Product Information

Endure™ Turbine Oil (6481-6482)

Advanced formula provides superior oxidation stability & deposit control for gas combustion turbines

Formulated specifically for use in gas combustion turbines, Endure™ Turbine Oil (6481-6482) features a unique blend of highly refined base oils and proprietary additive technology. Its advanced formula provides superior oxidative and thermal stability while preventing varnish and sludge formation on critical surfaces. Endure Turbine Oil ensures long-lasting, trouble-free performance in gas combustion turbines, minimizing unplanned outages and maximizing uptime.

Oil problems are estimated to be the cause of nearly one-fifth of all forced turbine outages, according to "A Comprehensive Guide to Industrial Turbine Lubricants," by Afton Chemical Corp. Chief among the various mechanisms inside a turbine system that can result in degradation of the oil while in service are oxidation and thermal degradation.

- **Oxidation** is the reaction of oxygen with a substance. When lubricants are exposed to oxygen, reactions occur that create new substances. For every 10°C (18°F) elevation in temperature, the rate of lubricant oxidation doubles, meaning at higher temperatures reactions speed up.
- **Thermal degradation** occurs during micro-dieseling, cavitation and static discharge events, which produce very high, localized temperatures that thermally degrade the oil molecules in a lubricant.

Oxidation and thermal degradation can lead to base fluid breakdown, additive depletion, increased viscosity, varnish and sludge formation, increased acid number, increased foaming, loss of water separation properties, filter plugging, valve sticking, and rust and corrosion. Bottom line – the lubricant's life span is shortened and equipment reliability is compromised. LE developed Endure Turbine Oil to address these problems.

Beneficial Qualities

- Exhibits superior oxidative and thermal stability for long-term performance
- Inhibits varnish, sludge and deposit formation
- Exhibits superior air release properties and suppresses foam
- Provides outstanding rust, corrosion and anti-wear protection
- Separates readily from water
- Is filterable for long-term oil cleanliness

Proprietary Additive

LE's proprietary additives are used exclusively in LE lubricants. Monolec Turbine Oil contains Monolec.

Monolec® wear-reducing additive creates a single molecular lubricating film on metal surfaces, vastly increasing oil film strength without affecting clearances. An invaluable component in LE's engine oils, industrial oils and many of its other lubricants, Monolec allows opposing surfaces to slide by one another, greatly reducing friction, heat and wear.

Endure™ Withstands Oxidation

TOVT Results Show Endure's Ability To Avoid Varnish Problems

As turbine oil begins to oxidize, byproducts form and start consuming the oil's antioxidant additives. As oxidation progresses, more and more of these byproducts form and begin to coalesce into larger insoluble bodies. With time, these insoluble bodies plate out as varnish in cooler areas of the turbine system, such as sumps, heat exchangers and hydraulic controls. The varnish can lead to serious situations such as trips or failure to start.

To ensure that its turbine oil would withstand oxidation and avoid these problems for its customers, Lubrication Engineers developed a turbine oil varnish test – TOVT. The purpose of this test is to study the oxidative behavior of new turbine oils in an accelerated oxidative environment, with each week of testing equivalent to approximately one year of real world use in a large frame combustion turbine, although there are many factors in actual use that could affect oil longevity.

TOVT was designed so that samples could be analyzed throughout the test to evaluate the fluid's condition.

TOVT Conditions

- A 350-ml sample of new turbine oil is placed in a glass test cell containing a steel/copper wire catalyst conforming to ASTM D5846 specification.
- The test cell – containing oil and catalyst – is placed in a 120°C solid block temperature bath and allowed to equilibrate to 120°C for 20 minutes.
- After equilibration, dry atmospheric air is bubbled through the oil at a rate of 3L/hour throughout the duration of the test.
- The sample is subjected to these aging parameters for up to 18 weeks (3,024 hours ± 20 min).
- After the required aging time has expired, the oil sample is immediately decanted from the test cell and allowed to sit undisturbed for three days prior to analysis.

Endure Survives Weeks of Simulated Oxidation Stress

In LE's TOVT experiment, one week of testing is equivalent to approximately one year of service in a large frame combustion turbine, although there are many factors in real world applications that could shorten (or extend) the life of the oil.

Endure™ Lasts 3x Longer

LE's Turbine Oil Outlasts Competitors in Oxidation Testing

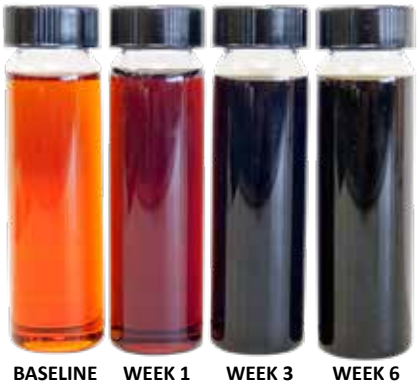
Competitor A

BASELINE WEEK 1 WEEK 3 WEEK 6

Competitor B

BASELINE WEEK 1 WEEK 3 WEEK 6

Competitor C



BASELINE WEEK 1 WEEK 3 WEEK 6

Week 6 Samples Show Dramatic Difference in Fluid Color

Turbine oils can vary widely in color. One of the first indications of oxidation in in-service fluid is color change. As the oils begin to degrade, they experience dramatic color changes and become darker as oxidation byproducts accumulate.

To achieve longer lubricant life, competitive turbine oils have been formulated with higher and higher levels of base oil refinement and increasing levels of antioxidants. However, this contributed to varnish and sludge formation in turbine systems.

Endure Turbine Oil resolves these problems with its unique balanced blend of base oils and additives, specially formulated and proven to inhibit varnish and sludge formation.
The competition – all equivalent turbine oils from major lubricant companies – did not fare as well in the testing.

ENDURE WEEK 6

Oil is still in good condition.

COMPETITOR C WEEK 6

Oil is completely oxidized and not considered usable.

1 WEEK OF TESTING SIMULATES APPROX. 1 YEAR OF USE

Endure™ Controls Degradation Byproducts

Most turbine oils have been designed around oxidative stability and longevity; thus, have not been optimized to resist deposit formation. Because of this, formulators have moved toward highly refined base oils, which are oxidatively more stable but have lower solvency power. This results in higher potential for insoluble varnish and sludge formation. LE designed Endure Turbine Oil to control the formation of degradation deposits. One of the ways this was accomplished was using a base oil blend that has the solvency power to ensure solubility of any degradation products that form, without sacrificing oxidative stability.

Patch Test Reveals Solvency Power of Turbine Oils

Endure Turbine Oil

BASELINE	WEEK 1	WEEK 3	WEEK 6	WEEK 9	WEEK 12	WEEK 18
ΔE 1.2	ΔE 1.6	ΔE 2.5	ΔE 2.8	ΔE 3.2	ΔE 3.9	ΔE 7.0

The Membrane Patch Colorimetry (MPC) test measures the amount of insoluble degradation deposits of in-service turbine oils.

MPC Conditions

- Insoluble deposits are extracted from in-service oil using nitro-cellulose membrane filter (0.45-micron pore size).
- Patch color is analyzed using spectrophotometer, and results are reported as ΔE value.
- MPC ΔE value is used to show insoluble deposits present in turbine oil, and potential for varnish forming on critical surfaces.

Suggested critically ranges for MPC ΔE values are:

- 0-15 – Normal
- 15-30 – Continue to monitor
- 30-40 – Abnormal; varnish might be present
- >40 – Critical; varnish is most likely forming on critical surfaces

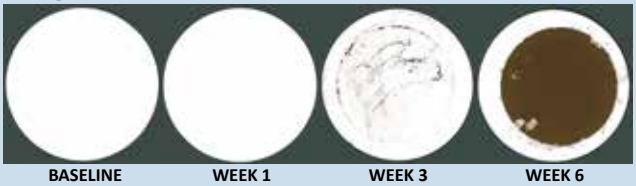
The MPC ΔE values of Endure and competitive turbine oils were measured after being subjected to the TOVT conditions for one to 18 weeks. All three competitor oils exhibited MPC ΔE values greater than 40 after six weeks, indicating they contained critical levels of insoluble deposits.

After 18 weeks under these same TOVT conditions, Endure's ΔE values remained normal, indicating the oil contained little to no insoluble deposits.

Competitor A

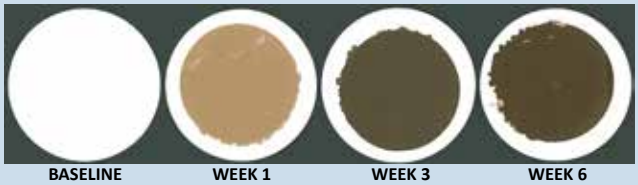
BASELINE	WEEK 1	WEEK 3	WEEK 6
ΔE 0.9	ΔE 32.0	ΔE 38.7	ΔE 64.3

Competitor B



BASELINE	WEEK 1	WEEK 3	WEEK 6
ΔE 3.4	ΔE 6.9	ΔE 12.8	ΔE 75.6

Competitor C



BASELINE	WEEK 1	WEEK 3	WEEK 6
ΔE 4.1	ΔE 38.0	ΔE 84.0	ΔE 102.0

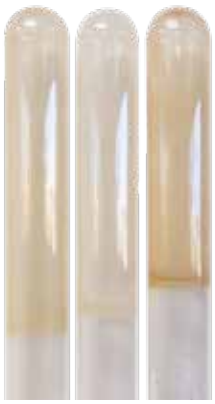
Endure™ Protects Against Varnish

As increasing levels of oxidative and thermal degradation byproducts, as well as degraded additives, form in the turbine oil, they begin to coalesce into larger molecules, which are insoluble in turbine oil. These insoluble degradation products start to plate out as varnish in the turbine system. The photographs below show the TOVT glass vessels of Endure Turbine Oil vs. three major brand competitive turbine oils. The Endure results indicate zero varnish on the TOVT vessels after 18 weeks of stress testing, whereas all three competitors show significant levels of varnish after just six weeks of stressing.

Endure Turbine Oil

NEW VESSEL | WEEK 1 | WEEK 3 | WEEK 6 | WEEK 9 | WEEK 12 | WEEK 18

Competitor A



WEEK 1 | WEEK 3 | WEEK 6

Competitor B

WEEK 1 | WEEK 3 | WEEK 6

Competitor C

WEEK 1 | WEEK 3 | WEEK 6

Additive Blend Key to Endure's Performance

Some antioxidants used in turbine oils become insoluble byproducts as they are consumed by the oxidation process, then end up contributing to varnish formation.

The carefully selected antioxidants in Endure, however, work synergistically to disrupt the oxidation process without causing varnish.

ENDURE WEEK 6

COMPETITOR C WEEK 6

Endure™ Protects Metal Surfaces

Highly Effective vs. Varnish, Rust, Corrosion, Contamination

Insoluble degradation byproducts tend to be polar molecules; therefore, they are attracted to metal surfaces, eventually forming varnish on turbine system surfaces. The biggest problem with turbine oils producing varnish is when the varnish affects valve performance in critical control systems. Varnish buildup on control system valves can cause valves to operate sluggishly or stick completely, resulting in costly skipping, failure to start and shutdowns.

Endure Turbine Oil

New Spring

Competitor A

Competitor B

Competitor C

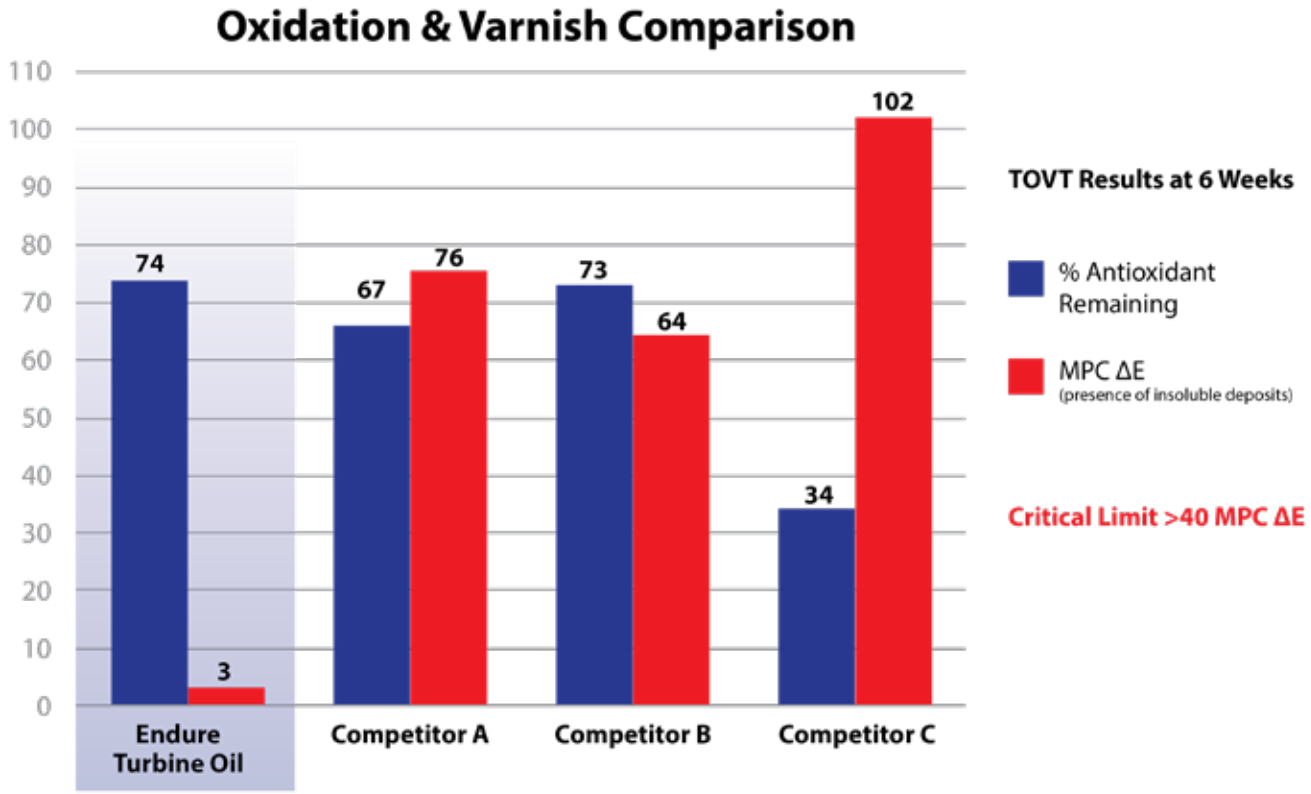
Catalysts Still Look New at TOVT Week 18

Endure Turbine Oil protects surfaces in two ways – first, by inhibiting degradation byproducts from polymerizing and becoming insoluble varnish; second, its advanced rust inhibitors and metal deactivators bind to the metal surface and form a protective layer, keeping contaminants away.

In addition, Endure's corrosion control properties prevent wear metals in the oil from causing a harmful chemical reaction, preventing further oil degradation.

In the TOVT experiment, the copper-iron catalysts of the competitor turbine oils show various levels of varnish buildup on the three- and six-week-aged samples, while the catalysts on Endure are still new in appearance after three, six and even 18 weeks of aging.

Endure™ Protects Gas Turbines



Antioxidant Remaining: The blue bars indicate the percentage of original antioxidants that remain in the fluid after being subjected to six weeks of TOVT stress conditions (equivalent to approximately six years in actual use). Measured using the ASTM D6971 RULER test method, this percentage gives us an idea of the antioxidant depletion rates of each fluid. Endure's antioxidant level remains above that of the other fluids, indicating very good oxidative stability and expected long life in the system.

Varnish Potential: The red bars show MPC ΔE values after six weeks of TOVT. These varnish potential results indicate that Endure is far superior to the competitive oils in mitigating varnish formation in turbine systems.

Keys to Turbine Oil Performance

Oxidation Stability

As the turbine oil is subjected to the stressful operating environment of a turbine system, the oxidative resistance of the fluid diminishes, which in turn increases the potential for varnish and sludge formation. Oxidation stability of the turbine fluid is not determined by the total quantity of antioxidants that are in the turbine fluid (or how large the RPVOT test data is), but rather the depletion rate of the antioxidant in the fluid. See blue bars in graph.

Deposit Resistance

The second key factor in determining how well a turbine oil will perform in use is the ability of the fluid to inhibit deposit formation. As explained previously, varnish deposits and sludge buildup result from base oil oxidation and degradation, additive degradation, and low base oil solvency power. No matter how great the oxidative stability of the turbine fluid, if it cannot effectively manage varnish and sludge formation, turbine issues will begin to occur well before the fluid reaches end-of-life conditions. See red bars in graph.

Technical Data

Endure™ Turbine Oil

	6481	6482
Color	Amber	Amber
Color ASTM D1500	L2.0	L2.0
ISO VG	32	46
Relative Density @ 60°F/60°F, ASTM D1298	0.857	0.863
Viscosity @ 100°C, cSt, ASTM D445	5.46	6.76
Viscosity @ 40°C, cSt, ASTM D445	31.97	45.30
Viscosity Index ASTM D2270	105	102
Flash Point °C (°F) (COC), ASTM D92	232 (449)	232 (449)
Pour Point °C (°F), ASTM D97	-24 (-11)	-24 (-11)
Rust Test 4 hrs @ 60°C, Sea H2O, ASTM D665B	Pass	Pass
Copper Corrosion 3 hrs @ 100°C, ASTM D130	1b	1b
Oxidation by RPVOT @ 150°C, minutes, ASTM D2272	1,150	1,150
Oxidation by TOST hours, ASTM D943	>10,000	>10,000
Four-Ball Wear @ 75°C, 1200 rpm, 40 kgf, 60 minutes, mm wear, ASTM D4172	0.50	0.48
FZG, DIN 51354, A/8.3/90, Failure Load Stage	10	10
Emulsion Characteristics @ 54°C, oil-water-emulsion/minutes, ASTM D1401	40/40/0-10	40/40/0-10
Foaming Characteristics @ 24°C/93.5°C/24°C, 3 sequences, ml of foam/time to break, ASTM D892	0/0, 0/0, 0/0	0/0, 0/0, 0/0
Air Release ASTM D3427 9.0-90.0 cSt @ 40°C: 50°C, minutes	3.0 max	4.0 max

Performance Requirements Met or Exceeded

- DIN 51515, Part I & II
- General Electric
- JIS K 2213 Type 2
- Siemens
- Solar Turbine

Typical Applications

- Combustion turbines
- Combined cycle turbines
- Centrifugal compressors

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