

EI 1583

Laboratory tests and minimum performance
levels for aviation fuel filter monitors

6th edition



EI 1583

LABORATORY TESTS AND MINIMUM PERFORMANCE LEVELS FOR AVIATION FUEL FILTER MONITORS

6th edition

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FOREWORD

This publication is intended to provide the industry with general mechanical specifications for new aviation fuel filter monitor designs, laboratory test procedures and minimum laboratory performance levels for selected aspects of the performance of filter monitor elements and systems. The aspects of performance selected for inclusion in this publication are primarily those where a laboratory test has been developed with sufficient experience to identify a minimum level of performance. No attempt is made to completely define all necessary tests or aspects of performance for products to be suitable for every application. In all cases the purchaser should discuss the particular application with the manufacturer.

This publication is not in any way intended to prohibit either the purchase or manufacture of filter monitor systems or elements meeting other requirements. It is hoped and anticipated that this publication will assist those involved in manufacturing and purchasing filter monitor systems and elements.

This is the sixth edition of this publication, which supersedes all earlier editions. With the publication of the sixth edition of EI 1583, the fifth edition is hereby formally withdrawn from publication.

It is imperative for manufacturers, purchasers, and users of filter monitors to be aware that the laboratory performance tests and minimum laboratory performance levels described herein may be of reduced utility in predicting in-service performance since it is not possible to replicate exactly in a laboratory the environmental and operational parameters to which a filter monitor system or elements may be exposed when in service in commercial aircraft fuelling applications. Laboratory performance testing of used filter monitor elements (qualified to earlier editions of 1583) removed from field service, has shown that water absorption performance may deteriorate to levels less than specified in EI 1583 for new elements. It has not been possible to identify with certainty the mechanisms that cause such deterioration in service, despite significant collaborative research and investigations by industry representatives. Evidence also suggests that even the performance of new elements may be sensitive to environmental parameters.

Thus, the use of filter monitors that meet the requirements of EI 1583 alone cannot provide assurance that free water in fuel will be prevented from passing onto an aircraft. Filter monitors that meet the requirements of EI 1583 are intended to be part of a comprehensive system to protect aviation fuel cleanliness, and cannot be regarded as fail-safe devices on their own. For further information on systems to protect aviation fuel cleanliness see API/EI 1550 *Handbook on equipment used for the maintenance and delivery of clean aviation fuel*. For further information on issues suspected or known to impact the performance of filter monitors (such as the temperature and salinity of free water) see API/EI 1550 Annex H (in first edition). This information however, is intended to only provide examples, not to capture all issues that must be addressed by a filter monitor manufacturer to produce a product that is fit-for-purpose.

It has also been stated that the use of filter monitors (qualified to earlier editions of 1583) may result in unknown quantities of super-absorbent polymer (SAP) passing downstream of filter monitors, even when filter monitors are operated in accordance with manufacturers' instructions. This edition of 1583 includes an ICP copper quantification method to determine what level of SAP may occur in fuel downstream of a filter monitor element under test. However, manufacturers and users shall note that the use of filter monitors that meet the requirements of this publication alone cannot provide assurance that SAP contamination in fuel will be prevented, since it is not possible to replicate exactly in a laboratory the environmental and operational parameters to which a filter monitor system or elements may be exposed when in service.

This publication is intended to be applied to the qualification of a model of filter monitor element and system. The destructive nature of these laboratory tests renders them unsuitable for 'every-element' quality control testing, see 1.3.3. Once a model of element has been qualified in accordance with this publication it is the intention that all production elements of that model are identical in their design, materials and production techniques, see also section 7.

It is anticipated that purchasers may wish to install filter monitor elements in vessels originally designed for use with other types of filter elements. In these cases the element general mechanical specification and minimum laboratory performance requirements of this publication may be used for the purchase of elements without a new filter monitor vessel.

Any manufacturer wishing to offer filter monitor systems and/or elements stated to comply with this publication is responsible for complying with all the mandatory provisions included herein. It is the responsibility of the manufacturer to further define any application and/or performance limitations that affect the serviceability of filter monitor systems in aircraft servicing. IN NO EVENT SHALL ANY MANUFACTURER REPRESENT A FILTER MONITOR AS BEING 'FIT-FOR-PURPOSE' IN AVIATION FUELLING OPERATIONS ON THE SOLE BASIS OF MEETING THE MINIMUM LABORATORY PERFORMANCE LEVELS INCLUDED IN THIS PUBLICATION. Nor shall the minimum laboratory performance tests described in this publication be taken as the only aspects of performance that a user should investigate prior to the routine use in their operations of any equipment that meets the requirements of those tests.

Purchasers are advised to make any enquiries of the manufacturer to confirm that the product is acceptable, and are strongly encouraged to conduct field testing, before deeming a product acceptable. The purchaser should make any investigations and conduct any testing necessary to confirm that the manufacturer has conformed to this publication and that the equipment meets the purchaser's requirements. The purchaser should not rely solely on the manufacturer's representation that the manufacturer's filter monitor has been 'qualified to' 1583, or that its filter monitors otherwise 'meet' the standard, as laboratory testing cannot assess the long-term durability, mechanical integrity and performance of filter monitor systems or elements in service.

The main changes in this edition from previous editions are:

- The deletion of categories of elements included in the fifth edition to provide options for manufacturers in addressing SAP migration.
- The addition of an ICP copper quantification method to determine the level of any SAP in effluent during Qualification Tests 1 (media migration and starting differential pressure) and 10 (partial water immersion).
- Testing resistance to salinity of water in fuel.
- Testing for end cap adhesion integrity.

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Technical editing and project co-ordination was carried out by Martin Hunnybun (EI).

1 INTRODUCTION AND SCOPE

1.1 INTRODUCTION

This publication describes laboratory tests and the minimum laboratory performance levels for selected aspects of performance of filter monitor elements and systems. A filter monitor system is comprised of a pressure vessel containing one or more filter monitor elements. Filter monitor vessels may be oriented vertically or horizontally. Any manufacturer wishing to offer filter monitor systems and/or elements stated to comply with this publication is responsible for complying with all the mandatory provisions included herein. However, no attempt is made to completely define the performance of products to be fit for a particular purpose. It is the responsibility of the manufacturer to further define any application and/or performance limitations that affect the serviceability of filter monitor systems in aircraft servicing.

The intended performance of a filter monitor system is to continuously remove particulate matter and water from aviation fuel to levels acceptable for servicing modern aircraft. It is also intended that in service a filter monitor system will restrict the flow of fuel before its capacity for particulate matter and/or water removal is exhausted.

A filter monitor system is not a fail-safe device for protecting aviation fuel cleanliness. The removal of water from fuel by absorption relies on chemical interactions that can be disrupted by extraneous agents, both known and unknown. The performance of filter monitor elements that comply with the mandatory requirements of this publication may also be sensitive to certain environmental or operational conditions, such as low temperatures or high salinity of free water. Filter monitor elements may differ in design in the selection of filtration and water absorbing materials. Different water absorbing materials may respond differently to field parameters such as fuel/water temperature, the salinity of free water, and the presence of trace contaminants. Further, the possibility of filter monitor elements releasing super-absorbent polymer (SAP) into the fuel stream (SAP migration) can depend upon materials selection, element design, element production methods, environmental and operational factors. Further details regarding issues suspected or known to impact the performance of filter monitors are included in API/EI 1550 *Handbook on equipment used for the maintenance and delivery of clean aviation fuel*. These issues should be separately addressed between the user and manufacturer to ensure that the performance capabilities of the filtration equipment are suitable for the intended application.

Thus, the use of filter monitors that meet the requirements of EI 1583 alone cannot provide assurance that water in fuel will be prevented from passing onto an aircraft, or that SAP migration from filter monitor elements will not occur. Filter monitor systems must therefore be regarded as only one component in a comprehensive system to protect aviation fuel cleanliness.

In no event shall any manufacturer represent a filter monitor as being 'fit-for-purpose' in aviation fuelling operations on the sole basis of meeting the requirements of this publication. Nor shall the minimum laboratory performance tests described in this publication be taken as the only aspects of performance that a user should investigate prior to the routine use in their operations of any equipment that meets the requirements of those tests.

1.2 SCOPE

This publication provides minimum recommendations for:

- Selected aspects of filter monitor system and element performance.
- The general mechanical specifications for new filter monitor elements.
- Laboratory tests and minimum performance requirements for the qualification of new filter monitor elements, including materials compatibility with low flash point fuels.
- Requalification and similarity requirements.

The laboratory tests specified in this publication are intended to provide standard methods of evaluating selected aspects of the performance of new filter monitor system and element designs thought to be relevant to field service. They are not intended to predict the actual performance of filter monitors in field service. Aspects of performance including degradation of water absorption and the migration of SAP may vary with fuel and operational environment. Users should work with their suppliers to ensure that their application of filter monitors provides the performance needed in the particular application.

The scope of this publication is limited to elements of 50 mm (2 in.) nominal diameter up to 76 cm (30 in.) nominal length flowing out-to-in, and 150 mm (6 in.) nominal diameter up to 145 cm (57 in.) nominal length flowing out-to-in or in-to-out. Any model of element can also be qualified as 'HS' (High Salt) by passing Qualification Tests 15 and 16 using synthetic seawater (ASTM D1141) *in lieu* of 0,5% (m/m) NaCl in water.

This publication does not address:

- Specific material requirements for the filter monitor element (other than those known to have an effect on fuel compatibility).
- Nominal diameters of elements other than 50 mm (2 in.) or 150 mm (6 in.)¹
- Water and/or particulate matter removal performance testing in low flash point fuels².
- Maintenance or service life performance.
- Trigger type elements.
- **The operation and performance of filter monitor systems and/or elements in fuels containing any fuel system icing inhibitor (FSII), also called diethylene glycol monomethyl ether (DiEGME). This fuel additive makes unusually difficult demands on filtration and water separation/removal devices and may promote the decomposition of filters and release of SAP into fuel.**
- Certain aspects of design and performance necessary to provide products that are fit for a particular purpose. Many aspects of filter monitor performance are neither measured nor controlled by this publication. Filter monitor elements may differ in design in the selection of filtration and water absorbing materials. Different water absorbing materials may respond differently to field parameters such as fuel/water temperature, the salinity of free water, free water, and the presence of trace contaminants. Further, the possibility of these elements releasing SAP can depend

¹ Although the laboratory tests included in this publication have been specifically developed for 50 mm (2 in.) and 150 mm (6 in.) elements only, the test protocols may be modified for use to evaluate the performance of other element diameters, as agreed between a manufacturer and user/purchaser. In such cases qualification to this publication cannot be claimed.

² Due to safety issues with the handling of low flash point fuels the water and/or dirt removal tests use only jet fuels. There is an acceptance, based on industry experience, that the measured performance of filters in jet fuels translates across to filter performance in low flash products such as aviation gasoline, jet B etc.

upon materials selection, element design, environmental and operational factors. These issues are beyond the scope of this publication, and thus should be separately addressed between the user and manufacturer to ensure that the performance capabilities of the filtration equipment are suitable for the intended application.

1.3 DEFINITIONS

1.3.1 Filter monitor system

A filter monitor system is a pressure vessel containing filter elements. A filter monitor system is one component of a system intended to only remove particulate matter and free water from aviation fuel. A filter monitor system is not, by itself, a fail-safe device. Filter monitor systems shall be regarded as one component in a comprehensive system to protect aviation fuel cleanliness.

1.3.2 Filter monitor element

A filter monitor element is the consumable component of a filter monitor system with particulate matter removal and water absorption capabilities. A filter monitor element is also sometimes referred to as a cartridge.

The filter monitor elements defined by this publication are:

- 50 mm (2 in.) nominal diameter with out-to-in flow, that have water absorption capabilities defined by a water blocking time of at least 10 minutes during Qualification Test 2 50 ppm water removal, rated flow and particulate matter holding capacity defined by a solids blocking time of at least 10 minutes during Qualification Test 6 Solids test.
- 150 mm (6 in.) nominal diameter with out-to-in, or in-to-out flow, that have water absorption capabilities defined by a blocking time of at least 40 minutes during Qualification Test 2 50 ppm water removal, rated flow and particulate matter holding capacity defined by a blocking time of at least 50 minutes during Qualification Test 6 Solids test.

Any element may be classified as HS if it meets the requirements of Qualification Tests 15 and 16 using synthetic seawater (ASTM D1141) *in lieu* of 0,5% (m/m) NaCl.

1.3.3 Qualified element model

A qualified element model is one of specific design and construction that is documented by a manufacturer to meet all mandatory tests specified in this publication. Tests are witnessed by a representative of the purchaser/user as described below. Any design, construction, materials or manufacturing changes to the qualified element model that exceed those described in section 7 shall constitute the creation of a new element model requiring full qualification. All production elements are required to be identical in their design, construction and materials to the qualified model. See Foreword.

1.3.4 Single element qualification test

A single element qualification test is a test that is performed with one filter monitor element in a purpose-built pressure vessel (as opposed to a full-scale test) with fuel flowing in single pass mode through the test facility. For a single element qualification test there has to be a sufficient volume of fuel in tank #1 to complete the test.

1.3.5 Full-scale qualification test

A full-scale qualification test is a test performed with a filter monitor system of at least 300 gpm, configured with the full complement of elements as intended for field service with fuel flowing in either single pass or recirculation mode through the test facility.

1.3.6 Water blocking time, or water holding capacity

This is the time taken for an element under test to reach 150 kPa (1,5 bar) pressure differential at full rated flow with a influent water addition rate of 50 ppmv.

1.3.7 Solids blocking time, or solids holding capacity

This is the time taken for an element under test to reach 150 kPa (1,5 bar) pressure differential at full rated flow with an influent solids addition rate of 10 mg/litre.

2 FILTER MONITOR SYSTEMS

2.1 PERFORMANCE FEATURES

A filter monitor system shall have the following general features:

- a. It shall monitor (filter) the full flowing fuel stream and may include a fail-safe feature to prevent unmonitored fuel from passing through the vessel.
- b. It shall require no external power supply.
- c. It shall be simple, strong, compact and easy to install and service.
- d. It shall not contaminate the fuel and fuel properties shall remain within the prescribed limits of the relevant fuel specification.
- e. It shall be suitable for the intended service.

Elements used in the filter monitor system shall meet the minimum performance requirements in section 5.

2.2 PERFORMANCE LIMITATIONS

The manufacturer shall advise each purchaser of any known performance limitations (such as free water salinity limits or low temperature operability limits) that apply in the proper use of filter monitor elements and systems. It is preferable that this information be included with each package of elements supplied.

Aspects of performance including degradation of water absorption and the migration of SAP vary with fuel and operational environment. Users should work with their suppliers to ensure that their application of filter monitors provides the performance needed in the particular application. The purchaser should fully describe the application to the supplier and request that the supplier verify that the filter monitor system will provide the intended performance.

The manufacturer shall also advise each purchaser and user of issues relating to operational life, maintenance requirements, capability of the filter monitor elements and their compatibility with fuel.

2.3 APPLICATION LIMITATIONS

A filter monitor system compliant with this publication is intended to be part of a comprehensive system to protect aviation fuel cleanliness. For further information see API/EI 1550. It should not, by itself, be considered intrinsically fail-safe. Manufacturers and suppliers shall not make any representation indicating that filter monitor elements or systems that comply with this publication are intrinsically fail-safe.

2.4 LIMITATIONS OF LABORATORY TESTING

Laboratory testing cannot assess the long-term durability, mechanical integrity and performance of filter monitor systems or elements. **Purchasers are strongly recommended to conduct field test evaluation of qualified filter monitor elements as part of any programme of implementation and use.** For further information see API/EI 1550, chapter 5.

Laboratory testing may not reproduce all of the field conditions that may lead to release of SAP into the fuel stream. Filter monitor products must be fully and carefully evaluated by the manufacturer/user to ensure that SAP migration does not occur.

3 FILTER MONITOR ELEMENT MECHANICAL SPECIFICATION

3.1 ELEMENT DIMENSIONS

3.1.1 Element length

The nominal length of an element is the approximate length of the element from end-cap shoulder to the end of the other end-cap. The effective length of an element is the actual media length exposed to fuel flow. The overall length is the entire length of the element, which is comprised of the length of the bayonet plus the length from end-cap shoulder to the end of the other end-cap.

For 50 mm (2 in.) diameter elements the actual measurements shall be as shown in Table 1.

The nominal length for 150 mm (6 in.) diameter elements shall be quoted by the manufacturer. Tolerances for 150 mm (6 in.) diameter element length are not specified but all elements assigned a nominal length shall fit all vessels requiring the stated element length without vessel modification.

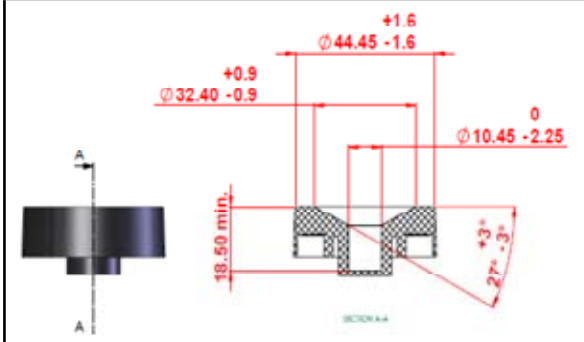
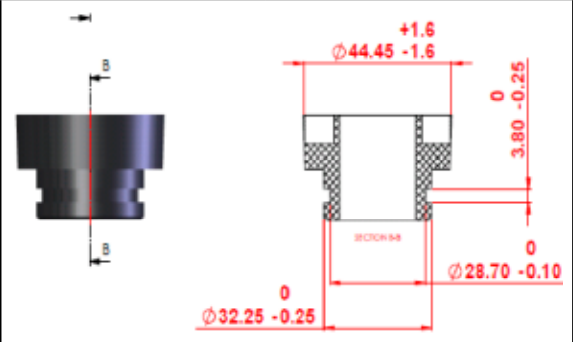
3.1.2 End cap dimensions

End caps for 50 mm (2 in.) diameter filter monitor elements shall conform to the dimensions contained in Table 2.

Table 1 Dimensions for 50 mm (2 in.) diameter elements

Nominal length		Length end-cap shoulder to end		Overall length	
30 in.	762 mm	30,250±0,0625 in.	768,4±1,6 mm	30,8125±0,0625 in.	782,6±1,6 mm
25 in.	635 mm	25,250±0,0625 in.	641,4±1,6 mm	25,8125±0,0625 in.	655,6±1,6 mm
20 in.	508 mm	20,250±0,0625 in.	514,4±1,6 mm	20,8125±0,0625 in.	528,6±1,6 mm
15 in.	381 mm	15,250±0,0625 in.	387,4±1,6 mm	15,8125±0,0625 in.	401,6±1,6 mm
10 in.	254 mm	10,250±0,0625 in.	260,4±1,6 mm	10,8125±0,0625 in.	274,6±1,6 mm
5 in.	127 mm	5,250±0,0625 in.	133,4±1,6 mm	5,8125±0,0625 in.	147,6±1,6 mm

Table 2 End cap dimensions

Blind end cap dimensions		Open end cap dimensions	
Outer diameter	1,75 ±0,0625 in. 44,45 ±1,60 mm	Outer diameter	1,75 ±0,0625 in. 44,45 ±1,60 mm
Support hole diameter	0,41 +0 in. -0,09 in. 10,45 +0 mm -2,25 mm	Shoulder diameter	1,27 ±0,01 in. 32,25 ±0,25 mm
Support hole minimum depth	0,73 in. 18,5 mm	'O' ring groove diameter	1,13 ±0,005 in. 28,70 ±0,10 mm
Support taper recess, slope relative to end face	27 ±3,0°	'O' ring groove width	0,15 +0 -0,01 in. 3,8 +0 -0,25 mm
			

The end caps for 150 mm (6 in.) diameter filter monitor elements may be open-ended or threaded-base. The specific dimensions are not currently specified but shall be compatible with the installed base of filter monitor and converted filter/separator vessels in service as filter monitor systems.

3.2 ELEMENT DESIGN AND CONSTRUCTION

3.2.1 Element sealing

Element seals, to suit the mounting arrangements according to API/EI 1596 *Design and construction of aviation fuel filter vessels*, should not allow bypassing at a differential pressure of 1 550 kPa (15,5 bar) when applied in the flow direction. Care shall also be taken to ensure that 'Knife' edges do not cut gasket surfaces. Providing a narrow flat area at the apex of the 'Vee' is one solution.

3.2.2 Element construction materials

All metal parts in contact with the fuel shall be free of zinc, cadmium and copper. Metal components of elements shall be non-corroding. All materials shall be chemically compatible with the fuel. All seals shall be Viton A™, or Buna N/nitrile rubber, or equivalent.

3.2.3 Element identification

Each individual element shall be permanently marked to indicate its model number and date of manufacture. Materials used to so identify the elements shall not contribute to contamination of, nor be affected by, aviation fuels. For 150 mm (6 in.) diameter elements the direction of flow (in-to-out or out-to-in) shall be indicated on the end cap (on the gasket for open-ended elements).

3.2.4 Element packaging

Elements shall be packed for shipment to guard against damage by crushing and individually protected against contamination by dirt and/or moisture with a poly-ethylene bag or similar wrapping.

Included in the packaging shall be information and advice to the purchaser on matters such as:

- a. Handling and installation including recommended torque for element installation.
- b. Any element/vessel flushing/commissioning procedures.
- c. Guidance on waste element disposal.
- d. Contact point for quality complaints.
- e. Recommended storage conditions and periods.
- f. Performance limitations.

4 LABORATORY QUALIFICATION TESTS FOR NEW FILTER MONITOR ELEMENTS AND SYSTEMS

4.1 GENERAL

Element qualification shall be achieved by testing the product(s) in accordance with the mandatory laboratory tests contained in 4.4 to confirm that they meet the performance limits described in section 5. All performance tests shall be undertaken on a test rig, the requirements for which are described in Annex A. Example test schedules are provided in Annex D.

Any manufacturer that markets products as being 'qualified to EI 1583' shall meet fully the requirements of this section.

4.1.1 Safety precautions

All personnel involved in following the laboratory testing requirements of this publication shall be either fully trained, and familiar with all normal laboratory and engineering safety practices, or under the supervision of a competent person who is. All appropriate safety practices shall be observed. It is the responsibility of users of this publication to ensure that they comply with the requirements of locally prevailing health and safety legislation/regulation.

4.1.2 Qualification test requirements

4.1.2.1 Witnessing, documentation and replicate requirements

A suitably qualified and competent person shall witness on behalf of the purchaser/user the qualification tests required by this publication.

In reporting the results of the following qualification tests, all data arising from witnessed tests shall be included. Any test failures or anomalous results shall be investigated with the witness(es). The report shall indicate the nature of the problem that occurred and the solution adopted. The wording describing the anomaly shall be agreed upon with the test witness(es). The list of witnesses to the tests shall indicate the dates and specific tests at which each witness was present.

4.1.2.2 Qualification requirements for replicate tests

One of each of the mandatory qualification tests shall be conducted in the presence of the witness, and data from previous successful tests made available to the witness for inspection. In the event of a qualification test not meeting the requirements of this publication, the issue shall be rectified and the qualification test conducted successfully three times: one of which shall be in the presence of the witness. The successful results from all three of the repeated qualification tests shall be included in the qualification test report.

4.1.2.3 Performance requirements

All tests shall be conducted as described in 4.4 with results meeting the limits in section 5.

4.1.2.4 Analytical testing

All analytical tests shall be carried out in accordance with the latest edition of the relevant ASTM or IP Test Methods or specified procedures. For the procedure for the laboratory analysis of media migration samples, see Annex B. For details of the ICP copper quantification method, see Annex C.

4.1.2.5 Element requirements

For 50 mm (2 in.) nominal diameter elements, the maximum length of element from the manufacturer's range shall be tested (typically 762 mm) (30 in.), unless specified otherwise in the qualification test. See section 7.2 for the qualification of other lengths of element by similarity.

For 150 mm (6 in.) nominal diameter elements, the length of the test element will depend on the range of lengths required to qualify by similarity (see section 7.2). The minimum length that shall be tested is 356 mm (14 in.).

Both nominal and effective lengths and the nominal flow rate and flow rate per effective media length shall be quoted in all qualification test documents.

In the event of an element model being produced with options for threaded-base or open-ended, the longest manufactured length of the threaded-base element shall be used for the structural tests. The open-ended version will then be covered by the threaded-base qualification test.

Elements shall be tested in their design flow format as assigned by the manufacturer (i.e. out-to-in or in-to-out). Qualification of one flow format does not automatically qualify an element for the reverse flow format (if available).

4.1.2.6 Qualification test schedule

A schedule of the sampling required during testing is given in Annex D.

4.2 QUALIFICATION TEST MATERIALS

4.2.1 Test fuel

The jet fuel used in all tests shall be procured to ASTM Specification D1655 *Aviation Turbine Fuels Jet A or Jet A-1* or Def Stan 91-91 *Turbine fuel, aviation kerosene type, Jet A-1 NATO Code: F35, Joint service designation: AVTUR* or the current issue of the AFQRJOS *Joint Fuelling System Checklist Specification for Jet A-1*.

The test fuel for all flow tests shall have a minimum temperature³ of 5 °C and a maximum temperature of 30 °C during testing. Test fuel temperature shall be maintained within ± 3 °C of the starting temperature of any individual qualification test.

4.2.2 Test contaminants

4.2.2.1 Test dust

The following test dusts shall be used:

- a. Elementis Red Iron Oxide R-9998⁴ or its exact equivalent.
- b. A1 Ultrafine Test Dust ISO 12103-1⁵ or its exact equivalent.

³ Temperature taken after the pump, as shown in Figure A.1.

⁴ R9998 can be obtained from Elementis Inc., 2001 Lynch Avenue, East St. Louis, IL 62205, USA.
www.elementispigments.com.

⁵ ISO 12103-1 can be obtained from Powder Technology Inc., P.O. Box 1464, Burnsville, MN 55337, USA.
www.powdertechologyinc.com.

The test dusts shall be oven dried at 100 °C for three hours within 24 hours of use and placed in sealed containers. All obvious agglomerated lumps shall be removed before use.

The solids test mixture shall consist of 10 % by weight of R 9998 and 90 % by weight A1 Ultrafine.

The solids test mixture shall be injected at a point upstream of the test vessel as a slurry in test fuel.

Contaminants shall be added continuously and evenly using apparatus consistent with that shown in Figure A.2 (for solids), within ± 10 % of the required rate and the average addition rate over the whole test period shall be within ± 3 % of the required rate.

Note: The test dusts contain fine particulate. The A1 Ultrafine test dust contains silica. The precautions prescribed by appropriate health regulations and standards must be applied when handling these materials.

4.2.2.2 Water

Locally supplied fresh water shall be used for the required water addition tests.

Note: It is the responsibility of users of this publication to be aware of the quality of the water in terms of solids content (SC), surface tension (ST) and pH. Recommended limits for these properties are SC <1,0 mg/l, ST >65 mN/m and pH 6-8.

4.2.3 Additives

The inclusion of additives in this publication is for testing purposes only and does not constitute acceptance or rejection of these additives in jet fuels.

The following additives shall be introduced to the qualification test fuel at the time and in the quantity and manner specified in the test procedure:

Additive I Stadis® 450 manufactured by Innospec⁶ conforming to the latest product specification.

Additive II DCI-4A, manufactured by Innospec conforming to the most recent edition of MIL-PRF-25017.

4.2.4 Test vessel

The filter monitor vessel for full-scale testing shall be examined by the witness to confirm that it complies with the mechanical specifications given in API/EI 1596.

Vessels used for single-element testing are not specified by this publication but shall be examined by the witness to ensure that they are fit-for-purpose, see also 4.3.1.

A schematic description of the test vessels with appropriate dimensions shall be provided. These data shall be included in the qualification report of the witnessed tests.

4.2.5 Test elements

Filter monitor elements from the batch from which test elements will be selected shall be examined by the witness to confirm the elements' compliance with the dimensional requirements of section 3.

The manufacturer shall provide a general description (including a diagram) of the element format showing the different materials of construction, amounts of material used and the way in which the element has been fabricated. Proprietary material may be identified by a code number or other appropriate descriptor. These data shall be included in the qualification report of the witnessed tests.

⁶ Offices worldwide www.innospecinc.com.

4.3 PREPARATION FOR QUALIFICATION TESTING

4.3.1 Qualification test vessel preparation

The qualification test vessel shall be examined by the witness to determine that the condition of the internal surface finish and the uniformity and condition of any lining are acceptable.

4.3.2 Qualification test element preparation

All filter monitor elements to be tested shall be critically examined by the witness before installation and any having visual defects shall be rejected and noted. Qualification test elements shall then be installed in the test vessel according to the manufacturer's instructions, with a note being made of the ease of assembly, security of elements and sealing methods.

4.3.3 Test fuel preparation

The test fuel shall be cleaned by pumping it through the test rig, bypassing the test position but including the clay treaters and clean-up vessel (filter/water separators). Pumping shall be continued until all additives have been removed. The fuel shall have a maximum conductivity of 10 pS/m and water separation character of >95 (ASTM D 3948) before additives are added. The fuel shall then be treated with the additive(s) listed in 4.2.3 in accordance with the procedure in 4.3.5. The test vessel shall then be slowly filled with fuel. Any leaks shall be noted and eliminated. During the filling operation there shall be no appreciable fuel flow out of the test vessel.

The fuel shall be sampled from the test vessel feed sample point for fuel quality checks. The water separation character (by ASTM D 3948) and the conductivity (IP 274 or ASTM D 2624) of the fuel shall be measured on samples taken before and after treatment.

4.3.4 Test rig cleanliness verification

The test facility, and the test fuel, shall be confirmed to be free of any SAP particles by passing the fuel from tank #1 to tank #2 and back to tank #1 with bag filter(s) installed (no filter elements in test vessel), stopping flow, removing the bag filter(s) and processing them as described in Table C.2. The ICP copper result shall be ≤ 50 ppb. A record of the baseline rig/fuel quality, including Millipore and aqua-glo values, shall be included in the qualification test report⁷.

If cleaning of the test facility is necessary to achieve this value consideration should be given to flushing the facility with a volume of deionised water sufficient for this purpose. The water used for flushing should be filtered before being deionised. The flow rate used for flushing should be sequentially increased and decreased, with at least 10 stop/starts performed at high flow rate (e.g. 100 gpm). Care should be taken to ensure all deadlegs are adequately flushed. After flushing care should be taken to thoroughly remove all water from the test facility. An unexpected increase in differential pressure during Qualification Test 1 may indicate that a quantity of water remained in the test facility.

⁷ Test rig cleanliness verification may be undertaken without the presence of the qualification test witness.

4.3.5 Additive additions

Unless specified otherwise in 4.4, qualification testing requires the addition of two additives to the test fuel. The additives are described in 4.2.3.

Additive I shall be added to the fuel at a concentration of 1,0 mg/litre. The fuel shall be circulated through the test facility, bypassing the test vessel and other filtration until the system is stabilised; i.e. three successive conductivity measurements taken five minutes apart are within ± 20 pS/m. The elapsed time from the end of the additive addition to the time when the system is stabilised shall be noted in the qualification test report as the mixing time.

Additive II shall be added to the test fuel at a concentration of 15 mg/litre with continued circulation of the fuel, bypassing the test unit and all other filtration for a period equal to or greater than the mixing time.

No further addition of any of the above additives shall be made during any qualification test.

Additives I and II may be added sequentially, but not together, without waiting for the system to stabilise between additives when adding Additives I and II in the above procedure. This saves preparation time but testers and witnesses should pay particular attention to the results of subsequent conductivity and water separation analyses to ensure that additives are homogeneously dispersed (three successive conductivity measurements taken five minutes apart are within ± 20 pS/m).

4.4 QUALIFICATION TESTS

During the following qualification tests, samples of fuel are required for analytical testing. The test schedule is provided for ease of reference in tabular form in Annex D, Table D.2.

4.4.1 Qualification Test 1 – Media migration and starting differential pressure test

This test shall be carried out with a new element and with new bag filter(s) installed in the bag filter housing.

1. Pump in single pass mode from tank #1 clean dry test fuel containing all additives through the test unit and through the bag filter(s) housing at rated flow to tank #2.
2. Immediately after pumping is started, measure and record the differential pressure across the test vessel (at rated flow) and take a membrane sample of effluent fuel (5 L) as described in IP 216 (ASTM D 2276) for media migration testing. Take samples for water separation and conductivity testing.
3. Continue pumping for 30 minutes.
4. Take a second membrane sample of fuel (5 L).
5. Measure and record the differential pressure across the test vessel (at rated flow).
6. Take samples for water separation and conductivity testing.
7. Shut down flow and remove the bag filter(s) in preparation for the ICP copper quantification processing, which is a mandatory part of this test.
8. Analyse the membrane samples as described in Annex B and report the results in the qualification test report. Measure and report the water separation and conductivity.
9. Process the bag filter(s) as described in Annex C.4.
10. Remove the element from the test vessel. If the element is to be used for Qualification Test 2 store it in clean, dry fuel until required. Install a new bag filter(s) and in recirculation mode pump test fuel from tank #2 through the test filter vessel and bag housing and back to tank #2 continuously until the fuel volume used in the test has

been recirculated twice. Stop fuel flow, remove bag filter(s), and process as described in Table C.2.

11. The requirements for passing this test are that media migration results meet section 5.1. The differential pressure shall meet the requirement of 5.6. Any change to the differential pressure from the start to the end of the test (from Steps 1 to 5) shall be within 5 %.

4.4.2 Qualification Test 2 – 50 ppm water test, full rated flow

Ensure the test facility is configured in single pass mode from tank #1 to tank #2. An element recently completing Qualification Test 1 or a new element shall be used.

1. Pump clean dry test fuel containing all the additives at rated flow through the test unit. When a new element is used (as opposed to an element that has completed Qualification Test 1) pump fuel through the element for 30 minutes before continuing with the next step.
2. Take effluent samples and test them to determine conductivity and water separation. Record the results.
3. Record the differential pressure across the test vessel.
4. Inject water into the centre of the fuel stream immediately before the rig pump, at a rate calculated to give 50 ppm of free water by volume dispersed in the fuel.
5. Continue the test until the differential pressure reaches 300 kPa (3 bar). During the test, the following test procedures shall be followed:
 - a. After three minutes of water addition record the differential pressure and perform a stop/start⁸ procedure. Measure the free water content of the effluent by Aqua-Glo (ASTM D 3240) and record the result. During the Aqua-Glo measurement (while fuel passes through the Aqua-Glo pad), simultaneously take a membrane sample as in Qualification Test 1 from a second sampling point (downstream of test vessel but before any clean up where the probe is positioned mid-stream facing upstream). The sampling procedure shall be to fully open the sample valves immediately before restarting the flow and leave each open until the required sample volumes are collected.
 - b. After the stop/start, once steady flow is re-established, record the differential pressure.
 - c. Record the differential pressure and fuel temperature and measure the free water content by Aqua-Glo and record the result every 10 minutes (from the start of water addition). When taking Aqua-Glo samples, simultaneously take membrane samples as in Qualification Test 1 whenever the differential pressure is 150 kPa (1,5 bar) or less.
 - d. When the differential pressure reaches 100 kPa (1,0 bar) then conduct a stop/start procedure and effluent water analysis as in Step C.
 - e. Record the elapsed time (of water addition) when the differential pressure reaches 150 kPa (1,5 bar).
6. When the differential pressure reaches 300 kPa (3 bar), record the differential pressure, elapsed time (of water addition), fuel temperature, and the total volume of water added then end the test.
7. Analyse all membrane samples by the procedure in Annex B and record the results.

⁸ A stop/start is an interruption of flow accomplished by shutting, in approximately four seconds, a quick-closing valve located downstream from the effluent sampling connection. The flow is then re-established and the test continued. Prior to starting the stop/start procedure, water or solids injection points should be isolated. These are re-opened immediately after re-establishing flow.

8. The requirements for passing this test are:
 - a. The initial differential pressure meets the requirement of section 5.6.
 - b. Media migration results meet section 5.1d.
 - c. All free water analyses during the test meet the requirement of section 5.1.c.
 - d. The water absorption capacity meets the requirement of section 5.4.
 - e. The fuel appearance meets the requirement of section 5.1.b.

4.4.3 Qualification Test 3 – Water slug test, full rated flow

This test shall be carried out with a new element, and shall be conducted using a rig as described in A.1.5 and shown in Figure A.3.

1. Fill the rig with clean dry test fuel⁹ ensuring that air is vented.
2. Charge the water vessel, by displacing fuel, with the water slug. The minimum volume of water used shall be equivalent to one litre/100 litres/minute of element rating or equivalent to the volume of the element (whichever is the greater). The maximum volume of water used shall be the above volume together with an amount equivalent to the volume of pipework between the water slug injection point and the test vessel plus the test vessel volume upstream of the elements.
3. Pump clean dry test fuel at rated flow through the test vessel with valve A positioned to bypass the water vessel.
4. With valve B open, actuate valve A to place the water vessel in the flow path.
5. When the inlet pressure reaches a minimum of 700 kPa (7 bar) (as fast as possible after water injection) close valve C and open the sample point valve. Record the time taken to reach 700 kPa (7 bar) after the water introduction.
6. Discard the effluent from the sample point for the first five seconds after opening the sample point valve (as the system depressurises).
7. Collect the effluent from the sample point in a designated container for one minute. Repeat with another container until a total of five samples, each of one minute duration, are collected then end the test.
8. Measure the volume of fuel and water in each of the five samples separately, using a calibrated glass measuring cylinder and record them on the test sheet.
9. Close the sample point and open valve C and record the inlet pressure.
10. The requirement for passing this test is that the total volume of fuel and water in each sample does not exceed the limit in section 5.5.

4.4.4 Qualification Test 4 – Mechanical integrity of saturated element test

This test shall be performed on the same element used in Qualification Test 3. If the pump stall pressure in Qualification Test 3 was 1 200 kPa (12 bar) or more then the first two steps of this test are not necessary because they are considered completed during Test 3. This testing may be performed in a different rig.

1. At the end of Test 3 the line pressure shall be increased until a pressure differential of 1 200 kPa (12 bar) is reached across the element, or until obvious failure occurs, whichever is the sooner.
2. This pressure shall be maintained for five minutes. If failure occurs the pressure differential at which the element broke down shall be noted.
3. Remove the element from the test vessel and inspect for any visual signs of SAP

⁹ Clay-treated non-additivated fuel may be used for this and other water slug tests.

extrusion through the element casing and/or any changes to the shape of the element, rupture of the element, etc. Any such observations shall be reported.

4. The requirement for passing this test is that the element neither ruptures nor shows indications of physical breakdown and there is no visual sign of SAP extrusion.

4.4.5 Qualification Test 5 – Water slug test, 10 % rated flow

This test shall be carried out with a new element.

This test is conducted by the same procedure as Qualification Test 3 (4.4.3) except that the fuel flowrate is 10 % of rated flow instead of rated flow.

Repeat as in Qualification Test 3.

4.4.6 Qualification Test 6 – Solids test

This test shall be carried out with a new element.

1. Pump clean dry test fuel containing all the additives at rated flow through the test unit.
2. Measure and record any effluent particulates with a downstream fuel quality monitoring system.
3. Take effluent samples and test them to determine conductivity and water separation (MSEP). Record the results.
4. Record the differential pressure.
5. Inject a slurry of the solids contaminant into the centre of the flowing fuel stream such that the fuel contains 10 mg of solids contaminants per litre fuel.
6. Continue the test until the differential pressure reaches 150 kPa (1,5 bar). During the test the following test procedures shall be followed:
 - a. Measure and record any effluent particulates with a downstream fuel quality monitoring system. If the device requires a fixed time to perform an analysis then start the subsequent analysis as soon as possible after each analysis finishes.
 - b. After five minutes of solids addition: record the differential pressure and fuel temperature, conduct a start/stop procedure and measure and record the particulate content of the effluent by IP 216 (ASTM D 2276). The sampling procedure shall be to fully open the sample valve immediately before restarting the flow and leave it open until the required sample volume is collected.
 - c. Take a membrane sample of effluent fuel (between 3,78 and 5 L) as described in IP 216 (ASTM D 2276) for media migration testing. Analyse the membrane sample by the procedure in Annex B and record the results.
 - d. After each ten minute interval from the stop/start in Step B, record the fuel temperature and differential pressure and measure and record the effluent fuel by IP 216 (ASTM D 2276) for particulate content.
 - e. When the differential pressure reaches 100 kPa (1,0 bar) then record the differential pressure and fuel temperature, conduct a start/stop procedure and measure and record the particulate content (as in Step B).
 - f. Record the elapsed time of solids addition when the differential pressure reaches 150 kPa (1,5 bar).
7. The requirements for passing this test are:
 - a. The initial differential pressure meets the requirement of section 5.6.
 - b. The solids holding capacity meets the requirement of section 5.3.

- c. Effluent particulate content analyses meet section 5.1.a.
- d. The fuel appearance meets the requirement of section 5.1.b.
- e. Media migration results meet section 5.1.d.

4.4.7 Qualification Test 7 – Mechanical integrity of solids contaminated element

This test shall be performed on the same element used in Qualification Test 6.

1. After Test 6 the element shall be loaded with additional solids until a pressure differential of 1 200 kPa (12 bar) is reached across the element, or until obvious failure occurs, whichever is the sooner. This testing may be performed in a different rig, with jet fuel or any appropriate fluid, and with any appropriate solids. The influent solids content may exceed 10 mg/litre.
2. This pressure shall be maintained for five minutes. If failure occurs the pressure differential at failure shall be recorded.
3. Remove the element from the test vessel and inspect for any visual signs of SAP extrusion through the element casing and/or any changes to the shape of the element, rupture of the element, etc. Any such observations shall be noted and reported.
4. The requirement for passing this test is that the element neither ruptures nor shows indications of physical breakdown and there is no visual sign of SAP extrusion.

4.4.8 Qualification Test 8 – Freeze/thaw tests

This test shall be carried out with a new element.

1. Pump clean dry test fuel containing all the additives at rated flow through the test unit.
2. Take effluent samples and test them to determine conductivity and water separation (MSEP). Record the results.
3. Record the differential pressure.
4. Inject water into the centre of the fuel stream immediately before the rig pump, at a rate calculated to give 50 ppm of free water by volume dispersed in the fuel.
5. Continue the test until the differential pressure reaches 100 kPa (1,0 bar). After two minutes, three minutes and every 10 minutes of water addition: record the differential pressure and fuel temperature and measure and record the water content of the effluent by Aqua-Glo (ASTM D3240).
6. Stop water injection and fuel flow, remove the element from the test vessel and immediately place it in a bath (or container) of cold fuel¹⁰.
7. Cool the element and maintain it for 24 hours at a temperature no warmer than -40 °C.
8. After 24 hours' cooling, permit the element to warm to ambient temperature, while it is protected from atmospheric water condensation, then install it in a single-element test vessel. This portion of the test shall be conducted in a rig as shown in Figure A.3. The fuel pump shall have a minimum stall pressure of 700 kPa (7 bar).
9. Charge the water vessel, by displacing fuel, with the water slug. The minimum volume of water used shall be equivalent to one litre/100 litres/minute of element rating or equivalent to the water holding capacity of the element(s) (whichever is the greater). The maximum volume of water used shall be the above volume together with an amount equivalent to the volume of pipework between the water slug injection point and the test vessel plus the test vessel volume upstream of the elements.

¹⁰ It is recommended that the volume of fuel used is minimised, and that the fuel should be dry.

10. Pump clean dry test fuel at rated flow through the test unit with valve A positioned to bypass the water vessel.
11. Record the differential pressure. If the differential pressure is ≥ 300 kPa (3,0 bar) proceed to Step 13.
12. Inject water into the centre of the fuel stream immediately before the rig pump, at a rate calculated to give 50 ppm of free water by volume dispersed in the fuel.
13. Continue water addition until the differential pressure reaches 300 kPa (3,0 bar). During the test conduct the following procedures:
 - a. After two minutes, three minutes and every 10 minutes of water addition: record the differential pressure and fuel temperature and measure the water content of the effluent by Aqua-Glo (ASTM D3240) and record the result.
 - b. When the differential pressure reaches 150 kPa (1,5 bar) record the differential pressure and perform a stop/start procedure. Measure the free water content of the effluent by Aqua-Glo and record the result. The sampling procedure shall be to fully open the sample valve immediately before restarting the flow and leave it open until the required sample volume is collected.
 - c. When the differential pressure reaches 300 kPa (3,0 bar), discontinue water addition, record the differential pressure and fuel temperature. Measure the effluent for free water content by Aqua-Glo and record the result. Take effluent samples and analyse them for conductivity and water separation. Record the results.
14. With valve B open, actuate valve A to place the water vessel in the flow path.
15. When the inlet pressure reaches pump stall, simultaneously close valve C and open the sample point valve.
16. Discard the effluent from the sample point for the first five seconds after opening the sample point valve (as the system depressurises).
17. Collect the effluent from the sample point in a designated container for one minute. Repeat with another container until a total of five samples, each of one minute duration, are collected then end the test.
18. Measure the volume of fuel and water in each of the five samples and record them on the test sheet.
19. The requirement for passing this test is that effluent water content results at Steps 5 and 13 meet the requirement of section 5.1.c, and that the total volume of fuel and water in each sample at Step 18 does not exceed the limit in section 5.5.

4.4.9 Qualification Test 9 – Full water immersion tests

This test shall be carried out with a new element.

1. Immerse an element in water for a minimum of 10 hours.
2. Remove the element and visually inspect it for any evidence of bulging, rupture or SAP extrusion. Any such observations shall be included in the report.
3. Install the element in a test vessel and pressurise it with fuel to a minimum of 700 kPa (7 bar) differential pressure.
4. The requirements for passing this test are:
 - a. The element neither ruptures nor shows signs of physical breakdown or visual signs of SAP extrusion.
 - b. The fluid leakage through the device at 700 kPa (7 bar) differential pressure shall not exceed 1 % of the rated flow.

4.4.10 Qualification Test 10 – Partial water immersion tests

This test shall be carried out with a new element. As this test requires investigation for SAP migration under flowing conditions on the test rig, baseline rig cleanliness shall meet the requirements of 4.3.4.

1. Wet the element with fuel by completely immersing it in fuel.
2. Briefly drain the fuel from the element.
3. For out-to-in flowing elements: stopper the open end and immerse the element, stoppered end down, in water such that 25-30 % of the media length contacts water.
4. For in-to-out flowing elements: seat a fixture to the open end that, while the element is oriented vertically with the open end down, permits water to contact the interior of the element such that the level is known (e.g. a 'sight-glass'). Add water such that 25-30 % of the element media length contacts water.
5. Permit the element to contact water for one hour. Maintain the water level by topping up as necessary.
6. Remove the element and visually inspect for bulging, rupture and media extrusion. Any such observations shall be included in the report.
7. Install the element in a test vessel and install bag filter(s) in the bag filter housing.
8. Pump fuel at rated flow through the test vessel and through the bag filter(s) housing.
9. Immediately after flow is established, record the differential pressure, measure the water content of the effluent fuel by Aqua-Glo and record the result, and collect a sample for media migration analysis in accordance with Annex B and record the result.
10. After five minutes of fuel flow repeat the analyses of Step 9.
11. Shut down flow and remove the bag filter(s) in preparation for the ICP copper quantification processing, which is a mandatory part of this test.
12. Process the bag filter(s) as described in Annex C.4¹¹.
13. Install a new bag filter(s) and in recirculation mode pump test fuel from tank #2 through the test filter vessel and bag housing and back to tank #2 continuously until the fuel volume used in the test has been recirculated twice. Stop fuel flow, remove bag filter(s), and process as described in Table C.2.
14. The requirements for passing this test are:
 - a. The effluent fuel shall meet the requirement of section 5.1.b.
 - b. Media migration results shall meet the requirement of section 5.1.d.
 - c. Water content results shall meet the requirement of section 5.1.c.
 - d. The element shall show no sign of rupture or physical breakdown.

4.4.11 Qualification Test 11 – Compatibility tests

A new element shall be soaked for 336 hours in each of the test fluids listed in Table 3. The required analytical testing of each of the soak fluids is also given in Table 3. For each test the volume of fluid required shall be equal to five times the volume of a solid having the same outside dimensions as the test element or piece of test element. For 50 mm (2 in.) diameter elements, 250 mm (10 in.) long versions shall be used. For 150 mm (6 in.) diameter elements, 14 in. long 'half-elements' (prepared by sectioning along the longitudinal axis) shall be used.

¹¹ It is recognised that this test may be adversely affected should the dp across the test vessel rise to greater than 100 kPa (1,0 bar). In such cases this should be noted in the qualification report against the SAP value obtained.

These compatibility tests are performed only once.

To avoid error or ambiguity the containers used in these tests shall:

- Be identical and have non-contaminating sealable lids or caps.
- Be of such dimensions that the test specimen can be totally immersed in the test fluid.
- Be inert to the test fluids (e.g. amber glass, aluminium or stainless steel containers are suitable). Since the test fluids may be light sensitive, it is recommended that during the soak period, the containers be kept in a dark enclosure. For reference one litre samples of each of the test fluids shall be stored in containers similar to those used in the compatibility tests.

Before commencing the test the containers shall be thoroughly rinsed with the respective test fluid.

Table 3 Schedule of tests

Test sample	Test fluid ¹	Hours on test	Analyses required on each solution ²
1	Jet A or Jet A-1	336	A, B, C, D
2	Jet A or Jet A-1 with 15 mg/l DCI-4A and 5 ppmv of Stadis 450	336	B, C, D
3	50 % Fuel System Icing Inhibitor (FSII) (DiEGME) in water	336	C
4	30 % vol. toluene/70 % vol. iso-octane	336	B, C, D

Note 1:

- Jet A or Jet A-1 used in Tests 1 and 2 shall be as specified in section 4.2.1 and shall be from the same refinery batch.
- Jet A or Jet A-1 used in Test 1 shall be clay treated until the conductivity is below 10 pS/m.
- Jet A or Jet A-1 used in Test 2 shall be clay treated until the conductivity is below 10 pS/m prior to additive addition.

The additives used in Test 2 shall be as specified in section 4.2.3.

In Test 3 DiEGME is diethylene glycol monomethyl ether. It is included in compatibility testing only to increase the severity of the test. Successful test results shall not be construed as evidence of compatibility or satisfactory performance of monitor elements in fuel containing DiEGME.

Note 2:

Immediately prior to the start of Tests 1 and 2 a representative sample of each solution shall be tested for A, B and D shown below.

Immediately prior to the start of Test 4 a representative sample of each solution shall be tested for B shown below.

Analysis A = MSEP (per ASTM D 3948);

Analysis B = Existent gum (per ASTM D 381);

Analysis C = Detailed visual inspection of all component parts;

Analysis D = Colour (per ASTM D 156).

Results shall be reported in a form similar to that shown in Annex D, Table D.1 together with copies of full refinery release certificates for the jet fuel. Note that the reference sample shall be analysed at the start and end of the test period. The requirements for passing this test are that all of the following results are obtained:

- A. MSEP does not fall below 85.
- B. The difference in existent gum between blank test and element test is < 7 mg/100 cm³.
- C. There is no visually detectable change in the test element.
- D. The colour does not decrease by more than four units compared to the blank measured after the same time as the soak period.

4.4.12 Qualification Test 12 – 50 ppmv water test, low flow

This test shall be carried out with a new element.

- 1. Pump clean dry test fuel containing all the additives through the test vessel at 10 % of rated flow.
- 2. Inject water into the centre of the fuel stream immediately before the rig pump, at a rate calculated to give 50 ppm of free water by volume dispersed in the fuel.
- 3. Continue to pump fuel until the differential pressure reaches 100 kPa (1,0 bar). This may take several days so the test may be suspended each evening and restarted each morning. During the test measure effluent fuel for free water content by Aqua-Glo every hour and record the results.
- 4. The requirements for passing this test are that all water content results meet the requirements of section 5.1.

4.4.13 Qualification Test 13 – Full-scale vessel 50 ppm water test

This test shall be conducted with a vessel of at least 300 gpm rated flow with a full set of new elements installed. The test fuel may be recirculated. The volume of fuel used shall be greater than the largest volume of fuel used in any one of the single element tests.

- 1. Recirculate clean dry test fuel containing Additive I at rated flow through the test unit.
- 2. Take effluent samples and test them to determine conductivity and water separation (MSEP). Record the results.
- 3. Record the differential pressure.
- 4. Inject water into the centre of the fuel stream immediately before the rig pump, at a rate calculated to give 50 ppm of free water by volume dispersed in the fuel.
- 5. Continue the test until the differential pressure reaches 300 kPa (3 bar). During the test, the following test procedures shall be followed:
 - a. After two minutes of water addition: record the differential pressure and fuel temperature and measure the water content of the effluent by Aqua-Glo (ASTM D 3240) and record the result.
 - b. After three minutes of water addition record the differential pressure and perform a stop/start procedure. Measure the free water content of the effluent by Aqua-Glo and record the result. The sampling procedure shall be to fully open the sample valve immediately before restarting the flow and leave it open until the required sample volume is collected.
 - c. After the stop/start, once steady flow is re-established, record the differential pressure.

- d. Every ten minutes (after the analysis at three minutes), record the differential pressure and fuel temperature and measure the free water content by Aqua-Glo and record the result. Measure the conductivity and readditise with Additive I to maintain the conductivity at the value found in Step 2.
 - e. When the differential pressure reaches 100 kPa (1,0 bar) then conduct a stop/start procedure and effluent water analysis as in Step B.
 - f. Record the elapsed time (of water addition) when the differential pressure reaches 150 kPa (1,5 bar).
6. When the differential pressure reaches 300 kPa (3 bar), record the differential pressure, elapsed time (of water addition), fuel temperature, and the total volume of water added then end the test.
 7. The requirements for passing this test are that all free water analyses from effluent samples during the test meet the requirement of section 5.1.c.

4.4.14 Qualification Test 14 – Full-scale vessel water slug test

This test shall be conducted with a vessel of at least 300 gpm rated flow with a full set of new elements installed.

1. Fill the rig with clean dry test fuel, containing either no additives or only Additive I, ensuring that air is vented.
2. Charge the water vessel, by displacing fuel, with the water slug. The minimum volume of water used shall be equivalent to one litre/100 litres/minute of element rating or equivalent to the water holding capacity of the element(s) (whichever is the greater). The maximum volume of water used shall be the above volume together with an amount equivalent to the volume of pipework between the water slug injection point and the test vessel plus the test vessel volume upstream of the elements.
3. Recirculate clean dry test fuel, containing either no additives or only Additive I, at rated flow through the test vessel with valve A positioned to bypass the water vessel.
4. With valve B open, actuate valve A to place the water vessel in the flow path.
5. When the inlet pressure reaches 700 kPa (7 bar), simultaneously close valve C and open the sample point valve.
6. Discard the effluent from the sample point for the first five seconds after opening the sample point valve (as the system depressurises).
7. Collect the effluent from the sample point in a designated container for one minute. Repeat with another container until a total of five samples, each of one minute duration, are collected then end the test.
8. Measure the volume of fuel and water in each of the five samples and record them on the test sheet.
9. Close the sample point and open valve C and record the differential pressure.
10. The requirement for passing this test is that the total volume of fuel and water in each sample does not exceed the limit in section 5.5.

4.4.15 Qualification Test 15 – 50 ppm with saline solution

This test shall be carried out with a new element.

1. Repeat Qualification Test 2 Steps 1-7 using 0,5 % NaCl in water. For HS elements repeat Qualification Test 2 Steps 1-7 using synthetic seawater (ASTM D1141 containing Stock Solution Nos. 1 and 2 but not Stock Solution No. 3) instead of 0,5 % NaCl.
 2. The requirements for passing this test are that all free water analyses meet the requirement of section 5.1.c.
-

4.4.16 Qualification Test 16 – Slug test at rated flow with saline solution

This test shall be carried out with a new element.

1. Repeat Qualification Test 3 Steps 1-9 using 0,5 % NaCl in water. For HS elements repeat Qualification Test 3 Steps 1-9 using synthetic seawater (ASTM D1141 containing Stock Solution Nos. 1 and 2 but not Stock Solution No. 3) instead of 0,5 % NaCl.
2. The requirement for passing this test is that the total volume of fuel and water in each sample does not exceed the limit in section 5.5.

4.4.17 Qualification Test 17 – End-to-end filter monitor element resistance

4.4.17.1 Points to consider prior to measurement

This qualification test assumes that the manufacturers' instructions for the insulation tester (e.g. megger), which may represent a high voltage shock hazard, are observed and that the correct PPE is used.

Care is needed to establish good contact at points A and B (Figure A.4). If the element is supplied with a non-conductive O-ring then the results may be sensitive to end load or element alignment. It is recommended that elements be supplied with conductive O-rings because the O-ring is the only point of an element where contact with the vessel is certain.

Resistance measurements fluctuate with time and therefore all measurements shall be made 30 seconds after application of the voltage.

4.4.17.2 Procedure

The measurement shall be made on a new fully assembled element that has not been exposed to fuel or water, with the normally supplied O-ring fitted. The equipment described in Annex A.1.6 is required.

1. Equilibrate the new element(s) to be tested for 24 hours at a temperature of 15-25 °C (59-78 °F) at humidity less than 60 %. (The element shall be situated such that air flow around it is unencumbered during this equilibration time.)
2. Connect the insulation tester leads to points A and B shown in Figure A.4.
3. Allow the insulation tester to reach operating temperature.
4. Measure the resistance without the element mounted to test for adequate insulation of the mounting blocks. Apply the voltage, wait 30 seconds, then read and record the measurement. The resistance value should be $>10^{12}$ ohms. If the resistance is less then the insulation of the mounting blocks should be improved and this step repeated.
5. Remove the test element from the equilibration chamber used in Step 1. The rest of this procedure shall be completed within 15 minutes of removing the element from equilibration conditions or the results are invalid.
6. Mount the equilibrated filter monitor element into the rig. Note a moderate end load should be applied to simulate the typical in-service mounting pressure.
7. Apply the voltage, wait 30 seconds then read and record the measurement. The resistance value should meet the requirement of section 5.9. If the value is greater then the element has failed and factors such as the conductivity of the end-caps, 'O'-ring or the media layers should be investigated.

4.4.18 Qualification Test 18 – End-cap adhesion integrity test

Elements that have been exposed to each of the test fluids required in 4.4.11 (with the exception of Test Sample #3; 50 % FSII/water), and the element used in 4.4.8 shall each be subjected to the following test:

For 50 mm (2 in.) models, the manufacturer shall demonstrate that the end cap bonding is suitable, by placing one end of each element in a suitable clamping mechanism and applying a pulling force to the other end cap.

For 150 mm (6 in.) models, the manufacturer shall demonstrate that the end cap bonding is suitable, by placing one end of each element in a suitable clamping mechanism and applying torque to the end cap. Testing performed on screw-base or threaded-base models shall qualify by similarity the open end or rod mount models.

The requirement for passing this test is described in 5.10.

5 QUALIFICATION REQUIREMENTS FOR FILTER MONITOR ELEMENTS AND SYSTEMS

5.1 EFFLUENT FUEL CONTAMINATION LIMITS

Determined from samples taken during the qualification tests, and analysed by the specified methods therein, the effluent fuel contamination shall not exceed:

- a. Total solids¹²
 - 0,26 mg/litre (1,0 mg/U.S. gal.) average
 - 0,5 mg/litre (1,9 mg/U.S. gal.) maximum
- b. Appearance
 - the effluent fuel shall be clear and bright
- c. Free water
 - 15 ppmv
- d. Media migration¹³
 - 10 fibres/litre

5.2 FLOW RATE

Two inch nominal diameter elements shall meet the performance requirements at a nominal flow rate (see section 2.1) of 2,5 litres/sec/m (1,0 gpm/in. length). Six inch nominal diameter elements shall meet the performance requirements at a nominal flow rate of 10 litres/sec/m (4,0 gpm/in. length).

Note: The nominal length of an element should be used when calculating the nominal linear flow rate.

More specifically, the flow rates for any length of element shall meet the effective flow rate criteria described in section 7.2.

5.3 SOLIDS HOLDING CAPACITY

The solids holding capacity is measured as the time taken for an element to reach 150 kPa (1,5 bar) pressure differential at full rated flow with an influent solids addition rate of 10 mg/litre.

- Blocking time for 50 mm (2 in.) nominal diameter elements shall be at least 10 minutes.
- Blocking time for 150 mm (6 in.) nominal diameter elements shall be at least 50 minutes.

¹² The average total solids in the effluent fuel will be the arithmetic average for each run calculated from the total solids passed and the total sample volume. No individual sample shall exceed 0,5 mg/litre. If a sample is being taken when an element reaches the differential pressure at which the test run should stop, sampling may be discontinued immediately and where possible the pro-rated result should be calculated and included in determining the average.

¹³ Any particle in the effluent having a length to diameter ratio of 10 to 1 or more and having a length of 100 microns or more, shall be counted as a fibre from the elements. The maximum number of such fibres permissible in the effluent is 10/litre of fuel. Also, the effluent fuel shall be clear and bright.

5.4 WATER HOLDING CAPACITY

The water holding capacity is measured as the time taken for the element to reach 150 kPa (1,5 bar) pressure differential at full rated flow with an influent water addition rate of 50 ppmv.

- Blocking time for 50 mm (2 in.) nominal diameter elements shall be at least 10 minutes.
- Blocking time for 150 mm (6 in.) nominal diameter elements shall be at least 40 minutes.

5.5 WATER SLUG

When subjected to a water slug, the element(s) shall effectively shut down flow (inlet pressure shall reach a minimum of 700 kPa (7 bar)) such that fluid leakage through the device in any one of the five one-minute samples shall not exceed 1 % of the rated flow. The inlet pressure after five minutes shall be > 630 kPa (6,3 bar), (section 4.4.3 Step 9).

Time to reach 700 kPa (7 bar) shall be <10 s for the rated flow tests and < 1,5 min. for the 10 % rated flow tests.

5.6 PRESSURE DIFFERENTIAL

The differential pressure across a vessel having new elements operating at rated flow with clean and dry fuel shall be a maximum of 62 kPa (0,62 bar).

5.7 ELEMENT STRUCTURAL STRENGTH

The element shall be capable of withstanding a maximum differential pressure of 1 200 kPa (12 bar) for five minutes without structural failure or extrusion of SAP. Deformation of the element shall not prevent the monitor from meeting the requirements of 5.5.

5.8 EFFLUENT FUEL CONDUCTIVITY REQUIREMENT

When tested in fuel containing Additive I (in accordance with section 4) the minimum effluent fuel conductivity shall be >50 pS/m. The term conductivity unit (cu) is equivalent to pS/m.

5.9 END-TO-END RESISTANCE

The end-to-end resistance of an unused dry filter monitor element shall be less than 6×10^9 ohms when measured by the procedure in section 4.4.17.

5.10 END CAP ADHESION INTEGRITY

To pass this test each element shall withstand the following pull force (for 50 mm elements) or torque values (for 150 mm elements) before the end caps have shown any movement or distortion from the portion of the element to which they are bonded:

- For 50 mm (2 in.) elements: 500 N
- For 150 mm (6 in.) elements: a complete element assembly shall withstand 125 % of the recommended assembly torque

6 PRODUCT QUALITY ASSURANCE

6.1 GENERAL REQUIREMENT

A product quality assurance programme shall be followed by the manufacturer to demonstrate that the performance of all manufactured products are consistent with the qualified element. The quality assurance programme shall be documented. The quality assurance programme documentation shall be made available to the purchaser upon request.

6.2 QUALITY CONFORMANCE TEST PROGRAMME

A quality conformance test programme shall be implemented by the manufacturer. As a minimum, the programme shall include the annual testing of each qualified element model by performing the mandatory single element test protocols included in this publication and quarterly testing of each qualified element model using Qualification Tests 2 and 3. Elements taken from the production line shall be used for these quality conformance tests. The test results shall be filed with the results of the original qualification tests and be made available to the purchaser upon request. The test results shall confirm that the element model continues to perform as it did in qualification testing. If the test results do not confirm this then the design shall be requalified.

6.3 BATCH TRACEABILITY PROGRAMME

Manufacturers shall ensure that if an issue arises with an element in service, it is possible to trace all other elements that may experience the same issue.

7 QUALIFICATION, SIMILARITY AND REQUALIFICATION

7.1 QUALIFICATION

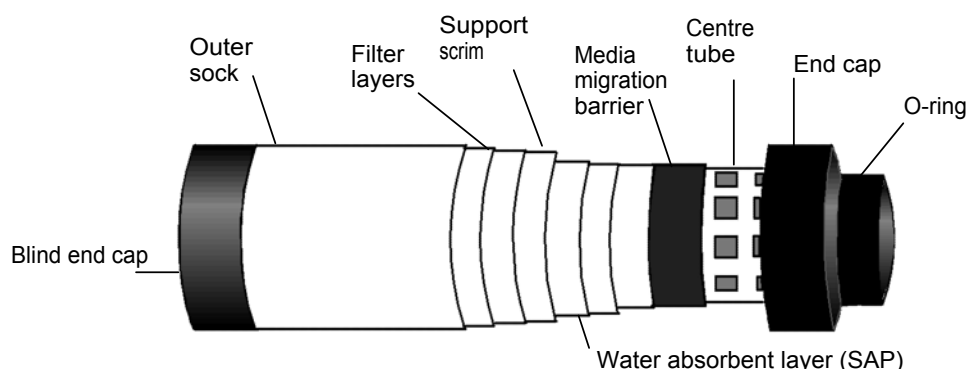
Purchasers are advised to make any investigations considered necessary to confirm that products conform to this publication. For example, purchasers should require that an expert in laboratory filtration testing, not affiliated with the manufacturer, observes ('witnesses') key aspects of qualification testing. Further the purchaser is not limited by this publication and may require additional testing.

When a purchaser accepts that a filter monitor system or filter monitor element model is fully documented as complying with the mandatory test requirements of this publication then the system or element model is 'qualified' to EI 1583 6th edition.

Note: This is not the same as an 'approval' from a purchaser.

Once the manufacturer has qualified a system or element model to EI 1583 6th edition, it shall be identified by a unique model number. A schematic diagram showing constructional information of the qualified system or element shall be included in the final qualification report, see Figure 1.

Figure 1 Schematic diagram of filter monitor element



7.2 QUALIFICATION BY SIMILARITY

7.2.1 General

This section describes a procedure for qualification of elements by similarity. Whilst qualification testing may be carried out on a particular length of element, typically 30 in. (762 mm) nominal, other lengths of the same model of element may be required for various operational reasons. Qualification results may be extended from tested ('qualified element') to other element lengths ('candidate element') provided that the elements are demonstrated to be similar by meeting the similarity conditions of 7.2.2.

The issue of similarity arises from the desirable practice of using longer, if not the longest, length of an element model in qualification testing. The element flow rates included in this publication are based on nominal lengths, which causes the effective linear flow rate

(the linear flow rate per unit of element between the end caps) to be greater in shorter elements because the end caps occupy a slightly larger proportion of the total length. Experience indicates that shorter elements, with higher linear flow rates, perform like longer elements when the similarity conditions of 7.2.2 are met.

In the event of an element model being produced with options for threaded-base or open-ended, the longest manufactured length of the threaded-base element shall be used for the structural tests. The open-ended version will then be covered by the threaded-base qualification test.

7.2.2 Similarity conditions

The similarity conditions for filter monitor elements are:

1. The only difference between qualified and candidate elements shall be their length except for 150 mm (6 in.) diameter monitors, which may use different mounting systems (threaded base and open-ended).
2. The adjusted effective linear rated flow (LF_{Ca} as calculated below) of the candidate element shall be less than or equal to the effective linear rated flow (LF_Q) of the qualified element.
3. The nominal length of the candidate element shall be no more than three times the length of the qualified element. When the candidate element is longer than the previously qualified element then the mechanical integrity tests (section 4.4.4 and 4.4.7) shall be conducted on the longest element of the model series to be covered by the qualification.

Candidate elements that do not meet these similarity conditions require full qualification testing (all tests in section 4).

7.2.3 Similarity calculation

The rated flow of filter monitor elements is 2,5 or 10 litres/sec/m (1,0 or 4 gpm/ in.) for 50 mm (2 in.) and 150 mm (6 in.) nominal diameter elements respectively, as specified in 5.2, times the nominal length. The linear effective rated flow (LF) is calculated by dividing the rated flow by the effective length (the length between the end caps) of the element.

Therefore, $LF_Q = (\text{rated flow of qualified element}) / (\text{length between qualified element end caps})$, and $LF_C = (\text{rated flow of candidate element}) / (\text{length between candidate element end caps})$.

For the purpose of similarity conditions the adjusted effective linear rated flow of the candidate element is calculated by:

$$LF_{Ca} = LF_C - LF_Q \times [0,05 \times (L_Q - L_C) / L_C]$$

where: L_Q is the nominal length of the qualified element.
 L_C is the nominal length of the candidate element.

7.2.4 Documentation

Similarity calculations for lengths of elements offered by a manufacturer which differ from the length that was qualified shall be provided in the qualification report for that element model.

7.3 REQUALIFICATION

Once a filter monitor system and/or element model has been qualified then no design, materials or construction changes are to be made by the manufacturer for production elements without first seeking the purchaser's prior agreement. The purchaser has the right to insist on a partial or complete requalification of the element by the manufacturer to confirm its performance continues to comply with the requirements of this publication. The process of documenting compliance with this publication by running a subset of the mandatory tests is known as requalification.

The changes in a qualified product need to be assessed on an individual basis and if considered significant then the element should be submitted for requalification by running all of the mandatory tests and given a different model number. Minor changes may be accommodated by performing selected qualification tests to document that the changes do not change performance. Suggested minimum recommendations for requalification testing are given in Table 4.

Table 4 Minimum recommendations for the requalification of previously qualified monitor elements

Component	Qualification test				
	Compatibility	Mechanical integrity	Media migration	Solids removal test	End-to-end resistance
Absorbent media Water removal	Full Qualification				
O-ring Material change Dimensional change	✓	✓			✓
End cap Material change Colour change Fixing arrangement	✓	✓			✓
Adhesive Type change	✓	✓			✓
Centre tube Paint finish (if applicable) Seam jointing arrangement Material change	✓	✓			✓
Centre tube Perforations/mesh size		✓		✓	✓
Support media Scrims Media migration layers Outer socks	✓	✓	✓	✓	✓
Filter media Particulate removal	✓	✓	✓	✓	
Markings Type and date marking	✓				

All changes to a requalified element shall be clearly recorded and an updated schematic diagram issued (see element history record, Table 5 and Figure 1). Every time there is a change an updated element history record (Table 6) shall be issued to all interested parties.

Purchasers may also request partial or complete retests should they have reasonable grounds for believing the performance of filter monitor elements may have deteriorated since the product was qualified.

Table 5 Element history record - Constructional details (example)

Component	Description	Details (number of wraps etc.)	Further comments
A	'O' ring		
B	End caps		
C	Centre tube	Steel perforated tube	
D	Support scrim		
E			
F			
G			

Table 6 Change record (example)

<i>Date</i>	<i>Component changed</i>	<i>Details of change</i>	<i>Comments</i>
DD/MM/YY			Element qualified
DD/MM/YY	B		Changed for supply reasons

ANNEX A (NORMATIVE)

TEST FACILITIES AND EQUIPMENT

A.1 TEST FACILITIES

A.1.1 General

Qualification tests shall be carried out using test facilities as described and illustrated in this annex. Test vessels shall be capable of withstanding shock-pressures expected during the start/stop operation. A test rig suitable for undertaking the qualification tests included in this publication is shown in Figure A.1.

Means shall be provided for:

- the introduction of test contaminants and additives;
- the housing of bag filters immediately downstream of the test filter monitor vessel, to filter all effluent (required to be used for Qualification Tests 1 and 10 only);
- measuring the flow rate through the test filter monitor vessel;
- measuring the influent temperature and pressure differential across the unit;
- sampling the influent and effluent streams from the test unit, and
- removing all significant particulate matter and free water from the test fuel.

For the dispersed water absorption tests the water shall be injected at a point as close as possible to the inlet side of the main pump to produce the necessary fine water droplets.

Test dusts shall be injected at a point upstream of the test vessel as a slurry in test fuel. The slurry shall be prepared using a recirculation system as shown in Figure A.2.

A.1.2 Sampling probes

Upstream facing, probe-type sampling devices shall be provided within 10 pipe diameters of the outlet or inlet of the test unit.

Such probes shall be installed in the pipe with five diameters of clear pipe before them to avoid upstream interference with the flow pattern. Sample pipe layout and size shall be designed to preclude particle settlement in areas upstream of the sampling point.

A.1.3 Fuel tanks

Test fuel volume shall be sufficient to accommodate a rated flow single element, single pass test. For 50 mm (2 in.) diameter elements the tested element length is typically 762 mm (30 in.) and for 150 mm (6 in.) diameter elements the element length to be tested is 356 mm (14 in.). The volume of fuel used for full-scale tests is required to be greater than the largest volume of fuel used in any one of the single element tests. At least two fuel storage tanks are therefore required. Fuel tanks shall be calibrated and calibration charts available, which may be requested by a witness. Where dip sticks are used, they shall also have calibration documentation.

A.1.4 Pumping unit

The test system pump shall be of the centrifugal type and have a minimum shaft speed of 2 950 RPM and a minimum pump stall pressure of 700 kPa (7 bar). It shall be capable of

pumping clean, dry fuel at 115 % of the full rated flow of the equipment on test without an excessive temperature rise. Note: For structural testing of elements a pressure of 1 200 kPa (12 bar) is required. If this cannot be achieved by the use of the above test system pump then a separate system will be required. In the alternative system to reach 1 200 kPa (12 bar), any pump capable of achieving the required pressure is acceptable.

A.1.5 Slug test facility

When used for slug testing the flow facility shall be configured as shown in Figure A.3.

A.1.6 End-to-end resistance measurement apparatus

The following equipment is required:

- An insulation tester (500 V minimum, e.g. megger) reading to at least $10^{12} \Omega$.
- Connecting leads.
- An isolated element-mounting rig as shown in Figure A.4. The rig is designed to simulate a normal element mounting. The rig mounting blocks should be adequately insulated. Any fixings should be completely isolated if they protrude through the insulation pieces.

A.1.7 Flow apparatus

All critical equipment used for measuring relevant specified parameters shall be calibrated within the ranges and to the accuracy required by this publication. Calibration data should be confirmed prior to conducting a qualification test.

A.1.8 Bag filter housing

The bag filter housing should be positioned downstream of the filter monitor test vessel as closely as possible to the outlet of the filter monitor test vessel. The housing will be required to accommodate two bag filters in parallel to obtain the fuel flow rates required for the testing of 6 in. (150 mm) nominal diameter elements¹⁴.

A.1.9 Bag filters

Bag filters shall be five micron (nominal) rated¹⁵. One bag filter was required during the testing of two-inch diameter elements, but two bag filters were needed (housed in parallel) to obtain the fuel flow rates required for the testing of six-inch elements.

¹⁴ A bag filter housing found to be suitable for this application in previous EI research is available from Filter Specialists, Inc (<http://www.fsifilters.com>).

¹⁵ A bag filter found to be suitable for this application in previous EI research is that from Filter Specialists, Inc. (<http://www.fsifilters.com>) part number BPENG5P2PWE).

Figure A.1 Test facility

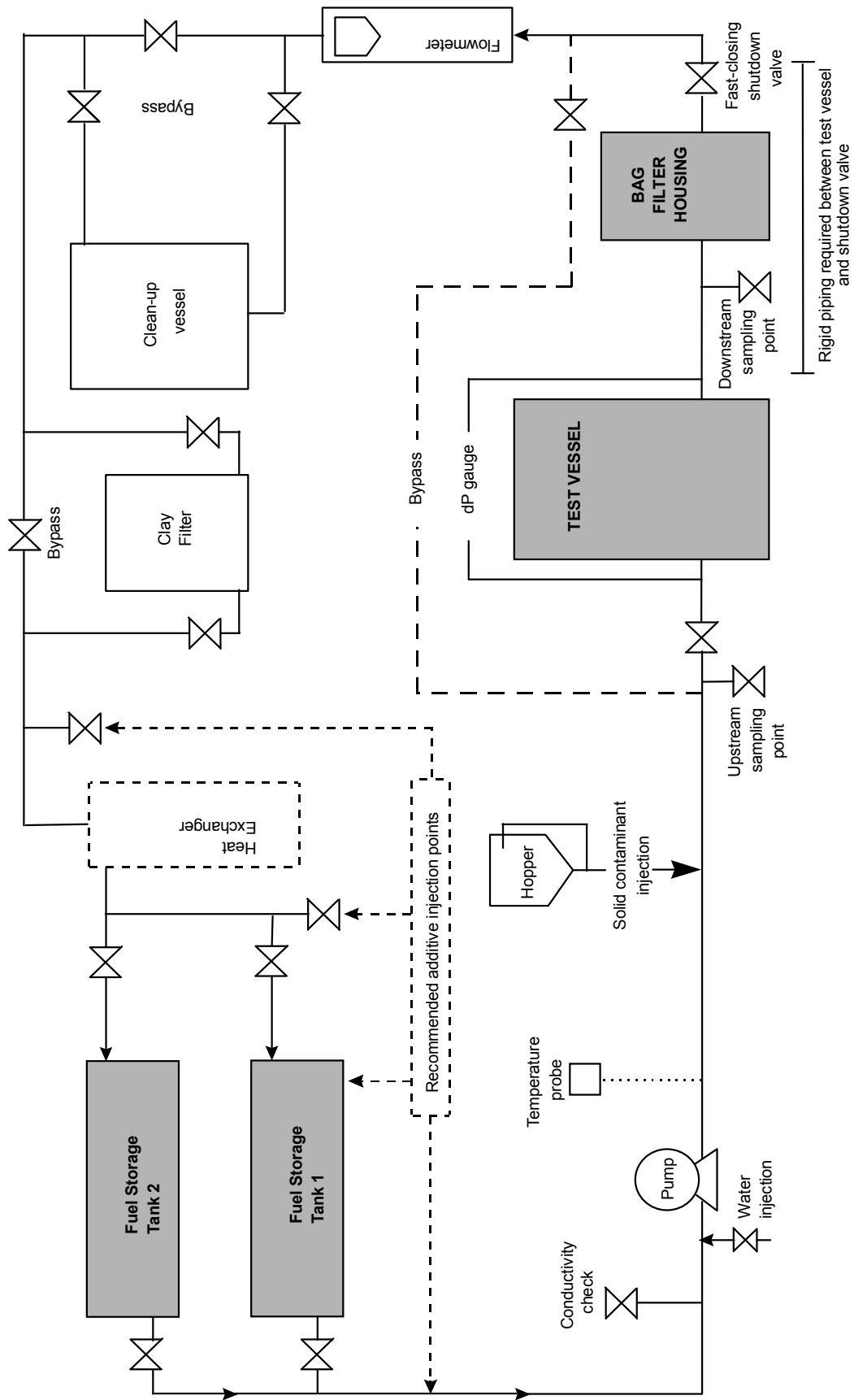
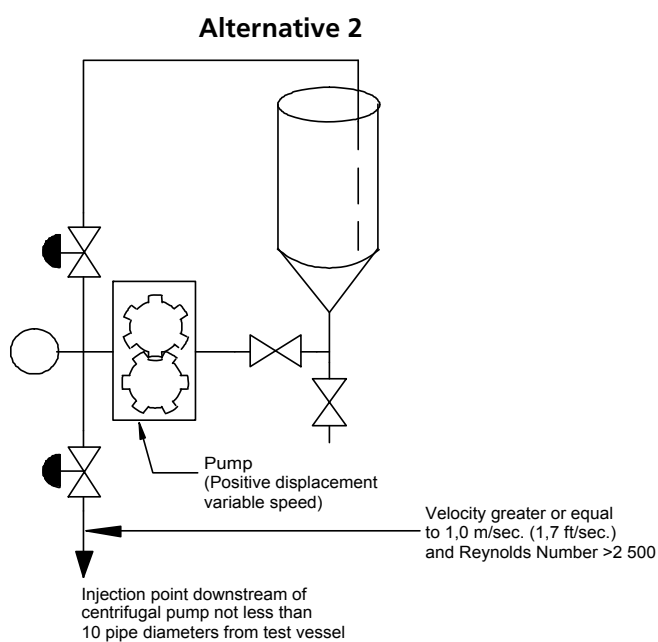
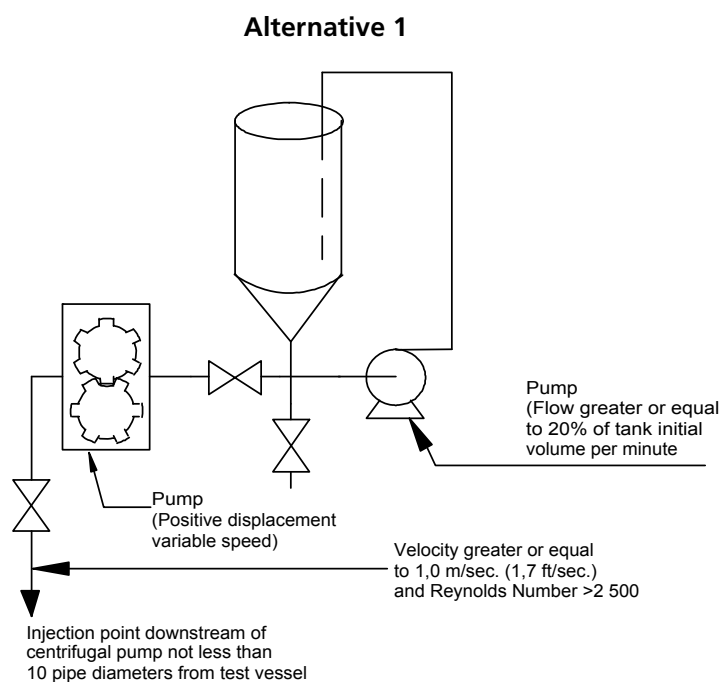


Figure A.2 Solids addition system



Notes:

1. Slurry volume concentration determined by flow rate (maximum 15 g/l).
2. Pump is variable positive displacement.
3. For Alternative 1, centrifugal pump sized to maintain slurry concentration constant in vessel (~20 % of initial tank volume/minute).
4. For Alternative 2, displacement pump sized to recirculation rate at ~ 20 % of initial tank volume/min at required injection rate.
5. For Alternative 2, injection rate must be measured by flow meter and/or level change.

Figure A.3 Water slug test facility

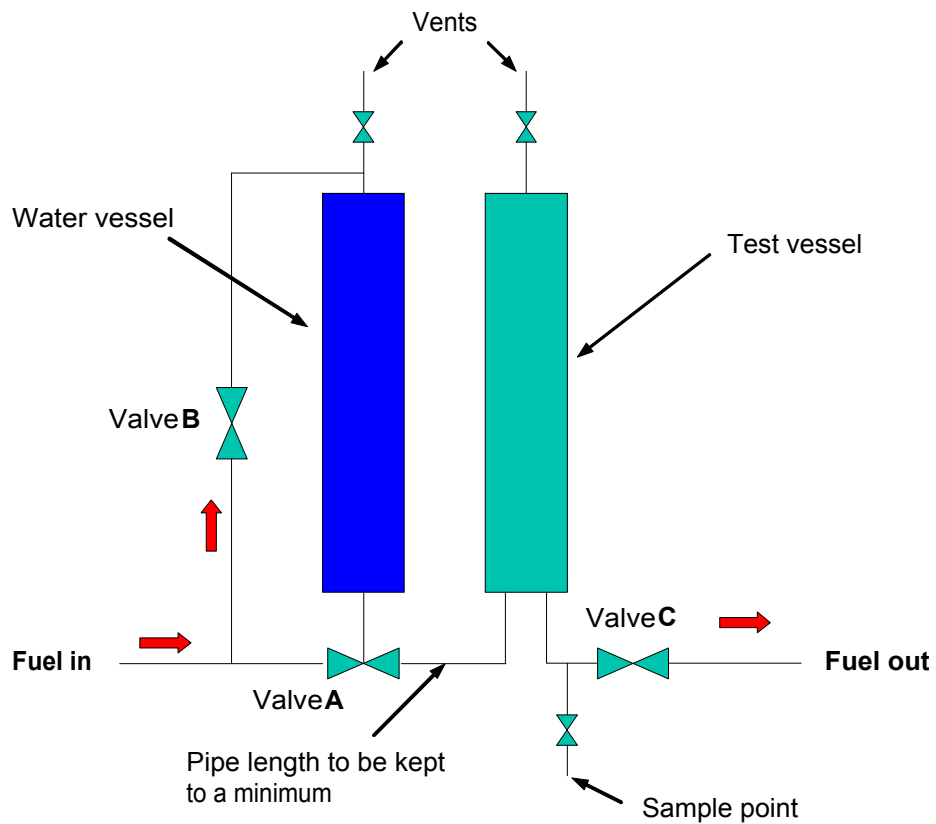
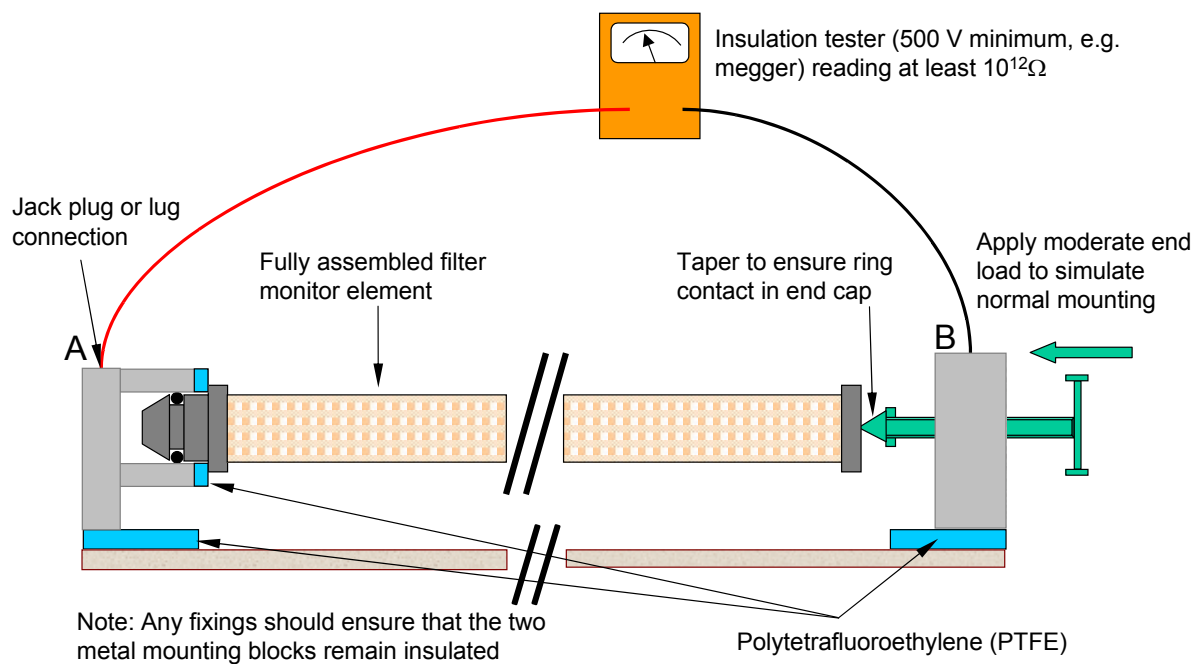


Figure A.4 End-to-end resistance measurement rig



ANNEX B (NORMATIVE)

PROCEDURE FOR THE LABORATORY ANALYSIS OF MEDIA MIGRATION SAMPLES

1. The contaminant is collected on a 0,45 µm nucleopore membrane and weighed, in accordance with IP 216 (ASTM D 2276). It is preferable to use gridded membranes as the grid markings facilitate the subsequent fibre counts. Report the result.
2. After weighing, place the test membrane under a low power binocular microscope (overall magnification about 20X) and examine the whole membrane surface for fibres. For the purpose of this procedure, a fibre is defined as any particle having a length equal to or greater than ten times its width, and having a length of 100 microns or more.
3. The number of fibres per litre of sample shall be reported. The presence of any unusual contaminant shall also be noted and reported.

ANNEX C (NORMATIVE)

ICP COPPER QUANTIFICATION METHOD

C.1 OBJECTIVE

The objective of the ICP copper quantification method is to quantify SAP migration from a filter monitor element during a qualification test, by filtering all the fuel effluent that passes downstream of the test vessel through one or more bag filters and then processing the bags.

C.2 GENERAL PRINCIPLES

During element testing a bag filter (or two bag filters in the case of 6 in. (150 mm) nominal diameter elements) is placed downstream of the element under test to capture any migrating SAP. At the end of the qualification test fuel flow is stopped and the bag filter(s) removed. The bag filter(s) are then processed by rinsing with a copper sulfate solution to react with any SAP present in the bag. The bag filter(s) are then water-washed to remove any residual copper sulfate. Finally, the bag filter(s) are washed with a hydrochloric acid solution to transfer any copper from any SAP into the acid solution. The copper content of a sample from the acid solution can then be measured by EPA Method 6010C *Inductively Coupled Plasma – Atomic Emission Spectroscopy* (ICP-AES).

An important point to note from previous EI research¹⁶ is that different types of SAP have different absorbency (for the same mass), and therefore the ICP copper result varies between SAP types. It is for this reason that the specific response of the SAP needs to be established, using known amounts of the SAP used in the model of element under test, to establish a correlation with ICP copper results (see C.3). The analysis can then be used to convert the ICP copper result to SAP (in mg). It is the mg of SAP that is required to be documented in the qualification report.

C.3 PROCEDURE TO ESTABLISH CALIBRATION OF ICP COPPER/SAP

Undertake the four steps in Table C.1 using the 'raw' SAP material used in the model of element to be qualified. At the end of step 4, continue with steps 5-23 from Table C.2. Perform the steps in Tables C.1 and C.2 using SAP at four concentrations: 12 mg, 25 mg, 50 mg and 100 mg, in each case using a new bag filter. A control shall also be performed with a new bag filter, following all steps, except step 4.

¹⁶ EI Research Report – Verification of a proposed test method to quantify the amount of super-absorbent polymer migration from aviation filter monitor elements during qualification testing.

Table C.1 Procedure to calibrate ICP copper to mg/l SAP

Step	Required action	Information	Time, minutes	Volume, L
1	Soak a new 5 micron bag filter in Jet A.	Only submerge 2/3 of the length of the bag, while held in upright position. Ensure top ring of bag filter stays above liquid level.	2	8
2	Remove bag and drain off excess fuel.	Fuel can be drained back into same container.	1	n/a
3	Re-soak the 5 micron bag filter in Jet A.	Reposition as in step 1. Can use same fuel.	1	8
4	Add measured quantity of SAP to the middle of the inside of the bag.	This is while the bag remains 2/3 submerged. The SAP is added into the fuel inside the bag.	n/a	n/a

The five ICP copper results obtained (0 mg, 12 mg, 25 mg, 50 mg and 100 mg) shall be plotted (ICP copper result in ppb vs SAP concentration in mg). This calibration shall be included in the qualification report.

If the model of element to be qualified contains more than one type of SAP, calibration is required for each SAP type.

C.4 PROCEDURE FOR USE AS PART OF QUALIFICATION TESTS 1 AND 10

The steps in Table C.2 shall be followed. Particular care is required to ensure that cross-contamination due to the handling process is minimised as far as practicable.

Table C.2 Bag filter processing procedure

Step	Required Action	Information	Time, minutes	Volume, L
5	Remove bag and drain off excess Jet fuel	This drain should be into another container in case any SAP contaminates the residual fuel.	3	n/a
6	Soak bag in iso-octane to remove excess fuel	The bag should be soaked in the same manner as in steps 1 and 3 (Table C.1).	1	8
7	Remove bag and drain off excess iso-octane	If the iso-octane used in step 6 is to be used to process another bag filter, this drain should be into another container to avoid potential cross-contamination.	3	n/a

Table C.2 Bag filter processing procedure (cont)

Step	Required Action	Information	Time, minutes	Volume, L
8	Soak bag in deionised water to activate SAP	Lower bag in its upright position into the container in the same manner as the previous soaking steps. Ensuring that the deionised water in this step is not reused for another bag filter will prevent cross-contamination.	2	8
9	Remove bag and drain off excess water	This drain can be into the container of deionised water from step 8, if the water is not going to be used to process another bag filter.	3	n/a
10	Soak bag in 5wt% (50 g per 1 L) CuSO ₄ solution	Lower bag in its upright position into the container in the same manner as the previous soaking steps. Any SAP in the bag should become visible as it turns blue.	2	6
11	Drain bag of excess CuSO ₄ solution	This drain should be into another container, so the remaining CuSO ₄ solution cannot be contaminated.	3	n/a
12	Wash#1 with deionised water to remove excess CuSO ₄ solution	This water wash is critical to ensure that only CuSO ₄ held by the SAP remains in the bag. Washing should be by soaking the bag in a container of deionised water handling it in the same manner as the previous soaking steps. Rinsing with a squeeze bottle is not acceptable.	1	12
13	Drain bag of excess water	The drain can be into the same container of deionised water as used in the previous step, or a separate container.	2	n/a
14	Wash#2 with deionised water to remove excess CuSO ₄ solution	This should be by the use of a new container of deionised water that has not previously been used to process a bag filter, to avoid the potential for any cross-contamination.	1	12
15	Drain bag of excess water	See 13	2	n/a
16	Wash#3 with deionised water to remove excess CuSO ₄ solution	See 14	1	12
17	Drain bag of excess water	See 13	2	n/a
18	Wash#4 with deionised water to remove excess CuSO ₄ solution	See 14	1	12

Table C.2 Bag filter processing procedure (cont)

Step	Required Action	Information	Time, minutes	Volume, L
19	Drain bag of excess water	See 13	2	n/a
20	Soak bag in 0,1 N HCl solution	Lower bag in its upright position into the container in the same manner as the previous soaking steps. Over time the blue colour will be removed from the bag.	2	8
21	Remove bag and drain off excess 0,1 N HCl solution	Drain bag into the container of 8 L HCl solution used in step 20.	2	n/a
22	Obtain 100 ml sample of 0,1 N HCl solution from the container of 8 L HCl solution from step 21 and seal in an appropriate container	A thin film of fuel may be present on top of the acid solution. The 100 ml sample should be extracted from the middle of the acid solution by using a pipette. Ensure the sample container is sealed securely. Consider appropriate storage/ packaging if necessary for transportation to an off-site laboratory.	2	n/a
23	Determine ICP copper result in ppb of 100 ml sample, using EPA Method 6010C		n/a	n/a
24	Add the ICP copper result from step 23 to any copper results obtained during the process described in 4.4.1 step 10			
25	Using the calibration established in C.3, report the SAP value in mg/cm or mg/in of the effective length of the element			

¹⁷ If the model of element to be qualified contains more than one type of SAP, the calibration for the type of SAP that produces the lowest copper by ICP result per unit mass SAP shall be used.

ANNEX D (INFORMATIVE)

TEST RESOURCES

D.1 COMPATIBILITY REPORTING SCHEME

Table D.1 Results of compatibility tests suggested reporting scheme

A–MSEP (ASTM D 3948)				
Test	Test fluid	Test hours		Comments
		0	336	
1	Jet A or Jet A-1			
	Reference Sample			
	Post element soak	N/A		

B–Existent gum (ASTM D 381)				
Test	Test fluid	Test hours		Comments
		0	336	
1	Jet A or Jet A-1			
	Reference Sample			
	Post element soak	N/A		
	Difference	N/A		
2	Jet A or Jet A-1 with 15 mg/l of DCI-4A and 5 ppmv of Stadis 450			
	Reference Sample			
	Post element soak	N/A		
	Difference	N/A		
4	30 % Toluene/ 70 % Iso-Octane			
	Reference Sample			
	Post element soak	N/A		
	Difference	N/A		

C–Detailed visual inspection of elements after soak		
Test	Test fluid	Comments
1	Jet A or Jet A-1	
2	Jet A or Jet A-1 with 15 mg/l of DCI-4A and 5 ppmv of Stadis 450	
3	50 % fuel system icing inhibitor (DiEGME)	
4	30 % Toluene/70 % Iso-Octane	

Table D.1 Results of compatibility tests suggested reporting scheme (cont)

D-Colour (ASTM D 156)				
Test	Test fluid	Test hours		Comments
		0	336	
1	Jet A or Jet A-1			
	Reference Sample			
	Post element soak	N/A		
	Difference	N/A		
2	Jet A or Jet A-1 with 15 mg/l DCI-4A and 5 ppmv of Stadis 450			
	Reference Sample			
	Post element soak	N/A		
	Difference	N/A		
4	30 % Toluene/ 70 % Iso-Octane			
	Reference Sample			
	Post element soak	N/A		
	Difference	N/A		

D.2 SAMPLING SCHEDULES

The sampling schedules are provided in Table D.2

Table D.2 Sampling schedules

Test	Test	When samples are taken	Sample size	Purpose	No. of samples	Sampling point	Sample type
Media migration	1	At start	As required	MSEP	1	Test unit effluent	Special container
		At start	As required	Conductivity	1	"	Bottle
		At start	5 litre	Media migration	1	"	In-line sampler
		30 mins.	5 litre	Media migration	1	"	In-line sampler
		End of test	As required	MSEP	1	"	Special container
		End of test	As required	Conductivity	1	"	Bottle
Water test, 50 ppmv at full rated flow	2	At start	As required	MSEP	1	"	Special container
		At start	As required	Conductivity	1	"	Bottle
		At 2, 3 mins. (stop/start) then every 10 mins. and after 100 kPa (1,0 bar) stop/start cycle	As required	Free water content	Varies	"	Aqua-Glo
		Continuous over 5 min. period	-	Leak-by volume	5	"	Graduated container
Water slug test (full flow)	3	Continuous over 5 min. period	-	Leak-by volume	5	"	Graduated container
Solids test	5	Continuous over 5 min. period	-	Leak-by volume	5	"	Graduated container
	6	At start	As required	MSEP	1	"	Special container
		At start	As required	Conductivity	1	"	Bottle
Freeze/thaw test		5 (stop/start), 15 mins. and then every 10 mins.	5 litre	Solids content	Varies	"	In-line sampler
	8	As per Tests 2 and 3					

Table D.2 Sampling schedules (cont)

Test	Test	When samples are taken	Sample size	Purpose	No. of samples	Sampling point	Sample type
Full water immersion test	9	Continuous over 5 mins.	-	Fuel appearance	5	"	Graduated container
Low flow water test	12	At start and after 5 mins. Hourly, and every 2 hours	As required	Free water content	2	"	Aqua-Glo
Full-scale vessel water test	13	As for Test 2	As required	Free water content Media migration	Varies	"	Aqua-Glo IP 216
Full-scale water slug test	14	As for Test 3					
50 ppm water test with saline solution	15	As for Test 2					
Water slug test with saline solution	16	As for Test 3					

ANNEX E

REFERENCED PUBLICATIONS

The following publications are cited in this publication; the latest available edition of each referenced publication applies.

API/EI¹⁸

API/EI 1550 *Handbook on equipment used for the maintenance and delivery of clean aviation fuel*
 API/EI 1596 *Design and construction of aviation fuel filter vessels*

IP Test Methods¹⁹

IP 216 *Determination of particulate contaminant of aviation turbine fuels by line sampling*
 (ASTM D 2276)
 IP 274 *Petroleum products — Aviation and distillate fuels—Determination of electrical conductivity* (ISO 6297)

ASME²⁰

Boiler and pressure vessel code, Section VIII: Rules for construction of boilers and pressure vessels

ASTM International²¹

D156 *Test method for saybolt colour of petroleum products (Saybolt chromometer method)*
 D381 *Test method for existent gum in fuels by jet evaporation*
 D1094 *Test method for water reaction of aviation fuels*
 D1655 *Specification for aviation turbine fuels*
 D2624 *Test method for electrical conductivity of aviation and distillate fuels containing a static dissipater additive*
 D3240 *Test method for undissolved water in aviation fuels*
 D3948 *Test method for determining water separation characteristics of aviation turbine fuels by portable separometer*

Joint Inspection Group (JIG)²²

AFQRJOS *Aviation fuel quality requirements for jointly operated systems*

¹⁸ Available from www.energypublishing.org.

¹⁹ Available from www.energypublishing.org.

²⁰ American Society of Mechanical Engineers, 3 Park Avenue, New York, New York 10016-5990 www.asme.org.

²¹ ASTM International, 100 Barr Harbour Drive, West Conshohocken, Pennsylvania 19428, USA www.astm.org.

²² Joint Inspection Group, c/o 35 Abercorn Place, London, NW8 9DR, UK. www.jointinspectiongroup.org.

UK Ministry of Defence (MoD)²³

Defence Standard 91-91/latest issue *Turbine fuel, aviation kerosine type, Jet A-1 NATO Code: F-35, Joint service designation: AVTUR* (DERD 2494)

US Environmental Protection Agency (EPA)²⁴

Method 6010C *Inductively Coupled Plasma – Atomic Emission Spectroscopy* (ICP-AES)

US Military²⁵

MIL-I-25017 *Inhibitor, corrosion (for aircraft engine fuels)*

²³ Ministry of Defence Directorate of Standardization, Room 1138, Kentigern House, 65 Brown Street, Glasgow G2 8EX, UK www.dstan.mod.uk.

²⁴ Available from National Homeland Security Research Center, U.S. EPA Office of Research and Development (NG16), 26 West Martin Luther King Jr. Drive, Cincinnati, OH 45268, USA, www.epa.gov/sam/method28.htm.

²⁵ US Military, Commanding Officer, Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, Pennsylvania 19120, USA.

ANNEX F

ABBREVIATIONS/UNITS

F.1 ABBREVIATIONS

The following abbreviations are used in this publication:

µm	micrometre
cu	conductivity unit
FSII	fuel system icing inhibitor
gal.	gallon
gpm	U.S. gallons per minute
kPa	kilopascal
lbf/in ²	pound per square inch
litres/sec/m	litres per second per metre length
mg	milligram
mm	millimetre
mN/m	millinewtons per metre
ppmv	parts per million by volume
pS/m	pico Siemens per metre
Ra	arithmetical mean deviation of an assessed profile
RPM	revolutions per minute
SC	solids content
ST	surface tension
TIR	total indicator reading

F.2 UNIT CONVERSION FACTORS

The following conversion factors are used in this publication:

1 U.S. gallon	3,785 litres
1 litre	0,264 U.S. gallon
1 Imperial gallon	4,546 litres
1 litre	0,220 Imperial gallon
1 kg	2,205 lbs
1 lb	0,454 kg
1 bar	14,50 psi
1 bar	100 kPa
1 psi	0,069 bar
1 psi	6,895 kPa
1 dyne/cm	1 mN/m
1 cu	1 pS/m
$T\text{ }^{\circ}\text{F} = 1,8 \times T\text{ }^{\circ}\text{C} + 32$	



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