TID No 2 – Filter Membrane Testing

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1. Introduction

This JIG Technical Information Document (TID) is to provide information on Filter Membrane Testing. It will discuss the test requirements, why and when the test should be performed, highlight the key requirements on how it should be carried out in accordance with the industry test methods, and provide guidance on the interpretation of the results. In addition, examples of unusual colors experienced in the field by some users are presented, along with possible interpretation of these unusual results and guidance to the users.

2. Filter Membrane Testing

Filter Membrane Testing involves the filtration of a known volume of fuel, sampled through a standard filter membrane to isolate particulates present in the fuel for evaluation.

Any build-up of particulate matter on the filter membrane will discolor it. Therefore, the filter membrane color rating provides a simple means of detecting changes in the fuel and assessments of particulate contamination in fuel. Changes in membrane color may be indicative of changes in fuel contaminant level and type, due to, for example, a change in the fuel handling system or refinery process conditions or a filter performance issue requiring further investigation. Therefore, filter membrane testing can be used for trend monitoring of fuel cleanliness and filter performance.

There are two ways of evaluating the particulates isolated on the membrane: by their color or their weight. These are known as Colorimetric Membrane Test and Gravimetric Membrane Test, respectively.

2.1. Colorimetric Membrane Test

Qualitative assessment of a locally prepared filter membrane after running 5 litres of product through it and comparing the membranes when wet and dry, after a period of drying, to an ASTM standard.

2.2. Gravimetric Membrane Test

This is a quantitative weight assessment of a laboratory prepared filter membrane after running 5 litres of product through it. The particulate contaminant is determined from the increase in mass of the test membrane filter relative to the control membrane filter.

2.3. Test requirements

To ensure standardisation, test requirements are detailed in the following two test methods:

- ASTM D2276/IP216 Standard Test Method for Particulate Contaminant in Aviation Fuel by Line Sampling
- ASTM D5452 Standard Test Method for Particulate Contamination in Aviation Fuels by Laboratory Filtration

Additional information can be found in ASTM Manual 5, Aviation Fuel Quality Control Procedures.

2.4. JIG Requirements

All filter membrane tests in the field (colorimetric and gravimetric) shall be carried out in accordance with ASTM D2276/IP216, at a flow of at least 50% of the rated flow of the filter. All results shall be recorded, and the colorimetric membranes retained for 3 years.

It is noted that although ASTM D2276 specifies that the volume of the fuel sample should be in the range of 3.785 L (1 gal) to 5 L (1.321 gal), JIG standards require that 5-litre samples shall be taken for all tests.

Samples for routine filter membrane testing shall be taken from the downstream side of the filter. For filters on fuelling vehicles, the tests may be carried out on the test rig, at the hose end or a sample point on the rig, immediately downstream of the delivery nozzle. The tests may also be carried out during aircraft fuelling using a sample point in the vehicle pipework, downstream of the filter.
3. **When should the test be carried out?**

JIG Standards specify requirements and frequency for Filter Membrane testing of Jet fuel filtration. These are as follows:

<table>
<thead>
<tr>
<th>Location</th>
<th>Single Membrane Colorimetric</th>
<th>Double Membrane Colorimetric</th>
<th>Gravimetric</th>
<th>JIG Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Refinery Filters</td>
<td>Not routinely required Monthly testing recommended</td>
<td>Not routinely required</td>
<td>Not routinely required</td>
<td>EI/JIG 1530 4.5.8.4 9.4.7 (g)</td>
</tr>
<tr>
<td>Terminal Filters</td>
<td>Not routinely required Monthly testing recommended</td>
<td>Not routinely required</td>
<td>Not routinely required</td>
<td>EI/JIG 1530 4.5.8.4 9.4.7 (g)</td>
</tr>
<tr>
<td>Airport Depot Upstream of Pipeline Receipt filtration</td>
<td>If concern with quality of fuel being received or increase in inlet filter DP</td>
<td>As part of an investigation, if concern with quality of fuel being received or increase in inlet filter DP</td>
<td>As part of an investigation, if concern with quality of fuel being received or increase in inlet filter DP</td>
<td>JIG2 4.2.3</td>
</tr>
<tr>
<td>Airport Depot Downstream of Product Receipt and Fueller Loading Filters</td>
<td>Monthly Can be extended to Quarterly (*)</td>
<td>Not routinely required</td>
<td>Not routinely required</td>
<td>JIG2 A6.2.3</td>
</tr>
<tr>
<td>Airport Depot Downstream of Into-hydrant filters</td>
<td>Monthly Can be extended to Quarterly (*) On representative number of into-hydrant filters such that each vessel is checked at least quarterly</td>
<td>Not routinely required</td>
<td>Not routinely required</td>
<td>JIG2 A6.2.3</td>
</tr>
<tr>
<td>Into-plane Fuelling Equipment Downstream of Filters</td>
<td>Monthly And after changing filter elements</td>
<td>Six Monthly</td>
<td>Not routinely required But alternative to double membrane colorimetric</td>
<td>JIG1 A6.2.3</td>
</tr>
<tr>
<td>Smaller airport (JIG4) All Filters</td>
<td>Not routinely required</td>
<td>Not routinely required</td>
<td>Not routinely required</td>
<td>-</td>
</tr>
</tbody>
</table>
Other occasions requiring Filter Membrane testing, on an ad-hoc (non-routine) basis:

- When investigating product quality issues – for example rapid plugging of receipt filtration
- A gravimetric test for new fuelling vehicles.
- After recommissioning into-plane fuelling equipment that has been out of service for more than a month
- When new refuelling hoses are installed (test before use).
- As part of Hydrant commissioning (Ref EI 1560)

Other occasions requiring a Double Membrane Colorimetric test:

- If a value of 4 (dry) or more, or an increase of 2 (dry) above the previous month’s color rating is obtained, a double membrane colorimetric membrane test should be performed as a first step in an investigation (Ref JIG1/2 A6.2.3).

Note: It is the intent of JIG to clarify in the next issue of JIG standards that if a value of 5 (wet) is obtained, that should prompt an investigation immediately, without waiting for the membrane to dry out for the dry rating to be observed.

(*) if fuel is demonstrably ‘consistently clean’. To be consistently clean, monthly records over a period of at least 2 years shall confirm filter element life in excess of 12 months and all downstream monthly colorimetric ratings of 3 (dry) or less.

4. Filter sampling connections

Sampling connections shall be provided at the inlet and outlet of all new filter vessels meeting the requirements of EI 1596, to enable membrane tests or other fuel quality checks to be carried out. All filter membrane test points should be stainless steel, aluminium or epoxy lined mild steel.

5. Apparatus

Equipment has been developed by several companies to carry out the test. The most common are shown below.
5.1. Typical apparatus for line sampling

*Reproduced with the permission of Gammon Technical products (http://www.gammontech.com)*

5.2. Typical apparatus for closed-circuit sampling

*Reproduced with the permission of Stanhope Seta (www.stanhope-seta.co.uk)*
6. Field Monitor capsule (field monitor holder)

A typical field monitor capsule is shown below.

The capsule shall always be handled with care to ensure it is maintained in a scrupulously clean condition. To avoid extraneous contaminant, field monitor protective plugs should be removed only for sampling and replaced immediately. The monitor should be opened only in a laboratory or clean and controlled environment, to eliminate potential contamination of the membrane(s).

7. ASTM Color Standards

The ASTM Color standards consist of three stepwise-graded scales intended to bracket in hue the color ordinarily encountered on jet fuel filter membranes. There are two color strips and one grey strip, each divided into eleven steps and assigned rating numbers from 0 to 10.

Reference: “Specification for Color Rating Booklet” incorporating the ASTM Color Standards is available from ASTM

Charts in use should be checked periodically against a reference set of color standards to eliminate the possibility that sunlight or soiling due to handling may have appreciably changed the colors. The reference set is a set of ASTM Color standards obtained new, stored in dry dark conditions, and is only used for the purpose of checking the standards in day-to-day use.

ASTM D2276 recommends that a production batch of ASTM Color rating books shall be considered acceptable for continued use until any color chip in the 0 to 5 range of scales A, B, or G has changed in lightness (value) as much as one rating number as indicated by the value (lightness) of the next lighter or darker color.
8. Key requirements for the testing procedure

The key requirements for testing procedure in accordance with ASTM D2276 are outlined below. It is recommended that a Site-Specific procedure is developed to cover the following requirements

7.1. Preparation of Filter Membranes

Filter Membranes may be prepared in a laboratory, but preferably at the facility as follows:

a) Select a field monitor capsule and mark it for identification.
b) Check that the capsule is clean, dry and in good condition.
c) Insert a clean support pad (backing pad), in the bottom half of the monitor.
d) Using flat bladed forceps carefully place a new, grade AA membrane filter in position on the support pad and reassemble the monitor. Ensure that the two halves of the monitor are tight, and the membrane is clamped correctly. Make sure connection is hand tight; extreme force is not necessary as the O-rings will create a tight seal.
e) Insert protective dust plugs in the monitor and store it in a clean and cool place until needed.
Double Membrane Colorimetric Testing

Monitors should be prepared in the same way as above, but with the insertion of two new, grade AA membrane filters in position on the support pad instead of one.

Gravimetric testing

Monitors should be prepared with the insertion of two new factory matched membranes that are placed together, one on top of the other on the support pad. Filter Membranes can be purchased as ‘matched weights’ so that it is not necessary to know the original weights. When ‘matched weights’ are not used, it will be necessary to weigh both membranes before and after use and to note which membrane is the ‘working’ and which the ‘control’ (Ref EI 1550).

Testing Procedure – Line sampling

Typical Sampling apparatus.

Samples should be taken at the tapping point, either upstream (e.g. as part of investigation) or downstream of filters (routine testing), in accordance with JIG requirements.

Install the monitor in the sampling apparatus. Place the field monitor in the holder with its lower half having the spider web pattern on the downstream side of the field monitor.

Ensure the flushing line is connected to the selector valve and lead the free end directly into a graduated sample receiver.

Ensure that the flexible drain line is connected to the bottom of the monitor holder and position the free end in the graduated sample receiver.

Ensure that the sampling apparatus is bonded with the graduated sample receiver.

Remove the dust caps from the connection and the flexible pressure hose connector and connect the sampling apparatus to the sampling connection with the selector valve in the ‘off’ position, or with the equipment ready to flush.

Line flow rate shall not be below 50% of the rated capacity of the equipment being checked, and the pressure should be maintained at 30 to 35 psi (2 to 2.4 bar) to obtain a reasonable sampling rate.

Sample should be obtained within 2 to 12 minutes (flush and sampling volumes). The pressure and flow conditions should be noted on the report form.

When the desired fuel flow and pressure conditions are established in the line or hose to be sampled, operate the selector valve to the ‘flush’ position.

When at least 2-litres of fuel have passed through, turn the selector valve to the ‘test’ position.

Take a 5-litre fuel sample into the graduated sample receiver, and on completion turn the selector valve to the ‘off’ position or disconnect the sampling apparatus from the sampling connection.

9. Back Pressure correction

Where during sampling the pressure is too low to obtain a proper fuel sample in a reasonable time, a back pressure may be applied by partly closing the valve, if a back pressure valve is fitted downstream of the sampling connection. However, line flow rate shall not fall below 50% of the rated capacity of the equipment being checked.

10. Additional considerations

If it is necessary to temporarily pause sampling, halt sampling before flow ceases. When flow is re-established and conditions stabilized, recommence sampling. Flushing is not necessary.

If leaks are observed from the monitor holder, O-rings shall be replaced with new ones. Over-tightening can cause membrane breakage around the clamped edge.

Never turn a flushing valve rapidly. Broken membranes can be caused by rapidly starting the flush cycle in a high-pressure system. The fuel bypasses the membrane, but it can enter the plastic monitor from the outlet side, compressing the trapped air in the monitor. A membrane has little strength and fails from this slight reverse flow. For this reason, turn the flushing valve very slowly.
11. Testing procedure – self-contained sampling apparatus

As an alternative to sampling into an open container, as detailed above, a closed-circuit sampler (such as the SSAFCON sampler), may also be used.

A SSAFCON mounting tray can be permanently installed at the sampling points downstream of the filtration system, typically at a designated static test site, hydrant dispenser or onboard the refuelling vehicle. The sampler connects to the mounting tray by self-sealing quick release couplings and a bonding clip. Docking/undocking of the Sampler is rapid and safe. A typical apparatus is shown below:

The bypass valve directs fuel through a filter cell containing the removable membrane filter or allows flushing of the sampler. Tested fuel may be routed to a flow line leading to a dump tank, without the need for buckets or containers.

An integral volume meter and pressure valve are used to control flow rate and monitor the volume of fuel passed through the filter.
12. Disconnection

After sampling is completed, allow 1 minute to pass before disconnecting the sampling unit from the sampling connection to allow electrostatic charges to dissipate. Replace dust caps.

Where a self-contained sampler is used (SSAFCON), the sampler should be disconnected from the tray after sampling, and the filter removed for gravimetric or colorimetric analysis, as described above.

Empty any fuel from within the monitor case using the suction device supplied with the field sampling kit. Make sure that suction is supplied gently and only to the outlet side of the monitor to prevent damage to the filter membrane(s).

13. Gravimetric

A 5-L sample is taken as described above through a field monitor containing either ‘matched weights’ or a pre-weighed 0.8-μm test membrane filter and a pre-weighed 0.8-μm control membrane filter, backed by a 34-mm support pad. After filtration the field monitor is returned, without opening, to the laboratory, and the gravimetric result determined in accordance with the IP/ASTM procedure.

14. Reporting of Results

The color of the membrane shall be recorded on a wet and dry basis, as follows:

14.1. Single Membrane Colorimetric test

The color on each filter membrane used is compared with the ASTM Color standards and assigned a rating letter and number.

The following conditions should be recorded:

- Date
- Monitor serial number
- Sample location and volume of sample
- Flowrate and line pressure
- Sampling time
- Name and Signature of operator who performed the test

14.2. Double Membrane Colorimetric test

For Double Membrane testing, follow the same procedure for draining and handling the exposed monitor. When the two membranes are removed, they should be separated and the ‘wet’ and ‘dry’ ratings of each individual membrane assessed and recorded.

See JIG Example Colormetric Filter Membrane Test Record: http://www.jigonline.com/extranet/publications/#456
The dry rating shall be recorded for future reference/comparison.

**Gravimetric testing:**

Follow the same procedure for draining, handling and rating the exposed monitors against the ASTM Color Standard.

Monitors containing either ‘matched weights’ or the pair of pre-weighed membrane filters shall be returned, without opening, to the laboratory for determination of the total contaminant. The final ‘dry’ ASTM color rating of gravimetric test membranes shall also be recorded in the laboratory report.

## 15. Interpretation of Results

The results of all colorimetric and gravimetric Membrane Filtration Tests shall be reviewed carefully, as below, to check whether any significant deterioration has occurred in comparison with earlier results on the same equipment and, in the case of gravimetric results, to confirm that the values are below the acceptable maximum limit.

As a guide only, the different ASTM Color Standard scales can be indicative of certain conditions/phenomena.

The ASTM Color standard scales were chosen during the original test method development as it is difficult to take a membrane with grey color and compare it to a brown color in terms of relative darkness. The scales were selected as the most commonly encountered color shades to simplify comparison.

If the color density is between two numbers, e.g. between B-3 and B-4, report the ‘lower’ number.
<table>
<thead>
<tr>
<th>Color scale</th>
<th>Indication</th>
</tr>
</thead>
<tbody>
<tr>
<td>The A (red) scale</td>
<td>The A (red) scale may be indicative of ferric type rust or possibly some paint linings (especially ships). Other causes could be marker dyes and a double membrane paper will show this with red color on both papers.</td>
</tr>
<tr>
<td>The B (brown) scale</td>
<td>The B (brown) scale is generally indicative of normal particulate – rust (hydrated ferric oxide or ferrous oxide) and sand/silica type particulates.</td>
</tr>
</tbody>
</table>
| The G (grey) scale| The G (grey) scale is indicative of a potential number of causes that should be further investigated.  
- Fresh metal (suggesting engineering/maintenance works – welding/grinding etc. or wear metals from component disintegration, such as meter blades or vanes).  
- Clay treater breakthrough.  
- Black iron oxide, black iron sulfides or heat exchanger leaks that are sometimes found when there has been a refinery upset.  
- Over use of a grease gun on swivel joints. |
Color rating in the wet condition after sampling provides an immediate indication of fuel cleanliness.

The membrane should then be left to dry in the air for at least 3hrs in a clean position that is shielded from dust before rating it again to obtain the ‘dry rating’. The advantage of rating in the dry condition is that the membrane will not change color in the dry state.

Typically, the ratings are one or two numbers lower after drying, although exceptionally the difference between wet and dry ratings may be as great as five numbers. Therefore, comparison based on mixed wet and dry ratings should not be made.

During the drying process either from oxidation or changes in morphology, it has been observed that a Wet A color dries to a B color and vice-versa. Dry colors are typically a lower color rating than wet.

The reason for using two membranes is to distinguish between particulate contamination and harmless color bodies. If the fuel is dirty, the upper (upstream) membrane may have a significantly darker color after testing than the lower membrane. If the fuel contains soluble color bodies, then both membranes will be stained by the test.

All results shall be checked and compared carefully with previous values, and appropriate action taken if high dirt levels are indicated

**As a general guide:**

(a) Results on properly maintained filtration equipment delivering fuel from airport storage should not normally be any higher than the corresponding vehicle hose end tests.

(b) Receipt filters at entry to airport storage may be expected to give slightly higher results (by one or two numbers).

For fixed filtration equipment, it is difficult to prescribe firm limits for the results of colorimetric tests. As in the case of vehicle hose-end results, it is the change in color rating that is most significant; if a significant increase in the colorimetric is seen, both the filtration equipment and the upstream fuel quality should be checked.

An Annual Record of the Colorimetric results on all filtration should be prepared (and maintained) for comparison purposes.
16. Acceptable membrane ratings

<table>
<thead>
<tr>
<th></th>
<th>Fixed Filters</th>
<th>Vehicle Filters</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Single Membrane</strong></td>
<td>Max 3 (dry)</td>
<td>Max 3 (dry).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Max 1 number difference from previous test result.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>If a value of 5 (wet) or 4 (dry) or more, or an increase of 2 (dry) above the previous month’s color rating is obtained, a double membrane colorimetric membrane test should be performed as a first step in an investigation.</td>
</tr>
<tr>
<td><strong>Double Membrane</strong></td>
<td>If the difference between the rating of the upper and lower membranes is 3 (dry) or more, the fuel may not be acceptable. To determine whether there is a problem, an immediate investigation, including a gravimetric filter membrane test and filter vessel inspection shall be carried out until the cause of the problem has been identified and a further double membrane or gravimetric test result is satisfactory.</td>
<td></td>
</tr>
<tr>
<td><strong>Gravimetric</strong></td>
<td>Any results outside the normal range for the location shall be investigated. Any result of 0.20mg/litre or more shall be reported immediately and a repeat gravimetric membrane test carried out. To determine whether there is a continuing problem an immediate investigation shall be carried out, including a double membrane colorimetric test and filter vessel inspection, until the cause of the problem has been identified or until the repeat gravimetric test result is reported as satisfactory.</td>
<td></td>
</tr>
</tbody>
</table>

If the test results are unsatisfactory additional tests should be carried out. If the results are confirmed, then the equipment should be taken out of service and the filter vessel opened for inspection.

17. Records

A record shall be maintained, showing clearly the month-by-month test results for each filter. In addition, the exposed colorimetric test membranes shall be retained. All results shall be checked and compared carefully with previous values, and appropriate action taken if high dirt levels are indicated.

To provide a visual record of any changes in fuel quality, both used membranes should be retained for a minimum of 3 years.

18. Equipment maintenance

Equipment shall be maintained in accordance the manufacturers recommendations.

Equipment that is found to be defective shall be removed from use.
### 19. Test Troubleshooting

<table>
<thead>
<tr>
<th>Issue</th>
<th>Action</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time for 5 litres is less than 2 minutes.</td>
<td>Test should be repeated. Check Membrane for damage, check back pressure is not too high.</td>
<td>If membrane is damaged, it must be replaced.</td>
</tr>
<tr>
<td>Time for 5 litres is greater than 12 minutes.</td>
<td>Check back pressure is at least 30 psi.</td>
<td>If back pressure was too low, repeat test. Long filtration times indicate high particulate and as this is downstream of the filter, filter should be opened.</td>
</tr>
<tr>
<td>Time for 5 litres is greater than 15 minutes.</td>
<td>Test should be repeated. Check back pressure is at least 30 psi. Check that the expected number of membranes are included in the cartridge.</td>
<td>Long filtration times indicate high particulate. Filter should be opened. Contact technical support for advice.</td>
</tr>
</tbody>
</table>
20. Non-standard Membrane Colors

Some JIG members have encountered instances where non-standard colors, e.g. greenish blue, were obtained on Filter Membranes when carrying out colorimetric Filtration Membrane tests during dedicated pipeline receipts. Examples of colors seen are shown below:

It is recommended that if non-standard colors are seen, an investigation should take place and full specification testing should be done.

![Color Examples](image)

<table>
<thead>
<tr>
<th>Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>Greenish</td>
</tr>
<tr>
<td>Greenish grey</td>
</tr>
<tr>
<td>Bluish Green</td>
</tr>
<tr>
<td>Bluish Grey</td>
</tr>
<tr>
<td>Dark Greenish Grey</td>
</tr>
</tbody>
</table>

These incidents were investigated, and in all cases, full testing of the fuel confirmed it met all the specification requirements, but the root cause for colors seen has not been completely identified.

During one investigation (see Appendix 1 for pictures of filter membranes obtained) it was confirmed that all the fuel samples that produced non-standard Membrane Filter colors were of normal color, in most cases water white, and full testing of the fuel confirmed it met all the specification requirements. However, some of the retention samples from the supply source analysed had a greenish tint to different extents. This suggested that under limited oxygen conditions, e.g. in sample cans, reactions were occurring that could lead to the production of colored species. These colored species could be produced in fuels that have been severely hydro-processed which happened to be the case for the majority of batches received. In normal conditions, as their concentration is very low, they are only detectable when the fuel is passed through a filter e.g. a Filter Membrane, where they can be concentrated on the normal particulate present in the fuel. The particulate matter found on the Filter Membrane in this case was identified as being consistent with normal material found in aviation distribution systems from ships, pipelines, filters and the atmosphere.

One action taken after the receipt of fuel that caused non-standard color membranes was to carry out a recertification test including a Thermal Stability Test on the fuel at 275 °C.

Any solid matter or material that can be gathered from the filter vessel walls should also be analyzed.
Appendix 1 - Examples of Filter Membranes with non-standard colors

Single Membrane Tests

Double Membrane Tests
Technical Information Document

Literature

- ASTM D2276/IP216 Standard Test Method for Particulate Contaminant in Aviation Fuel by Line Sampling
- ASTM D3830 Standard practice for filter membrane colour ratings of aviation turbine fuels
- ASTM D5452 Standard Test Method for Particulate Contamination in Aviation Fuels by Laboratory Filtration
- ASTM Manual 5 - Aviation Fuel Quality Control Procedures
- ASTM Specification for Color Rating Booklet
- JIG1 Aviation Fuel Quality Control & Operating Standards for Into-Plane Fuelling Services
- JIG2 Aviation Fuel Quality Control & Operating Standards for Airport Depots & Hydrants
- JIG4 Aviation Fuel Quality Control & Operating Standards for Smaller Airports
- EI/JIG 1530 Quality assurance requirements for the manufacture, storage and distribution of aviation fuels to airports
- EI 1550 Handbook on equipment used for the maintenance and delivery of clean aviation fuel
- EI 1596 Design and construction of aviation fuel filter vessels
- JIG Colormetric Filter Membrane test record-example

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