Standard Test Method for
Particle Count in Mineral Insulating Oil Using Automatic
Optical Particle Counters

This standard is issued under the fixed designation D6786; the number immediately following the designation indicates the year of
original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A
superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers the determination of particle
count and particle size distribution in mineral insulating
oil. It is suitable for testing oils having a viscosity of 6 to
20 cSt at 40°C. The test method is specific to liquid automatic
particle analyzers that use the light extinction principle.

1.2 This standard does not purport to address all of the
safety concerns, if any, associated with its use. It is the
responsibility of the user of this standard to establish appro-
priate safety and health practices and determine the applica-
bility of regulatory limitations prior to use.

2. Referenced Documents

2.1 ASTM Standards:
D923 Practices for Sampling Electrical Insulating Liquids
2.2 ISO Standards:
Coding the Level of Contamination by Solid Particles
11171:1999 Hydraulic Fluid Power—Calibration of Auto-
matic Particle Counters for Liquids

3. Terminology

3.1 Definitions:
3.1.1 coincidence—the presence of more than one particle
in the sensing zone of a particle analyzer at the same time,
causing mis-sizing and mis-counting of the particle present.
The coincidence limit of the counter is determined by the
maximum acceptable concentration of particles in the sensing
zone and is supplied by the instrument manufacturer.

3.1.2 concentration limit—a direct function of coincidence
and electronic saturation. The concentration limit of the system

1 This test method is under the jurisdiction of ASTM Committee D27 on
Electrical Insulating Liquids and Gases and is the direct responsibility of Subcom-
mitee D27.07 on Physical Test.
approved in 2002. Last previous edition approved in 2007 as D6786–07. DOI:
10.1520/D6786-08.
2 For referenced ASTM standards, visit the ASTM website, www.astm.org, or
contact ASTM Customer Service at service@astm.org. For Annual Book of ASTM
Standards volume information, refer to the standard’s Document Summary page on
the ASTM website.
3 Available from American National Standards Institute, 11 West 42nd Street,
New York, NY 10036.

is determined by the maximum acceptable concentration of
particles in the given sample and is supplied by the instrument
manufacturer.

3.1.3 electronic saturation level—particle concentration at
which the electronic circuitry of the analyzer ceases to function
properly due to excessive counting rates.

3.1.4 light extinction—the reduction in intensity of a light
beam passing through the sensing zone of a particle analyzer,
caused by the absorption and/or scattering of the light by
particles. Synonyms: light obscuration, light interruption, light
blockage.

4. Summary of Test Method

4.1 Samples are taken in particle-clean bottles that are
suitable for particle analysis. The sample bottle is agitated to
redistribute particles in the oil, then the oil is placed in an
automatic particle counter, where the number of particles and
their size distribution are determined by the light extinction
principle.

4.2 As particles pass through the sensing zone of the
instrument, the quantity of light reaching the detector is
obscured. This signal is translated to an equivalent projected
area diameter based on calibration with a NIST-traceable fluid
(ISO Medium Test Dust suspension).

5. Significance and Use

5.1 Particles in insulating oil can have a detrimental effect
on the dielectric properties of the fluid, depending on the size,
concentration, and nature of the particles. The source of these
particles can be external contaminants, oil degradation by-
products, or internal materials such as metals, carbon, or
cellulose fibers.

5.2 Particle counts provide a general degree of contamina-
tion level and may be useful in assessing the condition of
specific types of electrical equipment. Particle counts can also
be used to determine filtering effectiveness when processing
oil.

5.3 If more specific knowledge of the nature of the particles
is needed, other tests such as metals analysis or fiber identifi-
cation and counting must be performed.
6. Interferences

6.1 Dirty environmental conditions and poor handling techniques can easily contaminate the sample and/or test specimen. Care must be taken to ensure test results are not biased by introduced particles.

6.2 Air bubbles in the oil may be counted as particles giving false positive readings. Mixing or agitating the sample introduces bubbles into the oil, but these readily dissipate and generally do not interfere with insulating oil particle counts.

6.3 Suspended or free water in the oil will generally be counted as particles. Normally, free water concentrations below 10 ppm will not interfere.

6.4 Excessive concentrations of particles in the oil will cause coincidence and/or electronic saturation errors. Limits are determined by ISO 11171 and are generally supplied by the instrument manufacturer. These errors may be avoided by diluting the sample with particle-clean dilution oil or particle-clean solvent.

6.5 Odd-shaped particles and fibers may be improperly analyzed, depending on their orientation as they pass through the sensing zone of the instrument.

7. Apparatus

7.1 Automatic Particle Counter, liquid optical particle counter based on the light extinction principle. The instrument shall be capable of recording the size and number of particles as they pass across the detector. The particle counter shall include a bottle sampling apparatus that automatically delivers a predetermined volume of specimen at a controlled flow rate to the sensing zone of the analyzer.

7.2 Mechanical Shaker, paint shaker, table shaker, or other mechanical device to vigorously agitate sample bottles.

8. Materials

8.1 Particle-clean Bottles, recommended sample containers are cylindrical bottles made of polypropylene, polystyrene, PET, or glass with flat bottoms, fitted with a suitable non-shedding threaded cap. Bottles should be at least 100-mL capacity. The bottles shall meet the cleanliness criteria of contributing less than 1% of the total particles expected in the cleanest sample.

8.2 Particle-clean Solvent, petroleum spirits, hexane, kerosene, or other suitable solvent, filtered through a 0.45 µm membrane filter.

8.3 Calibration Fluid, suspension of ISO Medium Test Dust in oil or hydraulic fluid, either a primary sample obtained directly from NIST4 (SRM 2806) or a secondary sample prepared in accordance to ISO 11171 and traceable to NIST.

8.4 Dilution Oil, insulating oil that has been filtered to contain fewer than 1% of the total particles expected in the cleanest sample.

9. Sampling

9.1 Refer to Practice D923 for precautions for sampling from energized electrical equipment.

9.2 Proper sampling is crucial to particulate analysis. The following guidelines are offered to ensure representative sampling and to preserve sample integrity:

9.2.1 Wipe the sample port outlet with a clean lint-free towel. Open the sample valve and flush about 3 times the flow path volume of oil into a container.

9.2.2 While flushing, uncap the sample bottle and retain the cap in one hand and the bottle in the other. Without adjusting the valve or disturbing sample flow, fill the bottle to about 80-95% capacity. Do not completely fill the bottle since the headspace will be needed for sample agitation.

9.2.3 Cap the sample bottle, then close the sample valve.

10. Calibration

10.1 Calibration of the instrument shall be with a NIST-traceable calibration fluid in accordance with ISO 11171.

10.2 Calibrate the instrument annually, unless experience justifies longer or shorter intervals.

10.3 Interim calibration checks should be made regularly by using a particle count standard fluid prepared using the procedures of ISO 11171. The check values should be within 10% of the standard values.

11. Procedure

11.1 If necessary, wipe the outside of the sample bottle with a clean lint-free towel.

11.2 If other tests are to be run on the same sample, shake the sample bottle as described in 11.3 and transfer a specimen for particle count to another particle-clean bottle. Do this before running any other tests in order to avoid contamination.

11.3 Agitate the sample bottle vigorously for 30-60 s to redistribute particles, the length of time depending on the effectiveness of the method of agitation. Use hand shaking or a mechanical shaker. Do not use a magnetic stir bar or any other device that comes in contact with the oil. Do not use an ultrasonic bath as this may break up the large particles.

11.4 Allow a few seconds for gas bubbles to escape or apply vacuum to the bottle until bubbles dissipate.

11.5 Immediately analyze the sample with the automatic particle counter according to the manufacturer’s operating instructions. Usually the analyzer is flushed with a specimen of the oil prior to testing. After the initial flush, 2-3 runs on each sample are recommended.

11.6 When particle count runs are finished, flush the instrument with particle-clean solvent or particle-clean oil in accordance with the instrument manufacturer’s recommendations.

12. Report

12.1 Report the average of the particle count runs as the cumulative number of particles per mL >4, >6, >10, >14, >21, >38, and >70 µm (c). The “(c)” after the size indicates that the particle counter was calibrated using ISO 11171. These particle

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4 Available from National Institute of Standards and Technology, 100 Bureau Drive, Gaithersburg, MD 20899.
sized correspond approximately to >2, >5, >10, >15, >25, >50, and >100 µm for particle counters that were calibrated with the old ISO 4402 calibration standard. If only one particle count run is analyzed, report the results of the single run.

12.2 Optionally, also report the ISO solid contaminant code corresponding to the number of particles per mL >4, 6, and 14 µm (c), as prescribed in ISO 4406:1999.

13. Precision and Bias

13.1 The precision of this test method is based on an Interlaboratory Study of D6786 – Particle Count in Mineral Insulating Oil Using Automatic Optical Particle Counters – conducted in 2006–2007. Each of eleven laboratories tested four materials (in triplicate); covering seven particle size ranges to determine the intralaboratory and interlaboratory precision of D6786.5

13.1.1 Repeatability—Two test results obtained within one laboratory shall be judged not equivalent if they differ by more than the “r” value for that material; “r” is the interval representing the critical difference between two test results for the same material, obtained by the same operator using the same equipment on the same day in the same laboratory.

13.1.2 Reproducibility—Two test results should be judged not equivalent if they differ by more than the “R” value for that material; “R” is the interval representing the difference between two test results for the same material, obtained by different operators using different equipment in different laboratories.

13.1.3 Any judgment in accordance with statements 13.1.1 or 13.1.2 would have an approximate 95 % probability of being correct.

13.1.4 Results from the Interlaboratory Study are summarized in Tables 1-4. Data for the larger particle sizes were omitted because the small number of particles present did not produce good statistical results.

13.2 Bias—At the time of the study, no certified reference material suitable for determining bias was analyzed; therefore no statement on bias can be made from this data.

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<th>Table 1 New Oil</th>
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<td>Particle Size Range</td>
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<td>&gt;4 µm(c)</td>
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14. Keywords

14.1 optical particle counter; particle count; particulate contamination