# TRANSFORMER OIL PURCHASE SPECIFICATIONS

*(Developed Under the Auspices of the Doble Oil Committee)*

March, 2017

## COMPOSITION

This specifications covers new insulating oil for general applications for liquid-filled electrical equipment, which are manufactured from mineral crude, which may be either naphthenic, which has a very low naturally occurring n-paraffin (wax) content, or paraffinic, which contain substantial n-paraffins. Distillates may be refined using a number of processes, such as hydro-refining, solvent extraction, distillation, or other suitable means to yield acceptable mineral insulating oils at the point of delivery.

## 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.

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## 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.


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# TRANSFORMER OIL PURCHASE SPECIFICATION - TEST LIMITS

| TYPE OF TEST | Notes | ASTM METHOD | UNINHIBITED | INHIBITED | |
|---|---|---|---|---|---|
| | | | | Type I | Type II |
| Aniline Point, °C | | D611 | 63 min | | |
| Carbon Type Composition<br>% aromatics<br>% naphthenics<br>% paraffinics | a | D2140 | No limits<br>Product Continuity | | |
| Color | | D1500 | 0.5 max | | |
| Visual | | D1524 | Clear and Bright | | |
| Corrosive Sulfur – copper corrosion | b | D1275 | Non-corrosive | | |
| Covered Conductor Deposition (CCD) | c | Doble Procedure | Non-corrosive | | |
| Dielectric Breakdown, kV | d | D1816 | 20 min (1mm electrode gap) | | |
| | | | 40 min (2mm electrode gap) | | |
| Water Content, mg/kg (as received) | | D1533 | 30 max | | |
| Flash Point, °C | | D92 | 145 min | | |
| Furanic compounds, ug/L | e | D5837 | 25 max | | |
| Impulse Breakdown Voltage, kV at 25°C | f | D3300 | 145 min | | |
| Interfacial tension, mN/m at 25°C | | D971 | 40 min | | |
| Neutralization Number, mg KOH/g | g | D974 (modified) | 0.015 max | | |
| Pour Point, °C | h | D97 | -40 max | | |
| Power Factor at 25°C, % | | D924 | 0.05 max | | |
| Power Factor at 100°C, % | | D924 | 0.30 max | | |
| Specific Gravity, 60/60 | | D1298, D4052 | 0.910 max | | |
| Viscosity, Kinematic, $mm^2/s$<br>100°C<br>40°C<br>0°C | i | D445 | 3.0<br>11.0<br>76.0 | | |
| Oxidation Inhibitor Content, % by wt. | j | D2668 or D4768 | ND | 0.08 max | 0.3 max |
| Sludge Free Life (SFL), hrs | k | Doble Procedure | 40 min | 64 min | 80 min |
| Power Factor Valued Oxidation (PFVO), % (optional*) | l | Doble Procedure | <4.5 for 140 hours | | |
| Oxidation Stability at 72 hours<br>Sludge, % by weight<br>Total acid no., mg KOH/g | | D2440 | 0.15 max<br>0.5 max | 0.15 max<br>0.5 max | 0.1 max<br>0.3 max |
| Oxidation Stability at 164 hours<br>Sludge, % by weight<br>Total acid no., mg KOH/g | | D2440 | 0.3 max<br>0.6 max | 0.3 max<br>0.6 max | 0.2 max<br>0.4 max |
| Oxidation Stability (Rotating Pressure Vessel), minutes | | D2112 | Not Applicable | 195 min | 220 min |
| Gassing Tendency at 80°C, µl/minute (optional*) | m | D2300 | No limit requirement but prefer negative | | |
| Passivator, mg/kg | n | Doble Procedure | Requirements for non-passivated oils<br>None Detected | | |
| Dibenzyl Disulfide, mg/kg (optional*) | | Doble Procedure | <1 | | |
| Free/Elemental Sulfur, mg/kg (optional*) | | Doble Procedure | <1 | | |
| Stray Gassing, µ/l (optional*) | o | D7150 | No established limits | | |

*Optional tests can be required by the user of this specification; if required, then the values provided in the table are the specified limits that must be met.

Legend:
min = minimum max = maximum s = seconds hrs = hours ND = None Detected


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## Notes

a This method will yield no data for very highly refined oils with very low aromatic contents.

b Optional use of silver in place of copper is covered under ASTM D1275 and may be desirable depending on the intended application.

c Covered Conductor Deposition (CCD) 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. The most recent version of this method is provided with this specification.

d Either electrode spacing may be used.

e The 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 Needle negative to sphere grounded, 1-in (25.4-mm) gap

g Neutralization number is measured by using 1/100 normal potassium hydroxide standard alcoholic solution.

h Other limits may be agreed between purchaser and supplier; depending on climate, higher pour points may be acceptable.

i Requirements at lower temperature 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 is 1800$mm^2$/s and 2500$mm^2$/s at -40°C.

j 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.

k Sludge-Free Life (SFL)**:** The oil is sampled and tested for sludge precipitation every 8 hours over 140 hours of oxidation. The SFL is the number of hours the oil remains sludge-free.

l Power Factor Valued Oxidation (PFVO) is a graph of the oil power factor at 95°C recorded over the course of 140 hours of accelerated aging (graph shown in Figure 1 below). The PFVO and SFL are run concurrently from the same test set-up

m The characteristic is positive if gas is evolved under the conditions of the test and negative if gas is absorbed.

n 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.

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.

o Norms from a limited amount of data from one laboratory are given for reference in Table 1.

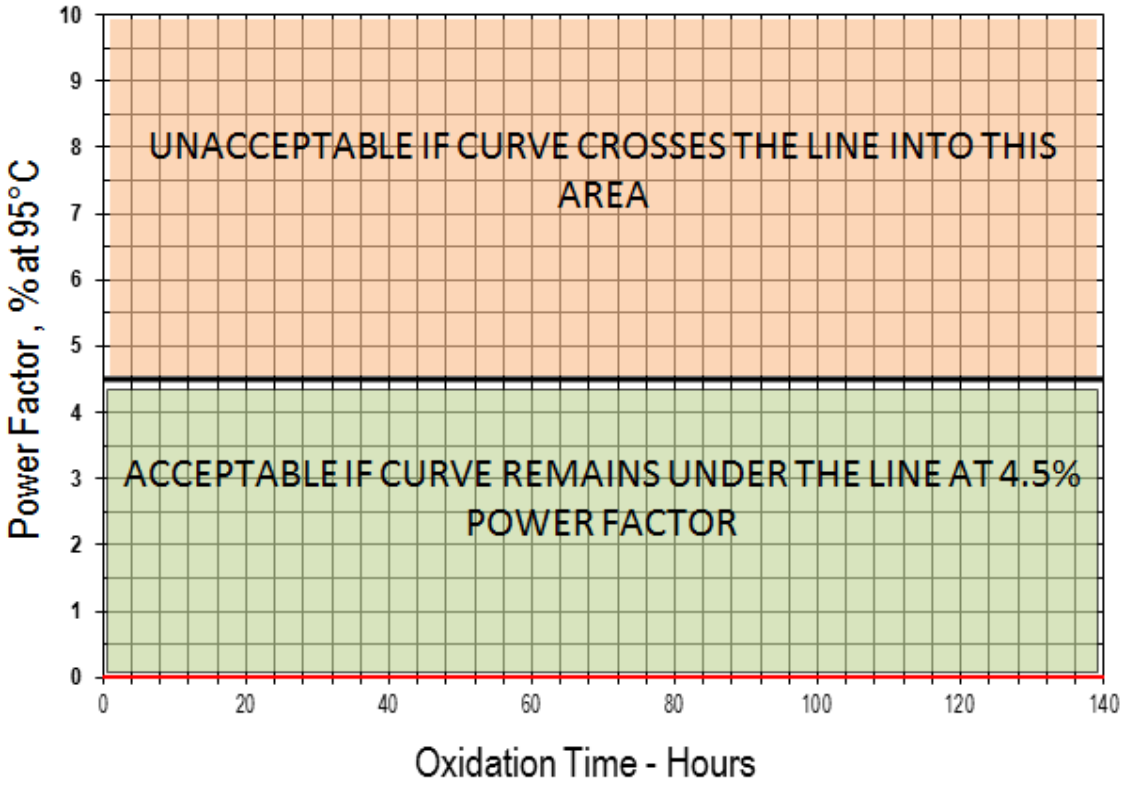



**Figure 1: PFVO Curve**

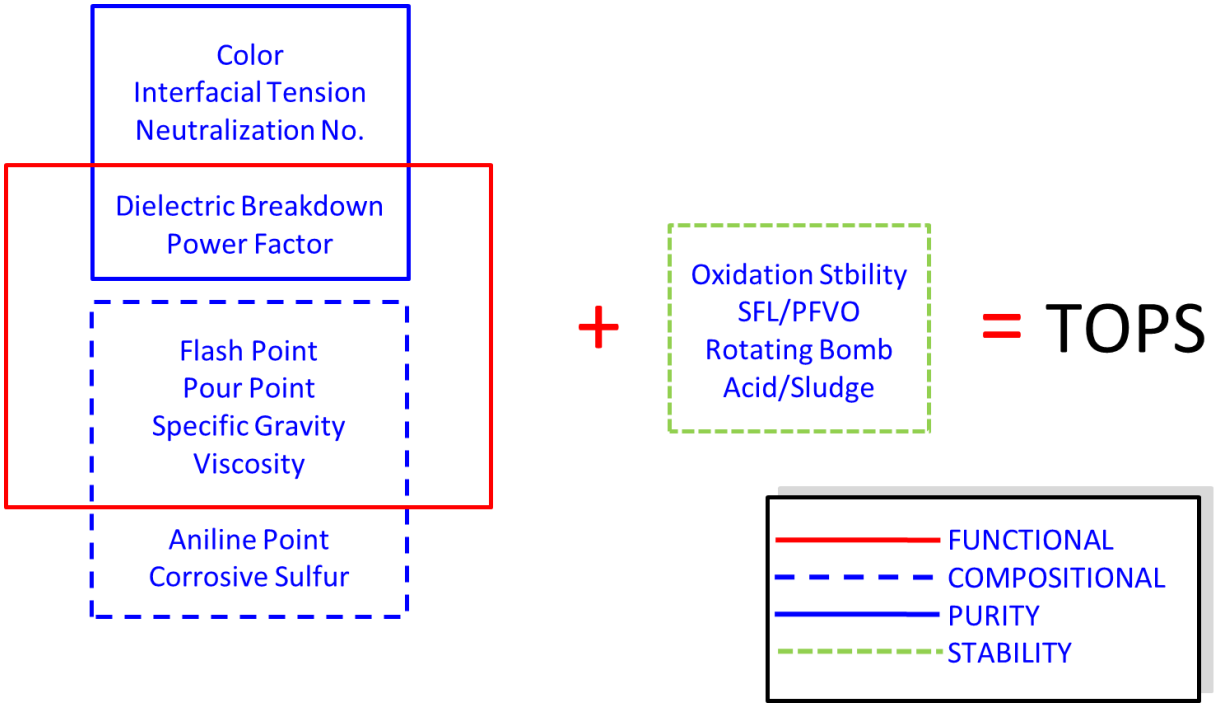
**Table 1**
**Typical Stray Gassing Values**
**95% Norms Determined by Doble over 3 years (with outliers removed)**

| | 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.

**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.

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

**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.

**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.

**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.

**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.)

**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 (D 924)** 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.

**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.

**Power Factor Valued Oxidation (PFVO)** This test, developed by the Doble Engineering Company, ~~periodically~~ measures the power factor of an oil while over a 140 hour period it is being aged at 95°C in the presence of copper and air. The resulting graph of power factor versus time is characteristic of an oil and is a continuity test, as well as a measure of oil quality. The test is run concurrently with the Doble Sludge-Free Life test that measures the time until the oil forms sludge.

**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.

**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.

**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.

**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.

**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.

**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.

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

**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.