

SPECIFICATIONS AND QUALIFICATION PROCEDURES  
FOR AVIATION JET FUEL FILTER/SEPARATORS

API/IP SPECIFICATION 1581

Fifth edition  
July 2002



THE INSTITUTE  
OF PETROLEUM



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Published jointly by  
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# FOREWORD

This publication is designed to provide comprehensive specifications and qualification test procedures for filter/separators used in systems that handle aviation jet fuel and is the result of collaboration between the American Petroleum Institute and the Institute of Petroleum. This publication is one of a series of joint standards related to aviation fuel handling.

The specifications in this publication are provided for the convenience of purchasers and manufacturers in fabricating and supplying filter/separators, but in no way prohibit either purchasers or manufacturers from purchasing or manufacturing equipment that meets other requirements.

Changes in construction, media, cross section of elements or in vessel design (general, profile and flow pattern) from that tested and qualified shall constitute a redesign, thereby nullifying previous approvals. Redesigned units shall be requalified.

Once an element model has been qualified, the manufacturer shall not change any aspect of element design or materials without prior approval from the purchaser(s) or requalifying the element in accordance with the conditions defined in this specification.

If the purchaser(s) is requested to approve a change to an element model then the purchaser(s) has the right to request a partial or complete retest of the filter/separator by the manufacturer to confirm its performance still complies with these specifications. Purchasers may also request partial or complete retests should they have reasonable grounds for believing the performance of the filter/separator has deteriorated from the original qualification tests.

A product quality assurance program shall be in place. As a minimum, such a program shall include the annual single-element testing of each element model by the test procedure in this publication using the fuel of the most stringent category for which the element was qualified. The test results shall be filed with the results of the qualification tests for the subject elements and shall be made available upon request.

Purchasers buying equipment in accordance with this publication should be aware that they have the right to conduct their own inspection independently of any supervisory inspection furnished by the manufacturer. Such an inspection should be based on the specifications of this publication. In addition, purchasers should avail themselves of audit reports of qualification tests and facilities inspections that may have been undertaken as part of an industry certification program.

The main change included in this 5<sup>th</sup> edition of API/IP 1581 is to remove Petronate L from all the test chemistries. Testing has shown that products currently qualified to the 4<sup>th</sup> edition meet 5<sup>th</sup> edition requirements for the category tested so that re-qualification is not required. This read-across from the 4<sup>th</sup> to the 5<sup>th</sup> edition applies only to the category tested and does not reduce the performance requirements of products produced to this publication.

The 4<sup>th</sup> edition of API/IP 1581 included a number of significant changes from the 3<sup>rd</sup> edition. While changes in the first three editions served mainly to improve the consistency of aviation filtration equipment, changes in the 4<sup>th</sup> edition were primarily designed to raise the level of performance and reduce the uncertainty inherent in aviation filtration. Specifically:

- The classes (A-C) of performance levels were eliminated. The analysis of data from the field indicated that product contained approximately the same magnitude of particulate through the entire handling system. This resulted in the conclusion that filtration needed to be equally effective at all points in the handling system. Water handling capacity of new systems on refuelling equipment was also enhanced. Finally, a coalescer element with minimal dirt handling capacity was specified, known as S-LD for low dirt, for use in intrinsically clean systems or in concert with microfilter systems.
- The group classification (I without and II with additives) of filter/separator systems was eliminated in favour of three new categories (M100 for JP-8+100, M for JP-8/JP-5, and C for Jet A/A1). That change brought commercial and military filtration requirements into a single specification.
- The composition of the test dirt was changed to ensure that it is a more consistent size (about 1 µm) than the dirt in the first three editions. This reduces the effect of agglomeration and provides for more consistent and realistic results.
- The inclusion of one or more additional stages to a filter/coalescer and separator system was explicitly permitted. Additional stages envisioned included a water absorbing or fuse stage located inside separators, and/or a prefilter stage located inside filter/coalescers.
- The testing protocol was changed to reduce the effort needed to qualify new elements. The individual runs are longer (water, dirt, water, 3 % water) but only one single-element test is needed for each model and configuration of filter/separator system. Multiple full-scale tests may reference one single-element test.
- Access to the information about the vessel and contents was improved by defining specific information on permanent labels affixed to the vessel.
- Access to the baseplate of new vessels was improved by decreasing the length versus diameter ratio of vessels.
- The similarity system was split into a separate document (API/IP 1582 *Specification for similarity for API/IP 1581 aviation jet fuel filter/separators*, February 2001) to permit the development of a more robust system.

As a result of the extensive changes from the 3<sup>rd</sup> to 5<sup>th</sup> editions, which enable significantly improved aviation filtration performance, delay is expected between the publication of this edition and the availability of elements qualified to it. The API Monogram Program will recognise the previous edition for one year after the publication of this edition. However, because of the benefits of this technology, it is recommended that API/IP 1581 5<sup>th</sup> edition elements be qualified and offered as soon as practical.

The American Petroleum Institute and The Institute of Petroleum are not undertaking to meet the duties of employers, manufacturers or suppliers to warn and properly train and equip their employees, and others exposed, concerning health and safety risks and precautions, nor undertaking their obligations under local and regional laws and regulations.

Nothing contained in any American Petroleum Institute or Institute of Petroleum joint publication is to be construed as granting any right, by implication or otherwise, for the manufacture, sale, or use of any method, apparatus, or product covered by letters patent. Neither should anything contained in the publication be construed as insuring

anyone against liability for infringement of letters patent.

It is hoped and anticipated that this publication will assist both the manufacturers and purchasers of jet fuel filter/separators. Every effort has been made by the American Petroleum Institute and the Institute of Petroleum to assure the accuracy and reliability of the data contained in this publication; however, API and IP make no representation, warranty, or guarantee in connection with this publication and hereby expressly disclaim any liability or responsibility for loss or damage resulting from its use or for the violation of any local or regional laws or regulations with which this publication may conflict.

Suggested revisions are invited and should be submitted to the director of the Downstream segment, American Petroleum Institute, 1220 L Street, N. W., Washington, D.C. 20005, or the Technical Department, The Institute of Petroleum, 61 New Cavendish Street, London, W1G 7AR.

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Shell Global Solutions  
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United Airlines  
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# 1

## GENERAL

### 1.1 SCOPE

- (a) This publication specifies the minimum performance and mechanical requirements and the testing and qualification procedures for aviation jet fuel filter/separators with flow rates ranging up to 9 500 lpm (2 500 gpm).
- (b) This specification defines procedures to qualify filter/separators with and without multi-stages. It does not qualify the actual multi-stage device(s).
- (c) The inclusion of additive packages in this publication is for testing purposes only and does not constitute acceptance or rejection of these additives in jet fuels by API/IP.
- (d) The performance specifications in this publication are for testing purposes only and do not necessarily constitute recommendations by API/IP for specifications in any application of the filter/separators.
- (e) Filter/separator systems currently qualified to the 4<sup>th</sup> edition of this specification are qualified as meeting the performance requirements of this

edition for the category tested. This provision does not reduce the performance requirements of products stated to meet this specification.

### 1.2 REFERENCED PUBLICATIONS

The following publications are cited in this publication:  
Note: For this standard, the latest available edition of each referenced publication applies.

#### API/IP<sup>1</sup>

- 1582 *Specification for similarity for API/IP 1581 aviation jet fuel filter/separators*
- 1583 *Specifications and qualification procedures for aviation fuel filter monitors with absorbent type elements*

#### ASME<sup>2</sup>

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

<sup>1</sup> Available from Portland Customer Services. Commerce Way, Whitehall Industrial Estate, Colchester, CO2 8HP. Tel: +44(0)1206 796 351, email: sales@portland-services.com; or API Publications, Global Engineering Documents, 15 Inverness Way East, M/S C303B, Englewood, CO80112-5776, USA. Tel: 303 397 7956, Fax: 303 397 2740, www.api.org

<sup>2</sup> ASME International, 3 Park Avenue, New York, New York 10016-5990, www.asme.org

SPECIFICATIONS AND QUALIFICATION PROCEDURES FOR AVIATION JET FUEL FILTER/SEPARATORS

ASTM <sup>3</sup>	U.S. Military Specifications <sup>4</sup>
D 156 <i>Test method for saybolt color of petroleum products (Saybolt chromometer method)</i>	MIL-PRF-4556: <i>Coating kit, epoxy, for interior of steel fuel tanks</i>
D 381 <i>Test method for existent gum in fuels by jet evaporation</i>	MIL-C-5541: <i>Chemical conversion coatings on aluminum and aluminum alloys</i>
D 1094 <i>Test method for water reaction of aviation fuels</i>	MIL-PRF-25017: <i>Inhibitor, corrosion/lubricity improver, fuel soluble</i>
D 1655 <i>Specification for aviation turbine fuels</i>	MIL-DTL-83133: <i>Turbine fuels, aviation, kerosene types, NATO F-34 (JP-8), NATO F-35, and JP-8+100</i>
D 2276 <i>Test method for particulate contaminant in aviation fuel by line sampling</i>	MIL-DTL-5624: <i>Turbine fuel, aviation, grades JP-4, JP-5, and JP-5/8 ST</i>
D 2624 <i>Test method for electrical conductivity of aviation and distillate fuels</i>	
D 3240 <i>Test method for undissolved water in aviation turbine fuels</i>	Joint Inspection Group Specifications <sup>5</sup>
D 3948 <i>Test method for determining water separation characteristics of aviation turbine fuels by portable separometer</i>	AFQRJOS <i>Aviation fuel quality requirements for joint operating systems</i>
D 4171 <i>Standard specification for fuel system icing inhibitors</i>	

<sup>3</sup> ASTM International, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428, [www.astm.org](http://www.astm.org)

<sup>4</sup> Available from Commanding Officer, Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, Pennsylvania 19120. U.S. military specifications are also available online from the ASSIST database at <http://astimage.daps.dia.mil/quicksearch>

<sup>5</sup> Available from the Joint Inspection Group, c/o 35 Abercorn Place, London, NW8 9DR, UK.

## 2

# DESCRIPTION

### 2.1 GENERAL

#### 2.1.1 Filter/separator

A filter/separator is a vessel containing filter/coalescer and separator elements that continuously removes dirt and water from aviation jet fuel to levels acceptable for servicing modern aircraft. A filter/separator can have either a vertical or a horizontal configuration. A filter/separator can consist of multiple stages.

*2.1.1.1* A two-stage system consists of filter/coalescer and separator elements contained within a vessel. The fuel flows through the filter/coalescer element(s) into the vessel and then flows through the separator element(s) to exit the vessel.

*2.1.1.2* A multi-stage system consists of a two-stage system that contains one or more additional stages. Additional stages may include currently qualified devices<sup>6</sup> located within each separator element capable of shutting off fuel flow if the filter/coalescer and separator elements fail to remove water to an acceptable level. Additional stages may also include currently

qualified devices<sup>6</sup> located within each coalescer element designed to remove dirt (prefilter) or contaminants (adsorption stage).

#### 2.1.2 Filter/coalescer

A filter/coalescer is an element that is capable of removing dirt and of coalescing fine droplets of water in the fuel to sizes that can be removed in the filter/separator vessel. Filter/coalescers are classified as Type S and Type S-LD (low dirt) according to the amount of dirt the elements are capable of removing as defined in Section 2.3.

#### 2.1.3 Separator

A separator is an element that prevents water droplets (coalesced by the filter/coalescer) from leaving the vessel in the effluent stream.

#### 2.1.4 Filter/separators

For the purpose of this specification, filter/separators are qualified for one or more of the three categories defined in Section 2.2.

---

<sup>6</sup> A qualified device is any device that meets a documented performance specification agreed to by purchaser and manufacturer.

### 2.1.5 Abbreviations

The following abbreviations and terms are used within:

- cm: centimetre
- gallon: U.S. gallon
- gpm: U.S. gallons per minute
- kPa: kilopascals (1 kPa = 0,144 psi)
- l: litre
- lpm: litre per minute
- mg: milligram
- mg/l: milligram per litre
- ml: millilitre
- mm: millimetre
- pinhole leak:  
A structural failure less than 1 mm in size. Discoloration on the sock of a filter/coalescer may indicate the presence of a pinhole leak but further investigation is necessary to ascertain
- ppmv: parts per million by volume
- psi: pounds per square inch (1 psi = 6,95 kPa)
- pS/m: picosiemens per metre (1 pS/m =  $10^{-12}$  siemens/metre. 1 siemens = 1 mho =  $1 \text{ ohm}^{-1}$  = 1 ampere per volt)
- rated flow:  
Rated Flow is the flow rate used for testing the performance of a filter/separator system in accordance with this specification. Note that the rated flow of a filter/separator system (meeting all specification requirements) is the maximum flow rate for that system in field applications
- rpm: revolutions per minute
- s/s: start/stop

## 2.2 CATEGORIES

### 2.2.1 Category C

2.2.1.1 Category C filter/separators (for commercial aviation fuel) are tested with a fuel containing an additive package in accordance with the procedures described in Section 4.

2.2.1.2 Category C filter/separators, coalescer/separators and multi-stage systems are suitable for use with aviation turbine fuels that might contain surfactants but do not contain dispersant additives used in some military applications to enhance the thermal stability performance of jet fuel.

### 2.2.2 Category M100

2.2.2.1 Category M100 filter/separators (for thermal stability enhanced military aviation turbine fuels) are tested with fuel containing an additive package that includes a dispersant, used to enhance thermal stability, in accordance with the procedures described in Section 4.

2.2.2.2 Category M100 filter/separators, coalescer/separators and multi-stage systems are suitable for use primarily with military aviation turbine fuels that include dispersant additives such as those used to enhance thermal stability.

### 2.2.3 Category M

2.2.3.1 Category M filter/separators (for military aviation turbine fuels) are tested with fuel containing an additive package used in military fuels in accordance with the procedures described in Section 4.

2.2.3.2 Category M filter/separators, coalescer/separators and multi-stage systems are suitable for use primarily with military aviation turbine fuels that contain static dissipater additive, metal deactivator additive, anti-oxidant, corrosion inhibitor, and anti-icing additive.

## 2.3 USES AND QUALIFICATION REQUIREMENTS

### 2.3.1 Filter/separators

Filter/separators can be used at all filtration points in an aviation fuelling system.

### 2.3.2 Type S filter/separators

Type S filter/separators can be used at filtration points where significant levels of water and dirt in the product can be expected. The qualification requirements for Type S filter/separators are:

- (a) The Type S filter/separator shall have a solids holding capacity totalling 1,43 grams per lpm (19 mg/l for 75 minutes) (5,4 grams per gpm) of rated flow without exceeding the pressure drop and contamination of the effluent fuel as specified in Sections 3.1.3.1 and 3.1.1 respectively. Note that

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maximum dirt-holding capacity is not tested in full-scale testing.

- (b) The filter/separator shall be able to effectively remove water from fuel without exceeding the effluent free-water levels specified in Section 3.1.1 when water is added according to the procedures specified in Section 4.

**2.3.3 Type S-LD filter/separators**

Type S-LD filter/separators (also known as coalescer/separators) can be used at all filtration points in an aviation fuelling system where significant levels of water but minimal amounts of dirt can be expected in the jet fuel. Examples of suitable locations could be immediately after a microfilter (used to remove dirt to acceptable levels) or at locations where acceptable dirt levels can be achieved without filtration. The qualification requirements for coalescer/separators are:

- (a) The Type S-LD filter/separator shall be able to maintain rated flow when it is contaminated with particulate to the level specified in Section 4 without the contamination in the effluent fuel exceeding the level specified in Section 3.1.1.
- (b) The Type S-LD filter/separator shall be able to effectively remove water from fuel without exceeding the effluent free-water levels specified in Section 3.1.1 when water is added according to the procedures specified in Section 4.

**2.3.4 Multi-stage systems**

*2.3.4.1* Multi-stage systems can be used at all filtration points in an aviation fuelling system where two-stage filter/separators are used but where additional performance or assurance is desired. Multi-stage devices include pre-filters (upstream of filter/coalescers) and water absorbing elements (downstream of separators). Water absorbing elements can be used for additional assurance that effluent water

will not exceed the level specified in Section 3.1.1. Examples of such locations could be systems where surfactants or additives might impair filter/separator performance or on fuellers and hydrant servicers where an additional precaution may be desired to keep water from aircraft.

*2.3.4.2* The qualification requirement for a multi-stage system is that the filter/separator shall be able to qualify under Section 2.3.2 or 2.3.3 when the multi-stage devices are installed.

Note: This specification applies only to the filter/separator portion of the system. No specific level of performance by a multi-stage system is implied by this specification.

**2.4 QUALIFICATION FOR OTHER CATEGORY AND/OR TYPE SYSTEMS**

**2.4.1 Categories**

*2.4.1.1 Single-element testing*

For single-element testing there is no automatic qualification between categories. Qualification for each category shall be established by testing.

*2.4.1.2 Full-scale testing*

- (a) Filter/separators qualified by testing to Category M100 also qualify for Category M at the test flow rate and conditions.
- (b) Filter/separators qualified by testing to Category M also qualify for Category C at the test flow rate and conditions.

Note: Category M100 testing does not qualify to Category C.

**2.4.2 Filter/separators qualified as Type S**

Filter/separators qualified as Type S by testing also qualify as Type S-LD at the tested flow rate and conditions.



# 3

## SPECIFICATIONS

### 3.1 PERFORMANCE

#### 3.1.1 Contamination of effluent fuel

Contaminants in effluent fuel samples, taken during the specified test procedure and analysed by the specified methods, shall not exceed the following limits:

- (a) Total solids content of 0,26 milligrams per litre (1,0 milligrams per gallon) by ASTM D-2276.
- (b) Free water content of 15 ppmv by ASTM D-3240.
- (c) Media migration of 10 fibres per litre (38 fibres per gallon).

#### 3.1.2 Media migration

Any particle in the effluent with a length-to-diameter ratio of 10:1 or more and a length of 100 microns or more shall be counted as a fibre.

#### 3.1.3 Solids holding capacity

*3.1.3.1* Type S filter/separators, as tested in the single-element test, shall hold a quantity of solids greater than or equal to 1,43 grams per litre per minute (19 mg/l x 75 minutes) (5,4 grams per gpm) of rated flow. The unit shall hold 67 % of the specified quantity of solids without exceeding a differential pressure of 105 kPa (15 psi) and shall hold the total specified quantity of solids without exceeding a differential pressure of 315 kPa (45 psi).

*3.1.3.2* Type S-LD filter/separators do not have a specified solids holding capacity. However, they must be able to sustain differential pressures of 155 kPa (22,5 psi) and 105 kPa (15 psi) developed in accordance with the procedures in Section 4.3.2.6.2 and 4.4.5.3.2 for a period of 45 minutes without exceeding the particulate contamination in the effluent greater than that specified in Section 3.1.1(a).

*3.1.3.3* Multi-stage systems shall meet the performance specifications for Type S or Type S-LD filter/separators, depending on which system is receiving the additional stages.

#### 3.1.4 Differential pressure

*3.1.4.1* Two-stage systems shall not exceed differential pressures of 70 kPa (10 psi) across a vessel having new elements and 42 kPa (6 psi) across the filter/coalescer stage when operating at rated flow with clean, dry fuel.

*3.1.4.2* Multi-stage systems shall not exceed a differential pressure across new filter/coalescer elements of 42 kPa (6 psi), as measured between points upstream and downstream of the filter/coalescers when operating at rated flow with clean, dry fuel. The total differential pressure across the vessel shall not exceed the sum of the differential pressure permitted for a two-stage system (Section 3.1.4.1) and the differential pressure permitted for the new multi-stage devices at rated flow.

### 3.1.5 Structural strength of elements

The filter/coalescer elements, coalescer elements, and the element sealing device shall be capable of withstanding a differential pressure of 520 kPa (75 psi) without rupture, by-passing of seals, or the emergence of pinhole leaks.

### 3.1.6 Structural integrity

Filter/coalescer and coalescer elements shall meet single-element and full-scale performance tests without showing indications of media or structural deterioration such as leaks or tears. Note that coalescer sock discoloration in the absence of supporting observation is insufficient to prove failure of structural integrity (see 4.3.2.8 and 4.4.5.5).

## 3.2 MECHANICAL SPECIFICATIONS

### 3.2.1 General

The acceptability of a design ultimately depends on satisfactory functioning of the vessel and components during the performance tests described in Section 4.

### 3.2.2 Vessel design and construction

#### 3.2.2.1 Design codes

Filter/separator vessels shall be designed and constructed in accordance with the most recent edition and revision of Section VIII of the ASME *Boiler and pressure vessel code* or with equivalent codes applicable in the region of intended use.

#### 3.2.2.2 Materials of construction

3.2.2.2.1 All metal parts that contact fuel, with the exception of sensing lines, shall contain no zinc, copper, or cadmium or their alloys. Vessels shall be of stainless steel, anodized aluminium, carbon steel, or aluminium chemically converted in accordance with the most recent edition and revision of MIL-C-5541. Carbon steel vessels shall be internally coated with a white or light-coloured surface coating which shall not deteriorate upon exposure to fresh or salt water or aviation fuels, nor shall the coating affect fuel quality. Epoxy coatings conforming to the most recent edition and revision of MIL-PRF-4556 or an equivalent specification and other purchaser-approved coatings that have demonstrated equivalent or superior performance (to these epoxy coatings) are suitable.

Vessels may be fabricated from uncoated aluminium upon agreement of purchaser and manufacturer.

3.2.2.2.2 The sensing lines in new installations shall be stainless steel.

#### 3.2.2.3 Vent and pressure relief taps

Each filter/separator shall be provided with a tap for a pressure relief valve to relieve pressure from thermal expansion of the fuel. A connection for an air eliminator shall be provided at the highest point in the vessel.

#### 3.2.2.4 Sample taps

Sample taps shall be provided to permit the taking of influent and effluent fuel samples during fuel flow. Each sample tap shall be large enough to accept, at least, a 1/4-inch National Pipe Thread probe assembly or an assembly of similar size, as applicable in the region of intended use.

#### 3.2.2.5 Pressure taps

Pressure taps shall be provided to connect the appropriate pressure gauges or sensors to the filter/separator. The gauges or sensors shall permit reading the inlet pressure to the vessel and the outlet or total differential pressure. For multi-stage systems, pressure taps to measure the pressure drops across the filter/coalescer and across the separator and additional stage(s) shall be provided.

#### 3.2.2.6 Cleanout/inspection connection

Access shall be provided to permit inspection and cleanout of all inaccessible chambers of the vessel, such as sumps and locations under or behind deck plates and manifolds. Acceptable provision for access shall be provided by the use of a 10 cm (4 inch) flanged cleanout connection when permitted by the design and construction code or an alternate scheme providing equivalent accessibility. Access schemes requiring the removal of the vessel's inlet or outlet piping are unacceptable. Access schemes should be engineered to minimize the volume of deadlegs.

#### 3.2.2.7 Drain and sample connections

Water drains, sample drains, or both shall be provided at the low points of the inlet and outlet compartments and of the deck plate. Welded half-couplings 19 mm (0,75 inch) in diameter, furnished with pipe plugs, will satisfy this requirement. To ensure positive drainage, drains shall run from the bottom of the sump collection area. Deck mounting plates shall have at least a 3 % positive slope to facilitate complete removal of

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accumulated water and debris during normal draining procedures. The fabrication of the sump shall be such that weld ridges or distortions do not prevent liquid from draining into the sump.

Note: Sump flooding can result in the transmission of water downstream. Systems/procedures should recognize this possibility and be designed accordingly e.g. see Sections 3.2.5.2-3.

### 3.2.2.8 Drain lines, sample lines, and vents

All drain lines, sample lines, and vents shall be piped to discharge in a manner that minimizes the risk of injury to personnel and damage to the environment.

### 3.2.2.9 Nameplate

3.2.2.9.1 A permanent stainless steel or non-ferrous metal nameplate shall be securely attached to the vessel. The nameplate shall include at least the following information:

- (a) The manufacturer's name and address.
- (b) The vessel's serial number and model number.
- (c) The date of manufacture.
- (d) The design code of the vessel.
- (e) The design pressure for the vessel.
- (f) The maximum allowable differential pressure across the deck plate.
- (g) The sump volume (the volume that activates a water defence system when present or else the volume up to the lowest separator stool, filter/coalescer stool, or element whichever is smaller).
- (h) The vessel cover gasket material and part number.

3.2.2.9.2 In addition to 3.2.2.9.1, a securely attached removable plastic or metal nameplate shall be provided with the following information:

- (a) The vessel's serial number and model number.
- (b) The vessel's API/IP category and type classification.
- (c) The vessel's rated capacity for jet fuel.
- (d) The count and model numbers of the coalescer and separator elements.
- (e) The manufacturer's recommended element-change pressure differential.
- (f) The recommended assembly torque for element installation.
- (g) The similarity certificate identification code.

### 3.2.2.10 Design pressure

The vessel's design pressure (maximum working pressure) shall be at least 1 035 kPa (150 psi gauge) at 35 °C (95 °F) or as specified by the purchaser.

### 3.2.2.11 Hydrostatic test pressure

3.2.2.11.1 Each filter/separator vessel shall be hydrostatically tested in accordance with the applicable code. In addition, the inlet manifold or chamber shall be blanked off after installation and tested to a minimum pressure of 795 kPa (115 psi gauge).

3.2.2.11.2 Where multi-stage systems are used, the outlet manifold shall be blanked off and tested to a minimum pressure of 795 kPa (115 psi gauge) or the required pressure specified for the qualified multi-stage element vessel, whichever is greater.

### 3.2.2.12 Marking of inlets and outlets

All inlet, outlet, and sump drain connections shall be permanently marked.

### 3.2.2.13 Element spiders

The free ends of all elements greater than 46 cm (18 inches) long, regardless of mounting assembly, shall be stabilized (supported firmly) to minimize vibration. One acceptable system uses an element spider to tie the elements together and stabilizes the spider to the vessel wall. A spider shall not be an unbonded charge collector: if the method of stabilization does not assure an electrically conductive bond between the spider and the vessel then the spider shall be separately bonded to the vessel. Element-locating devices shall be provided in the spider to support slightly misaligned elements securely without causing unnecessary strain.

### 3.2.2.14 Access to elements

Unless special installation conditions require otherwise, access to the elements shall be provided by a hinged or pivoted vessel cover. The use of swing bolts is recommended to facilitate quick access to the interior of the vessel. To permit access to the far end of the vessel for maintenance purposes, the vessel's length-to-diameter ratio shall be limited by the following expressions, unless otherwise specified by the purchaser:

For vessels  $\leq 61$  cm (24 inch) diameter:  $L/D \leq 1,75$   
For vessels  $> 61$  cm (24 inch) diameter:  $L/D \leq 2,5$

where:

L is the distance from the deck plate or manifold to the lid opening,

D is the inside diameter of the vessel.

#### 3.2.2.15 Spacing of elements

The layout of elements in the vessel shall provide a minimum clearance of 6,5 mm (0,25 inch) between elements and the vessel wall. New vessels shall have at least 13 mm (0,5 inch) clearance between elements and the vessel wall. The centre-to-centre distance between elements shall not be less than 15,9 cm (6,25 inches) and no surface shall be closer than 6,5 mm (0,25 inch) from the surface of another element. For new vessels, the centre-to-centre distance between elements shall be no less than 16,5 cm (6,5 inches).

#### 3.2.2.16 Gaskets

All gaskets in new vessels shall be composed of Viton A, Buna N or equivalent material meeting accepted industry standards or military specifications. Rubber-impregnated cork gaskets are acceptable in existing vessels that were designed to use them.

Note: Cork gaskets and gaskets containing asbestos are not acceptable.

#### 3.2.2.17 Exterior

The exterior of the vessel shall be cleaned to remove all dirt, grease, rust, and loose mill scale, and one coat of an approved metal primer shall be applied, unless otherwise specified. All nameplates, gauges, and the like shall be masked before painting. A head lift retaining device shall be fitted on all vessels 46 cm (18 inches) diameter and larger.

#### 3.2.2.18 Platforms

Work platforms shall be provided where necessary to permit elements to be replaced safely. The work platform shall be provided by the installation contractor unless otherwise agreed by the manufacturer and purchaser.

#### 3.2.2.19 New vessel cleanliness

New vessels shall be provided such that all surfaces normally contacting jet fuel are free of dirt (including sand-blasting agents), metal filings, water, and potential chemical contaminants.

### 3.2.3 Design and construction of elements

#### 3.2.3.1 Sealing

Element connections shall be sealed by one of the following methods:

- (a) A flat-base gasket seating against a blunted V-type knife-edge. The height of the V section shall be 1,5 mm (0,06 inch) +10 %/ -0 %.
- (b) A screw base with compressed O-rings and/or a flat gasket seating against a V-type knife edge, as described in (a).
- (c) For open-ended elements, a suitable gasket, a washer, or an O-ring fitted in a recessed washer, shall be specified to seal the end cap and retaining rod screw threads.
- (d) A piston-type O-ring.

#### 3.2.3.2 Materials of construction

All metal parts that contact fuel shall contain no zinc, cadmium, or copper. Metal components of elements shall be non-corrosive. All materials shall be chemically compatible with the fuel. All seals shall be composed of Viton A, Buna N, or an equivalent material.

#### 3.2.3.3 Identification

3.2.3.3.1 Each element shall be permanently marked with its model number and date of manufacture. Where possible, this identification should be located so that it can be seen when the element is installed in a vessel. The materials used to mark the elements shall not cause contamination of the fuel, nor shall the fuel affect them.

3.2.3.3.2 The endcaps of Type S-LD elements shall be suitably marked to indicate their Type.

#### 3.2.3.4 Packaging

Elements shall be packaged to minimise damage during shipping. Each element shall be individually protected from contamination by dirt and moisture by means of a polyethylene bag or similar wrapping. The manufacturer shall include details of element installation including the recommended torque and whether the threads shall be lubricated or not. The manufacturer's recommendations concerning maximum differential pressure and service life shall be clearly communicated.

#### 3.2.3.5 End caps

Element end caps and related hardware shall be designed to preclude entrapment of water. End caps shall be designed to withstand at least 200 % of the recommended assembly torque without permanent distortion, cracking, or failure. A complete element assembly shall withstand 125 % of the recommended assembly torque.

*3.2.3.6 Element mounting adapters*

Threaded mounting adapters shall be securely mounted to prevent rotation when elements are removed. The adapters shall be designed to withstand at least 150 % of the recommended assembly torque without permanent distortion, cracking, or failure.

**3.2.4 Mandatory filter/separator accessories**

*3.2.4.1 General*

The accessories described in Sections 3.2.4.2 through 3.2.4.4 shall be provided on all units.

*3.2.4.2 Equipment for measuring differential pressure*

*3.2.4.2.1* The condition and remaining life of filter elements are assessed by measuring and tracking the differential pressure at rated flow. A gauge that gives a direct reading of the differential pressure across the filter/separator elements shall be installed. It is required for new installations (and recommended for existing installations) that the gauge have a suitable three-way valve on its downstream side, arranged so that when the valve is turned to the "off" position, the gauge is vented. If required by the purchaser to aid in calibrating the gauge, quick-disconnect couplers shall be provided to facilitate attaching a master gauge.

*3.2.4.2.2* When vessels are equipped with a monitor or fuse stage then differential pressure gauges (or sensors) shall be installed across the filter/coalescers and also across the separators and monitor stages. Each gauge shall have a suitable three-way valve on its downstream side, arranged so that when the valve is turned to the "off" position, the gauge is vented. If required by the purchaser to aid in calibrating the gauge, quick-disconnect couplers shall be provided to facilitate attaching a master gauge.

*3.2.4.3 Air eliminator*

Each filter/separator vessel shall be fitted with a means of automatically venting trapped air from the top of the vessel. If associated piping could permit the vessel to drain and air to enter through the air eliminator, a soft-seated non-return (check) valve with an opening pressure of 6,95 kPa (1 psi) shall be installed to prevent the vessel from draining.

*3.2.4.4 Pressure relief valve*

Each filter/separator shall be fitted with a pressure relief valve to ensure that the design working pressure of the vessel is never exceeded.

*3.2.4.5 Water defence system*

Filter/separator systems used to refuel aircraft shall be equipped with one of the following water defence systems unless the purchaser agrees to eliminate it:

- A water-slug shutoff device as described in Section 3.2.5.2, or
- A sump water-level alarm as described in Section 3.2.5.3, or
- A water-absorbing/flow-restricting multi-stage device meeting Section 4.4.5.6.2.

Note: The implementation of monitoring procedures to assess the contents of the filter sump after aircraft fuelling is accepted by the industry as an alternative to the above hardware-based water defence systems.

**3.2.5 Optional filter/separator accessories**

*3.2.5.1 General*

The accessories described in Sections 3.2.5.2 through 3.2.5.6 are optional.

*3.2.5.2 Water-slug shutoff device*

A water-slug shutoff device is a sensor or float that, automatically, causes the fuel pump to be shut off or a valve downstream of the filter/separator to be closed when water fills the sump of the filter/separator vessel. This device shall be equipped with an external mechanism for testing. If a float control is used, it should be the "ballast" or spring-loaded type, which tests the buoyancy of the float when the external test mechanism is activated.

*3.2.5.3 Sump water-level alarm*

A sump water-level alarm is a device that notifies the operator when water fills the sump of the filter/separator vessel. This device shall be equipped with an external mechanism for testing.

*3.2.5.4 Sump heaters*

In very cold areas, accumulated water can freeze, and clog sumps and drains. Electric jackets or immersion heaters can be provided to remedy this problem.

*3.2.5.5 Flow limiters*

Flow limiters are necessary for installations where parallel pumps and parallel filter/separator vessels are manifolded together so that one filter/separator vessel can, by valve manipulation, receive more than its rated flow. Flow limiters are also necessary if the total flow from one pump is divided between two or more parallel filter/separators.

*3.2.5.6 Drawings*

A set of drawings providing sufficient detail of internal vessel layout to support hydrodynamic calculations (for calculating similarity) shall be provided with each new vessel upon purchaser request.

# 4

## TESTING AND QUALIFICATION PROCEDURE

### 4.1 QUALIFICATION BY SIMILARITY

#### 4.1.1 Qualification of filter/separators by similarity

Many manufacturers supply filter/separators of similar design but rated for different flow rates. Qualification testing of units similar to those already tested and qualified may not be necessary, provided the criteria specified in API/IP 1582 are met.

#### 4.1.2 Qualification of filter/separators

*4.1.2.1* Qualification of a filter/separator vessel consists of passing single-element tests and full-scale tests of vessels, elements and configurations similar to the vessel being qualified.

*4.1.2.2* Single-element tests described in Section 4.3 are necessary for each type of filter/coalescer and separator configuration and category. These single-element tests need not be repeated for every full-scale vessel test if the conditions specified in Section 4.2 are met by a completed single-element test.

*4.1.2.3* Full-scale tests described in Section 4.4 are necessary for each vessel configuration, filter/coalescer and separator configuration. These full-scale tests need not be repeated for every vessel-element configuration if the similarity conditions specified in API/IP 1582 are met.

### 4.2 TEST MATERIALS AND FACILITIES

#### 4.2.1 Test apparatus

*4.2.1.1* Qualification tests shall be performed using comparable single-element test facilities, as shown in Figure 1 and full-scale test facilities as shown in Figure 2. The solids injection facilities shall be designed as shown in Figure 3. The single-element test vessel shall have the same configuration (side-by-side or end-opposed) as the full-scale vessel.

*4.2.1.2* The single-element vessel shall be operated in the same orientation (either vertical or horizontal) as the full-scale vessel.

*4.2.1.3* No tees or dead legs shall be present in the section of piping between the contaminant-injection point and the test vessel.

*4.2.1.4* The test vessels used in single-element and full-scale tests are not required to comply with all the mechanical specifications in 3.2.2. For example, the element spacing and L/D ratios in commercial vessels specified by 3.2.2 may be incompatible with the practical requirements for test vessels. Note that this in no way modifies or relaxes similarity requirements.

*4.2.1.5* The media and construction of the elements tested shall be the same as those used in the full-scale vessel.

4.2.1.6 Data sheets, drawings, or both, that generally describe the design of the elements to be qualified, shall be included with the qualification test report. The appropriate single-element test report shall be referenced in each full-scale test report.

4.2.1.7 Single-element testing is conducted with a two-stage (filter/separator) system. Additional stages used in multi-stage vessels are evaluated only in full-scale testing. The filter and separator stages shall be fitted in the single-element vessel in the same relative position as in the full-scale vessel, in accordance with the following criteria:

- (a) The filter/coalescer elements shall be the same model (identical media and construction) in single-element and full-scale tests. The only differences permitted are the element lengths and end caps.
- (b) The coalescer shall have a nominal length of  $36 \pm 3$  cm ( $14 \pm 1$  inches). The flow rate per cm (inch) of the filter/coalescer shall be no less than the maximum flow rate per cm (inch) of the filter/coalescers in the full-scale vessel.
- (c) The diameter of the filter/coalescers qualified shall be a maximum of 15,5 cm (6 inches). The diameter of filter/coalescers can vary but shall be the same in both single-element and full-scale tests.
- (d) The separators in single-element and full-scale testing shall be constructed of the same materials.
- (e) The diameter of the separator qualified in the single-element test shall be a maximum of 15,5 cm (6 inches). The diameter (average diameter for non-cylindrical separators) shall be the same or less than the separator(s) tested in full-scale testing.
- (f) The effective length of the separator shall be no greater than 15,5 cm (6 inches).
- (g) The distance between the nearest coalescer and separator elements shall not be greater than the distance between the nearest coalescer and separator elements in the full-scale vessel ( $\delta_{F/C-S}$ ).
- (h) The shortest distances between the interior surface of the vessel and the outer surfaces of the coalescer and separator elements in the single-element vessel shall not be greater than the corresponding distances in the full-scale vessel ( $\delta_{F/C-V}$  and  $\delta_{S-V}$ ).

(i) The orientation of the filter/coalescer and separator shall be the same as the full-scale vessel.

(j) Vessel diameters:

(i) The single-element vessel diameter ( $D_V$ ) for side-by-side configurations shall be:

$$D_V \leq D_{F/C} + D_S + \delta_{F/C-S} + \delta_{F/C-V} + \delta_{S-V}$$

(ii) The single-element vessel diameter ( $D_V$ ) for end-opposed configurations shall be:

$$D_V \leq D_{F/C} + 2 \delta_{F/C-V}$$

or

$$D_V \leq D_S + 2 \delta_{S-V}$$

whichever is greater.

(k) Vessel areas:

(i) For side-by-side vessels, the single-element test vessel area shall be reduced by placing plates aligned with the flow path between filter/coalescer and separator elements such that the closest distance of the plate to the filter/coalescer shall be:

$$\leq 1,5 * \delta_{F/C-F/C}$$

and the closest distance between the separator and plate shall be:

$$\leq 1,5 * \delta_{S-S}$$

(ii) For end-opposed vessels, the single-element test vessel area ratio shall be:

$$A_{Ratio} \geq 0,95 * (\sum D_{F/C}^2) / D_{FS}^2$$

or

$$A_{Ratio} \geq 0,95 * (\sum D_S^2) / D_{FS}^2$$

whichever is greater,

where:

- $D_V$  is the diameter of single-element test vessel,
- $D_{FS}$  is the diameter of full-scale vessel,
- $D_{F/C}$  is the diameter of filter/coalescer,
- $D_S$  is the diameter of separator (average diameter for non-cylindrical separators),
- $\delta_{F/C-S}$  is the spacing between full-scale vessel separator and filter/coalescer as defined in Section 4.2.1.7.g,

$\delta_{F/C-V}$  is the spacing between full-scale filter/coalescer and vessel wall as defined in Section 4.2.1.7.h,  
 $\delta_{S-V}$  is the spacing between full-scale separator and vessel wall as defined in Section 4.2.1.7.h,  
 $\delta_{F/C-F/C}$  is the minimum spacing between two filter/coalescers in the full scale vessel,  
 $\delta_{S-S}$  is the minimum spacing between two separators in the full-scale vessel,  
 $A_{Ratio}$  is the area ratio of filter/coalescer or separator to vessel. For end-opposed vessels, this is defined as the ratio of the element outside diameter squared to the vessel internal diameter squared.

4.2.1.8 The pump unit in both the single-element and full-scale testing systems shall be of the centrifugal type and shall have a minimum shaft-rotation rate of 2 950 rpm.

**4.2.2 Test fuel**

4.2.2.1 *General*

The base fuel for all tests shall conform to ASTM D 1655 or AFQRJOS Joint Fuelling System Checklist Specification for Aviation Fuel Jet Fuel A or A-1. Before the start of each test series, the test fuel shall be tested by the methods shown in Table 1 and determined to be additive-free by meeting the Table 1 test limits.

4.2.2.2 *Volume*

The volume of test fuel shall be sufficient to conduct the single-element test, described in Section 4.3, in a single pass: the test fuel shall not be recycled during the test.

4.2.2.3 *Temperature*

During testing, the test fuel shall have a minimum temperature of 5 °C (40 °F). The test fuel maximum temperature shall not exceed 32 °C (90 °F). The test fuel temperature shall be maintained within ± 6 °C (±11 °F) of the starting temperature for any individual test series.

**4.2.3 Test contaminants**

4.2.3.1 *General*

The following contaminants shall be used for testing:

- (a) Copperas Red Iron Oxide R-9998<sup>7</sup> or its exact equivalent.
- (b) Arizona Test Dust ISO 12103-1, A1<sup>8</sup> (Ultra Fine) or its exact equivalent.
- (c) Fresh water meeting the following:
  - Solids content less than 1,0 mg/l.
  - Surface tension at least 65 millinewtons per metre at 24 °C (75 °F).
  - pH 6–8.
- (d) The test solid contaminant mixture shall consist of 10 % by weight of Copperas Red Iron Oxide R-9998 and 90 % Arizona Test Dust ISO 12103-1, A1 (Ultra Fine).

**Table 1 - Tests and limits for determining additive-free fuel**

Additive	Limit		Method
	Category M and M100	Category C	
Stadis 450	< 10 pS/m	< 10 pS/m	ASTM D 2624 or D 4308
Di-EGME	< 0,01 %	N/a	ASTM D 5006
Corrosion inhibitor	Minimal	Minimal	Note 1
JP8+100	< 25 mg/l	N/a	SPEC AID 8Q462 Residual test (see Note 2)
Free water	< 5 ppm	< 5 ppm	ASTM D 3240
Contaminants	> 95	> 95	ASTM D 3948
Note 1: Fuel shall be clay treated - no accurate test for determining absence of this component.			
Note 2: Test available from BetzDearbon. Any more precise analytical method accepted by BetzDearbon may be substituted.			

<sup>7</sup> R-9998 can be obtained from Elementis Pigments Inc., 11 Executive Drive, Suite 1, Fairview Heights, Illinois 62208, USA.  
<sup>8</sup> Arizona Test Dust ISO 12103-1, A1 can be obtained from Powder Technology Inc., PO Box 1464, Burnsville, Minnesota 55337, USA.

Note: The test dusts contain fine particulate. The Arizona Test Dust ISO 12103-1, A1 contains silica. The precautions prescribed by appropriate health regulations and standards must be applied when handling these materials.

#### 4.2.3.2 Addition

Contaminants shall be added continuously and evenly, within  $\pm 10\%$  of the nominal rate. The test particulate shall be prepared using the procedure described in Annex A. The slurry shall be added using the apparatus shown in Figure 3.

#### 4.2.4 Additive package

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

##### 4.2.4.1 Category C Fuels

- (a) Additive I - Stadis 450, manufactured by Octel Corporation and conforming to the latest product specification, shall be used at an initial concentration of 1,0 mg/l.

Note: This concentration is based on neat additive with a density of 899 kilograms per cubic metre (7,5 pounds per gallon).

- (b) Additive II - DCI-4A, manufactured by Octel Corporation and conforming to the most recent revision of MIL-PRF-25017, shall be used at an initial concentration of 15 mg/l.

##### 4.2.4.2 Category M100 and M Fuels

- (a) Additive A - SPEC AID 8Q462 Thermal Stability Additive, manufactured by BetzDearbon or Aeroshell Performance Additive (APA) 101 Thermal Stability Additive, supplied by Shell Aviation Ltd., and conforming to the most recent product specification shall be used at an initial concentration of 256 mg/l. This additive shall only be used for Category M100 fuels.

- (b) Additive B - Fuel System Icing Inhibitor, diethylene glycol monomethyl ether (Di-EGME) conforming to ASTM D-4171, Type III shall be used at an initial concentration of 0,15 % by volume.

- (c) Additive C - DCI-4A, manufactured by Octel Corporation and conforming to MIL-PRF-25017 shall be used at an initial concentration of 15 mg/l.

- (d) Additive D - Stadis 450 as defined in Section 4.2.4.1(a) shall be used at an initial concentration of 2,0 mg/l.

### 4.3 SINGLE-ELEMENT TEST FOR FILTER/SEPARATORS

#### 4.3.1 General

The testing and qualification procedure for filter/separators consists of a single pass of fuel through a single-element test unit during which various levels of contaminants are introduced to the fuel upstream of the test unit. Effluent samples and differential pressures are analysed and compared with performance specifications. The test unit shall meet the design criteria listed in Section 4.2. The main features of the single-element test are:

- (a) Element conditioning
1. Conducted in an element conditioning or single-element test unit.
  2. Comprises a low-flow additive-stabilization period.
  3. Fuel is Category C, or M, or M100 (with full additive package) as specified by the qualification category.
- (b) Water coalescence test - Clean element (0,01 % by volume water addition)
1. Conducted in a single-element test unit.
  2. Fuel flowed as a single pass.
  3. Fuel is Category C, or M, or M100 (with full additive package) as specified by the qualification category.
- (c) Solids holding test (19 mg/l solid addition)
1. Conducted in a single-element test unit.
  2. Fuel flowed as a single pass.
  3. Fuel is Category C, or M, or M100 (with full additive package) as specified by the qualification category.
- (d) Water coalescence test - Solids containing element (Two water concentrations tested: 0,01 % and 3 % by volume)
1. Conducted in a single-element test unit.
  2. Fuel flowed as a single pass.
  3. Fuel is Category C, or M, or M100 (with full additive package) as specified by the qualification category.

## 4.3.2 Fuel preparation

### 4.3.2.1 General

Fuel is prepared by introducing the required additives in a prescribed sequence to the storage tank/flow system and recirculating the fuel until the mixture is uniform. During this sequence, the test fuel is recirculated by-passing the test unit and any other filtration or treatment facilities.

### 4.3.2.2 Test fuel

4.3.2.2.1 The fuel used in the conditioning unit or single-element test vessel shall be, depending upon the qualification category tested, a Category C, Category M or Category M100 test fuel (including the full additive package specified in Section 4.2.4). The test fuel shall be tested by the methods shown in Table 1 and determined to be additive-free by meeting the Table 1 test limits before any additives are added. Each additive shall be added to the storage tank or at a point in the recirculation system.

4.3.2.2.2 To determine the duration of recirculation needed to achieve a well-mixed condition for each additive, conductivity shall be measured at 5-minute intervals for the first additive introduced to the fuel. The elapsed time from the end of the additive addition to the time where three successive conductivity measurements at 5-minute intervals are within  $\pm 20$  pS/m shall be noted in the test report as the "mixing time" ( $t_m$ ).

### 4.3.2.3 Additive addition

#### 4.3.2.3.1 Category C Fuel

4.3.2.3.1.1 The same procedure is used for preparing fuel to condition elements or for running a single-element test. Additive I shall be added to the test fuel in the manner described in Section 4.3.2.2.1 to achieve the concentration specified in Section 4.2.4.1.

4.3.2.3.1.2 The fuel shall be recirculated through the unit, by-passing the single-element test vessel, for a period  $\geq t_m$ . The samples taken to check the conductivity of the test fuel at the inlet of the test unit shall be collected downstream of the storage tank.

4.3.2.3.1.3 Additive II shall be added to the fuel in a manner similar to Additive I. Recirculation shall be continued at the same flow rate used for recirculating Additive I for a period  $\geq t_m$ .

#### 4.3.2.3.2 Category M100 Fuel

4.3.2.3.2.1 The same procedure is used for preparing fuel to condition elements or for running a single-element test. Additive A shall be added to the test fuel in the manner described in Section 4.3.2.2.1 to achieve the concentration specified in Section 4.2.4.2.

4.3.2.3.2.2 The fuel shall be recirculated through the unit, by-passing the single-element test vessel, for a period  $\geq t_m$ . The samples taken to check the conductivity of the test fuel at the inlet of the test unit shall be collected downstream of the storage tank.

4.3.2.3.2.3 Additive B shall be added to the fuel such that it disperses well and dissolves. Recirculation shall be continued at the same flow rate used for recirculating Additive A for a period  $\geq t_m$  after the additive has been added to the system.

4.3.2.3.2.4 Additive C shall be added to the fuel in a manner similar to Additive A. Recirculation shall be continued at the same flow rate used for recirculating Additive A for a period  $\geq t_m$ .

4.3.2.3.2.5 Additive D shall be added to the fuel in a manner similar to Additive A. Recirculation shall be continued at the same flow rate used for recirculating Additive A for a period  $\geq t_m$ .

#### 4.3.2.3.3 Category M Fuel

4.3.2.3.3.1 The same procedure is used for preparing fuel to condition elements or for running a single-element test. Additive D shall be added to the test fuel in the manner described in Section 4.3.2.2.1 to achieve the concentration specified in Section 4.2.4.2. The additive can be added directly to the storage tank or at any other point in the recirculation loop.

4.3.2.3.3.2 The fuel shall be recirculated through the unit, by-passing the single-element test vessel, for a period  $\geq t_m$ . The samples taken to check the conductivity of the test fuel at the inlet of the test unit shall be collected downstream of the storage tank.

4.3.2.3.3.3 Additive B shall be added to the fuel such that it disperses well and dissolves. Recirculation shall be continued at the same flow rate used for recirculating Additive D for a period  $\geq t_m$  after the additive has been added to the system.

4.3.2.3.3.4 Additive C shall be added to the fuel in a manner similar to Additive D. Recirculation shall be

continued at the same flow rate used for recirculating Additive D for a period  $\geq t_m$ .

#### 4.3.2.4 *Element conditioning*

4.3.2.4.1 The filter/coalescer elements to be used in a single-element test can be conditioned separately in a facility such as that shown in Figure 4 or in the single-element test unit. As indicated, more than one filter/coalescer can be conditioned at a time by using parallel test element vessels and a single storage tank and holding tank.

4.3.2.4.2 Each element to be conditioned is placed in the conditioning unit. Fuel is flowed from the storage tank to the receiving tank (single-pass) through the element at a rate of 10 litres/minute (3 gpm) for 30 minutes. The filter/coalescer element can then be removed from the conditioning vessel and used in single-element tests.

4.3.2.4.3 If the conditioned filter/coalescer element is not immediately tested, it can be stored, fully immersed, in additive-containing test fuel. These elements can then be drained and used in single-element tests as required.

4.3.2.4.4 The conductivity of the fuel downstream of the conditioning vessel shall be greater than 100 pS/m.

#### 4.3.2.5 *Water coalescence test - Clean element*

4.3.2.5.1 The conditioned test element is installed in the single-element test vessel, and the facility is operated at rated flow for at least 5 minutes until the flow is stabilized at the design flow rate. Next, water is continuously added at 0,01 % (by volume) of rated flow for 30 minutes. The sump valve shall remain closed while water is added.

At 10-minute intervals from the beginning of water addition, a stop/start procedure shall be performed.<sup>9</sup>

4.3.2.5.2 At the end of the 30-minute water addition period, the water shall be shut off and the water in the sump drained. Flow shall continue at the rated flow of the element.

#### 4.3.2.6 *Solids holding test*

After the water is drained from the single-element test unit, and the fuel flow has achieved steady state at the test elements' rated flow, then solids are added continuously using the solids addition facility described in Figure 3 such that the solids concentration in test fuel is 19 mg/l (72 mg/gallon).

4.3.2.6.1 *Type S filter/separators*: To meet the solids-holding capacity specified in Section 3.1.3.1, this test shall be run for at least 50 minutes without exceeding a pressure differential of 105 kPa (15 psi) and for at least 75 minutes without exceeding a pressure differential of 315 kPa (45 psi). At the end of the test period, solids injection shall be stopped.

At 15-minute intervals from the beginning of solids addition over the entire 75-minute solids addition period a stop/start procedure shall be performed.

4.3.2.6.2 *Type S-LD filter/separators*: There is no solids holding capacity criteria for Type S-LD filters, although there is a performance specification for contamination of effluent fuel. To test this, solids shall be added at the concentration of 19 mg/l (72 mg/gallon) until the pressure differential across the vessel reaches 155 kPa (22,5 psi). At this point solids injection shall be stopped and the test continued for another 45 minutes at rated flow. If the differential pressure falls below 138 kPa (20 psi) then solids injection shall be resumed until the differential pressure reaches 155 kPa (22,5 psi).

At 15-minute intervals from the beginning of solids addition over the entire test period, a stop/start procedure shall be performed.

#### 4.3.2.7 *Water coalescence test - Element containing solids*

4.3.2.7.1 Immediately after the solids holding test, the flow rate is maintained and water is continuously injected at 0,01 % by volume upstream of the feed pump for a period of 150 minutes. The sump valve shall remain closed while water is added at the 0,01 % rate.

At 30-minute intervals from the beginning of the water addition over the entire test period, a stop/start procedure shall be performed.

<sup>9</sup> A stop/start is an interruption of flow accomplished by shutting, in approximately 4 seconds, a quick-closing valve located downstream from the effluent sampling connection. The flow then is re-established and the test continued. Prior to starting the stop/start procedure, water or solids injection points can be isolated. These are reopened immediately after re-establishing flow.

4.3.2.7.2 At the end of the 150-minute 0,01 % water addition period, the rate of water continuously injected shall be increased to 3 % by volume for 30 minutes.

At 10-minute intervals from the beginning of the 3 % water addition, a stop/start procedure shall be performed.

Note: The high level of water injection during this phase of the test series generally requires that the sump be drained during the test. This should be done carefully to ensure that water does not exceed the maximum design level and impinge elements.

#### 4.3.2.8 Final inspection

After the 3 % water injection test, the flow shall be stopped as soon as all the samples are taken, the single-element vessel drained, and the filter/coalescer removed. The element shall be critically inspected for structural failure. The element shall be inspected for the presence of leaks or tears at the end caps and along the seams. Other areas shall be inspected for pinhole and larger leaks. Any such anomalies shall be reported as failure of the structural integrity of the element.

Discoloration of the coalescer sock does not, by itself, prove structural integrity failure. When the sock is discoloured, it shall be removed and the element examined for evidence of structural failure. If a specific point of failure is identified then this shall be reported as failure of the structural integrity of the element.

#### 4.3.2.9 Multi-stage systems

When qualifying a multi-stage system, the single-element testing in Sections 4.3.2.5 through 4.3.2.8 shall be performed with only the filter/separator stages in place. The additional stage(s) are tested only in full-scale testing.

### 4.4 FULL-SCALE TEST METHOD FOR FILTER/COALESCERS

#### 4.4.1 General

4.4.1.1 The full-scale test of a two- or multi-stage vessel is conducted in the facility shown in Figure 2. The test fuel is circulated from the storage tank through the test filter/separator vessel and returned to the storage tank. Any additional equipment, e.g. a clean-up filter/separator or clay treater is by-passed during testing.

4.4.1.2 Compliance with the similarity criteria specified in API/IP 1582 permits the qualification of a

filter/separator design based on successful full-scale testing of a similar design. Similarity criteria may be used to qualify a lower flow rate design than that tested, but not a higher flow rate design except as below. The range of flow rate for which this specification is valid is 0 – 9 500 lpm (0 – 2 500 gpm) except as below.

Although similarity criteria generally shall not be used to qualify vessels of higher flow rate than full-scale tested, existing vessels qualified to previous editions of API/IP 1581 with flow rates greater than 9 500 lpm (2 500 gpm) but no more than 19 000 lpm (5 000 gpm) may be qualified by meeting similarity criteria with vessels full-scale tested at 9 500 lpm (2 500 gpm). This provision for qualifying existing vessels does not reduce the responsibility of the qualifying entity of ensuring that vessel effluent dirt and water levels are consistent with intended use.

#### 4.4.2 Test fuel

The fuel used in the full-scale tests shall be that specified in Section 4.2.2. The fuel shall be additive free as defined by Table 1.

#### 4.4.3 Fuel volume

The volume of the test fuel shall be not less than 5 % of the total fuel volume circulated through the filter/separator vessel. Because additives may be depleted during testing, test fuel shall not be recirculated through the test vessel more than ten times. When necessary, the test may be interrupted near the mid point while the fuel is cleaned of all additives then readditized. When a test is interrupted, the test vessel shall be isolated from the flowing system by closing a downstream valve then an upstream valve. The vessel shall be undisturbed and protected from thermal shock until the test is resumed, with the pump on, by opening the upstream valve then the downstream valve to reestablish flow. Any reverse flow through the test vessel voids the test. When more than one fuel tank is used, the flow from any tank shall not differ by more than  $\pm 10$  % of the flow from any other tank.

#### 4.4.4 Additive addition

Additives shall be introduced to the test fuel at the time and the quantity defined in Section 4.2.4. The additives shall be introduced into the tank while the fuel is circulating (and by-passing the full-scale vessel and any additional equipment such as cleanup filter/separators and clay treaters). When a single tank is used, the

additives may be added directly to the tank and/or downstream of the tank in the recirculation loop. When multiple tanks are used, fuels shall be drawn equally from each tank (within  $\pm 10\%$  of the flow from any tank) and the additives shall be added downstream of the tanks. The protocol of additive addition is defined in Section 4.3.2.3.

#### 4.4.5 Full-scale test series

The full-scale test is a test of the complete design. It consists of an element-conditioning step (Media Migration), a water injection test, a solids handling test and a water injection test using solids contaminated elements.

##### 4.4.5.1 Media migration test

The test elements are installed in the test vessel and the vessel is filled with Category C, M, or M100 fuel. Fuel is then flowed for 30 minutes at 10% of the rated flow.

##### 4.4.5.2 Water coalescence (0,01 % water)

Upon completion of the Media Migration test (Section 4.4.5.1), the fuel flow rate is increased to rated flow. Water is injected at 0,01% (by volume) of rated flow for 30 minutes. The water sump drain shall remain closed during this period.

At 15-minute intervals from the beginning of the 0,01% water addition a stop/start procedure shall be performed. The flow shall be continued at the end of this part of the test (after 30 minutes 0,01% water addition) until all required samples are taken.

##### 4.4.5.3 Solids addition test

At the completion of the water addition test (Section 4.4.5.2), the water is drained from the sump, then solids are injected into the system (as indicated in Figure 2) such that the concentration of solids in the test fuel is 19 mg/l (72 mg/gallon).

**4.4.5.3.1 Type S filter/coalescers:** Solids are added to the system for 45 minutes. The pressure differential across the vessel may not exceed 105 kPa (15 psi). At the end of the test period, the solids addition shall be stopped.

At 15-minute intervals from the beginning of the solids addition, a stop/start procedure shall be performed.

**4.4.5.3.2 Type S-LD filter/coalescers:** Solids are added to the system for 45 minutes or until the differential pressure across the vessel is 105 kPa (15 psi). When

this pressure differential is reached, the solids flow is stopped for the remainder of the test. Fuel flow is maintained at rated flow for the remainder of the 45 minute "solids addition" time.

Note: It is acceptable for the differential pressure to relax to less than 105 kPa as the test continues after solids flow is stopped.

At 15-minute intervals from the beginning of solids addition, a stop/start procedure shall be performed.

##### 4.4.5.4 Water addition - Solids contaminated system

At the end of the 45-minute period, solids addition is stopped while fuel flow is maintained. Water is injected upstream of the pump at a rate of 0,01% (by volume) of rated flow for 90 minutes with the sump drain closed. After this period and after the required samples are taken, the sump may be drained of water. The water injection rate is then increased to 3% (by volume) and maintained for 15 minutes. The flow of fuel and water is stopped at the end of this test period after all required samples are taken.

At 30-minute intervals from the beginning of the 0,01% water addition, a stop/start procedure shall be performed. No stop/start procedure is performed during 3% water injection.

Although it is recommended that all filter/separator vessels be designed to give acceptable performance when challenged with 3% water, vessels qualified under previous editions may exist (e.g. vessels in mobile service) where there is limited potential for water contamination and less performance may be acceptable. In such vessels, the water injection rate can be lowered to 0,5% by volume instead of 3%. Vessels so qualified should be clearly marked as applicable for use in this service only.

##### 4.4.5.5 Final inspection

After the 3% water injection test, the flow shall be stopped as soon as all the samples are taken, the vessel drained, and the filter/coalescer removed. The elements shall be critically inspected for structural failure. The filter element shall be inspected for the presence of leaks or tears at the end caps and along the seams. Other areas shall be inspected for pinhole and larger leaks. Any such anomalies shall be reported as a failure of the structural integrity of the element.

Discoloration of the coalescer sock does not, by itself, prove failure of structural integrity. When the sock is discoloured, it shall be removed and the element examined for evidence of structural failure. If a specific point of failure is identified then this shall be reported as failure of the structural integrity of the element.

#### 4.4.5.6 Multi-stage systems

4.4.5.6.1 In qualifying a multi-stage system, the testing in Sections 4.4.5.1 through 4.4.5.5 shall be conducted with the additional stage(s) installed.

4.4.5.6.2 Additional stages shall be devices qualified to a documented performance specification agreed to by purchaser and manufacturer. The differential pressure across multi-stage water absorption devices downstream from the separator, when used, must not increase by more than 100 kPa (15 psi) over the entire qualification test.

### 4.5 STRUCTURAL TEST

4.5.1 At least three coalescer elements of the maximum length to be manufactured shall be subjected to a differential pressure test to determine structural strength, which shall meet the requirements of Section 3.1.5. Base fuel shall be circulated through the element at the design flow rate, with R-9998 particulate added until the pressure differential is at least 520 kPa (75 psi). This differential pressure shall be held for at least 5 minutes. There shall be no rupture of the element, bypassing of the seals, or bleed of the iron oxide through pinhole leaks in the element.

4.5.2 To pass the structural test, three filter/coalescer or coalescer elements, tested consecutively, shall meet the above requirements.

4.5.3 Structural tests conducted with the screw-base configuration of an element model satisfy the qualification requirements for the open-ended configuration of the same model. Structural tests of open-ended configurations do not satisfy qualification requirements for screw-base elements.

### 4.6 ENVIRONMENTAL TESTS

#### 4.6.1 General

4.6.1.1 In addition to meeting the performance and mechanical specifications, the test unit shall be guaranteed by the manufacturer to meet the following requirements in accordance with recognized test procedures.

4.6.1.2 The unit shall not be adversely affected by exposure to temperatures varying from  $-54^{\circ}\text{C}$  to  $+71^{\circ}\text{C}$  ( $-65^{\circ}\text{F}$  to  $+160^{\circ}\text{F}$ ).

4.6.1.3 The element media, gaskets, and sealing material and any internal coating shall not deteriorate as a result of exposure to fresh water, salt water, or aviation fuels and shall not promote the growth of fungi.

#### 4.6.2 Compatibility tests

4.6.2.1 Compatibility tests shall be performed by soaking the test elements (including separators) in the test fluids listed in Table 2. The elements used for this testing shall be the same model as the elements being qualified. If a specific model of elements has previously passed compatibility testing, then the testing does not need to be repeated in subsequent vessel qualification runs. Elements of the smallest available length [currently 36 cm (14 inches) or longer] may be used, provided they are from the same lot as the test element. The diameter of the elements shall be the largest size manufactured for that model. The volume of each solution in which the elements are soaked shall be five times the volume of the test element determined by the outside dimensions of the test element.

4.6.2.2 To avoid error, the containers used for testing shall have the following characteristics:

- (a) The containers shall be identical for all tests and each shall each have a sealable non-contaminating cap.
- (b) Containers shall be sized to permit the specimen to be totally immersed in the test solution.
- (c) The containers shall not affect the test results; for example, they shall be constructed of aluminium, or stainless steel, or epoxy lined metal. (Because fuel is light sensitive, containers that might transmit light should be stored in dark enclosures when containing fuel.)
- (d) Containers shall be thoroughly rinsed with the base fuel before use.

4.6.2.3 The test fluids are specified in Table 2. The fluids for Tests 1 and 2 shall be base (unadditized) fuel as specified in Section 4.2.2 with additives as specified in Section 4.2.4. The test fluid for Test 4 shall be 30 volumes of toluene (98 % min. purity) and 70 volumes

of iso-octane (98 % min. purity). The test fluid for Test 3 shall be diethylene glycol monomethyl ether (Di-EGME), (ASTM D 4171, Type III).

#### 4.6.2.4 Compatibility test procedure

4.6.2.4.1 *Reference samples:* One litre (1 quart) reference samples of test fluids 1, 2, and 4 shall be taken at the beginning of each soak period (before contact with elements).

4.6.2.4.2 *Soak periods:* Elements shall be soaked in appropriate test fluids for 336 hours in all tests. In Tests 1, 2, and 4, the elements shall be drained for 4 hours and subjected to a second 336-hour soak period using freshly prepared test fluid.

4.6.2.4.3 *Required samples:* A sample of each test fluid shall be taken at the end of each 336-hour element-contact period.

4.6.2.4.4 *Analyses and report:* Reference and test samples shall be tested by the analyses shown in Table 2 and reported in the form shown in Table 3.

4.6.2.5 Further testing, followed by a field service evaluation, may be required to identify a problem component within an element if one or more of the following results is obtained:

- (a) The water separometer index modified (MSEP) result in Test 1 drops below 85.
- (b) The water reaction results have an interface rating above 1b in Tests 1 and 2 and/or a separation rating above 2 in any test.
- (c) The colour in Tests 1, 2, and 4 decreases by more than 4 units when compared with that of the base fuel measured at the same time.
- (d) Further testing and subsequent field service evaluation is also required if requested by the purchaser.

4.6.2.6 Test samples shall meet the following criteria for existent gum, as determined by steam jet in accordance with ASTM D 381:

- (a) The existent gum level shall increase by less than 8 mg/100 ml in any test.
- (b) If existent gum increases by more than 3 mg/100 ml after the first soak period, the increase during the second soak shall be less than 50 % of the increase measured during the first soak period.
- (c) Elements from Tests 1, 2, and 4 that meet the

criteria above shall be subjected to the structural test specified in Section 4.5 to determine whether they meet the criteria outlined in Section 3.1.5. Because high differential pressures are not encountered in separators, no structural tests are necessary; it is sufficient for separators to meet the compatibility criteria listed in Table 2.

## 4.7 TEST SAMPLING

### 4.7.1 Schedule and procedures

#### 4.7.1.1 General

The test sampling schedules are the same for all Categories and Types of filter/separator systems. The sampling schedule for media migration of single-elements is specified in Table 4. The sampling schedule for single-element tests is specified in Table 4. The sampling schedule for full-scale tests is specified in Table 5. All test samples shall conform to the specification details specified in Section 3.1.

#### 4.7.1.2 Sample size

Sample sizes shall be:

- (a) For media migration - a minimum of 11 litres (3 gallons).
- (b) For weight of solids (non continuous) - a minimum of 4 litres (1 gallon).
- (c) For weight of solids (continuous) - a maximum of 11 litres (3 gallons).
- (d) For free water content - sufficient sample size to satisfy the test apparatus.
- (e) For fuel conductivity - sufficient to cover the electrodes of the conductivity cell.  
Note: Conductivity samples shall be taken only in metal containers.
- (f) For MSEP - 4 litres (1 gallon).

#### 4.7.1.3 Analysis procedures

Analysis procedures shall conform to the latest revisions of the following specifications:

- (a) For MSEP - ASTM D 3948 (microseparometer).
- (b) For media migration - ASTM D 2276.
- (c) For solids - ASTM D 2276.
- (d) For free water content - ASTM D 3240 (Aqua-glo).
- (e) For fuel conductivity - ASTM D 2624.

Note: Measurements of fuel conductivity shall be made within 5 minutes after the sample is drawn.

**4.7.2 Sampling device**

An upstream-facing sampling probe shall be provided within 10 pipe diameters of the test unit’s outlet or inlet (or other applicable location). The probe shall be installed in the pipe with five diameters of clear pipe before it to avoid upstream interference with the flow pattern. The layout and size of the sample pipe and of the piping upstream of the sampling device shall be designed to preclude particle or water settling.

**4.8 TEST DATA**

The test data shall be presented in tabular form, as shown in Tables 6 and 7. In addition, complete test data shall be provided for the test fuel in accordance with the applicable ASTM or Joint Inspection Group specification.

**Table 2 - Compatibility tests for filter/coalescer elements**

Test	Test Fluid	Test Specimen Needed in Container?	Analyses Required <sup>a)</sup>
1	Jet A or Jet A-1	Yes	ABCDE
2	Jet A or Jet A-1 with 12 mg/l of HiTEC E-580 and 3 mg/l of Stadis 450	Yes	BCDE
3	100 % fuel system icing inhibitor (Di-EGME)	Yes	D
4	30 % toluene/70 % iso-octane	Yes	BDE

a) A = MSEP (ASTM D 3948); B = Existent gum (ASTM D 381 (Steam jet)); C = Water reaction (ASTM D 1094); D = Detailed inspection and description of all component parts; E = Color (ASTM D 156).

**Table 3 - Report form for compatibility results**

<b>EXISTENT GUM</b>						
<i>Test</i>	<i>Test Fluid</i>	<i>Test Hours</i>				<i>Comments</i>
		Initial Soak		Second Soak		
		0	336	0	336	
1	<i>Jet A or Jet A-1</i>					
	No element					
	With element	NA		NA		
	Difference	NA		NA		
2	<i>Jet A or Jet A-1 with 12 mg/l of HiTEC E-580 and 3 mg/l of Stadis 450</i>					
	No element					
	With element	NA		NA		
	Difference	NA		NA		
4	<i>30 % toluene / 70 % iso-octane</i>					
	No element					
	With element	NA		NA		
	Difference	NA		NA		
<b>MSEP</b>						
<i>Test</i>	<i>Test Fluid</i>	<i>Test Hours</i>				<i>Comments</i>
		Initial Soak		Second Soak		
		0	336	0	336	
1	<i>Jet A or Jet A-1</i>					
	No element					
	With element	NA		NA		
	Difference	NA		NA		
<b>WATER REACTION TEST (INITIAL SOAK ONLY)</b>						
<i>Test</i>	<i>Test Fluid</i>	<i>Test Hours</i>				<i>Comments</i>
		Initial Soak		Initial Soak		
		0	336	0	336	
1	<i>Jet A or Jet A-1</i>					
	No element	NA		NA		
	With element	NA		NA		
	Difference	NA		NA		
2	<i>Jet A or Jet A-1 with 12 mg/l of HiTEC E-580 and 3 mg/l of Stadis 450</i>					
	No element					
	With element	NA		NA		
	Difference	NA		NA		
<i>Note: To report separator results, substitute "separator" for "element" above.</i>						

TESTING AND QUALIFICATION PROCEDURE

**Table 3 continued.**

DETAILED VISUAL INSPECTION						
<i>Test</i>	<i>Test Fluid</i>	<i>Comments</i>				
1	<i>Jet A or Jet A-1</i>					
2	<i>Jet A or Jet A-1 with 12 mg/l of HiTEC E-580 and 3 mg/l of Stadis 450</i>					
3	<i>100 % Fuel system Inhibitor(Di-EGME)</i>					
4	<i>30 % toluene / 70 % iso-octane</i>					
COLOUR						
<i>Test</i>	<i>Test Fluid</i>	<i>Test Hours</i>				<i>Comments</i>
		<i>Initial Soak</i>		<i>Second Soak</i>		
		0	336	0	336	
1	<i>Jet A or Jet A-1</i>					
	No element					
	With element	NA		NA		
	Difference	NA		NA		
2	<i>Jet A or Jet A-1 with 12 mg/l of HiTEC E-580 and 3 mg/l of Stadis 450</i>					
	No element					
	With element	NA		NA		
	Difference	NA		NA		
4	<i>30 % toluene / 70 % iso-octane</i>					
	No element					
	With element	NA		NA		
	Difference	NA		NA		

*Note: To report separator results, substitute "separator" for "element" above.*

**Table 4 - Test sampling schedule and procedures for single-element tests**

Test	Reference Section	Samples Are Taken	Sample Size (litres/gallons)	Purpose	No. of Samples	Sampling Point	Sample Type
Conditioning, Media migration	4.3.2.4	At start Continuously	4/1 11/3 <sup>a)</sup>	MSEP Media migration	2 1 <sup>b)</sup>	Storage tank Conditioning unit outlet	Special container In-line sampler
Water removal	4.3.2.5	At 5, 10, 20 and 30 minutes <sup>c)</sup>	As required by ASTM practice	Free water content	4	Test unit outlet	Aqua-glo
Solids handling	4.3.2.6	Every 15 minutes before and after stop-start	4/1	Solids	10	Test unit outlet	In-line sampler
Water removal: During 0,01 % water injection rate	4.3.2.7	At 2, 5, 15, 30, 45, 60, 75, 90, 105, 120, 135, and 150 minutes <sup>c)</sup>	As required by ASTM practice	Free water content	12	Test unit outlet	Aqua-glo
During 3 % water Injection rate		At 2, 5, 10 <sup>c)</sup> , 20 <sup>c)</sup> , and 30 minutes	As required by ASTM practice	Free water content	5	Test unit outlet	Aqua-glo
a) Minimum. b) One sample for each element conditioned - sample taken from point before common manifold when multi-elements conditioned. c) After stop/start - test continued until sample obtained.							

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**Table 5 - Test sampling schedule and procedures for full-scale tests**

Test	Reference Section	Samples Are Taken	Sample Size (litres/gallons)	Purpose	No. of Samples	Sampling Point	Sample Type
Conditioning, Media migration	4.4.5.1	At start Continuously	4/1 11/3 <sup>a)</sup>	MSEP Media Migration	2 1	Storage tank Outlet of filter/separator vessel	Special container In-line sampler
Water removal	4.4.5.2	At 5, 10, 20 and 30 minutes <sup>b)</sup>	As required by ASTM practice	Free water content	4	Outlet of filter/separator vessel	Aqua-glo
Solids handling	4.4.5.3	Every 15 minutes before and after stop/start	4/1	Solids	6	Outlet of filter/separator vessel	In-line sampler
Water removal: During 0,01 % water injection rate	4.4.5.4	At 2, 5, 15, 30, 45, 60, 75 and 90 minutes <sup>b)</sup>	As required by ASTM practice	Free water content	8	Outlet of filter/separator vessel	Aqua-glo
During 3 % water injection rate		At 2, 5, 10, and 15 minutes	As required by ASTM practice	Free water content	4	Outlet of filter/separator vessel	Aqua-glo
a) Minimum. b) After stop/start - test continued until sample obtained.							

Table 6 - Data sheet for single-element tests

Test Specification: API/IP 1581 5 <sup>th</sup> Edition												Date:	
Vessel:		Filter/Coalescer:				Separator:			Type: <input type="checkbox"/> -S <input type="checkbox"/> -S-LD				
Additive Addition		Model		Number		Model		Number					
Category:		<input type="checkbox"/> M-100			<input type="checkbox"/> M			<input type="checkbox"/> C					
Tank Volume	Gallon	Additive	Conc. (mg/l)	Amt. Added	k (pS/m)	Additive	Conc. (mg/l)	Amt. Added	k (pS/m)	Additive	Conc. (mg/l)	Amt. Added	k (pS/m)
		A	256			D	2,0			I	1,0		
Note:		B	0,15 %			B	0,15 %			II	15		
		C	15			C	15						
		D	2,0										
Mixing Time (min):													
Element Conditioning:		<input type="checkbox"/> -In-Situ			<input type="checkbox"/> -External								
Phase	Cum. Time (min)	Time (min)	Fuel Flow Rate (gpm)	ΔP (psi)	k (pS/m)	Water Flow Rate <input type="checkbox"/> ml/min <input type="checkbox"/> gpm	Water Conc. (ppm)	Solids Rate <input type="checkbox"/> mg/l <input type="checkbox"/> mg/gal	Filter Sample ID	Solids Conc. (mg/l)	Sample Size	Temp. <input type="checkbox"/> °C <input type="checkbox"/> °F	Notes/Comments
<i>Start-up</i>	0	0											
<i>Water 0.01 %</i>	5	0											
	10	5											
	15	10 s/s											
	25	20 s/s											
	35	30 s/s											

Table 6 - Data sheet for single-element tests continued. (Note For Type S filters only)

Phase	Cum. Time (min)	Time (min)	Fuel Flow Rate (gpm)	$\Delta P$ (psi)	k (pS/m)	Water Flow Rate □ ml/min □ gpm	Water Conc. (ppm)	Solids Rate □ mg/l □ mg/gal	Filter Sample ID	Solids Conc. (mg/l)	Sample Size	Temp. □ °C □ °F	Notes/Comments
<b>Solids Holding Test</b>	35	0											
	50	15											
		15 s/s <sup>a)</sup>											
	65	30											
		30 s/s											
	80	45											
		45 s/s											
		50											
	95	60											
		60 s/s											
	110	75											
		75 s/s											
a) s/s: sample taken immediately after conclusion of stop/start													

Table 6 - Data sheet for single-element tests continued. (Note For Type S-LD filters only)

Phase	Cum. Time (min)	Time (min)	Fuel Flow Rate (gpm)	$\Delta P$ (psi)	k (pS/m)	Water Flow Rate		Water Conc. (ppm)	Solids Rate		Filter Sample ID	Solids Conc. (mg/l)	Sample Size	Temp. <input type="checkbox"/> °C <input type="checkbox"/> °F	Notes/Comments
						<input type="checkbox"/> ml/min	<input type="checkbox"/> gpm		<input type="checkbox"/> mg/l	<input type="checkbox"/> mg/gal					
<i>Solids Holding Test (Continue until reaching 115 kPa/22.5 psi)</i>	35	0													
	50	15													
		15 s/s <sup>a</sup>													
	65	30													
		30 s/s													
	80	45													
		45 s/s													
	95	60													
		60 s/s													
	110	75													
	75 s/s														
<i>After <math>\Delta P =</math> 115 kPa/22.5 psi</i>		+ 15													
		+ 15 s/s													
		+ 30													
		+ 30 s/s													
		+ 45													
		+ 45 s/s													

Table 6 - Data sheet for single-element tests continued.

Phase	Cum. Time (min)	Time (min)	Fuel Flow Rate (gpm)	$\Delta P$ (psi)	k (pS/m)	Water Flow Rate □ ml/min □ gpm	Water Conc. (ppm)	Solids Rate □ mg/l □ mg/gal	Filter Sample ID	Solids Conc. (mg/l)	Sample Size	Temp. □ °C □ °F	Notes/Comments
<i>Water Coalescence Test – 0.01 %</i>	110	0											
	112	2											
	115	5											
	125	15											
	140	30 s/s											
	155	45											
	170	60 s/s											
	185	75											
	200	90 s/s											
	215	105											
	230	120 s/s											
	245	135											
	260	150 s/s											
<i>Water Coalescence Test – 3 %</i>	260	0											
	262	2											
	265	5											
	270	10 s/s											
	280	20 s/s											
	290	30											

Table 7 - Data sheet for full-scale tests

Test Specification: API/IP 1581 5th Edition						Single-Element Test Report Referenced:						Date:	
Vessel:			Filter/Coalescer:			Separator:			Type: <input type="checkbox"/> -S <input type="checkbox"/> -S-LD				
Additive Addition			Model		Number		Model		Number				
Category:		<input type="checkbox"/> M-100			<input type="checkbox"/> M			<input type="checkbox"/> C					
Tank Volume	Gallon	Additive	Conc. (mg/l)	Amt. Added	k (pS/m)	Additive	Conc. (mg/l)	Amt. Added	k (pS/m)	Additive	Conc. (mg/l)	Amt. Added	K (pS/m)
		A	256			D	2,0			I	1,0		
Note:		B	0,15 %			B	0,15 %			II	15		
		C	15			C	15						
		D	2,0										
Mixing Time (min):													
Phase	Cum. Time (min)	Time (min)	Fuel Flow Rate (gpm)	ΔP (psi)	k (pS/m)	Water Flow Rate <input type="checkbox"/> ml/min <input type="checkbox"/> gpm	Water Conc. (ppm)	Solids Rate <input type="checkbox"/> mg/l <input type="checkbox"/> mg/gal	Filter Sample ID	Solids Conc. (mg/l)	Sample Size	Temp. <input type="checkbox"/> °C <input type="checkbox"/> °F	Notes/Comments
<i>Media Migration</i>	0	0									4 litre		MSEP
	10	10											
	20	20											
	30	30											Media Migration

Table 7 Data sheet for full-scale tests continued.

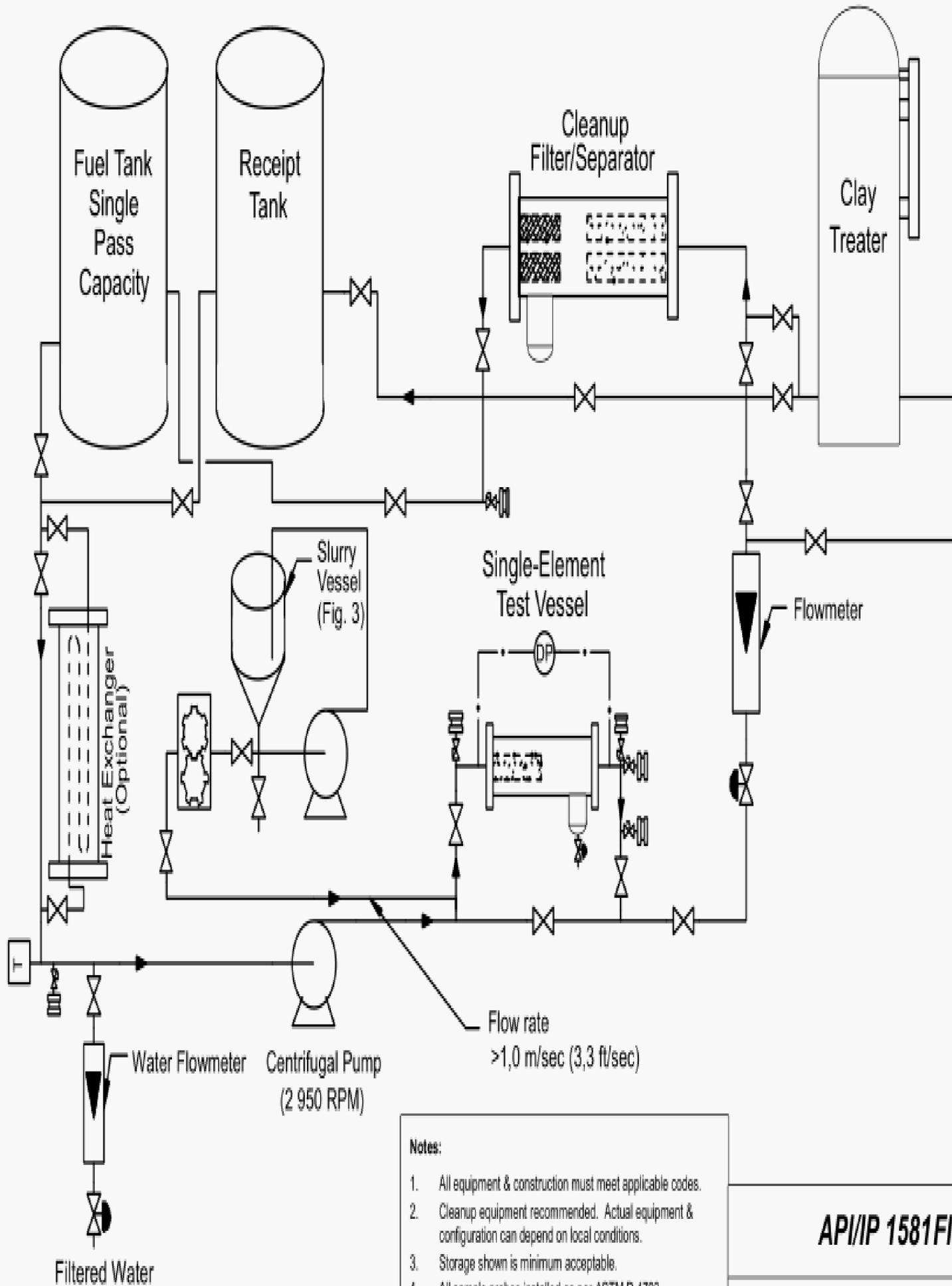
Phase	Cum. Time (min)	Time (min)	Fuel Flow Rate (gpm)	FC <sup>a)</sup> ΔP (psi)	System or 3 <sup>rd</sup> Stage ΔP (psi)	k (pS/m)	Water Flow Rate □ ml/min □ gpm	Water Conc. (ppm)	Solids Rate □ mg/l □ mg/gal	Filter Sample ID	Solids Conc. (mg/l)	Sample Size	Temp. □ °C □ °F	Notes/Comments
<i>0.01 % Water Addition</i>	30	0												
	35	5												
	40	10												
	45	15 s/s												
	50	20												
	60	30												
	60	30 s/s												
<i>Solids Holding Test (For Type S Only)</i>	60	0												
	75	15												
		15 s/s <sup>b)</sup>												
	90	30												
		30 s/s												
	105	45												
		45 s/s												
a) FC: filter/coalescer. b) s/s: sample taken immediately after conclusion of stop/start.														

Table 7 Data sheet for full-scale tests continued. (Note: For Type S-LD filters only)

Phase	Cum. Time (min)	Time (min)	Fuel Flow Rate (gpm)	$\Delta P$ (psi)	k (pS/m)	Water Flow Rate □ml/min □gpm	Water Conc. (ppm)	Solids Rate □mg/l □mg/gal	Filter Sample ID	Solids Conc. (mg/l)	Sample Size	Temp. □°C □°F	Notes/Comments
<i>Solids Holding Test (Stop solids addition @ 105 kPa/15 psi)</i>	60	0											
	75	15											
		15 s/s <sup>a)</sup>											
	90	30											
		30 s/s											
	105	45											
	45 s/s												
<i>After <math>\Delta P =</math> 115 kPa/22.5 psi</i>		+ 15											
		+ 15 s/s											
		+ 30											
		+ 30 s/s											
		+ 45											
		+ 45 s/s											
a) s/s: sample taken immediately after conclusion of stop/start.													

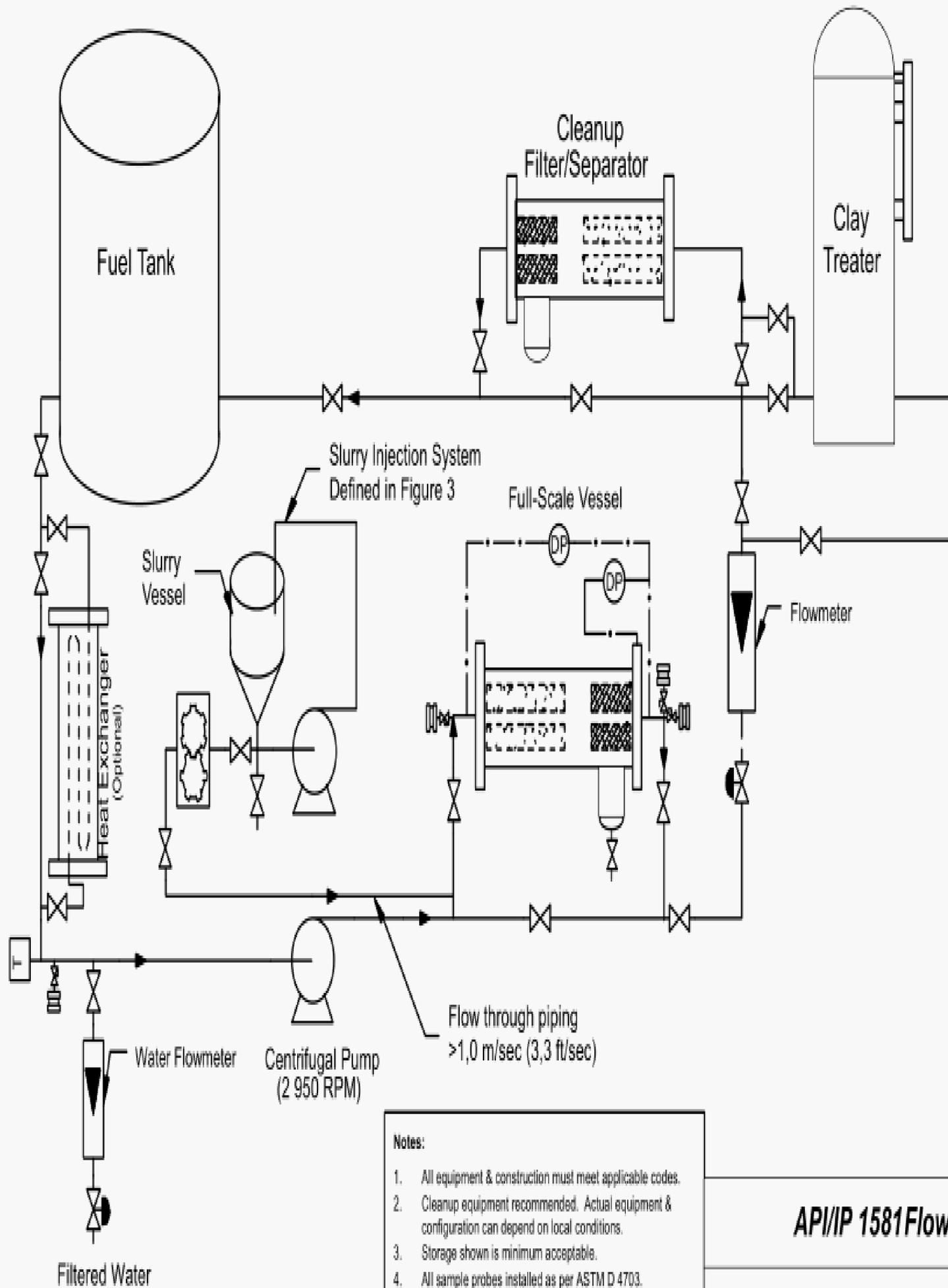
Table 7 Data sheet for full-scale tests (continued).

Phase	Cum. Time (min)	Time (min)	Fuel Flow Rate (gpm)	FC ΔP (psi)	System or 3 <sup>rd</sup> Stage ΔP (psi)	k (pS/m)	Water Flow Rate □ml/min □gpm	Water Conc. (ppm)	Solids Rate □mg/l □mg/gal	Filter Sample ID	Solids Conc. (mg/l)	Sample Size	Temp. □°C □°F	Notes/Comments
<i>Water Coalescence Test – 0.01 %</i>	105	0												
	107	2												
	110	5												
	120	15												
	135	30 s/s												
	150	45												
	165	60 s/s												
	180	75												
	195	90 s/s												
<i>Water Coalescence Test – 3 %</i>	195	0												
	197	2												
	200	5												
	205	10												
	210	15												



- Notes:**
1. All equipment & construction must meet applicable codes.
  2. Cleanup equipment recommended. Actual equipment & configuration can depend on local conditions.
  3. Storage shown is minimum acceptable.
  4. All sample probes installed as per ASTM D 4703.
  5. Slurry system details in Figure 3.
  6. Provision must be made to verify calibration of:  
 Flowmeters  
 Differential pressure gauges  
 Slurry flow rate  
 RPM of centrifugal pump

<b>API/IP 1581 Flowsheets</b>	
<b>Figure 1 - Single-Element Test Facility</b>	REVISION NO.: API/IP 1581 <sup>5th</sup> Edition
	REVISION DATE: Feb. 20, 2002



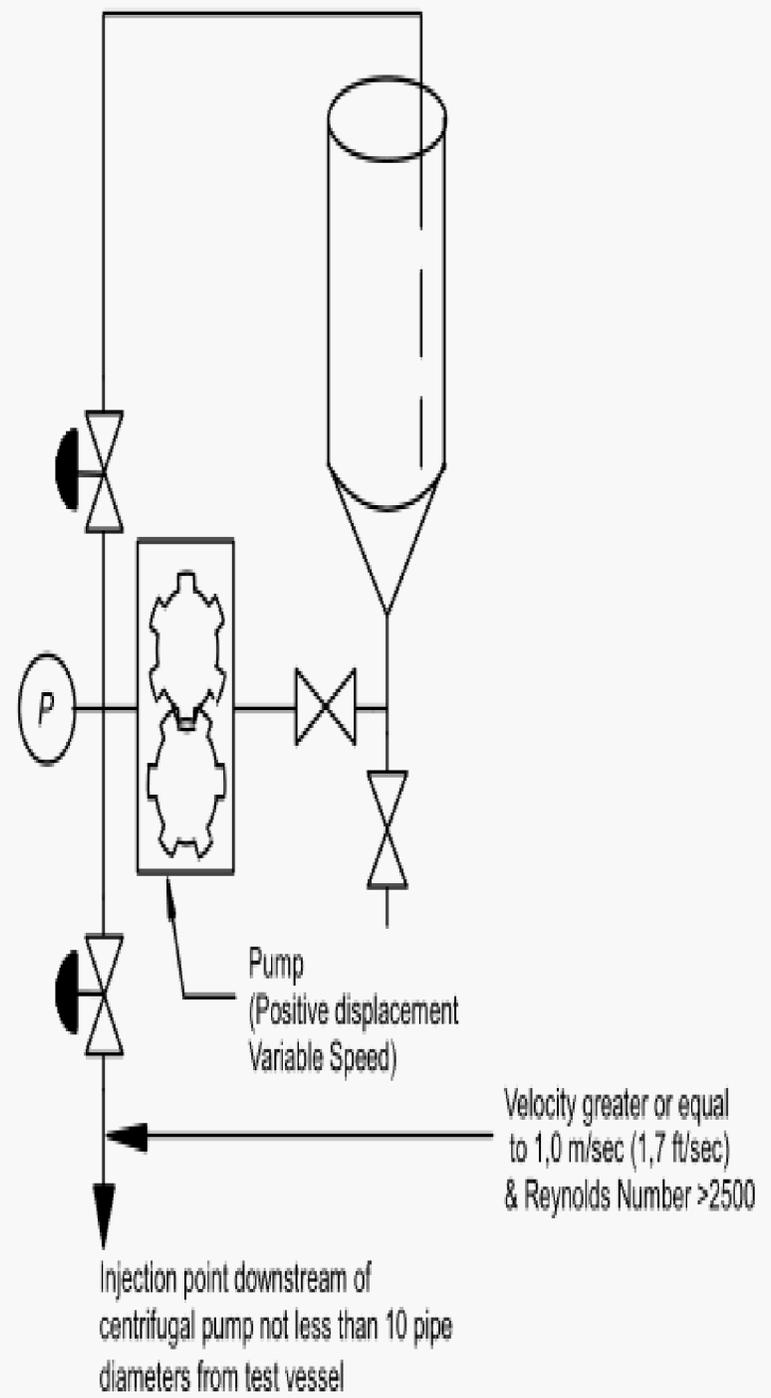
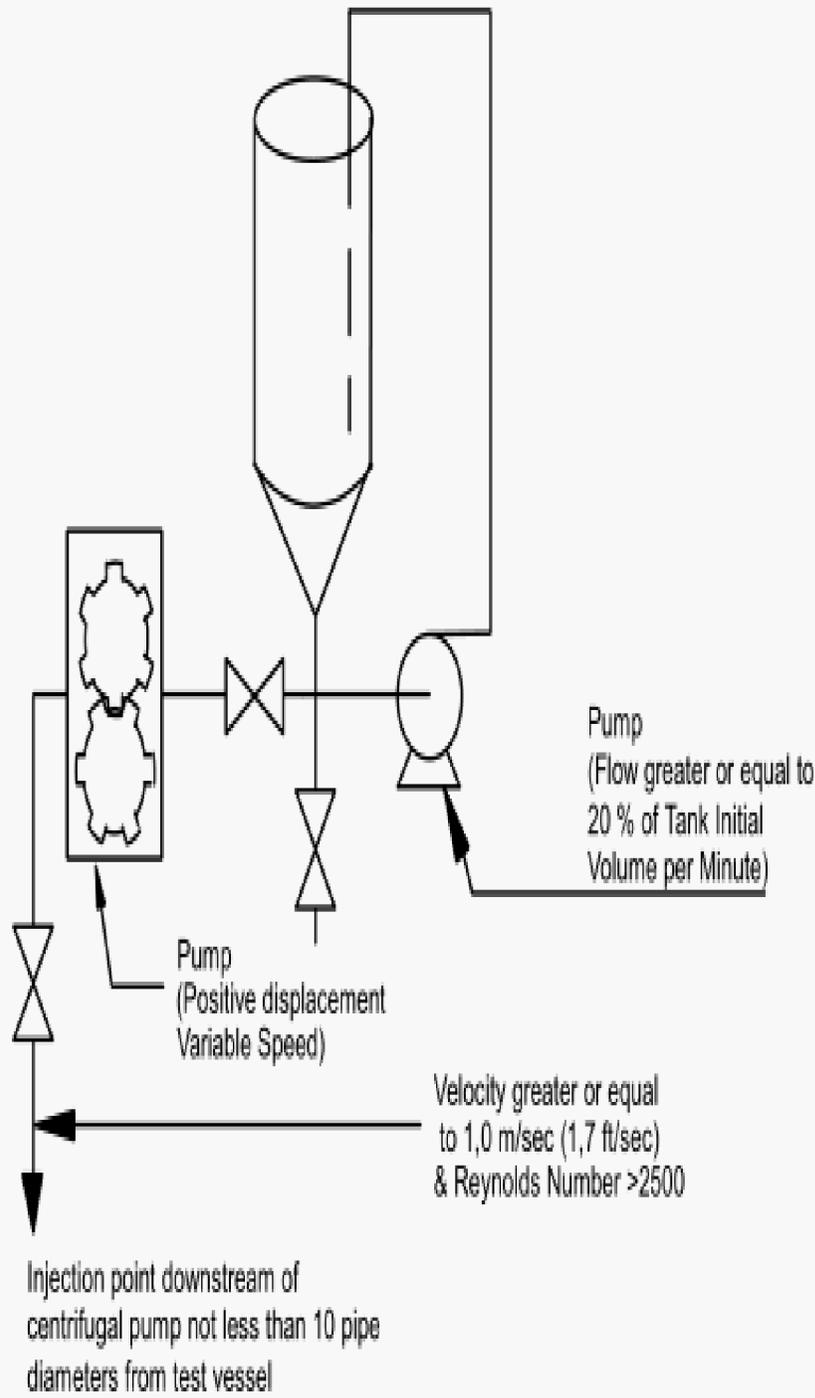
- Notes:**
1. All equipment & construction must meet applicable codes.
  2. Cleanup equipment recommended. Actual equipment & configuration can depend on local conditions.
  3. Storage shown is minimum acceptable.
  4. All sample probes installed as per ASTM D 4703.
  5. Slurry system detail in Figure 3.
  6. Provision must be made to verify calibration of:
    - Flowmeters
    - Differential pressure gauges
    - Slurry flow rate
    - RPM of centrifugal pump

<b>API/IP 1581 Flowsheets</b>	
<b>Figure 2 - Full-Scale Test Facility</b>	REVISION NO.: <i>API/IP 1581 5<sup>th</sup> Edition</i>
	REVISION DATE: <i>Feb. 20, 2002</i>

### Alternative 1

### Alternative 2

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**Notes:**

1. Slurry Volume concentration determined by flow rate (maximum 15 g/litre).
2. Pump is variable speed positive displacement.
3. For Alternative 2, displacement pump sized to recirculation rate at >20 % of initial tank volume/min at required injection rate.
4. For Alternative 2, injection rate must be measured by flow meter and/or level change.

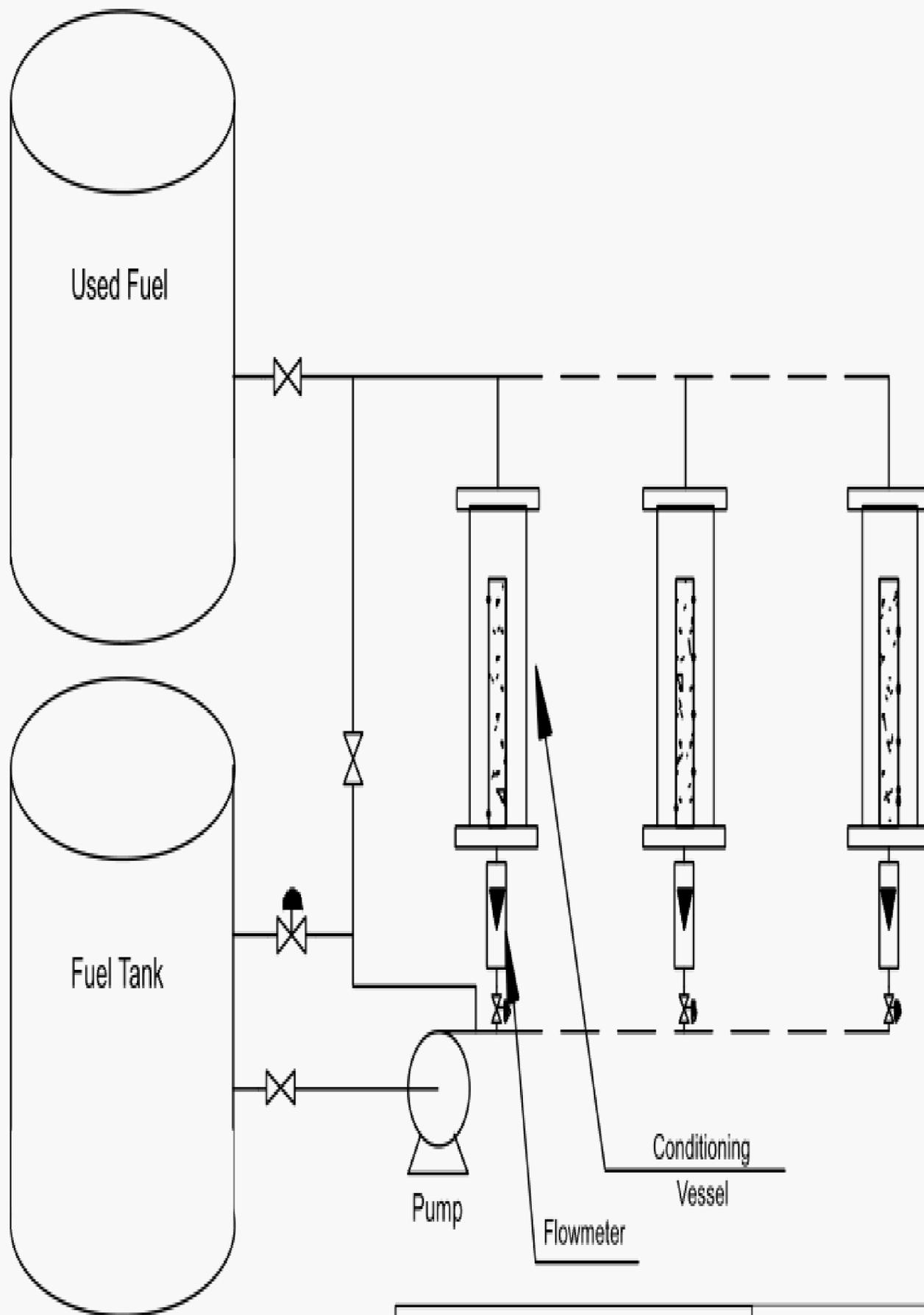
**API/IP 1581 Flowsheets**

**Figure 3 -**

**Solids Addition System**

REVISION NO.:  
API/IP 1581 5th Edition

REVISION DATE:  
May 7, 2002



Note:

Conditioning can be done as above or in place.

**API/IP 1581 Flowsheets**

**Figure 4-  
Element Conditioning  
Unit**

REVISION NO.:  
API/IP 1581 6<sup>th</sup> Edition

REVISION DATE:  
Feb. 20, 2002

# ANNEX A

## SOLIDS ADDITION PROCEDURE

### A.1 SOLID PREPARATION

The solids shall be dry (by heating at 100°C for 3 hours) and free from large agglomerates greater than 3–5 mm (0,12 in. – 0,20 in.).

### A.2 SOLID PROPORTIONS

The test solids shall be composed of 90 % Arizona Test Dust ISO 12103-1, A1 and 10 % Copperas Red Iron Oxide. Thus, for every 1 litre/minute flow rate of the coalescer in the single-element test (which requires 1,43 g solids per litre/minute flow), add to the slurry system:

- 1,29 g of Arizona Test Dust ISO 12103-1, A1,
- 0,14 g of Copperas Red Iron Oxide.

Additional solids in the same ratio should be added to compensate for the residual slurry volume if the slurry tank does not deliver all of its contents during the solids addition test.

### A.3 SLURRY PREPARATION

The solids can be added to the slurry tank in a number of ways:

- Add measured amounts of solids directly to the tank containing the correct amount of fully additized fuel.
- Add a concentrated slurry of the required solids directly to the tank.
- Add a concentrated slurry of the solids into a point in the recirculation loop of the slurry equipment (shown in Figure 3).

At the completion of adding the solids, the tank will be circulated for at least 20 minutes before injecting into the main piping as part of the solids addition tests.

### A.4 ADDITION

The solids slurry shall be metered into the test fuel flow system at the appropriate rate to provide a solids concentration of 19 mg/l (72 mg/gallon) in the test fuel.

