TRANSFORMER OIL PURCHASE SPECIFICATIONS (TOPS)

NOTICE OF REVISION

The Doble Transformer Oil Purchase Specifications (TOPS) was first developed in 1961 alongside the release of the first Annual Oil Survey to provide a benchmark for new insulating liquid manufactured from mineral crude. Since then, the market has expanded and this revision of Doble TOPS includes re-refined mineral oils and new oils refined from alternative hydrocarbon sources. It does not include esters liquids, either natural-based or synthetic types as these are covered under separate specifications. The first page in this specification details the oils which this specification is applicable to. Below is a list of changes made to the specification.

LIST OF CHANGES

- Revision of "Composition" section, page 2
- Removal of Power Factor Value Oxidation and Sludge Free Life testing
- Addition of dielectric constant testing
- Addition of dissolved elements testing for re-refined liquids only
- Increase of interfacial tension minimum limit
- Addition of corrosive sulfur – silver testing
- Addition of the phrase "max" to indicate viscosity limits are maximum values
- Addition of alternative carbon type composition test method
- Revision of stray gassing, dibenzyl disulfide, and free/elemental sulfur testing from optional to required
- Revision of TOPS diagram on page 6

 © 2026 Doble Engineering, a Doble-Megger Company. All Rights Reserved.

TRANSFORMER OIL PURCHASE SPECIFICATIONS (TOPS)

COMPOSITION

This specification covers new insulating oil for use in liquid-filled electrical equipment which are refined from hydrocarbon base product, such as mineral crude (naphthenic or paraffinic), natural gas feedstock, or other suitable hydrocarbon sources. Those refined from crude or gas are indicated by "Refined Mineral Crude or Gas" in the test limits table, while others fall under "Alternative Sourced Liquid". There are a number of different refining processes that may be employed, such as severe hydro-refining, solvent extraction, or other suitable means to yield the properties required, as specified herein.

Re-refined oils, where previously used mineral stock from non-arcing equipment is put through a rigorous refining process similar to that of virgin feed, is covered by this specification and indicated by "Re-Refined Liquid" in the test limits table. Used oil processed through a reclamation process, where contamination and aging byproducts are physically removed (for example using activated alumina or bauxite) are ***expressly excluded*** from this specification. Re-refined oils are classified as -R in this specification, and those from sources other than crude or gas are classified as -N. Equipment OEMs should be contacted to ensure use of -R and -N oils do not compromise any warranty.

ADDITIVES

All additives must be specifically identified or at a minimum identified by class of compounds if the specific information is proprietary. An additive is defined as a suitable chemical substance, which is deliberately added to a mineral insulating oil to improve certain characteristics. Some common examples would be pour point depressants, gassing tendency improvers, metal passivators to help mitigate corrosive sulfur, static electrification or improve oxidation stability, and antifoaming agents.

OXIDATION STABILITY

Uninhibited oils must be free of additives that are used to improve oxidation stability. This includes but are not limited to 2,6 ditetiary-butyl phenol, 2,6 dietertiary- butyl cresol, or metal deactivators such as benzotriazole and its derivatives.

Inhibited oils are insulating oils, which have been supplemented with either 2,6 ditetiary-butyl phenol or 2,6 dietertiary-butyl-p-cresol or any other specified and acceptable oxidation inhibitor. If an additive other than 2,6 ditetiary-butyl phenol or 2,6 dietertiary-butyl-p-cresol is used, appropriate limit values for oxidation stability tests (those for Type I or Type II oils) should be agreed to by the purchaser and seller.

Oils with any detectable amounts of passivator will be assessed using the oxidation stability limits for Type II oils.

PRODUCTION AND SHIPPING

Shipping containers should be dedicated to new transformer oils. It is recommended that if these cannot be provided, the purchaser should approve the cleaning process and documentation related to it prior to use. Recommended cleaning process is steam cleaning followed by hot air drying without the use of a detergent.

The shipping method and containers once agreed upon by purchaser and seller shall not be changed without prior approval of the purchaser.

For some applications, purchasers may use the oil without first degassing. In such cases it is of benefit to test the oil for dissolved gas analysis to obtain baseline data and to avoid introduction of high combustible gases into equipment.

 © 2026 Doble Engineering, a Doble-Megger Company. All Rights Reserved.

Table 1: Test Limits

Test	Notes	ASTM Method	Refined Mineral Crude or Gas	Re-Refined Oil -R	Alternative Sourced Oil -N
Aniline Point, °C		D611	63 min	63 min	63 min
Carbon Type Composition % aromatics % naphthenics % paraffinics	a	D2140	No limits (Product Continuity)	No limits (Product Continuity)	No limits (Product Continuity)
Color		D1500	0.5 max	0.5 max	0.5 max
Corr. Sulfur Copper		D1275	Non-Corrosive	Non-Corrosive	Non-Corrosive
Corr. Sulfur Silver		D1275	Non-Corrosive	Non-Corrosive	Non-Corrosive
Covered Conductor Deposition (CCD)	b	Doble	Non-Corrosive	Non-Corrosive	Non-Corrosive
Dibenzyl Disulfide, mg/kg		Doble	<1	<1	<1
Dielectric Breakdown, kV 1mm gap 2mm gap	c	D1816	1mm: 20 min 2mm: 40 min	1mm: 20 min 2mm: 40 min	1mm: 20 min 2mm: 40 min
Dielectric Constant at 25°C		D924	No limits	No limits	No limits
Dissolved Elements, mg/kg	d	D7151	N/A	0.5 max per element	N/A
Flash Point, °C		D92	145 min	145 min	145 min
Free/Elemental Sulfur, mg/kg		Doble	0.2 max	0.2 max	0.2 max
Furanic Compounds, ug/L	e	D5837	25 max per compound	25 max per compound	25 max per compound
*Gassing Tendency at 80°C, uL/min	f	D2300	No limit, but prefer negative	No limit, but prefer negative	No limit, but prefer negative
Impulse Breakdown Voltage kV at 25°C	g	D3300	145 min	145 min	145 min
Interfacial Tension mN/m at 25°C		D971	43 min	43 min	43 min
Neutralization Number, mg KOH/g	h	D974 (mod)	0.015 max	0.015 max	0.015 max

 © 2026 Doble Engineering, a Doble-Megger Company. All Rights Reserved.

Table 1: Test Limits Contd.

Test	Notes	ASTM Method	Refined Mineral Crude or Gas	Re-Refined Mineral Oil -R	Alternative Sourced Oil -N
Passivator, mg/kg	i	Doble	Requirements for non-passivated oils: None Detected	Requirements for non-passivated oils: None Detected	Requirements for non-passivated oils: None Detected
Polychlorinated Biphenyls (PCBs) mg/kg		D4059	<2	<2	<2
Pour Point, °C	j	D97	-40 max	-40 max	-40 max
Power Factor, % at 25°C at 100°C		D924	25°C: 0.05 max 100°C: 0.30 max	25°C: 0.05 max 100°C: 0.30 max	25°C: 0.05 max 100°C: 0.30 max
Specific Gravity 60/60		D1298 D4052	0.910 max	0.910 max	0.910 max
Stray Gassing, ul/l		D7150	See Table 3 – If any one gas exceeds the limits in Table 1, note that the oil may have a tendency to stray gas.		
Viscosity, Kinematic, mm^2/s 100°C 40°C 0°C	k	D445	100°C: 3.0 max 40°C: 11.0 max 0°C: 76.0 max	See Mineral Limits	See Mineral Limits
Visual		D1524	Clear and Bright	Clear and Bright	Clear and Bright
Water Content, As Received mg/kg		D1533	30 max	30 max	30 max

*Optional tests: can be required by the user of this specification; if required then the values provided in table are the specified limits that must be met
min=minimum, max=maximum, ND=none detected, N/A=not applicable

 © 2026 Doble Engineering, a Doble-Megger Company. All Rights Reserved.

Table 2: Oxidation Testing

All Oils					
Test	**Notes**	**ASTM Method**	**Uninhibited**	**Type I**	**Type II**
Oxidation Inhibitor Content, % by wt.	l	D2668 D4768	ND	0.08 max	0.3 max
Oxidation Stability at 72 hours Sludge, % by wt. Acid, mg KOH/g		D2440	0.15max 0.5max	0.15max 0.5max	0.1max 0.3max
Oxidation Stability at 164 hours Sludge, % by wt. Acid, mg KOH/g		D2440	0.3max 0.6max	0.3max 0.6max	0.2max 0.4max
Oxidation Stability, Rotating Pressure Vessel, minutes		D2112	N/A	195 min	220 min
Passivator, mg/kg		Doble	If any detectable passivator, consider to be Type II		

Notes

a. In the event that ASTM D2140 yields no data (such as for very highly refined oils with very low aromatic contents), ASTM D3238 may be substituted.
b. Covered Conductor Deposition (CCD) testing examines paper insulation in addition to copper for deposits of metal sulfides; both copper rod and Kraft paper must pass for oil to be deemed non-corrosive.
c. Either electrode spacing may be used.
d. Dissolved elements run on re-refined liquids only. This test is for fourteen elements: silver, aluminum, copper, iron, zinc, phosphorus, nickel, molybdenum, sodium, chlorine, magnesium, chromium, titanium, and tin. The limit of 0.5 mg/kg applies to each metal individually.
e. This test is for five furanic compounds, 5-hydroxymethyl-2-furfural, furfuryl alcohol, 2- furfural, acetyl furan, 5-methyl-2-furfural. The limit of 25 µg/l maximum applies to each compound individually.
f. The characteristic is positive if gas is evolved under the conditions of the test and negative if gas is absorbed.
g. Needle negative to sphere grounded, 1 in (25.4 mm) gap.
h. Neutralization number is measured by using 1/100 normal potassium hydroxide standard alcoholic solution.
i. There are oils on the market that contain passivators or similar compounds. In such cases, this requirement would not apply, but all additives must be disclosed to the buyer prior to purchase. Passivated oils are evaluated against Type II limits for oxidation stability testing. The requirements of None Detected are for non-passivated oils. Currently the passivators that can be routinely detected are Benzotriazol and Irgamet 36, both which would need to be <1 mg/kg but note that there are other passivators that can be used.
j. Other limits may be agreed between purchaser and supplier; depending on climate, higher pour points may be acceptable.
k. Requirements at lower temperatures may be agreed between the purchaser and seller. Viscosity is commonly specified at 10°C above the pour point with maximum values at -30°C being 1800 mm^2/s and 2500 mm^2/s at -40°C.
l. Both 2,6-ditertiary butyl-para cresol and 2,6-ditertiary butyl-phenol have been found to be suitable oxidation inhibitors for use in oils meeting this specification. Passivators have also been used to improve the oxidation stability of oils. If such compounds are added in any concentration, Type II limits will be applied to oxidation stability data.

 © 2026 Doble Engineering, a Doble-Megger Company. All Rights Reserved.

Table 3: Stray Gassing Limits

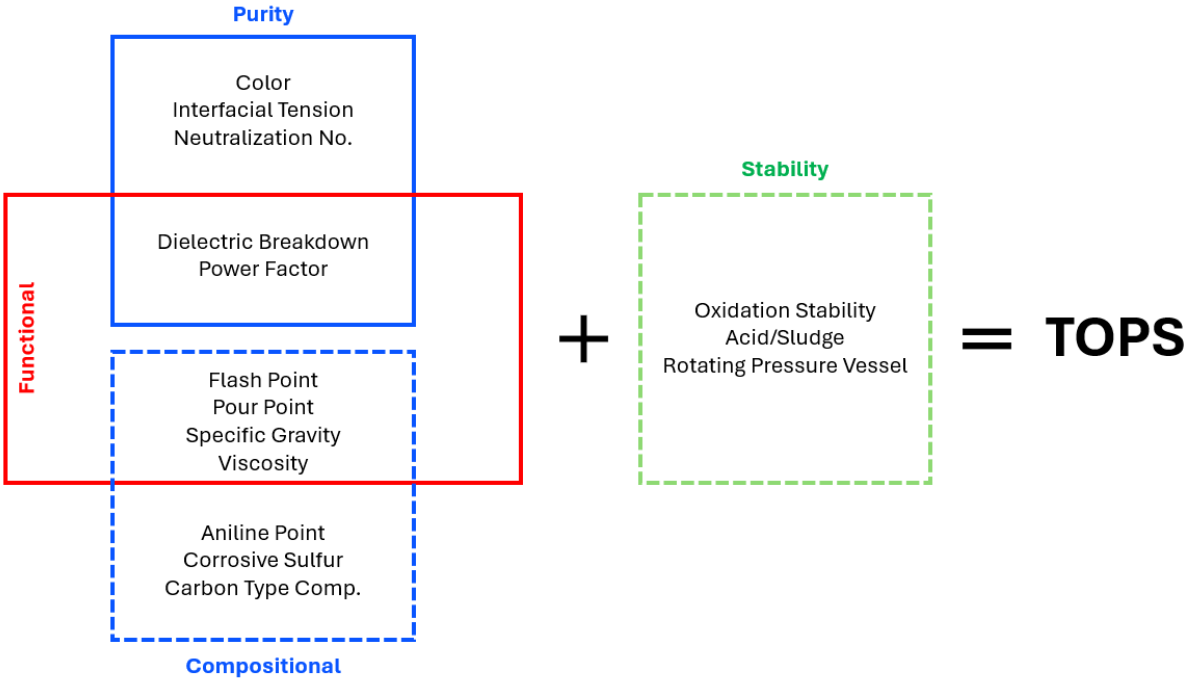
Limits determined by Doble by 95% norms over 3 years (with outliers removed)

	Concentration, ppm (uL/L)	
Gas	**Air Sparged**	**Nitrogen Sparged**
Hydrogen	590	250
Methane	120	80
Carbon Monoxide	450	115
Ethane	120	36
Carbon Dioxide	1580	385
Ethylene	8	6
Acetylene	0	0

Note: Analysis performed by ASTM D3612C after aging

SIGNIFICANCE OF TESTS

The following comments and interpretations, based on both technical understanding as well as empirical knowledge, emphasize those properties that are functionally important to transformer oils:



Aniline Point (D611) The aniline point is the temperature at which a mixture of aniline and oil separates. It provides a rough indication of the total aromatic content and relates to the solvency of the oil for materials that are in contact with the oil. The lower the aniline point, the greater the solvency effect.

Carbon Type Composition (D2140) The carbon type composition characterizes an insulating oil in terms of the percentage of aromatic, naphthenic, and paraffinic carbons. It can be used to detect changes in oil composition and to relate certain phenomena that have been demonstrated to be related to oil composition.

Color (D1500) The color of a new oil is generally accepted as an index of the degree of refinement. For oils in service, an increasing or high color number is an indication of contamination, deterioration, or both.

Corrosive Sulfur (D1275, copper or silver corrosion) This test detects the presence of objectionable quantities of elemental and thermally unstable sulfur-bearing compounds in an oil. When present, these compounds can cause corrosion of certain transformer metals such as copper and silver.

Dibenzyl Disulfide Detection (DBDS) (Doble Procedure) DBDS is a corrosive sulfur compound that has been found in a number of oils known to be involved in metal sulfide deposits inside transformers in service.

Dielectric Breakdown (D1816) The dielectric breakdown is the minimum voltage at which electrical flashover occurs in an oil. It is a measure of the ability of an oil to withstand electrical stress at power frequencies without failure. A low value for the dielectric- breakdown voltage generally serves to indicate the presence of contaminants such as water, dirt, or other conducting particles in the oil.

Dielectric Constant (Relative Permittivity) (ASTM D924) ASTM D924 This is a measure of how well a material can store electrical energy in an electric field compared to a vacuum. ASTM D924 states that “for the first use, a low value of relative permittivity is often desirable in order to have the capacitance be as small as possible, consistent with acceptable chemical and heat transfer properties.” Additionally, other values of relative permittivity may be considered better depending on the situation. ASTM D3487 lists typical values of dielectric constant for mineral oils to be 2.2 to 2.3.

Dissolved Metals (ASTM D7151) Stresses on metallic components in electrical equipment can cause elements to dissolve into the surrounding oil. Testing is done on re-refined oils only in order to detect the presence of any such elements. The elements tested are silver, aluminum, copper, iron, zinc, phosphorus, nickel, molybdenum, sodium, chlorine, magnesium, chromium, titanium, and tin.

Flash Point (D92) The flash point is the minimum temperature at which heated oil gives off sufficient vapor to form a flammable mixture with air. It is an indicator of the volatility of the oil.

Free/Elemental Sulfur (Doble Procedure) This is a very reactive form of sulfur that has been associated with transformers experiencing corrosive sulfur problems.

Furanic Compounds (D5837) Furanic compounds are byproducts of the degradation of cellulosic materials such as insulating paper, pressboard, and wood and serve as indicators of insulation degradations in service. Use of 2-furfural as an extraction solvent can be an unintended source of furans if not properly removed as part of the refining process. To ensure a low baseline, no significant furanic compounds should be present in new oil.

Gassing Under Electrical Stress (D2300) The gassing tendency is defined as the rate of gas evolved or absorbed by an insulating oil when subjected to electrical stress of sufficient intensity to cause ionization. The value is positive if gas is evolved and negative if gas is absorbed. Direct correlation of results with equipment performance is limited at present.

Impulse Breakdown Voltage (D3300) The impulse breakdown voltage is the voltage at which electrical flashover occurs in an oil under impulse conditions. It indicates the ability of an oil to resist transient voltage stresses such as those caused by nearby lightning strokes and high-voltage switching surges. The results are dependent on electrode geometry, spacing, and polarity.

Interfacial Tension (D971) The interfacial tension of an oil is the force in mN/m required to rupture the oil film existing at an oil-water interface. When certain contaminants such as soaps, paints, varnishes, and oxidation products are present in the oil, the film strength of the oil is weakened, thus requiring less force to rupture. For oils in service, a decreasing value indicates the accumulation of contaminants, oxidation products, or both.

 © 2026 Doble Engineering, a Doble-Megger Company. All Rights Reserved.

Neutralization Number (D974) The neutralization number of an oil is a measure of the amount of acidic or alkaline materials present. As oils age in service, the acidity and therefore the neutralization number increases. A used oil having a high neutralization number indicates that the oil is either oxidized or contaminated with materials such as varnish, paint, or other foreign matter. (A basic neutralization number results from an alkaline contaminant in the oil.)

Oxidation Inhibitor Content (D2668, D4760) These tests provide a method for the quantitative determination of the amount of oxidation inhibitor (2,6-ditertiary butyl- paracresol or 2,6 ditertiary phenol) present in an inhibited oil. Control of the inhibitor content is an important factor in maintaining long service life of inhibited insulating oils.

Oxidation Stability (acid/sludge) (D2440) This is a method of assessing the oxidation resistance of an oil by determining the amount of acid and sludge products formed under laboratory accelerated aging conditions. Oils which satisfy the requirements tend to preserve insulation system life and ensure acceptable heat transfer. The test may also be used to check the performance consistency of this characteristic of production oils.

Oxidation Stability (D2112) This test is used as a control test for evaluating the response characteristics of new oils to oxidation inhibitors. It may also be used to check the performance consistency of production oils.

Passivators (Doble Procedure) Passivators, also known as metal deactivators, are sometimes added to an oil to improve oxidation stability and also to reduce the rate of metal sulfide reactions.

Polychlorinated Biphenyls (D4059) Regulations prohibiting the commercial distribution of polychlorinated biphenyls (PCBs) mandate that insulating oils be examined for PCB contamination levels to assure that new products do not contain detectable amounts.

Pour Point (D97) The pour point is the lowest temperature at which oil will just flow. A low pour point is important, particularly in cold climates, to ensure that the oil will circulate and serve its purpose as an insulating and cooling medium.

Power Factor (D924) The power factor of an insulating oil is the cosine of the phase angle between a sinusoidal potential applied to the oil and the resulting current. Power factor indicates the dielectric loss of an oil; thus the dielectric heating. A high power factor is an indication of the presence of contamination or deterioration products such as moisture, carbon or other conducting matter, metal soaps and products of oxidation.

Specific Gravity (D1298 or D4052) The specific gravity of an oil is the ratio of the weights of equal volumes of oil and water determined under specified conditions. In extremely cold climates, specific gravity has been used to determine whether ice, resulting from the freezing of water in oil-filled apparatus, will float on the oil and possibly result in flashover of conductors extending above the oil level. The specific gravity of mineral oil influences the heat transfer rates. Oils of different specific gravity may not readily mix when added to each other and precautions should be taken to ensure mixing.

Stray Gassing (ASTM D7150) This test is used to evaluate the amount of combustible gases generated by an oil after seven days at 120°C. The oil is prepared by sparging one set of samples with oxygen and another set with nitrogen. This is used to simulate the preservation system in use and can influence the type and amount of gases generated in service. An understanding of the tendency of an oil to generate gases at moderate temperatures is beneficial when interpreting DGA data of the transformer in service.

Viscosity (D445) Viscosity is the resistance of oil to flow under specified conditions and is an important factor in assessing ability to act as an effective coolant as it influences heat transfer rates and consequently the temperature rise of an apparatus. The viscosity of an oil also influences the speed of moving parts in tap changers and circuit breakers. High viscosity oils are less desirable, especially in cold climates. Standard viscosity curves can be generated using Method D341.

Water Content (D1533) A low water content is necessary to obtain and maintain acceptable electrical strength and low dielectric losses in insulation systems.

 © 2026 Doble Engineering, a Doble-Megger Company. All Rights Reserved.