

Goodbye “Ghost Particles”: Improving Particle Counting Accuracy with the ASTM D7647 Dilution Method

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Abstract

ASTM D7647 is the ASTM-recommended dilution method for particle counting of in-service lubricants by light extinction. Although the method was specifically designed to eliminate counting errors caused by water and “soft” particles such as varnish and additive precipitates, the diluent list in Annex A1 (Table A1.1) admits both water-masking solvents (75 % toluene / 25 % isopropanol, dipropylene glycol n-propyl ether) and non-water-masking solvents (kerosene, Stoddard solvent, lamp oil). This investigation evaluated seven diluent options on eight lubricants spanning mineral, PAO, PAG and ester chemistries (126 individual analyses). Counts on a varnish-laden turbine oil rose from a 71,996 particles/mL undiluted reference to 142,505 (kerosene, 1:1) and 223,460 (Stoddard solvent - Varsol, 1:2) — increasing further with dilution. On an MTD calibration fluid spiked with 1 % water, the same non-water-masking diluents returned counts of 165,885–250,312 particles/mL versus a dry reference of 10,758. Across the eight samples, solvent choice alone moved the reported >4 µm(c) ISO 4406 cleanliness code by up to 12 codes — a factor of more than 4,000 in particle concentration on the same fluid. We propose limiting the D7647 diluent list to a Toluene/IPA mixture (75:25 or 90:10) and DPnB, and present evidence that 90 % toluene / 10 % isopropanol is the best overall performer when used at 1:2 sample-to-diluent dilution.

Keywords: particle counting, ASTM D7647, water masking, soft particles, varnish, dilution, ghost particles, ISO 4406, in-service lubricants.

1. Introduction

Solid particulate contamination is the dominant cause of mechanical wear and failure in lubricated and hydraulic systems. Particle counting by automatic optical particle counters (APCs) operating on the light-extinction principle has been the standard tool for monitoring this contamination for more than three decades. APCs detect a particle when its passage through a laser-illuminated sensing zone produces a transient drop in transmitted light intensity; the magnitude of the drop is converted to an equivalent particle size using a calibration curve derived from ISO 11171 [1].

This optical principle is non-discriminating. Anything that occludes the beam — a solid particle, an air bubble, a water droplet, an inhomogeneous region of soft varnish or sludge — is recorded as a particle. Water and soft contaminants therefore produce “ghost particles”: optical events that do not correspond to wear-relevant solids and that artificially inflate the reported cleanliness code, sometimes by orders of magnitude.

ASTM D7647, “Standard Test Method for Automatic Particle Counting of Lubricating and Hydraulic Fluids Using Dilution Techniques to Eliminate the Contribution of Water and Interfering Soft Particles by Light Extinction” [2], was introduced in 2010 specifically to address this problem. Its title is unambiguous: a dilution method whose purpose is to eliminate the contribution of water and soft particles. In practice, however, the method as written is non-specific about how that elimination is achieved. Annex A1 (Table A1.1) of the current revision, D7647-24, lists six allowable diluents — only two of which (75 % toluene / 25 % isopropanol, hereafter “75/25 T/IPA”, and dipropylene glycol n-propyl ether, hereafter “DPnB”) are classified as “water-masking” in the standard’s own definition (§ 3.2.8.1) [2]. Of the remaining four — kerosene, lamp oil, Stoddard solvent and 67:33 lamp oil:DPnB — the first three have no recognised ability to dissolve water at any level and, as the data presented here will show, also fail to keep many soft contaminants in solution after dilution.

The consequence is well documented. The temporary precision statement in Section 14 of D7647-24 reports reproducibility limits that are several times wider than the analogous limits for ISO 11500 on clean reference fluids. Round-robin and interlaboratory study (ILS) results have repeatedly shown unacceptably broad scatter, with the same sample drawing both the cleanest and the dirtiest result of any laboratory in a

given study — a pattern that becomes intelligible once it is recognised that participating laboratories have been free to choose any solvent in Table A1.1.

This paper revisits a 2023 investigation in which seven candidate diluents (six listed in Table A1.1 plus one new candidate — 90 % toluene / 10 % isopropanol, hereafter “90/10 T/IPA”) were evaluated on a panel of eight lubricants representing the principal in-service oil chemistries seen in industrial laboratories, plus a calibration fluid (MTD CAL) spiked with 1 % and 2 % distilled water. The dataset comprises 126 individual particle-counter analyses. The paper has three goals: (i) to quantify, on common samples, the magnitude of the “ghost particle” error introduced by non-water-masking diluents; (ii) to compare the two water-masking diluents already in Table A1.1 against a 90/10 T/IPA blend that has not previously appeared in the standard; and (iii) to support a forthcoming D02.96.05 ballot to remove non-water-masking diluents from D7647 and to add 90/10 T/IPA as a permitted alternative.

2. The ASTM D7647 method and the diluent table

D7647 is built around four sequential operations: agitation, dilution with a Table A1.1 diluent at typically 1:1 sample:diluent (mass basis, ~50 % undiluted fraction), agitation and degassing of the diluted sample, and triplicate counting through a sensor calibrated to ISO 11171. The dilution step has two purposes. The first is to bring the viscosity of high-viscosity gear and compressor oils down into the operating envelope of the APC (~1–10 cSt at the sensor inlet). The second — and the one that justifies the method’s existence — is to dissolve free or emulsified water and to dissolve soft contaminants such as varnish, oxidation product and additive precipitates so they no longer occlude the beam.

The standard is explicit that only two of the six listed diluents — 75/25 T/IPA and DPnB — are water-masking (§ 3.2.8.1, [2]). It is silent on whether soft particles dissolve in the non-water-masking solvents. The temporary precision statement (§ 14.1) is based only on diluents marked with an asterisk in Table A1.1, which are lamp oil and DPnB; the published precision is therefore not representative of the toluene/IPA blends used by many in-service laboratories. This combination — a permissive diluent list, an inconsistent precision basis, and an interlaboratory study population that mixes water-masking and non-water-masking solvents — is the structural cause of the ILS scatter reported by Subcommittee D02.96.05.

3. Materials and methods

3.1 Lubricant samples

Eight lubricants and a calibration fluid were selected to span the principal base-stock chemistries and viscosity grades encountered in industrial in-service oil analysis. The panel deliberately mixes used oils (where soft particle contamination is realistic) and fresh oils (where the count from a competent dilution should approach the count obtained on the undiluted sample). Sample details are summarised in Table 1.

Sample	Viscosity grade	Status	Base stock	Description
Mobil DTE 846	ISO 46	Used	Group II mineral	Turbine oil with high level of varnish contamination
Irving Compressor Fluid	ISO 46	Fresh	Group III mineral	Compressor oil
Mobil DTE 10 EXCEL 46	ISO 46	Fresh	Group III mineral	High-performance anti-wear hydraulic oil
Mobil Gear 600XP220	ISO 220	Fresh	Group II Mineral	EP industrial gear oil
Mobil SHC Gear 320	ISO 320	Fresh	Group IV PAO	Synthetic industrial gear oil
Petro Canada ATF D3M	ISO 46	Fresh	Group II+ Mineral	C4 automatic transmission fluid
IR SSR Compressor (Ultra Coolant)	50 cSt @ 40 °C	Used	Group V PAG	Glycol-based compressor fluid
PC Purity FG PAG Gear Oil	ISO 460	Used	Group V PAG	Food-grade synthetic gear oil
MTD calibration fluid (± 1 %, 2 % H ₂ O)	ISO 15	Spiked	Group II Mineral	ISO 11171 calibration fluid, used for the water-masking test

Table 1. Lubricant panel used in this investigation.

3.2 Diluents

Seven diluents were evaluated. Five appear in D7647-24 Table A1.1; one (90/10 T/IPA) is a new candidate; one (100 % butyl glycol) was tested as a possible cost-reduced alternative to DPnB. Toluene, isopropyl alcohol (IPA), butyl glycol, DPnB and K1 kerosene were obtained from Caledon Laboratory Chemicals or Sigma-Aldrich; Stoddard solvent (Varsol) was obtained at retail. All diluents were filtered through 0.45 μm polycarbonate membranes before use, with the contribution of the filtered diluent confirmed to be less than 12.5 % of the total counts in the diluted sample, as required by D7647-24 § 8.2 [2]. Diluent compositions are listed in Table 2.

Diluent (volumetric)	In D7647-24 Table A1.1?	Water-masking?	Rationale for inclusion
100 % butyl glycol (ethylene glycol n-butyl ether)	No	Partial	Cheaper alternative to DPnB
75 % toluene / 25 % IPA	Yes (water-masking)	Yes	Listed water-masking diluent
100 % DPnB (dipropylene glycol n-propyl ether)	Yes (water-masking)	Yes	Listed water-masking diluent
100 % kerosene (K1)	Yes	No	Listed non-water-masking diluent
100 % Stoddard solvent (Varsol)	Yes	No	Listed non-water-masking diluent
90 % toluene / 10 % IPA	No	Partial	Reduced-IPA candidate; less aggressive
67 % kerosene / 33 % DPnB	Equivalent to 67 % lamp oil / 33 % DPnB in A1.1	Partial (DPnB-driven)	Original ILS diluent for D7647:2010

Table 2. Diluents evaluated. “Water-masking” status is per D7647-24 § 3.2.8.1 [2].

3.3 Sample preparation and instrumentation

All counts were obtained on a single CINRG Systems APC22M auto-diluting particle counter equipped with a Klotz 45/50 sensor calibrated to ISO 11171. The instrument has a coincidence threshold of 25,000 particles/mL. Samples were homogenised by mechanical agitation followed by ultrasonic degassing (60 s, 40 kHz) and were transferred into 30 mL MC79 medicine cups. Sample volume was determined automatically from sample-height measurements with an accuracy of ± 0.3 mL at the 15 mL working volume. Each sample was diluted at two nominal sample-to-diluent ratios — 1:1 (undiluted fraction ≈ 0.5) and 1:2 (undiluted fraction ≈ 0.3) — with the actual undiluted fraction calculated gravimetrically and recorded for each measurement. Diluted samples were stirred for 60 s and counted within 90 s of agitation, in accordance with D7647-24 § 4.7 [2].

Each diluted sample was sampled at 30 mL/min through three sequential 7 mL counts on a single 23 mL syringe fill, with the first 2 mL dispensed to waste and only the central 5 mL of each 7 mL count quantified. Reported particle concentrations are the mean of the three 5 mL counts. ISO 4406 codes were calculated independently for each of the three counts and an average code reported. The dataset comprises 126 individual analyses across the eight samples, two dilution ratios and seven diluents, plus undiluted references where viscosity permitted. The complete dataset is available in the supplementary spreadsheet.

4. Results and discussion

4.1 Soft particle interferences: the Mobil DTE 846 used turbine oil

Mobil DTE 846 was sampled from a 24 MW turbine after several thousand hours of service. Visual inspection showed the colour and faint cloudiness associated with varnish formation; FT-IR confirmed elevated oxidation in the 1740 cm^{-1} region. Counts on the undiluted reference were 71,996 particles/mL > 4 $\mu\text{m(c)}$, corresponding to ISO 23/23/19. Counts on each diluted sample are presented in Table 3 and Fig. 1.

Diluent	U fraction	>4 $\mu\text{m(c)}$ per mL	>6 $\mu\text{m(c)}$ per mL	ISO 4406 code	Verdict
Undiluted reference	1.00	71,996	52,788	23/23/19	ref
75/25 T/IPA (1:1)	0.46	121	52	14/13/10	good
75/25 T/IPA (1:2)	0.31	129	54	14/13/10	good
90/10 T/IPA (1:1)	0.52	180	68	15/13/10	good
90/10 T/IPA (1:2)	0.30	76	27	13/12/9	good
DPnB (1:1)	0.49	141	60	14/13/11	good
DPnB (1:2)	0.32	79	35	13/12/10	good
67/33 K/DPnB (1:1)	0.49	1,081	334	17/16/13	marginal
67/33 K/DPnB (1:2)	0.32	120	43	14/13/10	good
Butyl glycol (1:1)	0.48	99	31	14/12/9	good
Butyl glycol (1:2)	0.31	162	67	15/13/11	good
Kerosene (1:1)	0.46	142,505	80,286	24/24/18	ghost
Kerosene (1:2)	0.29	193,128	74,317	25/23/16	ghost
Stoddard solvent (Varsol) (1:1)	0.49	138,949	89,120	24/24/19	ghost
Stoddard solvent (Varsol) (1:2)	0.28	223,460	118,433	25/24/18	ghost

Table 3. >4 $\mu\text{m(c)}$ and >6 $\mu\text{m(c)}$ counts on Mobil DTE 846 used turbine oil for each diluent and dilution ratio. Green = approaches the true count of dissolved varnish; red = ghost particles; yellow = marginal. The undiluted reference is shaded grey.

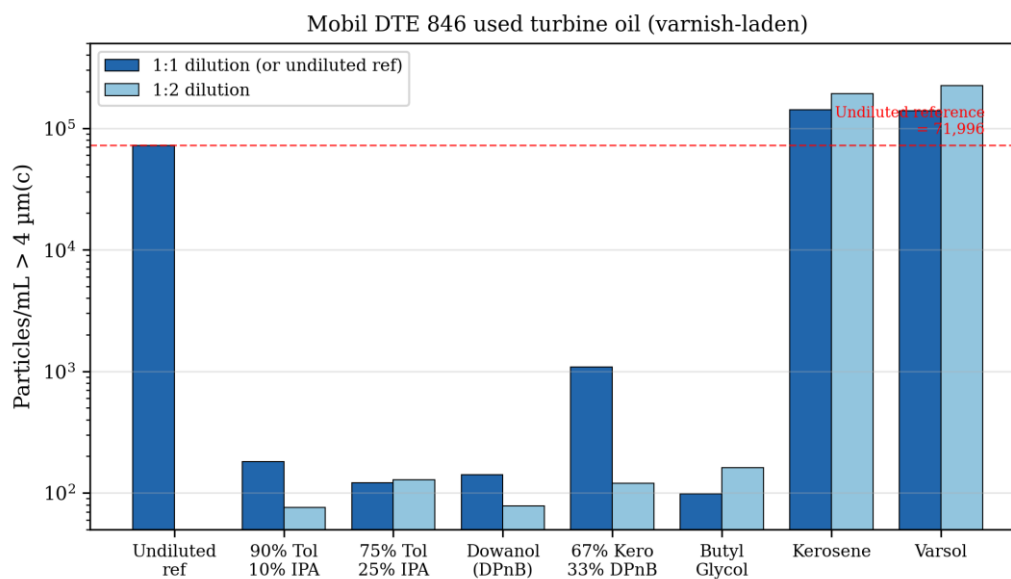


Fig. 1. >4 $\mu\text{m(c)}$ particle concentration in Mobil DTE 846 used turbine oil by diluent (log scale). The dashed horizontal line is the undiluted reference. Bars exceeding the reference indicate that the dilution step has created “ghost particles” rather than removing them.

Three behaviours are visible. The water-masking diluents (75/25 T/IPA, 90/10 T/IPA, DPnB) and butyl glycol all return counts in the range 76–180 particles/mL >4 $\mu\text{m(c)}$. This is the count that survives once the varnish has been fully dissolved into the diluted matrix; it is approximately 400–1,000 \times lower than the undiluted reference, which is consistent with the qualitative observation that the bulk of the >4 $\mu\text{m(c)}$ signal in the undiluted sample is varnish, not solid wear debris. The 67/33 K/DPnB blend returns 1,081 particles/mL at 1:1 but recovers to 120 at 1:2, indicating that the kerosene fraction approaches its solubility limit for this varnish at high sample loadings.

Kerosene and Stoddard solvent (Varsol) behave fundamentally differently. At a 1:1 dilution, both produce counts that are approximately 2 \times the undiluted reference; at 1:2 dilution, both produce counts that are 2–3 \times the 1:1 result. Diluting the sample further makes the count rise. The only mechanism that can produce

this signature is the precipitation of varnish from the diluted phase as the kerosene/Stoddard solvent (Varsol) fraction increases — the ghost particle problem the standard was created to eliminate. The reported ISO codes confirm the magnitude of the error: 25/24/18 for Stoddard solvent (Varsol) at 1:2, against 13/12/9 for 90/10 T/IPA at 1:2 — a 12-code disagreement on the same sample. Each ISO 4406 code represents a factor of two in particle concentration, so the same fluid is being characterised as more than four orders of magnitude apart in cleanliness depending only on which solvent the laboratory chose to use.

4.2 Water masking: the MTD calibration fluid spike test

To isolate the water-masking question from the soft-particle question, MTD calibration fluid was spiked with 1 % and 2 % distilled water by mass and analysed against a dry MTD reference (Table 4 and Fig. 2). The dry reference returned 10,758 particles/mL >4 µm(c) (ISO 21/19/16). The undiluted MTD + 1 % H₂O sample returned 37,319 particles/mL with all six ISO codes saturated at 22 across all sizes, the unmistakable signature of a water haze.

Diluent	Sample	U fraction	>4 µm(c) per mL	ISO 4406 code
None (dry reference)	MTD dry	1.00	10,758	21/19/16
None (water reference)	MTD + 1 % H ₂ O	1.00	37,319	22/22/22
75/25 T/IPA (1:1)	MTD + 1 % H ₂ O	0.44	10,877	21/19/16
75/25 T/IPA (1:2)	MTD + 1 % H ₂ O	0.34	11,117	21/19/15
75/25 T/IPA (1:1)	MTD + 2 % H ₂ O	0.43	10,393	21/19/16
75/25 T/IPA (1:2)	MTD + 2 % H ₂ O	0.30	10,845	21/19/15
DPnB (1:1)	MTD + 1 % H ₂ O	0.43	11,451	21/19/16
DPnB (1:2)	MTD + 1 % H ₂ O	0.28	11,773	21/19/16
DPnB (1:1)	MTD + 2 % H ₂ O	0.49	10,440	21/19/17
DPnB (1:2)	MTD + 2 % H ₂ O	0.28	9,578	20/19/17
90/10 T/IPA (1:1)	MTD + 1 % H ₂ O	0.41	23,623	22/21/21
90/10 T/IPA (1:2)	MTD + 1 % H ₂ O	0.27	8,881	20/19/16
90/10 T/IPA (1:1)	MTD + 2 % H ₂ O	0.46	103,864	24/24/23
90/10 T/IPA (1:2)	MTD + 2 % H ₂ O	0.27	36,516	22/21/21
Butyl glycol (1:1)	MTD + 1 % H ₂ O	0.44	14,561	21/20/16
Butyl glycol (1:2)	MTD + 2 % H ₂ O	0.32	15,369	21/20/16
67/33 K/DPnB (1:1)	MTD + 1 % H ₂ O	0.51	23,646	22/21/21
67/33 K/DPnB (1:2)	MTD + 1 % H ₂ O	0.28	11,186	21/20/18
Kerosene (1:1)	MTD + 1 % H ₂ O	0.46	170,500	25/25/24
Kerosene (1:2)	MTD + 1 % H ₂ O	0.31	250,312	25/25/25
Stoddard solvent (Varsol) (1:1)	MTD + 1 % H ₂ O	0.47	165,885	25/24/24

Table 4. >4 µm(c) counts and ISO 4406 codes on MTD calibration fluid with 0 %, 1 % and 2 % water spike, by diluent and dilution ratio.

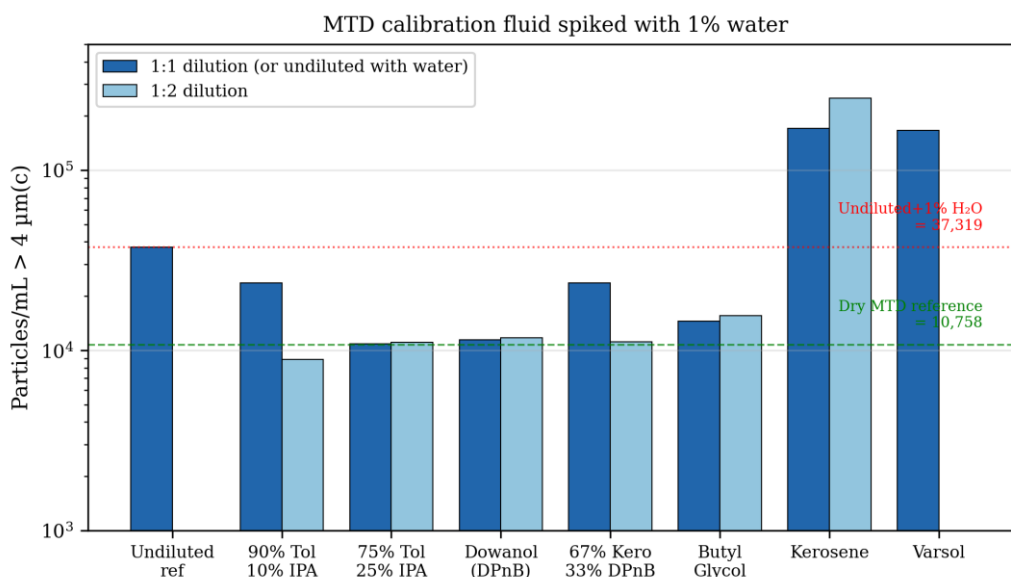


Fig. 2. $>4 \mu\text{m(c)}$ counts on MTD calibration fluid spiked with 1% water (log scale). Green dashed line: dry MTD reference. Red dotted line: undiluted MTD + 1% water. A diluent that masks water should pull the count from the red line down to the green line; a diluent that does not mask water leaves the count at the red line or higher.

The 75/25 T/IPA blend masks 1% and 2% water at both 1:1 and 1:2 dilutions, returning counts within 5% of the dry reference and ISO codes identical to the dry reference. DPnB matches this performance at 1% water and is one half-code worse at 2% water. These two diluents are correctly identified as water-masking by D7647-24 § 3.2.8.1.

Kerosene and Stoddard solvent (Varsol) return counts an order of magnitude higher than the undiluted spiked sample, which is the expected behaviour: not only do they fail to dissolve the water haze, the additional non-polar solvent further reduces the IPA-equivalent activity of the diluted phase and encourages additional water droplet formation as the solvent evaporates from the syringe. ISO codes saturate at 25/25/24 (kerosene 1:1) and reach 25/25/25 at 1:2 — the maximum reportable value across all three sizes. These results confirm that kerosene and Stoddard solvent (Varsol) have no role in any sample where water contamination is even a possibility, and that the standard's practice of permitting an operator to choose them at the bench is unwise.

The 90/10 T/IPA blend, with its reduced IPA fraction, masks 1% water successfully only at 1:2 dilution (ISO 20/19/16, count 8,881 — within 18% of the dry reference). At 1:1 dilution it masks an effective 0.5% water but fails at 1%. At 2% water it fails at both dilutions. This is consistent with the expected polar-solvent stoichiometry: at a 1:2 dilution the diluted sample contains $\approx 6.7\%$ IPA, of which $\approx 1\%$ is available to dissolve the water phase — sufficient for typical in-service oils, which rarely accumulate more than 0.5–1% free water before being flagged for action. Operators using 90/10 T/IPA as a routine diluent must therefore use a 1:2 sample-to-diluent ratio whenever water is suspected and must fall back to 75/25 T/IPA for samples with very high water ($>1\%$) loading.

4.3 Cross-sample performance and the magnitude of the ILS problem

Fig. 3 summarises the $>4 \mu\text{m(c)}$ count returned by each diluent on each sample, normalised so that the lowest count for that sample = $1\times$. Reading the figure horizontally shows that 90/10 T/IPA is the lowest-counting diluent on six of the seven oil samples in which it could be measured, and is within $1.5\times$ of the lowest on the seventh (the IR SSR PAG/ester compressor coolant). 75/25 T/IPA is consistently within $1.5\times$ of 90/10 T/IPA. DPnB is generally close behind, with two notable insolubility failures (Mobil SHC Gear 320 and PC Purity FG PAG, where neither DPnB alone nor butyl glycol could keep the sample in solution).

Reading the figure vertically tells the ILS story. The same sample, the same particle counter, the same operator, the same calibration fluid — only the choice of diluent varies — and the reported count moves by $100\times$ to $4,000\times$. The corresponding ISO 4406 code at $4 \mu\text{m(c)}$ varies by 3 codes (Mobil DTE 10 EXCEL 46, the cleanest sample) up to 12 codes (Mobil DTE 846, the varnish-laden used turbine oil). For reference, the temporary D7647-24 reproducibility limit for the $4 \mu\text{m(c)}$ channel is approximately 1.5 ISO codes [2]; the diluent-driven disagreement we observe is between $2\times$ and $8\times$ the published reproducibility, and it is a systematic bias rather than random scatter.

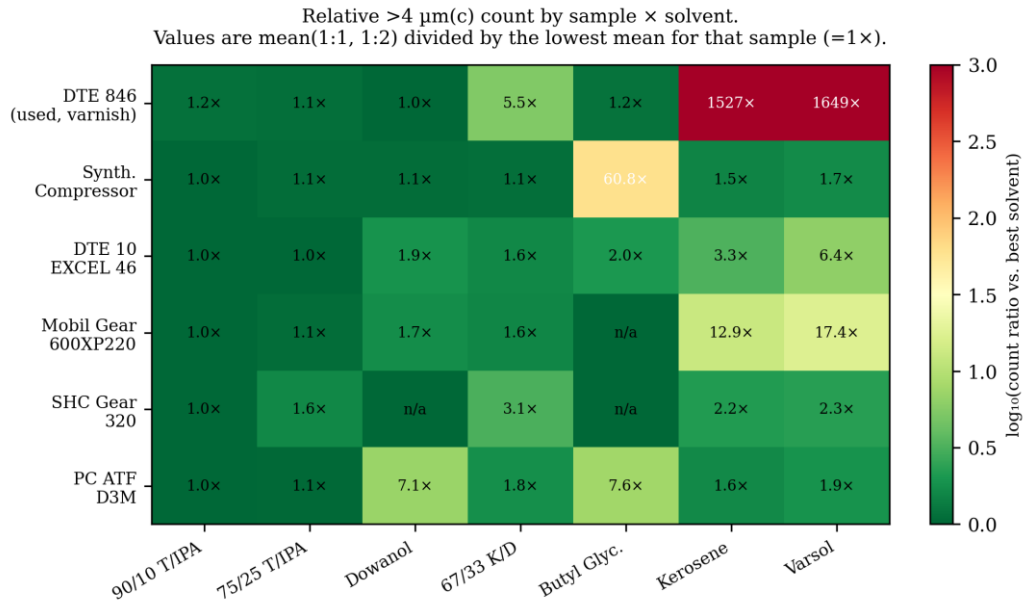


Fig. 3. Relative >4 $\mu\text{m}(c)$ count for each (sample, diluent) cell, normalised so the lowest mean count for that sample = 1 \times . Cell colour and label show the multiplicative penalty paid by choosing each diluent. The dynamic range is approximately 4,000 \times .

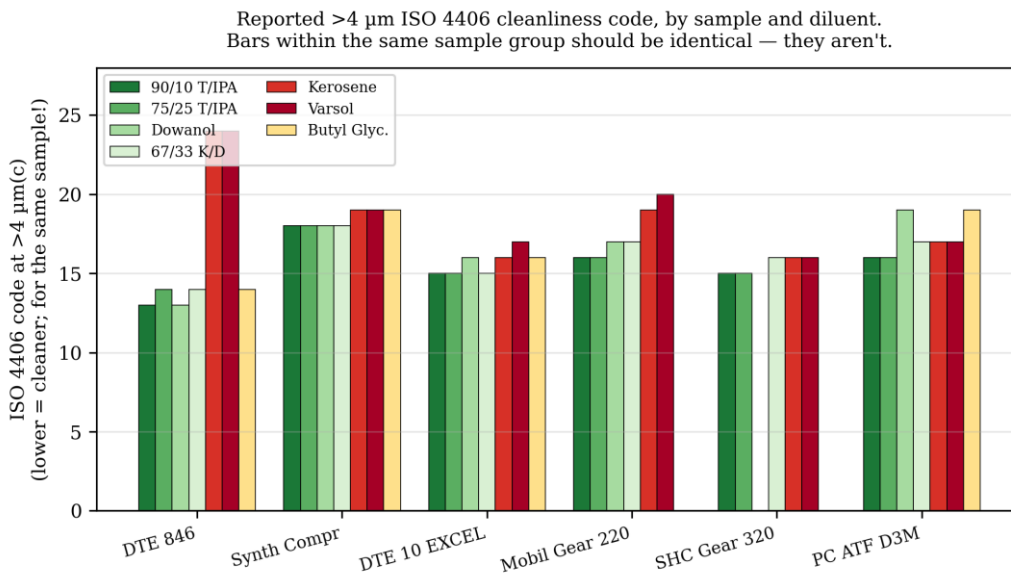


Fig. 4. Reported ISO 4406 cleanliness code at >4 $\mu\text{m}(c)$ for each sample, by diluent. Bars within the same sample group should be identical; the visible spread is the systematic between-laboratory bias that has caused D7647 round-robin scatter.

4.4 Effect of dilution ratio

With a competent water-masking diluent, the difference between 1:1 and 1:2 dilution is minor for most samples. On Mobil DTE 846 the 1:1 and 1:2 counts with 75/25 T/IPA differ by only 7% (121 vs 129); with 90/10 T/IPA the 1:2 count is approximately half the 1:1 count (76 vs 180), reflecting more complete varnish dissolution at the higher dilution. The exception is the highly viscous PAO Mobil SHC Gear 320, where a 1:1 dilution leaves enough undissolved sample to scatter at high count rates (8,121 particles/mL with 75/25 T/IPA) while a 1:2 dilution returns the expected clean value (237 particles/mL, ISO 15/13/8). This is consistent with the standard's recommendation in § 9.6 that very viscous oils benefit from a higher dilution.

With kerosene or Stoddard solvent (Varsol), the dilution-ratio effect runs in the wrong direction — 1:2 returns a higher count than 1:1 — because the soft particle precipitation increases as the kerosene fraction increases. This sign reversal is itself diagnostic: a competent dilution should produce monotonically lower

counts as the dilution increases, until the sample is dilute enough that diluent counts dominate. Any laboratory observing the opposite trend should treat the diluent as compromised for that sample chemistry.

4.5 Final ranking and implications for the standard

Table 5 summarises the diluent ranking for each sample, separately for soft-particle removal and for water masking. The ranking confirms three points:

Sample	First	Second	Third
Mobil DTE 846 (used, varnish-laden)	90/10 T/IPA	DPnB	75/25 T/IPA
Irving Synthetic Compressor	90/10 T/IPA	75/25 T/IPA	DPnB
Mobil DTE 10 EXCEL 46	90/10 T/IPA	75/25 T/IPA	67/33 K/DPnB
Mobil Gear 600XP220	90/10 T/IPA	75/25 T/IPA	67/33 K/DPnB
Mobil SHC Gear 320	90/10 T/IPA	75/25 T/IPA	Kerosene*
Petro Canada ATF D3M	90/10 T/IPA	75/25 T/IPA	Kerosene*
IR SSR Compressor Ultra Coolant	Kerosene	90/10 T/IPA	Varsol
PC Purity FG PAG Gear Oil	90/10 T/IPA	75/25 T/IPA	DPnB
MTD CAL + 1–2 % H ₂ O (water masking)	75/25 T/IPA	DPnB	Butyl glycol

*Table 5. Diluent ranking for each sample. Solvent performance was rated on the combined performance of the 1:1 and 1:2 dilutions. * indicates a third-place ranking for kerosene only because samples with no soft-particle or water issues are insensitive to diluent choice.*

First, 90/10 T/IPA is the highest-performing single diluent across the eight oil samples, with seven first-place rankings out of eight. Second, 75/25 T/IPA is the safest diluent for samples with even slightly suspect water status. Third, kerosene and Stoddard solvent (Varsol) have no overall first-place finishes on any oil where soft particles are present and have catastrophic failures on water-bearing samples; their only positive results are on samples (such as the IR SSR Ultra Coolant) where they happen to dissolve a problematic ester additive that confounds the more polar diluents. We recognise that these single edge-cases were the original argument for keeping the non-water-masking diluents in Table A1.1; the Ultra Coolant data in our panel show that the polar diluents 75/25 T/IPA and 90/10 T/IPA are within a factor of 1.4× of kerosene on this sample and remain acceptable.

On this evidence we propose three changes to D7647 in the next revision cycle. (1) Remove kerosene, lamp oil and Stoddard solvent from the permitted-diluent list in Table A1.1, except as a clearly-flagged option for samples where water can be conclusively excluded and where soft particle interference is verified to be absent. (2) Add 90 % toluene / 10 % isopropanol as a permitted water-masking diluent, with a note that it must be used at a 1:2 sample-to-diluent ratio when free water exceeds 0.5 %. (3) Update the precision statement in § 14 so that it is based on the water-masking diluents only, which would substantially tighten both the repeatability and the reproducibility limits.

These changes also address a long-standing question in the user community: whether the visual assessment of a diluted sample as “clear” is adequate to declare the dilution successful. The 1:1 Mobil DTE 846 / kerosene sample appeared clear by eye and yet returned counts twice the undiluted reference. Visual inspection is a necessary but not sufficient check, and the optical particle counter itself is the most sensitive indicator of incomplete dissolution — specifically through the dilution-ratio sign test described in § 4.4 above.

5. Conclusions

ASTM D7647-24 has the right title, the right principle, and a diluent list that undermines both. By permitting non-water-masking solvents (kerosene, Stoddard solvent, lamp oil) alongside water-masking solvents (75/25 T/IPA, DPnB), the standard allows two laboratories to follow the same procedure on the same sample and arrive at ISO 4406 codes that differ by up to 12 codes — more than four orders of magnitude in particle concentration. This is the structural cause of the reproducibility scatter that has dogged D7647 since its publication.

The data presented here, drawn from 126 individual analyses across eight in-service lubricants and a calibration fluid, supports four specific conclusions:

1. **Kerosene, Stoddard solvent (Varsol) and lamp oil generate ghost particles** in samples containing varnish, oxidation product or other soft contaminants. The ghost-particle signal scales upward with dilution ratio, the opposite of a competent dilution.
2. **Kerosene, Stoddard solvent (Varsol) and lamp oil have no water-masking ability.** On a 1 % water spike they return counts more than 15× the dry reference. They cannot be used safely on any in-service sample whose water status is unknown.
3. **A blend of 90 % toluene and 10 % isopropanol is the highest-performing single diluent** across the eight oil samples tested, ranking first on seven of eight, and is recommended as a new addition to Table A1.1. Its water-masking ability is reduced relative to 75/25 T/IPA but remains adequate for the 0.5–1 % free-water levels typical of in-service samples when the sample is diluted at 1:2.
4. **75 % toluene / 25 % isopropanol remains the safest diluent for high-water samples** and should remain in the standard. DPnB is acceptable but suffers solubility failures on PAO and PAG-rich samples. Butyl Ether was included in the evaluation as being similar to DPnB but considerably less expensive, however it showed inferior performance with some samples and cannot be considered as a direct substitute.

Restricting D7647 to water-masking diluents would tighten the published precision statement, restore the standard's consistency with its title, and remove the most common single source of laboratory disagreement on in-service oil cleanliness reporting. We recommend that Subcommittee D02.96.05 ballot these changes in the next revision cycle.

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