTM D445	mmÇ/s	10.4	18.9	25.6
Viscosity Index	ASTM D2270	--	140	143	148
Timken OK Load test	ASTM D2509	kg/lb	34/75	34/75	34/75
FZG Gear Scuffing test -A/8.3/90	ASTM D5182	Failure Load Stage	>12	>12	>12
Pour Point	ASTM D97	°C/°F	-45/-49	-36/-32	-36/-32
Flash Point - open cup method	ASTM D92	°C/°F	227/441	228/442	228/442
API Gravity	ASTM D287	--	35.4	33.4	33.0
Specific Gravity @ 16°C /60°F	ASTM D1298	--	0.848	0.858	0.860
Pounds per Gallon	ASTM D287	--	7.06	7.14	7.16

Castrol® Alphasyn T™ [REPLACES Castrol SHL Lubricant 150, 220, 460]

The Castrol Alphasyn T gear oil range of synthetic lubricants are based on polyalpha-olefin (PAO) fluids and sulphur/ phosphorus anti-wear additive technology providing outstanding thermal stability and good load carrying capacity.

Application

Alphasyn T is suitable for various applications where a lubricating oil is used under high temperatures, e.g. from hydraulic systems through to large, slow moving gears. All products in the Alphasyn T range have very low pour points and excellent viscosity and temperature characteristics,

allowing their use in both low and high temperature applications.

The Alphasyn T range is fully compatible with nitrile, silicone and fluropolymer seal materials. Alphasyn T is also suitable for bearings and circulatory systems operating at high temperatures.

The Alphasyn T range has been formulated for use in most types of light to medium duty enclosed gear systems, but should not be used for heavy or shock loaded systems.

Features and Benefits

Castrol Alphasyn T is a PAO based lubricant that provides good compatibility with seals, paints and mineral oil based lubricant. Castrol AlphasynT offers the following benefits:

- Good thermal and oxidative stability, providing reliable operation and extended operating life when compared to mineral oil based products.
- Inherently high viscosity index (VI), making the product suitable for operations operating over a wide temperature range.
- Good anti-wear and load carrying abilities, minimizing gear wear and prolongs gear tooth life.
- Reduced down time through water separation and demulsification characteristics, resulting in prolonged lubricant life and increased equipment reliability.

Classifications

Alphasyn T is classified as follows:

- DIN Classification is CL

Alphasyn T grades meet the requirements of:

- DIN 51517 Parts 2
- David Brown Type A

Castrol® Alphasyn T™ [REPLACES Castrol SHL Lubricant 150, 220, 460]

Typical Characteristics

Test	Method	Units	150	220	320	460
Density @ 15°C	ASTM D4052	g/ml	0.87	0.87	0.87	0.87
Kinematic Visc. @40°C	ASTM D445	mm2/s	150	220	320	460
Kinematic Visc. @ 100°C	ASTM D445	mm2/s	17.8	23.9	31.7	41.8
Viscosity Index	ASTM 2270	--	131	135	138	141
Pour Point	ASTM D97	°C/°F	-42/-44	-42/-44	-30/-22	-30/-22
Flash Point, COC	ASTM D92	°C/°F	271/520	277/531	282/540	285/545
Foam Seq I	ASTM D892	mls/mls	10/0	10/0	10/0	20/0
Rust Test (24 hrs/synthetic sea water)	ASTM D665B	--	Pass	Pass	Pass	Pass
FZG fail stage (A8.3/90)	DIN 51354	--	12	12	12	12

Castrol® AP Gear Lubricant

Multi-purpose Lubricant

Castrol AP (all purpose) Gear Lubricant is formulated with high-quality base oils and additives that provide excellent load-carrying ability, EP properties, wear resistance, oxidation stability and anti-rust, anti-corrosion and anti-foam properties.

Thermally Stable

Castrol AP Gear Lubricants are multi-purpose, extreme pressure gear oils that are thermally stable and will provide transmission, differential and other application protection beyond that specified for the current MIL-PRF-2105E and API GL-5 requirements. This thermal stability extends oil service life and reduces critical component wear.

Castrol AP Gear Lubricants meet the requirements of API (American Petroleum Institute) gear oil classification GL-5 and SAE J2360 (Formerly MIL-PRF-2105E). These multi-purpose gear oils are formulated with high quality base oils and additives to provide excellent load carrying ability, EP properties, wear resistance, oxidation stability, anti-rust and anti-corrosion qualities and anti-foam protection.

Castrol AP Gear Lubricants are recommended for make-up and complete refill of most passenger car and light truck conventional differentials, transmission and steering gears.These multi-purpose, extreme pressure gear oils are now considered thermally stable and will provide transmission, differential, and other application protection beyond that specified for SAE J2360 (Formerly MIL-PRF-2105E) requirements. This thermal stability extends oil service life and reduces critical component wear.

Castrol AP Gear Lubricants are recommended for the following applications:

- SAE J2360
- MIL-PRF-2105E
- API MT-1 (80W-90)
- Mack Truck GO-J
- BMW
- General Motors
- Dodge
- Euclid
- Ford Motor Company
- Volkswagen
- Navistar
- API Service GL-5
- American Motors
- Chrysler Corporation
- Clark Equipment Company
- John Deere Company
- Eaton
- Nissan
- Renault
- Rockwell International

Note: Castrol AP Gear Lubricants meet or exceed other automotive, construction and other heavy duty applications.

Castrol® AP Gear Lubricant

Typical Analysis

Test	Method	Typical Results
Kinematic Viscosity at 40° C, cSt	ASTM D445	326
Kinematic Viscosity at 100° C, cSt	ASTM D445	31.6
Viscosity Index	ASTM D2270	135
Flash Point, °C (°F)	ASTM D92	240(464)
Pour Point, °C (°F)	ASTM D97	-27(-17)
Brookfield Viscosity, -20°C, cP	ASTM D2983	44,600
20 Hr KRL Shear Test After Shear cSt @ 100°C	CEC-L45-20	31.4
% Viscosity Loss		-0.66
FZG Gear Scuffing, Pass Load Stage	ASTM D5182	12
FZG Gear Wear, mg wt Loss	ASTM D4998	13
Gravity, API	ASTM D287	31.4
Pounds per Gallon	ASTM D287	7.23

Castrol® EP Gear Lubricant

Castrol EP Gear Lubricants are exceptional quality gear oils that are designed for severe duty applications. Castrol EP Gear Lubricants offer excellent gear protection and possible extended lubricant usage with periodic checks by Castrol's Oil Analysis Program. Castrol EP Gear Lubricants are formulated with selected base oils that are coupled with an extremely stable sulfur/phosphorous additive package that make them the ideal choice where AGMA EP type gear oils are recommended.

Castrol EP Gear Lubricants excel in applications demanding outstanding U.S. Steel 224 performance.

Features	Advantages	Benefits
Excellent thermal and oxidation stability.	Enhanced lubricant stability under all operating conditions. Minimal viscosity increase. Sulfur/phosphorous package remains stable at high temperatures. Minimal sludge formation.	Longer equipment life. Efficient gear operation. Reduced maintenance cost. Longer lubricant life.
Excellent demulsibility.	Will separate water readily where water contamination is present.	Reduced maintenance costs. Longer equipment life. Less downtime.
Good corrosion, rust and anti-foam protection.	Reduce catalytic effects of corrosion and wear on various system metals.	Longer lubricant and equipment life. Less maintenance.

Industry Specifications and OEM Approvals

- ANSI/AGMA Standard 9005-E02
- DIN 51517 Part 3
- U.S. Steel 224

Castrol® EP Gear Lubricant

Typical Analysis

Test	Method	150 (4 EP)
Viscosity @40°C, cSt	ASTM D445	159.3
Viscosity @100°C, cSt	ASTM D445	15.3
Viscosity @100°F, SUS	ASTM D2161	837.4
Viscosity @210°F, SUS	ASTM D2161	80.8
Viscosity Index	ASTM D2270	97
Flash Point, °C (°F)	ASTM D92	223(435)
Pour Point, °C (°F)	ASTM D97	18(-2)
Gravity, °API	ASTM D287	26.5
Specific Gravity @60°F	ASTM D1298	0.8956
Pounds per Gallon	ASTM D287	7.458
Timken OK Load	ASTM D2509	75

Castrol® Syngear™ Lubricant

Castrol Syngear is a premium, synthetic, heavy duty, multi-grade gear lubricant that meets API GL-5 service. Castrol Syngear provides excellent cold weather performance, outstanding stability under higher than normal operating temperatures, and substantial load carrying ability for cooler operation and longer equipment life. Castrol Syngear is ideal for severe service environments and customers who want to extend service intervals.Castrol Syngear Lubricants will meet or exceed all performance requirements of the following applications:

- API GS-5
- API MT-1
- MIL-PRF-2105E
- SAE J2360
- Dana SHAES 429 Rev. A.
- Dana SHAES 256 Rev. C
- Mack Truck GO-J Plus
- International TMS 6816

Castrol Syngear contains 100% synthetic base stocks for outstanding oxidation control and thermal stability for improved fuel economy and longer equipment life. A premium additive package inhibits rust, corrosion, and wear to protect against premature bearing failure and gear tooth wear. Excellent shear stability protects against viscosity loss to safely extend service intervals. Castrol Syngear lubricants are accepted and approved by the Eaton Corporation as alternatives to their Eaton Roadranger gear oils and acceptable for use in conjunction with the Eaton Roadranger Extended Warranties.

Features	Advantages	Benefits
100% synthetic base stocks.	Faster start ups, greater load carrying ability and cooler operation. Oxidation minimized through excellent thermal stability.	Longer equipment life. Fuel economy.
Shear, stable base stocks.	Viscometric stability under all operating conditions. Lower operating temperatures due to increased efficiency and reduced viscosity loss.	Fuel economy. Longer equipment life.
SAE J2360 (Formerly MIL-PRF-2105E). Certified API GL-5 quality.	Protection against premature bearing failure. Minimal gear tooth wear under severe operating conditions.	Less down time. Longer gear box and axle life.
Anti-rust, corrosion, and anti-foam additives and excellent demulsibility.	Further protection for bearings and gears.	Longer equipment life. Less down time.

Castrol® Syngear™ Lubricant

Typical Analysis

Test	Method	75W-90	80W-140
Viscosity @40°C, cSt	ASTM D445	117	29.2
Viscosity @100°C, cSt	ASTM D445	15.0	312
Viscosity, cP @-40°C	ASTM D2161	109,000	--
Viscosity Index	ASTM 2270	139	139
Flash Point, °C (°F)	ASTM D92	204 (399)	218 (424)
Pour Point °C (°F)	ASTM D97	-45(-49)	-33(-27)
Gravity, ° API	ASTM D287	33.4	31.3
Specific Gravity @60°F	ASTM D1298	0.8581	0.8692
Pounds per Gallon	ASTM D287	7.15	7.24

GPS

F

Greases

Castrol

F

Greases

Background & Properties

Product Data

Castrol®

General Information

When heavy-duty equipment requires a lubricant that has staying power, thickness and the ability to provide a seal between moving parts, a grease is typically recommended.

The National Lubricating Grease Institute (NLGI) defines grease as: "A solid to semi-solid dispersion of a thickening agent in a liquid lubricant. Additives imparting special properties may be included." This means that grease is mainly base oil plus soap or thickener and additives. Each of these grease components is reviewed in depth below:

Thickeners

Grease is usually identified by the type of thickener or soap used in its formulation. Each thickener has several inherent characteristics that enhance the finished grease product. The following is an explanation of the most common grease thickeners and their properties.

Note: The temperatures quoted below represent the suggested maximum service temperature for each type of thickener. This is not the same as the thickener's dropping point, which is, on average, 100°F higher.

In practice, upper end service temperatures are limited by flash point and oxidation of base oil.

- **Sodium Soap:** A fibrous thickener that provides natural rust resistance but has poor water resistance. It is generally associated with poor low temperature properties. A sodium soap is recommended for use in a maximum temperature range of 200-275°F. This thickener is basically obsolete.
- **Calcium Soap (Simple):** Calcium soap is known for its smooth structure and excellent water resistance. Its maximum service temperature is 250°F.
- **Calcium Soap (Complex):** Calcium complex is still smooth in texture but contains inherent extreme pressure load-carrying abilities and good water resistance. Its maximum service temperature is 300°F.
- **Calcium Sulfonate:** This thickener is noted for its excellent rust protection and service temperature that tops 400°F. Its texture is smooth.
- **Lithium Soap (Simple):** Another smooth-textured thickener, a lithium soap boasts good water resistance and mechanical stability. Its maximum service temperature is 325°F.
- **Lithium Soap (Complex):** Like its simple counterpart, lithium complex soap has good water resistance and mechanical stability but a higher service temperature of 400+°F. Its texture is smooth but slightly stringy.
- **Aluminum Complex:** A smooth gel with excellent water resistance, shear stability and pumpability. Its maximum service temperature is 400+°F.
- **Clay:** A smooth-structured thickener known for its ability to resist melting and excellent water resistance.
- **Polyurea:** An opaque, slightly mealy thickener, Polyurea has good oxidation and water resistance. Its maximum service temperature is 350°F.

General Information

Base Stock

The liquid lubricant portion of a grease can be composed of almost any base oil. A base oil is usually selected for its low and high temperature performance, oxidation stability and elastomer compatibility. In addition to these performance characteristics, a base fluid is chosen for the service level and application in which it will work.

The base stock makes up the largest portion of the finished grease and can be a mineral, vegetable, re-refined, partial synthetic or full synthetic. High viscosity index and oxidation resistance are generally desirable characteristics in a grease's base fluid.

Additives

Additives enhance the performance of a finished grease. Additives in grease may be either chemically active or chemically inert. Chemically active additives are ones that chemically affect the grease's performance, such as extreme pressure agents or rust inhibitors. Chemically inert additives affect a grease's physical properties, like structure or water tolerance. The most common additives found in grease are anti-oxidants, rust inhibitors, anti-wear agents, extreme pressure agents and solids.

A premium-performing grease is one that uses top quality additives, a premium base oil and a good thickener. Low quality grease can seriously impact equipment performance and bottom line results. Research regarding the correct grease for critical equipment may save money in maintenance and labor in the long run.

Important Properties

The NLGI has initiated two grease performance areas that define where and how grease can be used. The first relates to where grease can be used and is outlined below:

- LA and LB: Indicates the grease's suitability for use in chassis bearings and applications
- GA, GB, GC: Shows the grease's suitability for wheel bearing applications and the temperature at which the grease can operate successfully.

A NLGI GC/LB grease meets the highest performance specifications for both chassis and wheel bearing applications.

Category	Service	Performance
LA chassis	Frequent relubrication intervals (>3200 km). Mild duty (non-critical applications).	Oxidation resistant, shear stable and corrosion and wear protective.
LB chassis	Prolonged relubrication intervals (<3200 km). Mild to severe duty, high loads, vibration, exposure to water.	Oxidation resistant, shear stable, and corrosion and wear protective, even under heavy loads and in presence of aqueous contamination. Temperature range -40 to 120°C.

These specifications are largely directed toward automotive products, and in some instances may not be adequate for heavy-duty equipment.

NLGI Grades-Greases		
NLGI Grade Number	Penetration ASTM	Description and Typical Use
000	445-475	Semifluid: Centralized Systems
00	400-430	Semifluid: Centralized Systems
0	355-385	Semifluid: Centralized Systems
1	310-340	Very Soft: Grease guns or Centralized Systems
2	265-295	Soft: Grease guns or Centralized Systems
3	220-250	Light: Grease guns
4	175-205	Medium: Pressure guns
5	130-160	Heavy: Grease guns
6	85-115	Bloc: Open Grease Collars

The second performance area relates to the "body" or consistency of the grease. The consistency of the grease is similar to the viscosity of an oil. Grease consistency is graded from 6 to 000 and is usually found next to the NLGI indicator. For example, the most widely used grease is a NLGI GC/LB 2.

Industry Specifications

There is little standardization for grease testing in the industry, but there are several industry tests that rate a grease's performance characteristics. To determine whether a grease can offer extreme pressure (EP) protection, pumpability, mobility and stay-in-place performance, review the results of these critical industry tests:

Grease Tests

Penetration

The test for penetration is one of the primary quality control tests for the grease industry. Many grease suppliers quote penetration test results as a performance indicator for their product. Unfortunately, penetration alone simply measures the consistency of a grease and does not indicate how a grease will perform in a component.

The penetration test involves a one pound cup of grease, held at a controlled temperature, with the air bubbles removed from it. A weighted cone is dropped into the grease. The depth of the cone immersed in the grease is measured in millimeters. A range of penetration in millimeters determines the NLGI grade of the grease. The farther the cone penetrates the grease, the lower the NLGI grade. A grease's pumpability or mobility characteristics cannot be predicted from penetration test results.

Timken OK Load

The Timken test measures a grease's ability to withstand extremes of load and pressure. It is performed under line-to-line contact with a specific amount of pressure applied to a greased block. The test is run for ten minutes, and at the end of the test, the block is rated in terms of how much it is scored. A little scoring is considered a pass; a significant amount of scoring is a fail.

The Timken test is performed with different weighted loads, usually between 10 and 70 pounds. A typical value for the Timken test is a 40-pound pass. An excellent value for the Timken test is a 70-pound pass. The latter grease exhibits outstanding extreme pressure protection over standard greases. Greases able to pass the Timken OK Load test have balanced additive packages containing extreme pressure agents. Maintenance managers using a grease in high load applications should research Timken test results.

4-Ball Weld

Another test designed to measure extreme pressure properties, the 4-Ball Weld, evaluates point-to-point contact using ball bearings for better reproducibility and more consistent data. Three greased, rotating balls are placed in a cup and one stationary ball is on top.

A load of up to 800 kilograms is added to the ball bearings. The test runs for one minute (under load for 10 seconds) and if the balls keep rotating for the full minute, the grease has passed. If the balls weld together before one minute has passed, the test shuts down and the grease fails. A typical EP grease will usually weld around 250 kilograms. Grease with excellent extreme pressure properties can handle a load of 800 kilograms—the highest test load.

Industry Specifications

Water Washout

Water Washout, like Penetration, is another widely quoted industry test. But the results are not always valid. In the Water Washout test, an open-faced bearing is doused with a steady stream of water. However, test results can be difficult to replicate from different grease suppliers. Water Washout results are quoted in terms of percentage of grease washout.

Water Spray Off

A much better test for stayability in wet environments is the Water Spray Off test. During this test, a 2- by 4-inch metal panel is sprayed with a light coating of grease and weighed. Water at 100°F is then sprayed onto the panel at 40 psi. Once the test is complete, the grease that remains on the panel is weighed and results are quoted in terms of percentage of grease sprayed off.

This is a much more realistic test for heavy-duty grease users for two reasons. First, there is less chance to manipulate data; therefore, it is a much more reproducible and repeatable test. And second, the test conditions—water being sprayed at 40 psi— is what many maintenance managers actually face on the job.

US Steel Mobility

Mobility is another test that, in and of itself, does not give grease users a lot of usable information. Its purpose is to predict pumping ease or difficulty at various temperatures. The US Steel Mobility test uses a packed grease cylinder with a small capillary at the bottom of the cylinder. Grease is packed into the cylinder and allowed to flow through the capillary with gravity behind it. Mobility is generally tested at 60°F and measured in grams per minute.

It is safe to assume that grease with good mobility will also have acceptable pumpability, since pressure, not gravity, will be forcing the grease from the drum to final application. But for a grease to be effective, mobility/pumpability must be balanced with stay-in-place capabilities. Most greases sacrifice tack and adhesion to have good mobility and pumpability. Mobility and pumpability information alone will not relay how well the grease will stay in place once in use or in the presence of water. Mobility numbers should always be quoted alongside water spray off results. As a norm, mobility of 200 grams/minute at 60°F and water spray off of less than 20 percent is considered very good for grease. The ultimate grease is one that offers the pumpability of an NLGI 1 grease with the tack and adhesion of an NLGI 3 grease.

To take the mobility information one step further, it is helpful to have mobility numbers for a full range of ambient temperatures. For example, a grease can flow at 1,000 grams/minute at 60°F and 0 grams/minute at 20°F. Look for mobility information on temperatures of 0, 20, 40, 60 and 77°F to get a complete understanding of how a grease will flow and pump during all temperatures and seasons.

Dropping Point

A grease's dropping point is the temperature at which the grease changes from a semi-solid to a liquid state. The dropping point is not the grease's operating temperature. As a rule of thumb, a grease's operating temperature is approximately 100°F to 150°F lower than the published dropping point.

Dropping point is noted when a grease becomes so hot that the oil separates from the soap and runs out of the cup.

Industry Specifications

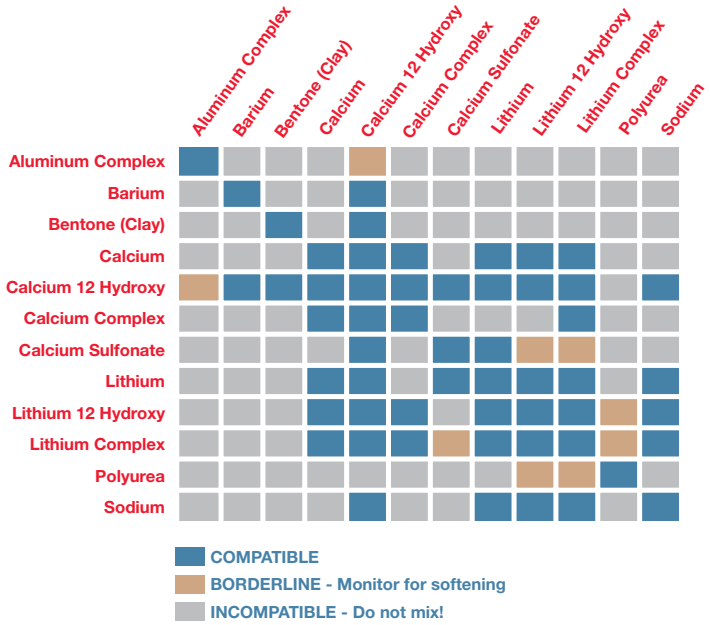
A Note on Compatibility

For years, the heavy-duty industry believed that grease incompatibility resulted primarily from mixing the thickeners in finished greases. But the additive package, not solely the thickener, is responsible for most incompatibility problems in a finished grease. If you have ever seen grease run out of a component, the cause is usually not the grease's thickener, but the additive chemistry. Certain additives in one grease can chemically attack the soap in another grease, causing it to soften excessively or "go to soup." This occurrence is often easily excused as incompatibility due to the type of thickener with which each grease is formulated, when in reality, it is influenced more by the additive package.

To avoid compatibility problems when switching greases, purge the system completely, if possible, with the new grease. Once the grease is pumped into the component, monitor it closely. Any compatibility problem will become apparent very quickly.

There are laboratory tests available that can analyze grease compatibility by measuring the penetration of the mixed grease at 0, 60 and 10,000 strokes. Compatible greases should experience only minor softening—about one grade on average. Softening above one grade is not acceptable and the greases should be labeled incompatible. But if greases have been labeled incompatible, it does not mean that they cannot be used. Thoroughly purge the component with the new grease. Once the component has been purged with the new grease, continue to monitor it closely and increase grease service intervals gradually to ensure complete removal of the previous grease.

BINARY GREASE MIXTURE COMPATIBILITY



Please Note: This chart is grouped according to thickener type and represents only a **GENERAL Guideline.** The chart does not consider the *complete* makeup of a *particular* grease. Mixing different types of grease in the field should be monitored closely and service intervals changed gradually to ensure complete removal of the previous grease.

Castrol® Pyroplex® Gold

Castrol Pyroplex Gold provides the ultimate protection against wear for critical equipment. A semi-synthetic, extreme pressure grease, Castrol Pyroplex Gold contains more than 20% solids, including 6% molybdenum disulfide, to give equipment a protective lubricant barrier against wear, even during conditions of high load.

High Loads/Heavy Loads Performance

Castrol Pyroplex Gold is recommended for heavily-loaded pin joints and other components routinely subjected to high shock loads in extreme conditions. Castrol Pyroplex Gold demonstrates protection against extreme loading, in both "point" and "line" contact modes. It carries a 70-pound OK load in the Timken Test Method, without the use of heavy metals such as antimony, lead, barium or chlorinated compounds. Additionally, Castrol Pyroplex Gold's outstanding wear protection was further validated after it received the highest possible score (800 kg) in the Four-Ball Weld Test (ASTM D 2596).

Low Temperature Performance

Castrol Pyroplex Gold's semi-synthetic base stock and specially chosen thickeners allow it to maintain pumpability in low temperature environments. This ensures that Castrol Pyroplex Gold will reach critical parts at temperatures that would make other greases too thick to pump. Other greases with high solid content may not be as mobile, subjecting equipment to accelerated wear and possibly premature failure. US Steel Method results prove that Castrol Pyroplex Gold easily surpasses competitive greases in mobility during low temperatures. This confirmed mobility makes Castrol Pyroplex Gold an ideal choice for most equipment with central lubricating systems.

Stayability

Castrol Pyroplex Gold uses Castrol's trademarked Hydro-Activation™ technology to guard against water spray off. When exposed to moisture, Castrol Pyroplex Gold's hydro-activated additive actually causes an increase in tack and adhesion rather than a softening with eventual washout. The Water Spray Off (ASTM D 4049) test results show that in comparison to other premium greases, Castrol Pyroplex Gold has outstanding adherence to metal surfaces, which lowers grease consumption and maintenance costs.

Mobility

Castrol Pyroplex Gold combines the mobility of a typical NLGI grade 1 grease with the staying power and extreme pressure performance of a NLGI grade 3 grease.

Applications and Recommendations:

- Castrol Pyroplex Gold will excel in multiple bearing applications, sliding applications and high pounding and loading environments.

Castrol® Pyroplex® Gold

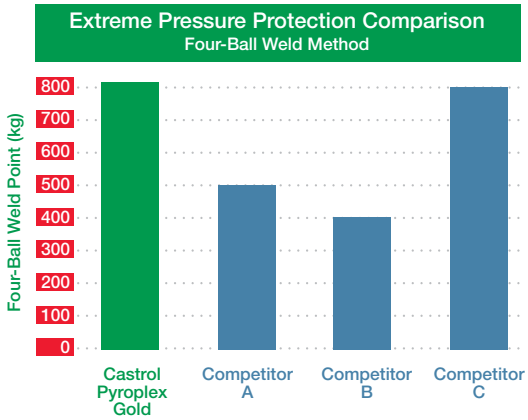
Industry Test Results

Timken OK Load (ASTM D 2509)

Castrol Pyroplex Gold proves its excellent load-carrying capacity by passing the Timken load test with a 70-pound load. The ability to withstand this load is testimony to Castrol Pyroplex Gold's ability to maintain a substantial protective film around critical components, even during high load conditions.

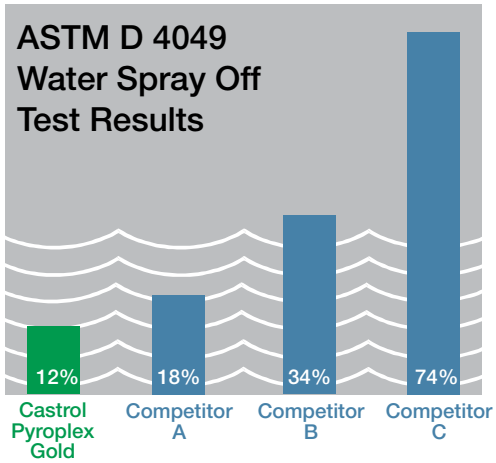
4-Ball Weld Test (ASTM D 2596)

Castrol Pyroplex Gold easily passes the 4-Ball Weld test under the highest load possible (800 kg), which is testimony to its outstanding extreme pressure performance.



Mobility and Water Spray Off

Castrol Pyroplex Gold boasts excellent mobility through a wide temperature range and still has excellent staying power as evidenced by this chart. Castrol Pyroplex Gold combines the staying power of a NLGI grade 3 grease with the mobility of a NLGI grade 1 grease.



Castrol® Pyroplex® Gold

Field Test Results

Concrete Company

Castrol Pyroplex Gold was used on a front end loader at a concrete company in Pennsylvania. Testing confirmed an extended grease interval of 100 hours on track/roller applications. In relationship to the amount of work performed, the truck moved over 400 tons of concrete during ten-hour shifts without having to re-grease. The customer was able to double grease intervals in roller applications using Castrol Pyroplex Gold. Per ton of concrete and at previous intervals, the volume and cost of grease are lower than the competitive product at this facility.

Castrol Pyroplex Gold successfully eliminated the dry spots on the rollers, which were a serious complaint and safety issue. As a result, it is now used on the rollers of every vehicle.

Industrial Company

An industrial customer was chosen as a test site for Castrol Pyroplex Gold due to the severity of the test environment. Castrol Pyroplex Gold was used to lubricate the most severe, four-bearing applications on a Nitrate Roaster. Ambient temperatures on two of the trunnion bearings are close to 800°F; they are extremely wet; and all four are in a very dusty, abrasive environment under heavy loads. The company's main objectives for testing Castrol Pyroplex Gold was to reduce operating temperatures and minimize water washout and bleeding.

Lubricating at normal intervals, temperatures were taken prior to lubricating the equipment. Castrol Pyroplex Gold, with over 20% lubricating solids, can effectively increase tack and adhesion and increase load bearing area, which reduces unit pressures, operating temperatures and wear.

Castrol Pyroplex Gold successfully lowered operating temperatures by an average of 115°F in 48 hours and 300°F in six weeks with no bleeding or water washout. In the very harsh environment of battery acid and component production, Castrol Pyroplex Gold is now being used on the entire Roaster and is being implemented in other applications.

Castrol Pyroplex Gold is a uniquely formulated, semi-synthetic, aluminum complex grease that excels in heavily loaded construction, mining, and industrial equipment where extreme operating conditions prevail. Castrol Pyroplex Gold contains a high level of synergistic solids, including 6% molybdenum disulfide, for outstanding surface adhesion and added extreme pressure characteristics. Its tough, durable lubricating film will protect all lubricated parts in high shock loads and boundary conditions.

Castrol Pyroplex Gold's Hydro-Activated™ polymers coupled with the aluminum complex thickener and carefully selected semi-synthetic base fluids provide excellent "stay-in-place" ability and performance in the presence of very wet and or high humidity environments. The advanced formulation couples extreme pressure performance and "stay-in-place" ability in selected applications with outstanding mobility through all seasons. Castrol Pyroplex Gold (NLGI 2) has assured pumpability in most cold environments, thus eliminating the traditional approach of changing to a NLGI 1 grade in winter.

Castrol Pyroplex Gold has exceptional extreme pressure and high temperature performance as demonstrated through field test conditions and the Timken and Four-Ball Weld tests on page F9. In noting the performance characteristics, Castrol Pyroplex Gold will excel in multiple bearing applications, sliding applications and high loading and pounding environments.

Castrol® Pyroplex® Gold

Typical Analysis

NLGI Grade		1	2
Thickener Type		Aluminum Complex	Aluminum Complex
Color		Gold	Gold
Appearance		Smooth-Tacky	Smooth-Tacky

Test	Method	Results	
		1	2
Penetration W60	ASTM D217	330	272
Dropping Point °F.	ASTM D2265	500	500
Base Oil Viscosity	ASTM D445		
SSU @100°F.		700	1,214
SSU @210°F.		78	114.5
cSt @40°C		134.2	232
cSt @100°C		14.6	23
Four Ball Weld	ASTM D2596	800 kg	800 kg
LWI	ASTM D2596	115	120.2
Scar-mm	ASTM D2266	0.40 mm	0.39 mm
Timken OK Load	ASTM D2509	70	70
Water Spray-off	ASTM D4049	30	11.7
Mobility g/min	USS		
@77°F.		1810	624
@60°F.		908	305
@40°F.		421	85.2
@20° F.		91	20.8
@0°F.		12.1	1.6
Wheel Bearing Life	ASTM D3527	140 hrs.	140 hrs.
Copper Corrosion	ASTM D4048	1A	1A
Rust Prevention	ASTM D1742	Pass	Pass

Castrol® Pyroplex® Blue

Stayability

Castrol Pyroplex Blue maintains mobility while building tack and adhesion when faced with water contamination. This Hydro-Activated™ technology helps Castrol Pyroplex Blue resist softening and washout when exposed to wet conditions on a continued basis. Castrol Pyroplex Blue users can expect excellent equipment performance when using this grease.

Long Bearing Life

The extreme pressure and anti-wear additives in Castrol Pyroplex Blue promote extremely long bearing life. This translates to less downtime and more profitable operations for users.

Outstanding Lubricant Film Strength

Castrol Pyroplex Blue, in high temperature environments, adheres to metal surfaces and provides a strong barrier of protection for critical components.

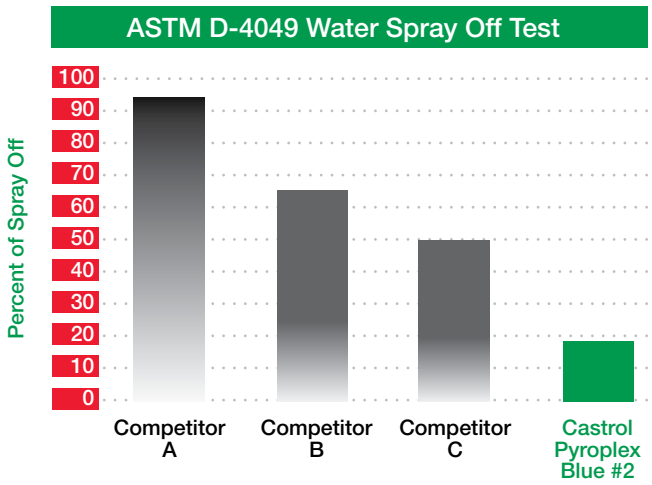
Extended Service Intervals

Because Castrol Pyroplex Blue stays in place, there is less need to add grease, which equals less grease usage and extended lubrication intervals.

Industry Test Results

Water Spray Off Test (ASTM D 4049)

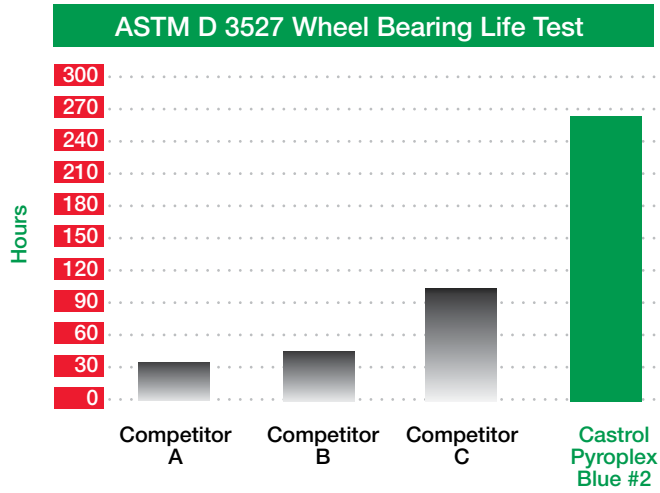
Castrol Pyroplex Blue 2 experiences a low 15 percent water spray off as tested in ASTM D 4049. Competitive greases have as much as 96 percent spray off.



Castrol® Pyroplex® Blue

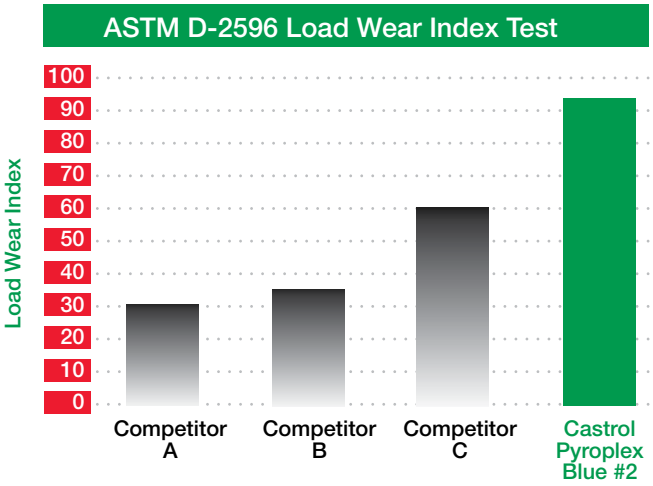
Wheel Bearing Life Test (ASTM D 3527)

The ASTM D 3527 measures the high-temperature performance of a grease in wheel bearings. Castrol Pyroplex Blue shows exceptionally long bearing life as evidenced by this chart.



Load Wear Index Test (ASTM D 2596)

Castrol Pyroplex Blue delivers almost twice the level of anti-wear performance when compared to a typical multi-purpose EP grease as measured by the ASTM D 2596 test.



Castrol® Pyroplex® Blue

Field Test Results

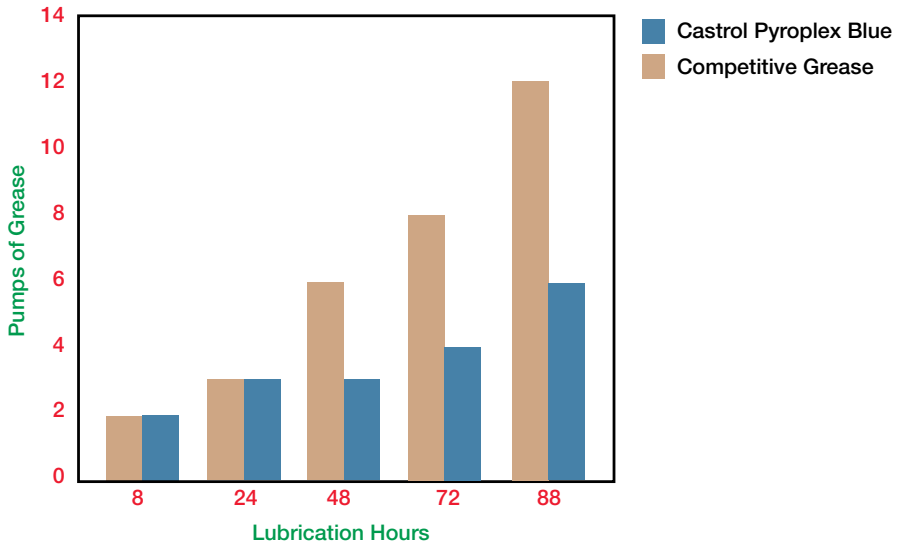
Construction Company

Castrol Pyroplex Blue was put to the test at a New Jersey construction company. Two new zero-hour front end loaders were selected for the test. Similar workloads, lubrication intervals, shift changes and ambient temperature ranges helped to facilitate an equal comparison.

Each grease was reviewed on several key characteristics: grease consumption, pumpability, adhesion, cohesiveness, water washout, extreme pressure capability, anti-wear protection and service duration. The grease was used to lubricate the entire machine with special attention given to bucket pins. The front-end loaders were performing high volume stock piling/loading with normal lubrication intervals. The first phase of the test ran for over 2,000 hours.

At the end of this phase, a second test phase was launched that measured extended service capabilities. The lubrication interval on each machine was extended one operating shift and grease consumption was compared to the baseline established in the previous test phase. Castrol Pyroplex Blue emerged as the winner of both test phases for several reasons. Compared to the premium competitive grease, it took less Castrol Pyroplex Blue to lubricant the machine. The loader with the competitive grease experienced pin squealing, as a result of no lubrication at 85 hours. Castrol Pyroplex Blue, at 88 hours, was going strong with no squealing. After breaking down the loader with Castrol Pyroplex Blue, the bucket pins showed no visible signs of wear after over 2,000 hours of service—a testament to Castrol Pyroplex Blue's ability to withstand the most severe operating conditions and seal out dirt and water.

This company is now a firm believer and user of Castrol Pyroplex Blue. They save money using Castrol Pyroplex Blue because it takes less Castrol Pyroplex Blue to lubricate their machines. Overall, the switch to Castrol Pyroplex Blue has increased revenue per ton for this company due to a reduction in grease and maintenance costs.



Castrol® Pyroplex® Blue

Castrol Pyroplex Blue is the ultimate lubricant for very wet and performance-challenging on- and off-highway environments. Castrol Pyroplex Blue's unique multifunctional solid lubricant additive builds tack and adhesion when exposed to water saturated environments. When performance is challenged in the presence of water and humidity, Castrol Pyroplex Blue not only resists softening and washing out, but grows in tack and adhesion with continued exposure. In high temperature environments, film strength is increased between metal surfaces, and the affinity for metal surfaces is enhanced. This produces a slippery physical barrier of protection.

Castrol Pyroplex Blue's enhanced load-carrying ability is coupled with dramatic oxidative characteristics and high-temperature structural stability for exceptional performance in heavily loaded bearings.

Features	Advantages	Benefits
Unique multifunctional, non staining solid film lubricant.	Better adhesion with improved mobility. Increased tack in the presence of water.	Optimal off/on highway and industrial performance for equipment durability.
Enhanced extreme pressure and anti-wear performance.	Bearing life greatly improved.	Extended equipment life.
Lithium complex.	Excellent shear stability and very stable at high temperatures. (Note: Drop Point.)	Dependable performance under varying conditions for reduced maintenance costs.

Castrol Pyroplex Blue's environmental impact is reduced through the non-utilization of antimony, barium, lead or chlorinated compounds.

Castrol® Pyroplex® Blue

Typical Analysis

NLGI Grade	1	2
Thickener-Type	Lithium Complex	Lithium Complex
Color	Blue	Blue
Appearance	Smooth-Tacky /Stringy	Smooth-Tacky /Stringy

Test	Method	Results	
		1	2
Penetration W60	ASTM D217	325	280
Dropping Point °F	ASTM D2265	530	550
4 Ball EP	ASTM D2596		
Weld Point		500 kg	500 kg
LWI		90	93
4 Ball Scar-mm	ASTM D2266	0.33 mm	0.39 mm
Timken OK Load	ASTM D2509	60	60
Mobility - gsm/min			
@77°F		660	410
@60°F		300	170
@40°F		82	55
@20°F		27	14
@0°F		6	2
Water Spray Off	ASTM D4049	40.0	18.0
Base Oil Viscosity	ASTM D445		
SSU @100°F		750	1150
SSU @210°F		75	115
cSt @40°C		114	247
cSt @100°C		60	24
Rust Prevention	ASTM D1743	Pass	Pass
Wheel Bearing Life	ASTM D3527	225	240
Wheel Bearing Leakage	ASTM D4290	9.3	1.9
Oxidation Stability (psi loss)	ASTM D942	2	2
Copper Corrosion	ASTM D4048	1B	1B

Castrol® Pyroplex® Red

High Temperature Performance

Castrol Pyroplex Red is a high temperature EP lithium complex grease that meets the highest performance standards of automotive GC-LB (particularly disc brake wheel bearings), fleet, industrial and off-highway applications. Its ability to withstand extreme high temperatures makes it a particularly good grease for use with disc brake wheel bearings. It is highly dependable in a variety of machines and applications.

Formulated from selected base stock and containing unique oxidation inhibitors, this grease possesses outstanding thermal stability. In selecting the extreme pressure and anti-wear package, great care was exercised in choosing only additives that had temperature characteristics similar to the grease itself. Castrol Pyroplex Red has excellent rust protection, mechanical stability and compatibility with other greases.

Shear Stability

Castrol Pyroplex Red has the shear stability to stay in grade and in place over long periods of use.

Additive Package

Castrol Pyroplex Red employs top-quality extreme pressure and anti-wear additives. As a result, Castrol Pyroplex Red can withstand conditions of severe shock and high loads.

Compatibility

Castrol Pyroplex Red has demonstrated excellent compatibility with other greases.

Industry Test Results

4-Ball Weld (ASTM D 2596)

Castrol Pyroplex Red passes the 4-Ball Weld test with a load of 400 kg.

Timken OK Load

Castrol Pyroplex Red passed the Timken OK Load test with a 60 lb. load.

Mobility (in grams per minute)	1	2
@60°F	600	470
@40°F	378	280
@20°F	120	65
@0°F	16	9
Water Spray Off (D 4049)	75%	55%

Castrol® Pyroplex® Red

Features	Advantages	Benefits
Lithium complex	Versatility for all types of machinery in almost any industry. Versatility of application: i.e., bearings of all kinds, coupling, gears, etc.	Longer equipment life through noted dependability in these applications.
Excellent shear stability (or ability to stay put in a bearing).	No breakdown or run out over long periods of use.	Maintenance cost savings through dependable lubrication.
Storage characteristics are good over long periods of time when required.	Retains all of its properties in storage, in packing for pre-lubricated bearings, etc.	Longer equipment life. Less overall maintenance costs through noted dependability.
Excellent extreme pressure and anti-wear package.	Outstanding service under conditions of high loading and severe shock loading.	Less equipment downtime. Longer equipment life and less maintenance cost.

Typical Analysis

NLGI Grade	1	2
Thickener-Type	Lithium Complex	Lithium Complex
Color	Red	Red
Appearance	Tacky	Tacky

Test	Method	Results	
		1	2
Penetration, worked @ 77 °F.	ASTM D217	314	270
Dropping Point, °F.	ASTM D2265	502	538
4 Ball EP	ASTM D2596		
Weld Point		400	400
LWI		53	60
4 Ball Scar - mm	ASTM D2266	0.43	0.43
Timken OK Load	ASTM D2509	60	60
Mobility - gms/min			
@60°F.		600	470
@40°F.		378	280
@20°F.		120	65
@0°F.		16	9
Water Spray Off	ASTM D4049	75	55

Castrol® Pyroplex® Red

Test	Method	Results	
		1	2
Base Oil Viscosity	ASTM D445		
SSU @100°F.		900	900
SSU @210°F.		101	101
cSt @40°C		194	194
cSt @100°C		21	21
Viscosity Index		125	125
Rust Prevention	ASTM D1743	Pass	Pass
Water Washout, % Loss @175°F.	ASTM D1264	5.1	3.2
Oil Separation %	ASTM D1742	5.3	2.8
Wheel Bearing Life - hrs	ASTM D3527	85	100
Wheel Bearing Leakage, g	ASTM D4290	3	1.5
Oxidation Stability @ 100 hr, psi loss	ASTM D942	2	1
Copper Corrosion	ASTM D4048	1b	1b

Castrol® Pyroplex® Protection ES

Castrol Pyroplex Protection ES is a specially formulated synthetic lithium complex grease designed for extended service performance in challenging on-highway applications. Its unique inhibitor additive system provides excellent protection against rust, oxidation and corrosion. When performance is challenged in severe corrosive environments, Castrol Pyroplex Protection ES not only resists rust and corrosion, but provides unmatched protection for moving parts, reducing component wear and promoting longer equipment and lubricant life. Its inherent flow properties across wide temperature ranges make Pyroplex Protection ES ideal for automatic lubrication systems on mobile equipment.

Castrol Pyroplex Protection ES is an extension of Castrol's exclusive Hydro-Activation™ technology coupled with a lithium complex thickener, tackifiers, corrosion inhibitors, proprietary additives and carefully selected synthetic base fluids that provides corrosion resistance, extreme pressure performance, and "stay-in-place" ability with outstanding mobility through all seasons.

Features	Advantages	Benefits
Full synthetic.	Provides excellent low and high temperature performance. Oxidation minimized through excellent thermal stability. Noted load carrying ability.	In most climates, the NLGI #2 can be used year round due to exceptional pumpability. Cooler operation carrying ability. Longer equipment life. Longer lubricant life.
Unique inhibitor additive system.	Provides excellent protection against rust, oxidation and corrosion in extreme environments.	Field corrosion protection assured for longer component life. Extended service protection.
Castrol's exclusive Hydro-Activation™ technology.	Better adhesion with outstanding mobility. Increased tack in the presence of water.	Excellent on-highway performance for equipment durability and extended service.
Extreme pressure and anti-wear performance.	Bearing life greatly improved.	Extended equipment life.

Castrol Pyroplex Protection ES' environmental impact is reduced through the elmination of antimony, barium, lead or chlorinated compounds.

Castrol® Pyroplex® Protection ES

Typical Analysis

NLGI Grade	1	2
Thickener Type	Lithium Complex	Lithium Complex
Color	Light Purple	Light Purple
Appearance	Smooth-Tacky	Smooth-Tacky

Test	Method	Results	
		1	2
Penetration Worked at 77 °F.	ASTM D217	325	280
Dropping Point °F.	ASTM D2265	550	550
Base Oil Viscosity	ASTM D445		
SSU @100°F		1480	1480
SSU @210°F		144	144
cSt @40°C		320	320
cSt @100°C		30	40
Four Ball:			
Weld, kg	ASTM D2596	400	400
Scar, mm	ASTM D2266	0.50	0.40
Timken OK Load	ASTM D2509	50	50
Water Washout	ASTM D1264	10%	3%
Mobillity, g/min	USS		
@60°F		550	475
@40°F		296	146
@20°F		74	25
@0°F		10	3
Emcor Corrosion	ASTM D6138		
5% NaCl, 7 days		0,0	0,0
Copper Corrosion	ASTM D4048	1B	1A
Rust Prevention	ASTM D1742	Pass	Pass
Oxidation Test @210°C, min	ASTM D5483	Greater than 30	Greater than 35
Wheel Bearing Life, hrs.	ASTM D3527	160	160
Wheel Bearling Leakage, g	ASTM D4290	3	1.5

Castrol® Spheerol® SHL 00 [PREVIOUSLY Castrol SHL 00]

Synthetic NLGI 00 Lubricant

Castrol Spheerol SHL 00 is a semi-fluid synthetic (PAO) lubricant that can be used for the lubrication of truck wheel hub assemblies where minimal leakage is desired and long service life is essential. Castrol Spheerol SHL 00 can help alleviate oil leakage from wheel seals that can damage brake shoes, increase maintenance costs and affect the overall safety of the unit. Castrol Spheerol SHL 00 can be utilized in many types of wheel end systems designed for oil and many systems using conventional greases.

Castrol Spheerol SHL 00 is formulated with a lithium complex thickener for exceptional service life, synthetic (PAO) base stocks for low and high temperature performance and stability, and is fortified with extreme pressure and anti-wear additives for extended bearing life. Castrol Spheerol SHL 00 can also be used in certain industrial, quarry, mining or construction applications where a semi-fluid synthetic lubricant is recommended.

Extended Service Protection

With Castrol Spheerol SHL 00's incredible staying power, maintenance managers can safely extend lubricant life and service intervals. Its high/low temperature performance characteristics work to keep the lubricant in service longer, protecting equipment during extreme temperature conditions.

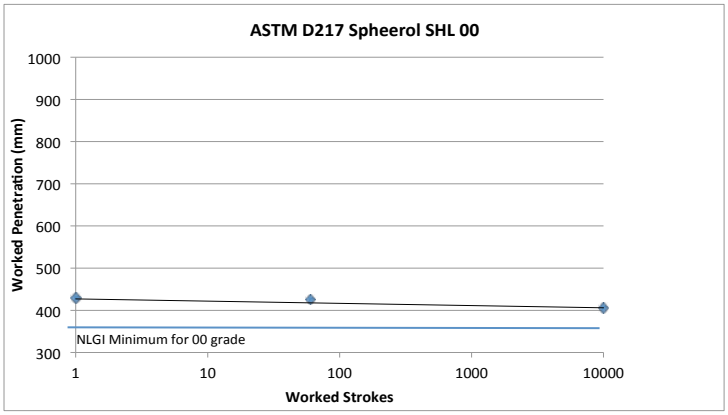
Wear Protection

Castrol Spheerol SHL 00 contains an additive package that promotes long bearing life and guards against wear, rust and corrosion. It is fortified with anti-wear and extreme pressure agents that contribute to extended bearing life.

Industry Test Results

ASTM D 217 Extended Working Test

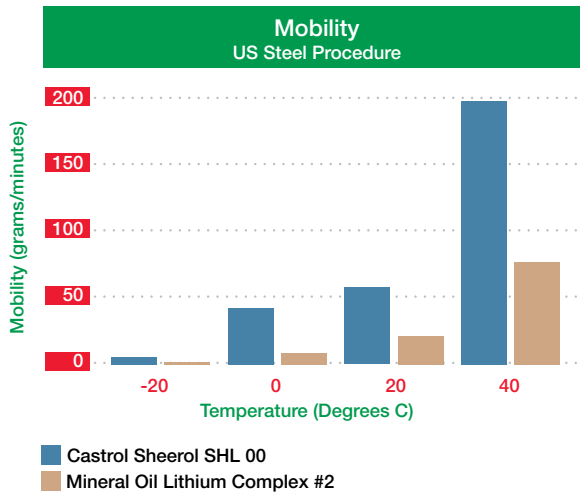
Castrol Spheerol SHL 00 shows incredible stability due to its formulation. As demonstrated by the test below, even after 10,000 strokes worked, Castrol Spheerol SHL 00 experiences little softening or change in its physical makeup.



Castrol® Spheerol® SHL 00 [PREVIOUSLY Castrol SHL 00]

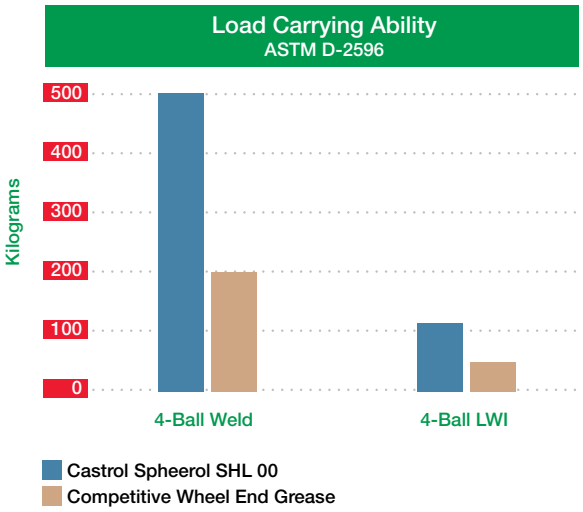
US Steel Mobility

Castrol Spheerol SHL 00 displays good mobility at a wide range of temperatures.



4-Ball Weld

Castrol Spheerol SHL 00 passes the 4-Ball Weld test under a 500 kg load, testimony to its extreme pressure protection.



Castrol® Spheerol® SHL 00 [PREVIOUSLY Castrol SHL 00]

Features	Advantages	Benefits
NLGI 00 consistency.	Couples the lube advantages of a fluid with the "stay put" characteristics of a grease.	Less gear case and wheel seal leakage.
Synthetic (PAO) base stocks	Low temperature mobility and high temperature stability.	Extended service protection.
Lithium complex thickener.	Good water resistance, excellent shear stability and very stable at high temperatures.	Assured performance over the life of the lubricant.
High performance additive package.	Bearing life protection against wear, rust, corrosion and high temperatures.	Longer component life.

Typical Analysis

NLGI Grade	**00**
Thickener Type	Lithium Complex
Color	Blue

Test	Method	Results
Penetration, worked at 77 °F.	ASTM D217	425
Dropping Point, °F.	ASTM D2265	400
Base Oil Viscosity	ASTM D445	
@40°C, cSt		460
@100° C, cSt		42.3
Timken OK Load	ASTM D2059	60
Four Ball EP	ASTM D2596	
Weld Point, kg		500
LWI		110
Four Ball Wear Scar, mm.	ASTM D2266	0.40
Rust Prevention	ASTM D1743	Pass

Castrol® Contractor Special

Castrol Contractor Special is a lithium complex extreme pressure lubricant containing 3% molybdenum disulfide. Castrol Contractor Special is formulated to offer high temperature and heavy-duty performance coupled with good pumpability for applications where a tough, durable lubricating film is needed.

Applications:

- For heavily loaded equipment such as bulldozers, shovels, loaders & off-highway trucks.
- Plain and anti-friction bearings, ball joints, king pins, hinge and bucket pins, heavy-duty chassis lubrication.

Features	Advantages	Benefits
Lithium complex	Provides lubrication at elevated temperatures without breakdown or "run out."	Extended lubricant usage, longer equipment life, reduced lubrication frequency.
3% molybdenum disulfide	Offers an outstanding lubricating film that reduces wear. Enhanced retention on lubricated parts.	Better productivity and less downtime where "boundary lubrication" exists.
Excellent film strength and anti-wear package.	Exceptional performance under conditions of high loading, severe shock & oscillating motion.	Reduced downtime. Longer equipment life. Lower maintenance costs.
Pumpability plus	Readily dispensed from manual pumps as well as automatic systems.	Reduces time and effort to grease the bearings, especially in cold winter months.

Castrol® Contractor Special

Typical Analysis

NLGI Grade		1	2
Thickener-Type		Lithium Complex	Lithium Complex
Color		Gray	Gray
Appearance		Smooth Tacky/Stringy	Smooth Tacky/Stringy
Test	**Method**	**Results**	
		1	2
Penetration	ASTM D217	329	285
Worked @ 77 °F.			
Dropping Point, °F.	ASTM D2265	530	550
4 Ball EP Weld Point	ASTM D2596	400	400
Load Wear Index	ASTM D2596	55	54
4-Ball Wear Scar, mm.	ASTM 2266	0.4	0.39
Timken OK Load	ASTM D2509	50	50
Mobility - g/min	USS		
@77°F.		696	552
@60°F.		400	300
@40°F.		180	110
@20°F.		71	41
@0°F.		15	6
Water Spray Off	ASTM D4049	45	27
@ 100 °F., % Loss			
Base Oil Viscosity	ASTM D445		
SSU @100°F.		700	2,710
SSU @ 210°F.		70	188
cSt @40°C		151	511
cSt @100°C		13	39
Rust Prevention	ASTM D1743	Pass	Pass
Copper Corrosion	ASTM D4048	1B	1B

Castrol® HD Lithium

Castrol HD Lithium is a smooth, dark brown lithium 12-hydroxy stearate EP grease formulated in NLGI 0, 1 and 2 consistencies. It is intended for use on ball and roller anti-friction bearings as well as conventional sleeve bearings.

Castrol HD Lithium is rust inhibited and has good water resistance and long storage life. The base oils utilized in the Castrol HD Lithium grease, coupled with an oxidation inhibitor and EP additives, enable the grease to withstand continuous heavy loads and shock loads.

Typical Analysis

Name NLGI		HD Lithium 0	HD Lithium 2
Thickener-Type		Lithium 12	Lithium 12
Color		Dark Brown	Dark Brown
Texture		Smooth	Smooth

Test	Method	Results 0	 2
Penetration, Worked @ 77 °F	ASTM D217	370	280
Dropping Point °F	ASTM D2265	340	370
Timken OK Load	ASTM D2509	45	50
Base Oil Viscosity			
SUS @100°F		2521	1250
SUS @210°F		151	120
cSt @40°C		470	239
cSt @100°C		31	24
Rust Prevention	ASTM D1743	Pass	Pass

Castrol® HD Lithium 00

Castrol HD Lithium 00 grease is a smooth, dark amber colored, lithium 12-hydroxy stearate grease. Castrol HD Lithium 00 Grease is intended for service where an NLGI 00 grade lithium grease is required, including some automatic grease systems.

[For Castol HD Lithium 000, CONTACT Castrol tech support at 630-961-6562]

Typical Analysis

Test	Method	Results
Color	Visual	Dark Brown
Penetration, Worked @ 77°F	ASTM D217	415
Dropping Point °F	ASTM D2265	300
Base Oil Viscosity	ASTM D445	
SUS @100°F		2630
SUS @210°F		154
cSt @40°C		490
cSt @100°C		32
Timken OK Load	ASTM D2509	40
Rust Prevention	ASTM D1743	Pass

Castrol® Fifth Wheel Grease

Castrol Fifth Wheel Grease has been designed specifically for fifth wheel applications where stay-in-place performance is critical under all weather and application conditions.

Fifth wheels typically experience extreme fretting, which is defined as the removal of finely divided metal particles from rubbing surfaces due to oscillation, sliding or vibration. Castrol Fifth Wheel Grease's graphite/moly formulation and high percent of tackifiers give it a true affinity for metal surfaces. The tacky tenacious properties of Castrol Fifth Wheel Grease, coupled with 10% lubricating solids, further enables this grease to provide outstanding adhesion to fifth wheels in even the toughest of operating conditions.

Typical Analysis

Test	Method	Results
Appearance	Visual	Black/Very Tacky
Penetration, Worked @ 77°F	ASTM D217	270
Water Spray Off @ 100°F, %	ASTM D4049	<10%
Rust Prevention	ASTM D1743	Pass
Copper Corrosion	ASTM D4048	1B
Mobility, g/min @60°F	USS	100

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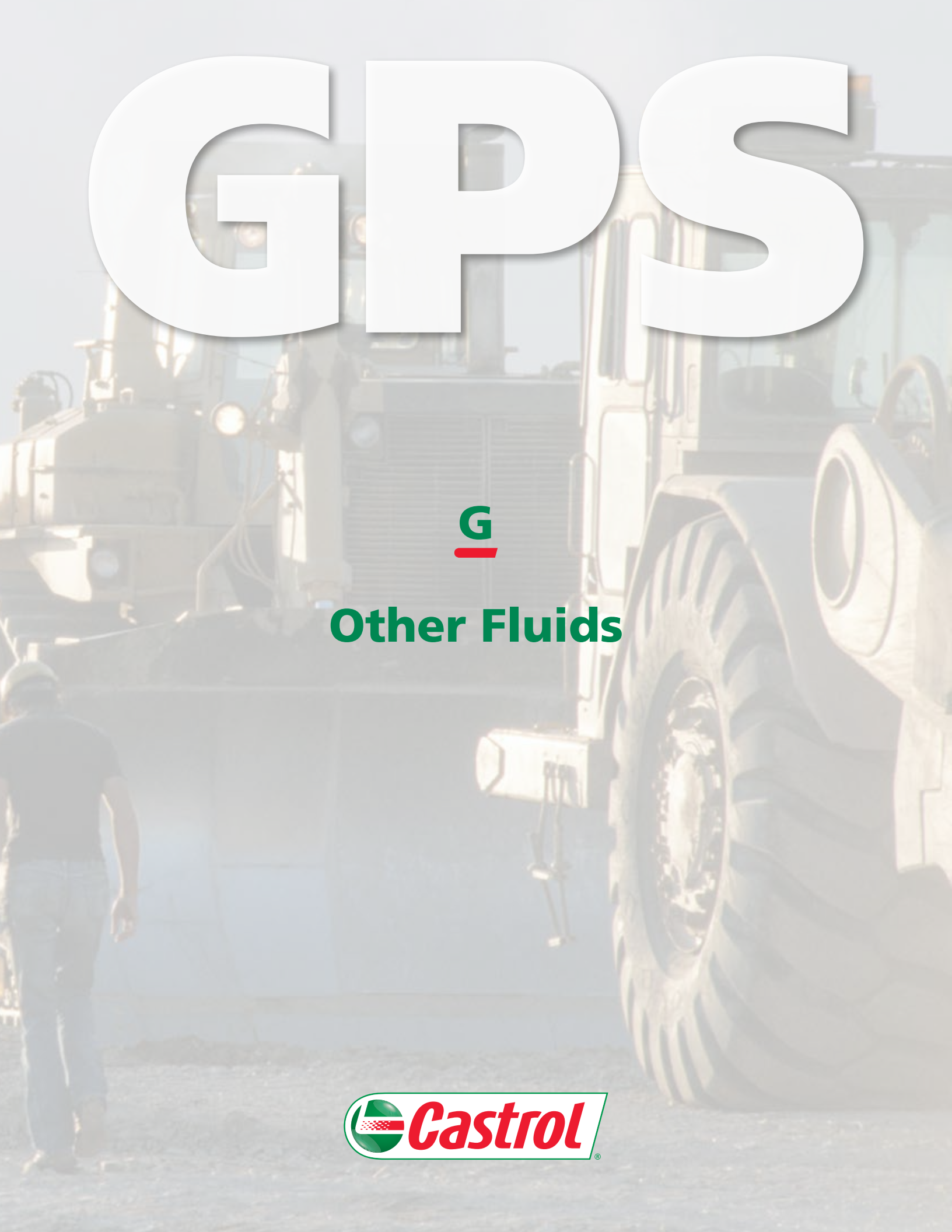
Other Fluids



Other Fluids

Product Data

Castrol® Aircol® SR G2
[REPLACES Castrol SHL Lubricant 32, 46, 68]

Castrol® Magna® RD G4
[PREVIOUSLY Castrol Rock Drill Oil]

Castrol® Magna® SW D G6
[REPLACES Castrol Way Lubricant]

Castrol® Aircol® SR [REPLACES Castrol SHL Lubricant 32, 46, 68]

The Castrol Aircol SR compressor oil range of premium lubricants are designed for use in rotary screw compressors and are based on polyalphaolefin (PAO) fluids.

Application

Castrol Aircol SR is suitable for use in oil flooded rotary screw compressors operating under extreme climatic conditions, harsh environments and severe operating conditions where very high air discharge temperatures (> 100°C) are experienced.

These oils are also suitable for use in compressor units operating at normal operating conditions, with the maximum air discharge temperature =/< 100°C, as defined by ISO 6743-3:2003.

For normal operating conditions, these products can be used for extended drain intervals up to 8000 hours.

The Castrol Aircol SR range is fully compatible with nitrile, silicone, polyurethane and fluropolymer seal materials typically used in compressor units. It is not compatible with butadiene styrene (SBR) or ethylene propylene (EPDM) seals.

Features and Benefits

Castrol Aircol SR is a PAO based lubricant offering good compatibility with seals and mineral oil based lubricants and allowing changeover to Aircol SR without compatibility issues. Castrol Aircol SR offers the following benefits:

- Increased oil service life of typically up to 8000 hours in most systems, depending on the operating environment.
- Very low deposit-forming tendency, thus extending the service life of filters and separators.
- Outstanding oxidation stability and antiwear performance, providing long lubricant and equipment life.
- Ester-free formulation that eliminates the formation of corrosive acids leading to longer equipment life.
- Excellent water separation characteristics, allowing condensation to readily separate from the oil.This minimizes the risk of emulsions, which could block the oil separator element.

Classifications

Aircol SR is classified as follows:

- DIN 51506 classification - VDL
- ISO 6743/3 - DAG, DAH and DAJ for rotary air compressors

Aircol SR grades meet the requirements of:

- Atlas Copco 8000 hour oil drain interval
- Kaeser

Castrol® Aircol® SR [REPLACES Castrol SHL Lubricant 32, 46, 68]

Typical Characteristics

Test	Method	Units	32	46	68	100
Density @ 15.6°C	ASTM D4052	g/ml	0.83	0.84	0.84	0.84
Kinematic Visc. @ 40°C	ASTM D445	mm^2/s	32	46	68	100
Kinematic Visc. @100°C	ASTM D445	mm^2/s	6.1	7.8	10.7	14.0
Viscosity Index	ASTM 2270	--	137	137	142	142
Pour Point	ASTM D97	°C/°F	-54/-65	-54/-65	-54/-65	-48/-51
Flash Point, COC	ASTM D92	°C/°F	264/507	264/507	264/507	280/536
Foam Seq I	ASTM D892	mls/mls	10/0	10/0	10/0	10/0
Rust Test (24 hrs synthetic sea water)	ASTM D665B	--	Pass	Pass	Pass	Pass
RPVOT	ASTM D2272	mins	4,500	3,000	3,000	3,000
FZG fail stage (A8.3/90)	DIN 51354	--	8	8	9	9

Castrol® Magna® RD [PREVIOUSLY Castrol Rock Drill Oil]

Castrol Magna RD Range Oils consist of selected mineral oils specially compounded with lubricity fortifiers, corrosion inhibitors and tackiness additives.

Extreme Pressure Requirements:

Rock drill splines are subject to sliding action under intense pressure. To prevent metal-to-metal contact, a lubricant must have outstanding extreme pressure characteristics. Exceptionally high extreme pressure ratio of 300,000 pounds per square inch is one of the many reasons that Castrol Magna RD is so effective in reducing wear.

Tackiness:

Castrol Magna RD contains a tackiness agent that provides excellent adhesive characteristics to drill surfaces.

Rust and Corrosion Protection:

Castrol Magna RD provides rust and corrosion protection of all internal parts of the drills, even during extended idle periods. Serious rust and corrosion is also prevented in the presence of heavily moisture-laden compressed air. Castrol Magna RD has a balanced additive package that provides good oxidation stability to minimize oxidation and gumming of any parts exposed to high temperatures.

Features and Benefits

Design features and benefits of the Castrol range of high quality rock drill oils include:

- High film strength
- Reduced friction
- Provide a suitable seal between piston and cylinder
- Reduced wear
- Helps maintain maximum percussion efficiency
- Preferentially adhere to metal surfaces and resist blow-off
- Improved protection wear against wear caused by poor lubrication
- Helps maintain operating speed
- Reduced wear, allowing operation in conditions of high or low temperatures

Castrol® Magna® RD [PREVIOUSLY Castrol Rock Drill Oil]

Applications

- Mining
- Quarry
- Construction
- Road work
- Tunneling
- Excavation

Magna RD oils are recommended for companies including Gardner-Denver, Atlas Copco and SIG. However, the correct grade should be selected against specific equipment and for local operating conditions. Most manufacturers include selection charts in their handbooks to assist in the selection of the correct grade.

Typical Characteristics

Name	Method	Units	RD46	RD100	RD150	RD220	RD320	RD460
ISO Viscosity Grade			46	100	150	220	320	460
Density @ 15°C/59°F	ASTM D4052	g/cm^3	0.88	0.89	0.89	0.89	0.90	0.90
Kinematic Viscosity @ 40°C/104°F	ASTM mm2		46	100	150	220	320	460
Kinematic Viscosity @ 100°C/212°F	ASTM D445	mm^2	6.8	11.2	14.7	18.7	24.2	30.5
Pour Point	ASTM D97	°C/°F	-21/-6	-18/0	-15/ 5	-15/ 5	-12/10	-9/16
Flash Point, - open cup method	ASTM D92	°C/°F	220/428	230/446	240/464	260/500	255/491	255/491

[For Castol Magna RD 68, CONTACT Castrol tech support at 630-961-6562]

Castrol® Magna® SW D [Replaces Castrol Way Lubricant]

Castrol Magna SW D is specially formulated for the lubrication of slideways on machine tools. These oils are fortified with selected oiliness, extreme pressure additives and a special material to impart tackiness and adhesiveness.

Magna SW D lubricants are noted for their ability to overcome the stick-slip motion ordinarily associated with slow moving tool parts. They reduce machine tool carriage chatter and possess the necessary adhesive characteristics to prevent squeezing out of the lubricant.

Features and Benefits

Castrol Magna SW D offers the following user benefits:

- Outstanding demulsifying properties to help prevent soluble oil emulsions on plastic slideway surfaces.
- Avoids downtime and expensive slideway repair or replacement.
- Exceptional resistance to stick slip – helps to ensure highly accurate and repeatable machining.
- High quality output is maintained.
- Protects metals against staining and corrosion.
- Oil-wetted surfaces remain in good condition.
- Avoids downtime and expensive slideway repair or replacement.
- Highly filterable – filters in oil supply remain unblocked

Typical Analysis

Name	Method	Units	32	68	100	150	220
Density @ 15°C / 59°F	ASTM D4052	kg/m³	870	880	890	890	890
Kinematic Viscosity	ASTM D445	mm²/s					
@ 40°C/104°F			32	68	100	150	220
@ 100°C / 212°F			5.4	8.7	11.1	14.5	19.2
Viscosity Index	ASTM D2270	--	102	99	98	98	98
Flash Point - open cup method	ASTM D92	°C/°F	206/403	232/450	232/450	232/450	249/480
Rust test - distilled water (24 hrs)	ASTM D665A		pass	pass	pass	pass	pass
Rust test - synthetic seawater (24 hrs)	ASTM D665B		pass	pass	pass	pass	pass
Copper corrosion (3 hrs@100°C/ 212°F)	ASTM D130	Rating	1b	1b	1b	1b	1b
Brugger test	DIN 51347	N/mm²	--	44	--	--	--
Four Ball Wear test Wear Scar Diameter (40 kgf/75°C/1200 rpm/1 hr)	ASTM D2266	mm	0.3	0.3	0.3	0.3	0.32
Four Ball Weld Load test - Weld Point	ASTM D2783	kgf	170	180	180	190	200
Stick-slip ratio	Cincinnati Lamb test	Ratio	0.74	0.74	0.74	0.74	0.74
Cincinnati Lamb Specification	--	--	P-53	P-47	--	--	P-50

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Services

Services

Castrol LABCHECK NEXTGENERATION

The Future of Oil Analysis Technology

For generations, used oil analysis has helped enhance the performance and extend the lifespan of critical machinery around the globe. Today, it's the most widely used form of proactive maintenance technology in the world. In fact, monitoring lubricant conditions within the internal environment of machinery is the **single-most cost-effective method** for extending lubricant drain intervals, preventing catastrophic failure and increasing the lifespan of vital equipment.

Castrol® Labcheck® Next Generation represents the future of oil analysis technology. At the heart of this new program is a cloud-based application that provides the tools and technology needed to get accurate test results and actionable data faster and easier than ever before.

Castrol's mission is to provide the most comprehensive, responsive and intuitive oil analysis service in the industry. This innovative program — and the service representatives behind it — embody a renewed commitment to each and every Castrol customer: Labcheck Next Generation is designed to help you streamline your workload … and simplify your job.

Features and Benefits

Virtually any piece of equipment that has a lubricating system is a candidate for oil analysis. In fact, all service and maintenance managers in construction and mining, as well as on-road and off-road fleet managers, will see substantial benefits from the tools and features engineered into Castrol's Labcheck Next Generation.

By offering clear, analytical data and professional recommendations, Castrol Labcheck Next Generation oil analysis program saves time and effort, enabling users to:

- Identify and measure lubricant contamination
- Assess equipment conditions
- Prevent breakdowns and minimize downtime
- Maximize component lifespan
- Reduce fuel and oil consumption and decrease operational costs
- Eliminate unnecessary overhauls, in-service failures and field repairs
- Establish optimal service schedules

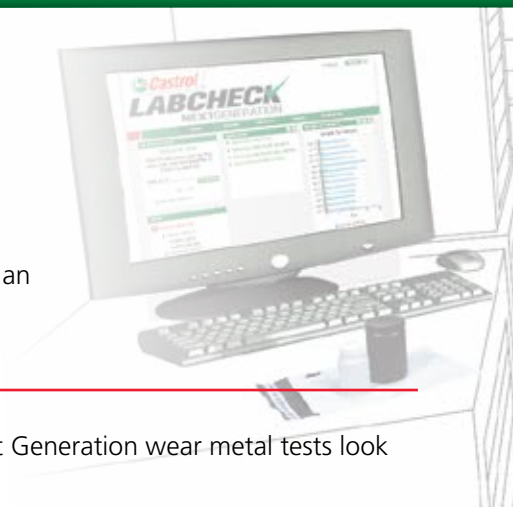
Redesigned with easy-to-use features and helpful shortcuts, Labcheck Next Generation is the most advanced, intuitive used oil analysis program in the industry. It performs a variety of measurements, helping to save real dollars in maintenance, repairs and unscheduled downtime. Sample analysis is completed within 24-48 hours of sample receipt at the laboratory, and critical fleet information is available online 24 hours a day.

Convenient Online Functionality

Directly from the Castrol Labcheck Next Generation home page, you can:

- Locate sample information using simple "search" functions
- Spot items that require immediate attention
- Chart samples by severity
- Track the samples from each worksite
- Review turnaround times
- Monitor first signs of critical wear

Castrol LABCHECK NEXTGENERATION | A Closer Look at Tests



Core Tests

Along with identifying fluid properties and detecting contaminants, our core tests provide an overall picture of the health of your equipment. The seven core tests include:

1. Wear Metals

Wear metals are tested to help locate premature wear and component risk. Labcheck Next Generation wear metal tests look for an abnormally high presence of:

- Silver (Ag)
- Aluminum (Al)
- Chromium (Cr)
- Copper (Cu)
- Iron (Fe)
- Molybdenum (Mo)
- Nickel (Ni)
- Lead (Pb)
- Tin (Sn)
- Other metallic elements, monitoring a total of 21 distinct metals

2. Contaminant Metals

Contaminant metals are monitored in each sample to detect contamination of the fluid in specific compartments. Fluid contamination can cause components to lose efficiency.

3. Viscosity

Viscosity is tested to detect a change in the oil's fluid properties. High viscosity promotes overheating in equipment, restricted oil flow, accelerated wear, impeded low temperature operation and increased friction. Low viscosity promotes overheating, metal-to-metal contact, accelerated wear and increased lubricant leakage. Changes in viscosity can be the result of other problems in the sampled compartment.

4. Fuel Dilution

Used oil is tested for the presence of unburned fuel. Using oil diluted by fuel can lead to rapid and catastrophic component failure due to reduced viscosity and film strength, as well as increased wear/ and the possibility of a fire hazard.

5. Soot

Soot can cause a host of problems, including:

- poor engine performance
- decreased fuel economy
- increased wear
- shortened fluid life
- deposit and sludge formation
- clogged filters
- increased operating costs

This test measures the soot content of used engine oils and flags every sample containing 5% soot or higher.

6. Glycol (Antifreeze)

Antifreeze in any compartment other than the cooling system is a critical problem and can lead to rapid and catastrophic component failure. This test looks for and reports the presence of glycol in components.

7. Water

This test looks for the presence of water, performing moisture checks for coolant leaks or condensation formation. Water contamination can promote acid formation, which can cause components to lose efficiency.

Castrol LABCHECK NEXTGENERATION | A Closer Look at Tests

Optional Tests

When specific problems are detected, more detailed information may be required. Labcheck Next Generation "Optional" tests provide these details. These tests include:

1. Oxidation & Nitration

Excessive oxidation can cause increased wear, decreased engine performance, shortened equipment life, deposits, oil-filter plugging, increased oil viscosity, corrosion of metal parts, increased acidity in oil and restricted oil flow. Heat and oxygen in oil can cause it to break down. Low crankcase oil temperatures accelerate the rate of nitration. By-products cause accelerated oil thickening, formation of acidic by-products, increased cylinder and valve train wear, combustion-area deposits, increased acidity in oil and accelerated sludge formation. Our oxidation & nitration test looks for evidence of all these elements, including the presence of nitrogen by-products, which can accelerate oil breakdown.

2. Acid Number

Increases in the acid number of a fluid may be caused by oxidation, nitration or contamination. The acid number can determine the serviceability of a lubricant in specific applications. A high acid number may indicate corrosion of metallic components, oxidation, oil degradation and additive depletion.

3. Base Number

Engine oil usually begins with a relatively high base number that decreases during use — this is an important factor in establishing oil drain intervals. By monitoring the base number, the potential for oil degradation, increased wear and corrosion of metal parts can be detected.

4. Particle Counting (hydraulic, turbine, and transmission fluids)

This test measures the cleanliness of an oil by determining the level of contaminants. Utilizing two extremely accurate methods, particles over two microns in size can be detected. By closely monitoring the particle counts in a fluid, maintenance professionals can detect wear-causing abrasion at the onset and correct conditions that can cause the level of particulate matter to increase.

5. Ferrography

This test quantifies larger particles that cannot be seen by standard used oil analysis equipment and can correlate them to a problem in the system. Ferrography is typically run for forensic investigative measures to identify the origin and nature of wear or failure mode.

Castrol LABCHECK NEXTGENERATION Test Packages

Labcheck Next Generation also offers standardized "packages" or combinations of routinely performed tests. These consist of tests that the lab can perform in volume, so significant savings are realized when a test "package" is selected. Your Castrol sales rep can assist you in selecting the appropriate combination of tests when you begin your program. The following chart outlines Labcheck Next Generation test packages.

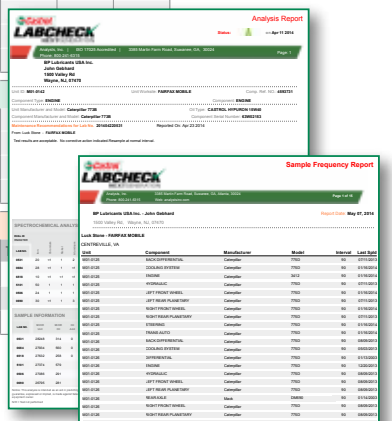
ENGINE		TESTS										
PACKAGE	DESCRIPTION	METALS	FD	SOOT	OX	NTR	V100	V GRADE	W%	GLY	TBN 4739	LEMS
9904EB	Engine Basic	•	•	•	•	•	•	•	•	•		
9904ES	Engine Standard	•	•	•	•	•	•	•	•	•	•	
9904EP	Engine Premium	•	•		•	•	•	•	•	•	•	•

NON-ENGINE		TESTS							
PACKAGE	DESCRIPTION	METALS	V100	V40	V GRADE	W%	GLY	TAN	PQI
9904NEB	Non-Engine Basic	•	•*	•*	•	•	•		
9904NES	Non-Engine Standard	•	•*	•*	•	•	•	•	
9904NEP	Non-Engine Premium	•	•*	•*	•	•	•	•	•

HYDRAULIC		TESTS							
PACKAGE	DESCRIPTION	METALS	V100	V40	V GRADE	W%	TAN	PC	KF
9904HYB	Hydraulic Basic	•	•*	•*	•	•			
9904HYS	Hydraulic Standard	•	•*	•*	•	•	•		
9904HYP	Hydraulic Premium	•	•*	•*	•		•	•	•

NATURAL GAS ENGINE		TESTS							
PACKAGE	DESCRIPTION	METALS	OX	NTR	V100	V GRADE	W%	GLY	TAN
9904NGB	NGE Basic	•	•	•	•	•	•	•	
9904NGS	NGE Standard	•	•	•	•	•	•	•	•
9904NGP	NGE Premium	•	•	•	•	•	•	•	•

Labcheck Next Generation Test Packages



Sample UOA Report

Sample Management Report

Reduce your costs and maximize your equipment life with Castrol Labcheck Next Generation.

Make Labcheck Next Generation part of your long-term maintenance program. If you manage a maintenance operation or a fleet of heavy-duty equipment, large or small, the Labcheck Next Generation used oil analysis program can save you time, energy and money — lots of money. If you're ready to unleash the power of Labcheck Next Generation, give us a call and we'll help you get started.

Getting Started Is Easy

Reach one of our knowledgeable sales representatives by contacting Castrol toll-free at **1-888-CASTROL (1-888-227-8765)**.

For Technical Support

The Castrol Labcheck Support Desk provides industry-leading program and technical support. The support desk can be reached toll-free at **1-866-LABCHECK (1-866-522-2432)** from 7:00 am - 6:30 pm CST.

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GUIDE TO HEAVY DUTY PRODUCTS AND SERVICES

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