TECHNICAL REPORT

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Effect of conductivity on multipass testing as per ISO 4548-12:2017

Effet de la conductivité sur les essais multi-passes selon l'ISO 4548-12:2017

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Foreword

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This document was prepared by Technical Committee ISO/TC 70, *Internal combustion engines* Subcommittee SC 7, *Tests for lubricating oil filters*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

ISO 4548-12:2000 and ISO 4548-12:2017 state that oil (MIL-PRF-5606, AIR 3520 and other suitable fluids) conductivity is to be set to “at least 1 000 pS/m” prior to conducting a lubricating oil filter, with a recommended level of “1 500 pS/m +/- 500 pS/m.” Prior to the revision of ISO 4548-12:2000 (started in 2016), fluid conductivity had received increasing attention. Some labs reported issues with maintaining fluid conductivity during these tests and discussed the effects conductivity can have on filter capacity results. Testing showed the fluid conductivity can decrease during a test, which corresponded to an increase in filter capacity. A task force was established within ISO/TC70/SC7/WG2 to investigate this issue. Findings from this work are summarized in this document. The root cause of the fluid conductivity problem was not discovered and most labs did not report any issues with maintaining conductivity during ISO 4548-12 testing.

Experiments were conducted by one laboratory, oil was examined by two laboratories, and survey results were sent from nine laboratories. Three sets of experiments were conducted including testing with flat sheet samples and commercially available filters to examine the effect of fluid conductivity change. Fresh and aged oil were examined to see if any components of the fluid were depleted during normal use.

Effect of conductivity on multipass testing as per ISO 4548-12:2017

1 Scope

This document outlines the importance of conductivity in multi-pass filter testing per ISO 4548-12. This information also applies to filters tested per other multi-pass filter test standards, such as ISO 16889 and ISO 19438. Filters tested according to each method can experience similar changes in performance during the fluid conductivity changes outlined within this document.

The objectives of this document are to clarify the following issues:

— Examine how conductivity affects filter capacity test results when filters are tested per ISO 4548-12:2017.

— Compare findings to ISO 4548-12:2017 operating parameters.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 4548-1, *Methods of test for full-flow lubricating oil filters for internal combustion engines — Part 1: Differential pressure/flow characteristics*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 4548-1 apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

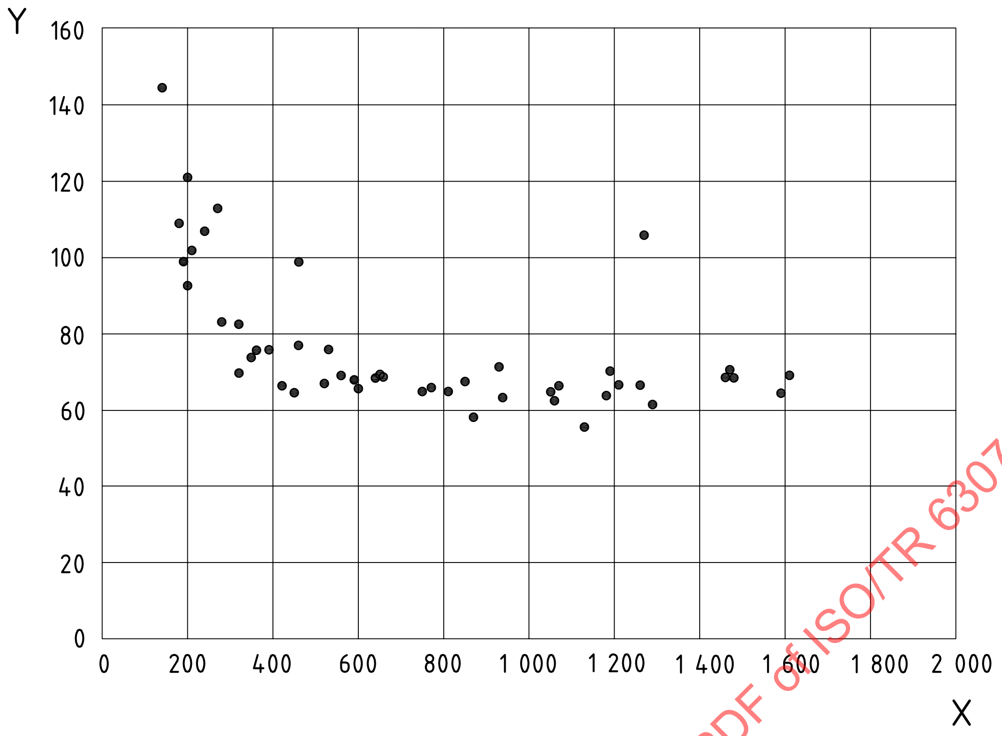
— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

4 Reference filter testing

This issue was first reported after a lab used “reference filters” to monitor the consistency of their multi-pass test system. These are typical production spin-on filters, but specifically manufactured to limit filter-to-filter variation. These reference filters are constructed with synthetic media and a media area of 3 039 cm^2. These filters are typically used as hydraulic/transmission oil filters on heavy-duty diesel engines for off-road equipment.

From 2012 to 2015, this lab gathered data from periodic testing of these reference filters per ISO 16889:2008 (Figure 1). Initial and final conductivity were logged during this testing. Test technicians noticed final conductivity would significantly drop during some tests, corresponding with a higher than expected capacity. Specific parameters of this testing are shown below.



Key

X final conductivity (pS/m)

Y retained capacity (g)

Flow Rate: 75 lpm

BUGL: 10 mg/l of A3 dust per ISO 12103-1:2016

Terminal dP: 345 kPa

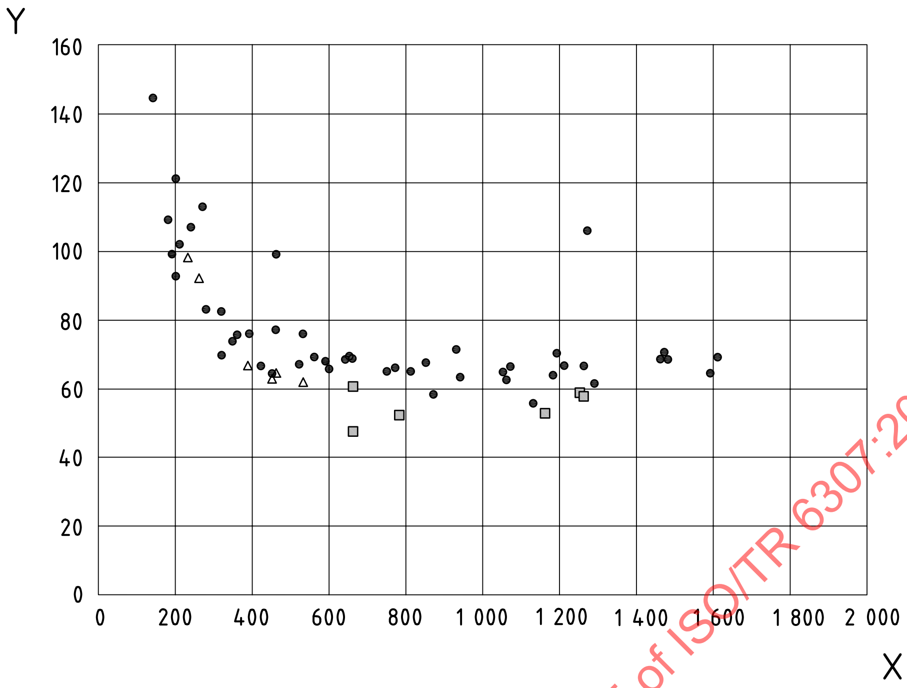
Expected capacity: 60 – 70 g

Expected performance: β200 = 14 µm(c) / β1,000 = 19 µm(c)

Figure 1 — Reference filter capacity versus final conductivity

When a reference filter test results were outside of the expected results (tolerance), the fluid in the test system would be changed. This fixed the issue and allowed the reference filter to test within expected results. Reference filter testing has continued at this lab, but in 2015 more attention was paid to fluid change-outs of the test system. Reference filters were tested in old oil (used for some time and ready to be changed) and new oil, at different levels of initial conductivity (results shown in Figure 2). Figure 2 also shows the results from testing reference filters throughout 2015 as "Historical Data." This is normal lab practice for monitoring the status of the test system and fluid.

The 2016 Study conducted with old and new oil was done at initial conductivity levels of 1 000 pS/m, 1 500 pS/m, and 2 000 pS/m. The reference filter capacity results were significantly higher than historical results when tested with the old fluid, signifying the need for the fluid to be changed. This old fluid was left in the test system for the 2016 study. The new fluid was a fresh batch of oil, removed from the drum, added to the test system, and additized with conductivity improving fluid to establish the initial conductivity level(s).



Key

X final conductivity (pS/m)

Y retained capacity (g)

● historical data (conductivity was not actively maintained)

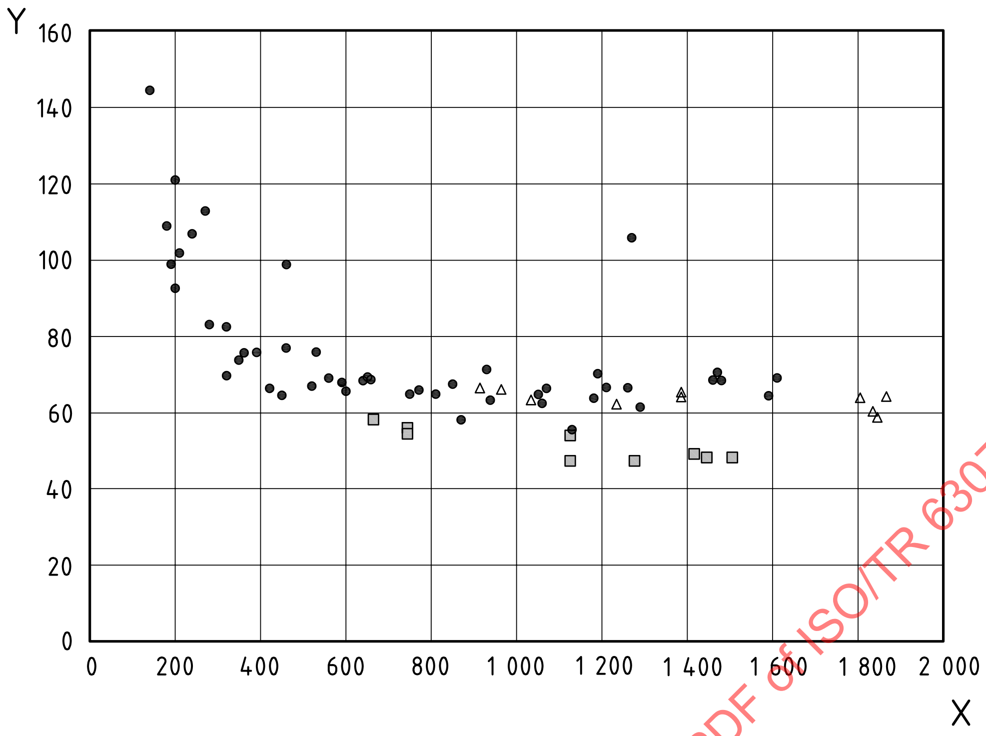
□ new oil, 2016 study (conductivity was not actively maintained)

△ old oil, 2016 study (conductivity was not actively maintained)

Figure 2 — Reference filter capacity vs final conductivity from 2016 Study when conductivity was not maintained and historical data.

A method (conductivity dosing system) for maintaining oil conductivity was developed and tested in 2016 to see how maintaining the conductivity would affect reference filter performance. Conductivity improving/increasing fluid (Stadis 450[1)]) was continuously added in small doses during each multi-pass test (up to 50 ml) to not significantly affect the fluid level of the main tank. This dosing was consistent throughout each test as the conductivity was actively controlled. Conductivity was monitored with an in-line conductivity sensor that provided real-time feedback. Initial and final conductivity measurements were also taken with a hand-held conductivity meter in the main tank, as specified in ISO 4548-12. All conductivity data presented in this report was measured in the main tank with a hand-held conductivity sensor. This method was effective at maintaining an oil conductivity within ± 200 pS/m of the initial conductivity during each test. The new oil was not actively maintained because the final conductivity did not decrease significantly during the current work testing. Testing with the “new” oil was conducted over the course of one (1) week. The results are shown below in Figure 3.

1) Stadis 450 is the trademark of a product supplied by Innospec. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO of the product named. Equivalent products may be used if they can be shown to lead to the same results.



Key

X final conductivity (pS/m)

Y retained capacity (g)

● historical data (conductivity was not actively maintained)

□ new oil, 2016 study (conductivity was not actively maintained)

△ old oil, 2016 study (conductivity was actively maintained)

Figure 3 — Reference filter capacity vs final conductivity 2016 Study when conductivity was maintained and historical data.

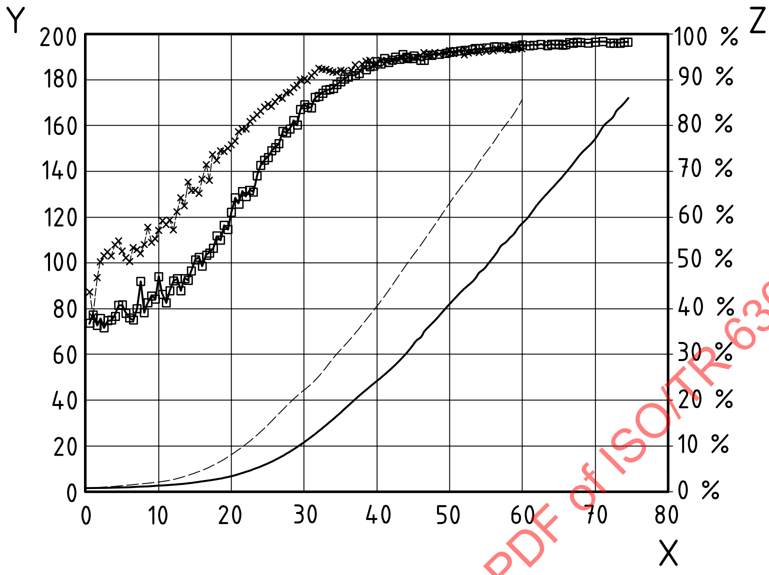
Figure 2 and 3 show the importance of maintaining conductivity for obtaining consistent and reliable test results in multi-pass testing (such as ISO 4548-12). Figure 2 shows that when conductivity decreases during the test (which can occur in older / heavily used oil), the final conductivity can reach a level that allows the filter to reach a much higher capacity compared to when conductivity is maintained.

In the new oil, the reference filters tested at a lower capacity than historical results. The root cause of this was not investigated because shortly after completing the 2016 study the reference filters began testing within their expected range. This could have been due to the lack of a dust cake on the test system clean-up filters, which would lower their efficiency, especially for smaller particles (less than 4 um). This could have lowered the capacity of tested filters until adequate dust cake was deposited on the new test system clean-up filters.

5 Flat sheet media study

In 2015, conductivity related effects during filter testing were evaluated further through flat sheet testing at different levels of oil conductivity. This testing was conducted using a Single-pass system to avoid any changes in fluid conductivity. Testing was conducted at fluid conductivity levels of 1 500 and 6 000 pS/m with ISO Medium test dust (ISO 12103-1:2016, A3 dust) in MIL-PRF-5606 hydraulic oil. Flat sheet holder media area was 6,1 in^2 (39 cm^2). Flow rate through the media was maintained at 300 ml/min. Temperature was maintained at 25 °C. The media used in this testing was typical, production-level, engine liquid filter media. Samples were tested to 172 kPa terminal differential pressure.

Testing showed a higher initial efficiency for the higher conductivity level of the fluid (Figure 4), which caused the filter to load faster, resulting in a lower capacity compared to the lower conductivity level fluid. The high conductivity fluid loaded in 60 minutes. The low conductivity fluid sample loaded for an additional 15 minutes (75 minutes to load to terminal dP), resulting in approximately 25 % increase in calculated capacity for the low conductivity sample.



Key

X test time (minutes)

Y dP – pressure drop across flat sheet sample (kPa)

Z Eff – flat sheet sample efficiency (≥4 µm)

_ _ 6 000 pS/m – dP

—— 1 500 pS/m – dP

–×– 6 000 pS/m – Eff

–□– 1 500 pS/m – Eff

Figure 4 — Flat sheet results from Single-pass testing.

Figure 4 shows the filter sample tested in low conductivity fluid (1 500 pS/m) needed more time to fully load compared to the high conductivity fluid (6 000 pS/m). The difference in conductivity therefore makes the lower conductivity sample appear to have approximately 25 % longer life than the high conductivity sample, even though it is the same media. This study illustrates the importance of a narrow conductivity range. ISO 4548-12 currently specifies an initial conductivity within the range of 1 500 pS/m ± 500 pS/m.

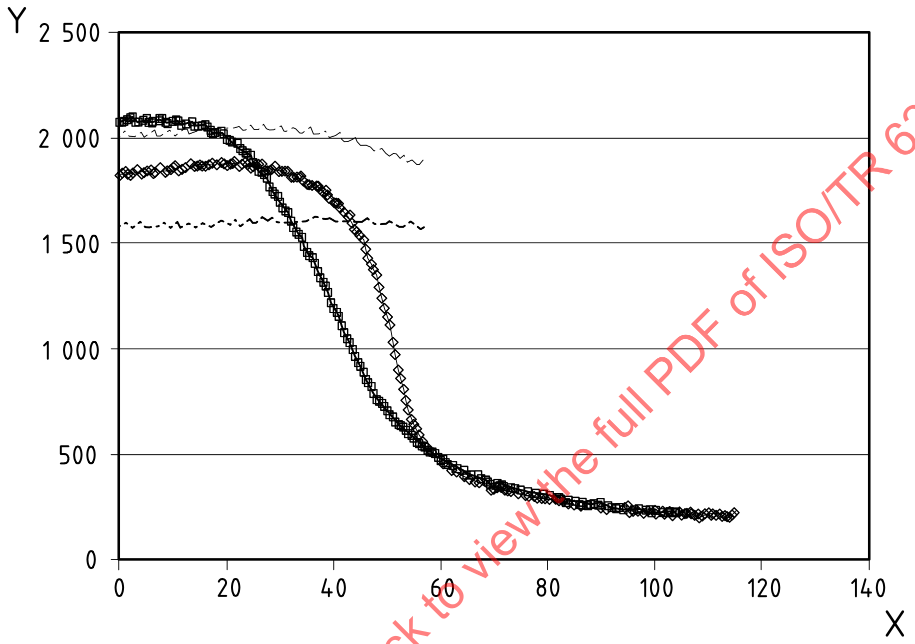
6 Commercially available filter study

In 2016, commercially available filters were obtained for testing. Two (2) of the filter models were selected because they had tested at much higher capacity then calculated capacity indicated (calculated from flat sheet testing and media area). These filters were tested per ISO 4548-12 with and without the active dosing system that allows conductivity improver fluid to be added to the main tank of the ISO 4548-12 test system during the test.

Filter A and Filter B were tested sequentially with the same oil and test equipment. Initial conductivity was set at 1 500 pS/m ± 500 pS/m for each test, per ISO 4548-12. The conductivity improver dosing system was not used during this first phase of testing. The filters were loaded to a terminal pressure drop of 345 kPa. All filters tested were β(10 µm) = 1 000 per ISO 4548-12. Table 1 below shows the results from two (2) tests conducted with each filter. Figure 5 shows the real-time conductivity of the oil.

Table 1 — Capacity results for commercially available filters tested per ISO 4548-12.

Sample Tested	Capacity (g)	Media Area (m^2)	Capacity per Unit Area (g/m^2)
Filter A	95,2	0,75	127
Filter A	92,8	0,75	124
Filter B	172,5	0,73	236
Filter B	193,0	0,73	264



Key

X test time (minutes)

Y real-time conductivity (pS/m)

filter A, sample 1

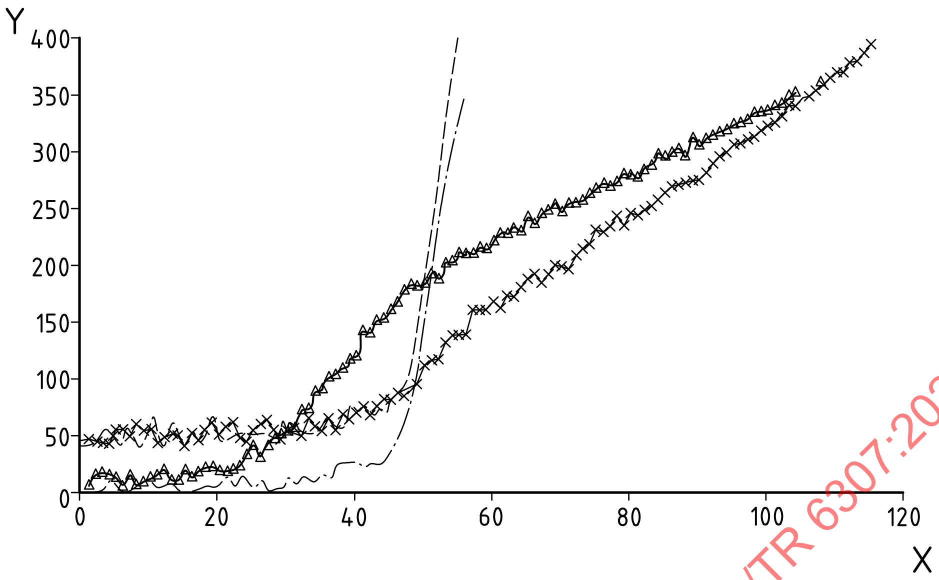
filter A, sample 2

filter B, sample 1

filter B, sample 2

Figure 5 — Real-Time conductivity vs. time during commercially-available filter tests.

The test results in Table 1 showed approximately double the capacity for Filter B compared to Filter A with no significant difference in media area. This testing showed a significant decrease in conductivity for Filter B (Figure 5). Testing continued with the conductivity dosing system connected to the multi-pass test system. Conductivity improving fluid was actively dosed into the main tank. Figure 6 shows loading curves from the original testing (conductivity was not maintained) and Figure 7 shows loading curves from the testing with the conductivity maintaining device. Additional filters were tested during the second round (with conductivity maintained) that were similar to the first-round filters. Filters A and D were similar, and Filter B and C were similar. This is due to limited samples and needed sourcing additional samples for the second round of testing. Samples sourced during this are assumed to have not differed from the initial testing round.



Key

X test time (minutes)

Y pressure drop across filter element (kPa)

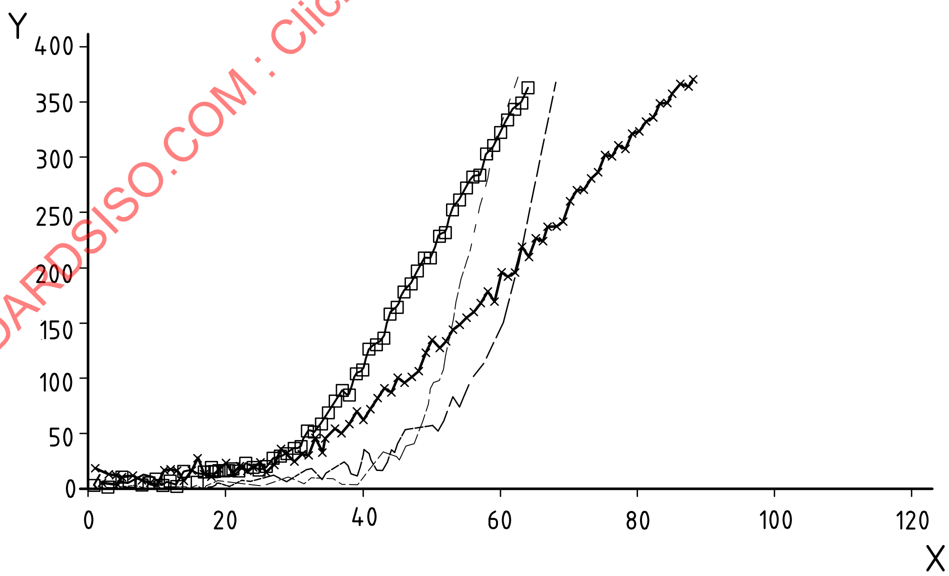
_._ filter A, sample 1

_ _ _ filter A, sample 2

—△— filter B, sample 1

—×— filter B, sample 2

Figure 6 — Loading curves for commercially-available filters tested per ISO 4548-12, when conductivity was not maintained near 1 500 pS/m during the test.



Key

X test time (minutes)

Y pressure drop across filter element (kPa)

_ _ _ filter A

—□— filter B

—×— filter C

_ _ filter D

Figure 7 — Loading curves for commercially-available filters tested per ISO 4548-12, when conductivity was maintained near 1 500 pS/m during the test.

Table 2 below shows a summary of this testing. When conductivity is maintained, the capacity per unit area of Filter A remains similar to the results from the first round of commercially available filter testing, when conductivity was not maintained. However, Filter B experienced a large drop in capacity and capacity per unit area when conductivity was maintained. The data in Figures 6 and 7 show how the slope of the filter loading curve changes when conductivity of the oil decreases.

Table 2 — Capacity Summary of Commercially Available Filter tests when conductivity is maintained and not maintained.

	Conductivity was NOT Maintained		Conductivity was Maintained	
	Capacity (g)	Cap./Area (g/m^2)	Capacity (g)	Cap./Area (g/m^2)
Filter A	94	125	107	142
Filter B	183	250	129	161
Filter C	-	-	108	131
Filter D	-	-	113	152

This experimentation showed examples of commercially available filters that cause a large decrease in fluid conductivity during ISO 4548-12 testing, resulting in a large increase in filter capacity. The cause of the conductivity decrease is unknown but is likely caused by the filter media or filter construction. This testing was conducted with new oil, which was shown to not cause a decrease in conductivity during reference filter testing. Old oil and new oil were analysed to look for changes in the oil that could be causing the conductivity issues.

7 Oil analysis

In 2017 and 2018 samples of oil were gathered from three types of oil (MIL-PRF-5606): old / aged, fresh out of the barrel, and new oil in the bench (additized with conductivity improving fluid). Results from 2017 showed no significant difference in total acid number (TAN) or total base number (TBN) between these samples. In 2018 the samples were analysed for several fluid properties. None of the properties analysed showed a significant difference (shown below in Table 3). It is possible that an additive within the oil is depleted as the oil is used for multi-pass tests. Finding the correct additive is very unlikely without knowledge of the additive package components which can only be obtained from each oil supplier/manufacturer.

Table 3 — Oil analysis results for old, new, and new (additized) MIL-PRF-5606.

Property	New, For Testing	Old, Being Changed	New, Fresh out of Barrel
Viscosity @ 40 C (cSt)	14,43	14,47	14,31
Viscosity @ 100 C (cSt)	5,311	5,316	5,251
Viscosity Index	370	370	368
API Gravity @ 60 F	30,2	30,2	30,2
Neut. Number (mg KOH/g)	0,11	0,11	0,11
Conductivity (pS/m)	970	580	10
Calcium (ppm)	2	1	1
Nickel (ppm)	0	0	1
Phosphorus (ppm)	387	377	411
Sodium (ppm)	0	0	0

