Designation: D8184 – 18

Standard Test Method for
Ferrous Wear Debris Monitoring in In-Service Fluids Using a Particle Quantifier Instrument[1]

This standard is issued under the fixed designation D8184; 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 describes the use of offline particle quantification (often referred to as PQ) magnetometers to trend wear rates in machinery by monitoring the amount of ferromagnetic material suspended in a fluid sample that has been in contact with the moving parts of the machinery. It is particularly relevant to monitoring wear debris in lubricating oils and greases.

1.2 The values stated in SI units are to be regarded as standard. Values of the burden (mass) of ferrous wear debris in the sample are reported as a PQ Index. The PQ Index is a numerical value that scales with the ferrous debris burden.

1.3 *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 appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.4 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]
D4057 Practice for Manual Sampling of Petroleum and Petroleum Products
D4175 Terminology Relating to Petroleum Products, Liquid Fuels, and Lubricants
D4177 Practice for Automatic Sampling of Petroleum and Petroleum Products

D5185 Test Method for Multielement Determination of Used and Unused Lubricating Oils and Base Oils by Inductively Coupled Plasma Atomic Emission Spectrometry (ICP-AES)
D6300 Practice for Determination of Precision and Bias Data for Use in Test Methods for Petroleum Products and Lubricants
D7720 Guide for Statistically Evaluating Measurand Alarm Limits when Using Oil Analysis to Monitor Equipment and Oil for Fitness and Contamination

3. Terminology

3.1 *Definitions:*

3.1.1 *condition monitoring, n*—the recording and analyzing of data relating to the condition of equipment or machinery for the purpose of predictive maintenance or optimization of performance.

3.1.2 *ferromagnetic, n*—metals, alloys, and other materials that exhibit medium to high magnetic permeabilities; further classified into "hard" and "soft" magnetic materials when capable of becoming permanently magnetized or not, respectively.

3.1.3 *inductively coupled plasma optical emission spectroscopy (ICP-OES), n*—a form of emission spectroscopy that uses a plasma to excite atoms and ions that subsequently emit electromagnetic radiation in the visible region; the emission wavelengths are characteristic of a particular wavelength, and the intensity of emission is related to the concentration of the emitting element.

3.1.4 *machinery health, n*—qualitative indication of the overall condition of equipment or machinery; may depend on data and trend analysis from several sources.

3.1.5 *PQI, n*—a dimensionless index related to the ferromagnetic content of an oil or grease sample.

3.1.5.1 *Discussion*—The scale is defined by a 750 PQI primary standard developed by The University of Swansea in the 1980s. The original primary standard is currently in the possession of Parker Hannifin Manufacturing Ltd. (Littlehampton, UK) who manufacture and supply secondary standards for instrument validation purposes.

3.1.6 *rotating disc electrode optical emission spectroscopy (RDE-OES), n*—similar to ICP-OES, but the exciting medium is now an electrical discharge between an electrode and a rotating disc with the oil sample located within the discharge.

3.1.7 *trend analysis, n*—the interpretation of regular or continuous (in time) condition monitoring data in order to determine any changes indicative of deterioration or incipient failure in equipment or machinery.

3.1.8 *wear, n*—the loss of material from a surface, generally occurring between two surfaces in relative motion, and resulting from mechanical or chemical action, or a combination of both.

4. Summary of Test Method

4.1 *Lubricating Oils*—A sample of oil is extracted from the machinery and collected in a bottle to a depth sufficient to exceed the flux field of the sensing coil in the instrument. Distortion of the flux field due to the presence of any ferromagnetic material is determined and a numerical value (PQ Index) assigned to the extent of the distortion. This index is related to the concentration and spatial distribution of the ferromagnetic material within the sensing volume of the coil. If the oil sample has been undisturbed for some time, this is the same as the concentration within the bulk. However, if the ferrous burden undergoes settling, for example, from an initial well-shaken state, then the signal may exhibit a time dependency due to debris mobility. It is possible to derive information on the size (mass) of the debris from the rate of any time dependent behavior noted.

4.2 *Greases*—A sample of grease is similarly extracted from a bearing housing or similar and transferred to a small volume (5 mL) pot.[3] Reliable trending information requires the use of the same size and shape of pot for reasons of consistency. Mobility of debris within grease is restricted, the contents of the pot are completely within the flux field of the sensing coil, and no time dependent behavior is observed.

5. Significance and Use

5.1 This test method is intended for the application of PQ magnetometry in assessing the progression of wear in machinery, for example, engines and gearboxes, by trending the mass of ferrous debris in samples of lubricating oils or greases.

5.2 In-service oil analysis is carried out routinely by commercial laboratories on a wide range of samples from many sources and is accepted as a reliable means of monitoring machinery health by trend analysis. In particular, the extent of wear can be readily assessed from any changes in the ferrous debris burden within periodically extracted samples as reflected in the PQ Index.

5.3 PQ measurements can be used as a means of rapidly screening samples for the presence or absence of ferrous wear debris, allowing quick decisions to be made on whether or not to proceed to a more detailed spectroscopic analysis for probable wear metals in the sample.

5.4 The use of standardized sample containers and a consistent protocol enables reliable trending information to be recorded. Although it is not possible to assign general limits or thresholds for abnormal conditions, it is recommended that interpretation of PQ values should be carried out in consultation with historical data, equipment logs, and/or service history in order to formulate guidelines on individual items of machinery. Guide D7720 is particularly useful in this context.

6. Interferences

6.1 *Sample Related Interferences:*

6.1.1 PQ instruments have a high sensitivity to the presence of low concentrations of ferromagnetic materials in the test material (iron, steel, and so forth) due to their magnetic susceptibility. However, large concentrations of high conductivity metals, for example, copper, can cause a small distortion to the excitation field through the generation of eddy currents in the debris particles. These eddy currents generate an opposing ac magnetic field to the excitation field (Lenz's law), which causes an imbalance and hence a detectable signal. Note that this phenomenon is several orders of magnitude lower in effect than that due to the magnetic permeability of ferrous materials. The presence of any suspected high conductivity metal contamination can be verified or eliminated by, for example, Test Method D5185.

6.2 *External (Environmental) Interferences:*

6.2.1 As noted in 9.2, the toner material in some printed labels can contain iron powder and care should be taken to eliminate this interference by careful label positioning and/or the use of non-iron containing inks.

6.2.2 PQ instruments should not be sited on or close to large metallic structures due to the possibility of field distortion caused by their proximity, see 10.1.

7. Apparatus

7.1 PQ instruments are of a propriety design and currently manufactured by Parker Hannifin Ltd., Littlehampton, U.K.[4,5] The development of PQ test methodology began at Swansea University in the 1980s. Instruments have been manufactured under license, since the initial development, by Swansea Oil Analysis Program (SOAP) Ltd., Analex Ltd., and Kittiwake Developments Ltd, and a large number are still in operation in many commercial laboratories. Current PQ instruments are marketed and supported globally by Parker Hannifin Ltd.

7.2 A description of the apparatus and method can be found in the patents listed in Related Materials. In brief, PQ instruments comprise an excitation coil providing an ac magnetic

---

[3] The sole source of supply of the apparatus (recommended grease sample pots) known to the committee at this time is Parker Hannifin Ltd., Littlehampton, UK. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,[1] which you may attend.

[4] The sole source of supply of the apparatus known to the committee at this time is Parker Hannifin Ltd., Littlehampton, U.K.. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,[1] which you may attend.

[5] PQ – GB trademark number 2210262 for "Apparatus and instruments for the detection and/or quantification of wear debris in lubricating fluids and hydraulic fluids," applies to the instrument and not the measurement index.

field with a frequency between 1 kHz and 10 kHz, two sense coils arranged above and below the excitation coil and with the sample sited close to one of the excitation coils. See Fig. 1 and Fig. 2 for details. In Fig. 2, 11 and 13 are the sample and a support plate, 2 is the excitation coil wound on a former (1), 3 is an oscillator driving this coil, 4 and 5 are the two sense coils arranged in a differential manner (initially balanced by some means to provide a null signal), with 6 through 8 providing a means to detect and amplify any subsequent imbalance in the two sense coils from the presence of wear debris in the sample. 9 is a display or recording device for this out-of-balance signal.

7.3 To measure the ferrous burden in a sample in the form of the PQ index, the response of the instrument must be calibrated against the primary standard. This will have been done by the manufacturer who will also supply secondary check standards to verify the long-term performance of the instrument on an appropriate usage schedule. Consult the manual for guidance on this matter. Note that the sample platter also contains an embedded ferrous reference for the purposes of compensating for any short-term drift.

7.4 A full operational cycle consists of three measurements; zero PQI, embedded reference, and finally, the test sample. This is achieved by rotating the platter on which the sample is placed in a stepwise fashion, pausing at each position to make the appropriate measurement.

8. Reagents and Materials

8.1 No reagents are required in order to determine the PQ Index of a sample.

8.2 It is recommended that PQ instruments are regularly calibrated and their performance monitored using the manufacturer's recommendations and check standards.

9. Sampling, Test Specimens, and Test Units

9.1 In-service oil and grease samples should be collected in accordance with the practices described in Practice D4057 or Practice D4177. Oil samples should be transferred to clean 100 mL bottles or 5 mL pots and sealed (Fig. 3). Grease samples should be transferred to 5 mL pots and similarly sealed. Suitable containers are available from several manufacturers. For oil samples in 100 mL bottles, a minimum fill depth of 40 mm is recommended (Fig. 4). The 5 mL pots should be completely filled with either oil or grease samples; a consistent approach with respect to sample volume in this step will provide the most reliable results.

9.2 Note that certain printer toners and inks can contain iron oxides. If it is required to attach printed labels to sample bottles for identification purposes, it is recommended that either the labels are sited well away from the measurement zone or that the labels be prepared using thermal type printers, in order to avoid erroneous measurements.

9.3 Check standards are available from the manufacturer to use as test specimens for day to day validation and confidence checking.

10. Preparation of Apparatus

10.1 PQ instruments are susceptible to variable temperature effects and the presence of stray magnetic fields. They should be sited in a stable, draft-free environment and kept well away from any sources of electromagnetic interference, for example: power supplies, generators, microwave ovens, loudspeakers, and so forth. Note also that the close proximity of large steel or iron equipment may also disturb the measurement field and PQ instruments should not be sited near to gas cylinders or placed on steel workbenches.

10.2 Sufficient time should be allowed for the instrument to warm up and equilibrate after first switch on. The manufacturers recommend waiting for a 2 h period before performing tests. It is anticipated that most PQ instruments will be left in a "permanently on/standby" state.

10.3 In addition, cold sample bottles may affect the instrument when placed on the measurement platter, and they should also be given sufficient time to equilibrate before performing measurements.
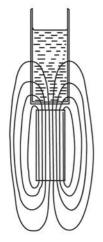

FIG. 1 Principle of PQ Magnetometry (left) and a Modern Instrument (right)