



API/EI 1585

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Guidance in the cleaning of  
aviation fuel hydrant systems at airports

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2nd edition

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AVIATION FUEL HYDRANT SYSTEMS  
AT AIRPORTS

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November 2007



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# CONTENTS

	<b>Page</b>
<b>Foreword</b> .....	vii
<b>Acknowledgements</b> .....	viii
<b>1 Introduction</b> .....	1
<b>2 Referenced publications</b> .....	3
<b>3 Definitions and abbreviations</b> .....	5
3.1 Definitions .....	5
3.2 Abbreviations .....	5
<b>4 Determining the level of cleanliness of a fuel hydrant system</b> .....	7
<b>5 Methods of cleaning</b> .....	9
<b>6 Cleaning operations</b> .....	11
6.1 Flushing .....	11
6.2 Pigging .....	12
6.3 Other mechanical cleaning methods .....	13
6.4 Assessment of the cleaning operation .....	13
<b>7 Methods to be followed during construction of hydrant systems to avoid ingress of contaminants and to provide for future cleaning</b> .....	15
<b>8 Fuel filtration</b> .....	17
<b>9 Handling fuel used in flushing and cleaning</b> .....	19
<b>10 Commissioning new and extensions/additions to existing hydrant systems</b> .....	21
10.1 General .....	21
10.2 Procedures .....	22

<b>Contents Cont....</b>	<b>Page</b>
<b>11 Operational practices to keep hydrant systems clean</b> .....	23
11.1 General .....	23
11.2 Filtration .....	23
11.3 Tank inspection and cleaning .....	23
11.4 Low point flushing .....	23
11.5 Hydrant pit valve flushing .....	24
11.6 Membrane filtration testing .....	24
<b>12 Hydrant system design for cleaning</b> .....	25
<b>13 Safety considerations</b> .....	27
<b>14 Records</b> .....	29
<b>15 Microbiological problems</b> .....	31
<b>16 CCTV survey</b> .....	33
<b>Annexes</b>	
<b>Annex A – Examples of forms</b> .....	35
<b>Annex B – Table of safe velocities</b> .....	41
<b>Annex C – Flow/Velocity tables</b> .....	43

# FOREWORD

This publication has been prepared jointly by the Energy Institute's (EI) Aviation Committee and the API Aviation Technical Services Sub-Committee. It is intended to provide the industry with guidance in the cleaning of existing fuel hydrant systems that are showing signs of having become contaminated with water, particulate material and/or microbiological activity. It also gives guidance to ensure that the construction and commissioning of a system does not cause subsequent adverse effects on fuel quality. In addition, it contains some operational guidelines to assist in the maintenance of continued cleanliness.

A fuel hydrant system is a custom designed item and is very site specific. No one set of conditions can be applied to all systems. Users of this publication should amend the guidance given to suit local conditions. Local and regional law and regulations should also be reviewed with respect to specific circumstances.

The EI and API are not undertaking to meet 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 EI and API 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.

Although it is hoped and anticipated that this publication will assist those responsible for designing, constructing, commissioning, operating and maintaining aviation fuel hydrant systems, the EI and the API cannot accept any responsibility, of whatever kind, for damage or loss, or alleged damage or loss, arising or otherwise occurring as a result of the application of the guidance contained herein.

Suggested revisions are invited and should be submitted to the Director of Standards, API, 1220 L Street, N.W., Washington, D.C. 20005, or the Technical Department, The Energy Institute, 61 New Cavendish Street, London, W1G 7AR.

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# 1

## INTRODUCTION

This publication is intended to give operators of airport fuel hydrant systems guidance in:

- (a) Determining the state of cleanliness of existing hydrant systems and possible causes of contamination.
- (b) Methods of cleaning hydrant systems that are showing signs of contamination with particulate material, water and microbiological material.
- (c) Methods to be followed during construction of new systems or extensions to existing systems to prevent the entry of unwanted materials.
- (d) Commissioning procedures.
- (e) Operational practices to maintain the system in a clean condition.
- (f) The design of hydrant systems to aid cleaning.

If the hydrant system is clean when placed in service and adequate filtration is given to the fuel entering it, the hydrant should remain clean in service. In general, only if users are experiencing shorter than normal fuelling vehicle filter element life, or are obtaining unsatisfactory samples upstream of their filters, need action be taken. It should be recognised that sub-micronic particulate will never settle and will eventually

be carried to the users' vehicles. On the other hand, larger debris may never come out so ensuring that none is present is the best way of preventing problems. Such material in the system may provide an environment to trap moisture and promote microbiological growth.

The key to successful cleaning of supply lines and hydrant systems is to fully understand the subject facilities and to develop a detailed implementation plan with objectives, expected results and how the results will be measured. Hydrant operators should formulate their own procedures, which should be incorporated in manuals and operating procedures. In order to assist, it is essential that 'as built' drawings and associated records are produced after initial construction and that these are kept up-to-date following any subsequent modification.

Training is very important; hydrant operators should be properly trained to recognise signs of trouble and to act upon information and advice regarding fuel quality and the state of pits etc. from hydrant users.

**It cannot be too strongly stressed that the key is to ensure that the hydrant system is clean in the first place.**



## 2

# REFERENCED PUBLICATIONS

The following publications are cited in this publication, the latest available edition of each applies:

### **API/EI**

API/EI 1540 *Design, construction, maintenance and operation of aviation fuelling facilities* (EI Model Code of Safe Practice, Part 7) (hereinafter referred to as API/EI 1540)

API/EI 1581 *Specifications and qualification procedures for aviation jet fuel filter/separators*

API/EI 1590 *Specifications and qualification*

*procedures for aviation fuel microfilters*

API/EI 1594 *Initial pressure strength testing of airport fuel hydrant systems with water*

### **EI**

Model Code of Safe Practice, Part 21, *Guidelines for the control of hazards arising from static electricity*

*Guidelines for the investigation of the microbial content of petroleum fuels and for the implementation of avoidance and remedial strategies*



# 3

## DEFINITIONS AND ABBREVIATIONS

### 3.1 DEFINITIONS

The following terms are used within this publication:

**cleaning sledge:** hydrant device designed and patented by a major joint venture hydrant operating company.

**contaminant:** any material that has, or could have, an adverse effect on the quality of aviation fuel and its fitness for use in aircraft engines. This may take the form of free water, solids in particulate matter form, construction debris and microbiologically formed materials.

**critical flow:** flow greater than *laminar* but less than *turbulent*. It may be taken as having a mean *Reynolds number* of between 2 000 and 4 000.

**laminar flow:** flow that is orderly and even in pattern; the velocity is at its maximum at the pipe axis and decreases sharply to zero at the wall. It may be taken as having a mean *Reynolds number* of less than 2 000.

**Reynolds number:** a dimensionless combination of the pipe diameter, the density and dynamic viscosity of the flowing fluid, and the velocity of flow. It may be considered as the ratio of the dynamic forces of mass flow to the shear stress due to viscosity.

**soak test:** the period of time between the initial filling

of the hydrant system with fuel and the taking of samples to check that the fuel has not been affected by the hydrant system. See API/EI 1540 Section 5.8.

**turbulent flow:** flow that is greater in velocity than *critical flow*. It may be taken as having a *Reynolds number* greater than 4 000 and is characterised by random eddy flow patterns.

### 3.2 ABBREVIATIONS

The following abbreviations have been used in this publication:

µm	micrometre (micron)
CCTV	closed circuit television
ft/sec	feet per second
in.	inch
m <sup>3</sup>	cubic metre
m/sec	metres per second
mg/L	milligram per litre
pS/m	picosiemens per metre

Although it is usual to denote litres by l, in order to prevent any confusion or misunderstanding when, in certain fonts l and I may be misread, litres is denoted by L in this publication.



## 4

# DETERMINING THE LEVEL OF CLEANLINESS OF A FUEL HYDRANT SYSTEM

**4.1** It is not always obvious that there is a dirt or water problem within a hydrant system. Experience has shown that despite clean samples being obtained from low points and pit valves, systems can be contaminated with particulate matter, free water, construction debris or microbiological material, or a combination of these.

**4.2** Into-plane operators should be encouraged to report to the hydrant operator, any less than satisfactory samples taken during or after fuelling. It is incumbent on the hydrant operator to properly investigate such reports without undue delay. With the use of fuel filter monitors in fuelling vehicles, the condition of the hydrant fuel is that shown on samples taken from the inlet side of the vessel, as this fuel has not passed through the on-board filter.

**4.3** Into-plane operators may experience slugs of water and sediment but later sampling by the hydrant operator may not identify the presence of such material. Monitoring the sumps of into-hydrant filter water separators and other points, from which water and solids can be detected and removed, should be meticulously carried out at a frequency that accords with industry agreed procedures. The presence of water should be investigated to find the source.

**4.4** When taking low point and hydrant pit valve flushing samples, especially if a contamination problem is being investigated, the initial quantity of fuel flushed

should be visually checked for the presence of any solids or water droplets before these are flushed into the tank of the servicing vehicle or unit. The vehicle pipework system should be designed to facilitate the examination of the samples flushed from the low point. Frequent inspection of the flushing tank should be carried out to check on contents. If an unusual amount of particulate and water is noted, the records should be checked to see which other low points and pit valves have been flushed. Repeat flushing of some pits to determine which have produced the material may be required. Note: it is important that the tank of any flushing unit used for this type of investigation is itself flushed and cleaned before the hydrant flushing is undertaken to ensure that the samples obtained are representative.

**4.5** If less than normal element life in into-hydrant filters is experienced, or depot tank samples or inspections show evidence of unusual sediment, particulate or water, the matter should be investigated. If necessary, the fuel supplier should be notified.

**4.6** When circulation of the hydrant system back to depot tanks is undertaken, the condition of the tank before and after should be noted. Any increase in sediment or water will indicate that the hydrant system contained such material. Further action should be assessed.

**4.7** One difficulty in assessing the condition of a hydrant system is lack of entry capability. It is recommended that whenever major work is undertaken and, for example, block or sectioning valves are removed, the inside of the pipework should be examined as far as is practicable. For this adequate lighting will be required and all due precautions taken to ensure safe working conditions and equipment. A record should be made of the examination including the cleanliness or otherwise of the pipe, and where used, the condition of the internal lining.

Wherever investigations are undertaken to determine the extent and type of contamination, it is essential to maintain good records of the locations checked and the results of sampling or other examinations. For instance, maintaining a record of the quantity and description of any solid matter flushed from low points or through hydrant pits on a plan of the hydrant may help locate or narrow down the source. If the hydrant system is looped, then the flow pattern may

also need to be carefully studied to determine the most likely direction that any contamination may be moved around the piping network. Where the flow has been changed (for instance, due to hydrant maintenance or extension works), then close monitoring for any changes in quantity or type of contaminants retrieved from the flushing samples is required.

**4.8** Closed circuit television (CCTV) survey can be a very helpful tool in determining the state of the hydrant system. One benefit of CCTV is that it shows the current condition and, by recording this on videotape, a visual record of the condition of the system checked can be established. This may be useful in assessing the build-up of unwanted material over a period.

Note: CCTV technology may be of limited availability in some regions. If CCTV is to be used, it must be suitable for the conditions that will be encountered (in flammable liquids, atmosphere etc.).

# 5

## METHODS OF CLEANING

**5.1** If, after considering all possible evidence, it is considered that there is a need to remove contaminants from the hydrant system, it is necessary to find the extent of the contamination and the cleaning that is required.

**5.2** If sampling indicates that the problem is confined to a particular section, and that section can be adequately isolated from the remainder of the system, it can be treated independently of the rest of the system. If there is indication of a widespread problem, or the section in question cannot be properly isolated, then it may be necessary to clean a significant part, or the

whole, of the system.

**5.3** Cleaning may have to take place whilst operating the system due to shutdown time limitations. Cleaning of one section whilst the remainder of the system is in operation may have to be undertaken. Positive segregation is essential under such circumstances.

**5.4** Flushing at higher than normal flow is perhaps the first option to be considered. Other options include mechanical cleaning by using pigs, cleaning sledges or reverse flow nozzles. These are discussed in Section 6.



## 6

# CLEANING OPERATIONS

### 6.1 FLUSHING

**6.1.1** To move particulate and water in a hydrant system, a minimum flow velocity of approximately 1 m/sec (approx. 3 ft/sec) is necessary. To achieve such flow at the pipe wall, where it is needed, requires a higher mean flow velocity. In Annex C, tables show velocities required in flushing. Table C1 shows typical velocities at given flow rates in several pipe sizes. Table C2 shows the minimum velocity required to move alumina particles of 10, 100 and 1 000  $\mu\text{m}$ . Table C3 shows a method of calculating velocities in a range of pipe sizes.

**6.1.2** Particle sizes are relevant to hydrant operations. For example, 10  $\mu\text{m}$  particles are liable to block filters and the 1 000  $\mu\text{m}$  size probably would not cause a problem. However, these larger particles, particularly if of clay or earth, may break up under the influence of fluid movement and present a problem later.

**6.1.3** Work undertaken by the industry to establish particle dynamics resulted in Table C2. As very high velocities may not be practical, average velocities of from 2 to 3 m/sec should be the target. In the larger diameter pipes, some mechanical assistance, such as pigs, may be necessary.

**6.1.4** Industry research has shown the slopes commonly used in hydrant system design do not in themselves assist migration of particulate and water to the low points even in pipes with a smooth internal surface. Movement caused by fluid velocity is required.

However, a positive slope is useful when draining down the system.

**6.1.5** As is shown in Table C2, high flow rates are required, especially in the larger diameter pipes, to achieve the necessary flow velocity to move contaminants to a low point.

**6.1.6** Though normally not a feasible option, the installation of temporary pumps to achieve the flow rate required is advocated by some. Ideally, the flushing should be carried out through a return pipe system, to a storage tank. The return system should include a means to control the flow to a safe level consistent with the pump characteristics, tank venting and static electricity charge generation control. Return to a tank may not always be possible, particularly on older systems that were built on the single spur line principle. The installation of temporary piping may make it possible to flush to a depot tank.

Note: If additional pumps are to be used, the hydrant system engineering design should be reviewed. There could be a risk of overstressing the system, particularly on older systems that have been extended/modified without appropriate re-engineering assessment. Additional pumps may cause unacceptable pressures, flows exceeding filter rating and flows that exceed the floating suction capacity of the supplying tank and other undesirable conditions.

**6.1.7** If high flow flushing back to a tank is undertaken, it is necessary to ensure that the venting capacity of the tank is not exceeded. If there is any

doubt, a roof manhole, dip hatch or other top opening should be opened during the receipt of the fuel.

**6.1.8** Fuel conductivity should be considered, see Section 13 and Table B1.

**6.1.9** If a 'return to tank' system is not possible, the flushing should be carried out through the system, preferably into temporary fixed tankage. Where temporary fixed tankage cannot be provided, tank vehicles or refuellers can be used, but the limited flushing volume makes the associated operational and safety aspects more difficult to manage. As there may be limited refueller capacity at airports with a hydrant system, the use of outside road tank vehicles should be considered.

The temporary flushing or vehicle tanks need to be in a clean condition, or be able to be cleaned to this standard, to allow the product to be returned to normal jet fuel storage. If this is not possible, the flushed product may have to be downgraded to non-aviation use unless it is confirmed by laboratory testing against the relative fuel specification that it is fit for use in aircraft.

**6.1.10** To achieve the high flow, it may be necessary to install a manifold at the end of the line to be flushed so that the fuel may be pumped into more than one temporary tank, into the compartments of a single vehicle, or into more than one vehicle.

**6.1.11** It is recommended that at least two, preferably three, times the capacity of the section being cleaned, be flushed at the fastest flow velocity achievable. Up to 3 m/sec is desirable.

**6.1.12** Where there is a shortage of access points some types of low point may be converted for flushing by removing the small sampling/flushing line and installing a pit valve on the riser. In this way, a faster flow through the hydrant system is possible. If a low point is used, the dry-break should be removed to avoid damage, jamming with debris etc.

**6.1.13** After each flushing sequence, low points should be checked for cleanliness (with 'sample tubes' replaced, if removed as in 6.1.12).

**6.1.14** Where a hydrant is looped back to storage tankage, the flushing should be undertaken in one direction until clean and then, if possible, the flow reversed and the flushing continued until the product is again clean. In large hydrants, experience shows that flowing in one direction is not always sufficient to completely clean the system.

**6.1.15** Those involved in flushing operations should decide whether to remove the pit valves on the risers used to connect to the receiving vehicle, or to leave them in place. It is recommended that if flushing into vehicles, the pit valves should be left in place. If flushing into a larger capacity fixed tank, the pit valves may be removed provided that a ball or other quick acting valve is installed in a readily accessible position, not in the pit.

**6.1.16** If it is known that the system contains levels of particulate that could cause damage to, or malfunction of, the pit valves, they should be removed and an alternate means of stopping fuel flow provided, see 6.1.15 and 10.2.8.

## 6.2 PIGGING

**6.2.1** Pigging is a very efficient way of cleaning but it will require much preparation work if the system was not originally designed to be pigged. Safety procedures will have to be put in place. Only soft pigs should be considered.

**6.2.2** Any obstructions within the diameter of the pipe, for example, low point probes that pass through the diameter of the pipe, if not removable, will prevent the passage of a pig. A means of entering and removing the pig needs to be provided.

**6.2.3** If pigging is to be carried out, pigs that are flexible enough to negotiate bends that may be present, such as soft foam pigs or polypigs, should be considered. Experience shows that soft foam pigs are very flexible; for example, a 30 cm (12 in.) pig will negotiate an 20 cm (8 in.) line. A pig with polyurethane bands fitted may be used; this will not damage the internal lining if it is in good condition.

**6.2.4** If the system has been designed to be pigged, then there will be some means of handling the 'dirt' built in.

**6.2.5** If the system is not designed to be pigged, it may be difficult to handle the dirt-laden product that may be displaced by the pig. The section to be pigged should be emptied. Clean, oil free compressed air may be used to propel the pig with some water ahead of it. This will lead to intermittent travel of the pig as the air pressure decreases and is then restored. Water use requires complete isolation from any live sections of hydrant and careful drying of the line on completion.

Note: Air should not be used unless the line being

pigged is empty of fuel. Only low air pressure, sufficient to propel the pig, should be used.

**6.2.6** Examination of the pig after traversing the line will indicate the internal condition. If the pig is clean, no further action may be required but if it is dirty, the process should be repeated. Multiple passes may be required and should be carried out until a clean condition is obtained.

### **6.3 OTHER MECHANICAL CLEANING METHODS**

**6.3.1** At one airport, a patented 'Cleaning Sledge' was designed and successfully used to clean out extensive sections of the hydrant in pipes down to 40 cm (16 in.). The sledge was fed along the line with a CCTV camera following it to observe and record the results on videotape.

**6.3.2** After depressurising the section, removing the hydrant pit valves and lowering the level of fuel if necessary, the sledge was inserted into the main hydrant line through a 15 cm (6 in.) diameter riser. The sledge can be fed along to the next riser with an effective range at present of approximately 50 m, which is considered to be sufficient to work from stand to stand.

**6.3.3** The sledge was fitted with magnets to pick up any ferrous material and a suction hose to pick up non-ferrous material and water, where present. The hose was connected to a pump with good suction characteristics, in this case the pit servicing vehicle, with a coarse strainer fitted in the suction line to catch any large debris and to protect the pump.

**6.3.4** It was seen that time should be allowed for adequate settling of any fine 'mist' of particulate that may be disturbed by the movement of the sledge, which may not be pumped out, before reinstating the line to service. It is usual to flush at least twice, or preferably three times, the capacity of the section cleaned into a tank vehicle to ensure that quality control requirements are met before returning the section to service. The time that the line can be made available to carry out such work will dictate how much line can be cleaned at each session.

**6.3.5** Although not yet used in jet fuel on an operational hydrant system, a reverse flow nozzle (nozzle with vents pointing backwards, see Figure 1) is very commonly used in drain clearing. This method has been used successfully to remove dirt from a newly

constructed hydrant system and from an underground pipework system in a depot. This was done before hydrotesting of the system. Water was used to blow back the dirt.

This device travels forward by the propulsion provided by the reverse flow. The pressure may be adjusted to ensure that the dirt is dislodged. The dirt can be vacuumed out by a suction device (such as the cleaning sledge) or returned to the truck used for the pumping. Precautions should be taken to ensure that the dirt being blown back does not pass the entry point (possibly a cleaned out section of the hydrant). This method does not limit travel to 50 m (theoretically unlimited for a straight section of the hydrant) as it has a built-in propulsion system. As the nozzle is small in size, the volume of water required to propel it forward and blow back the dirt is relatively small but at a high pressure. After the nozzle has travelled the maximum distance that it is intended to travel, it may be retracted slowly while pumping through the nozzle continues.

The dirt and debris continue to be blown back as the nozzle is retracted. A tandem powerful suction device can be used.

**6.3.6** CCTV survey has shown that small 'cone shaped' mounds of particulate can build up in the hydrant main below risers. This may be caused by fine debris starting to rise in the pipe during high flow only to drop back under gravity when the flow reduces or stops. Such debris may be pumped out by lowering a hose or metal lance down the riser after removing the pit valve. If a metal lance or equivalent is used, care is necessary to avoid causing damage to the internal lining of the pipe.

### **6.4 ASSESSMENT OF THE CLEANING OPERATION**

**6.4.1** The certificate of quality of the fuel to be used for flushing should be made available, preferably before commencing the flushing. If the fuel in the tank(s) to be used is from more than one batch, a full certification test should be carried out on the product in each tank involved to establish a quality baseline against which the quality of the flushed fuel may be compared.

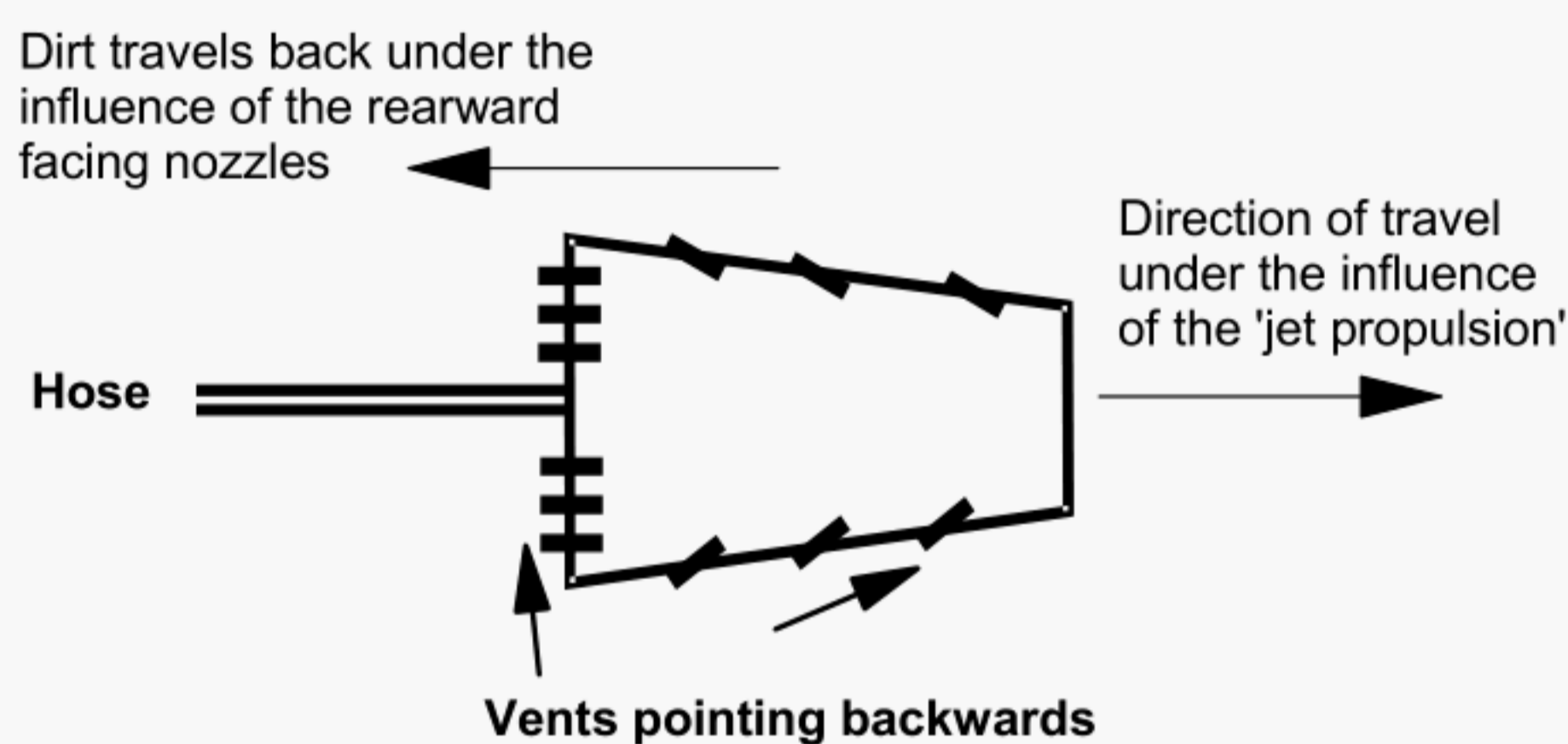
**6.4.2** The efficiency of a clean-up should be monitored during cleaning and assessed on completion of the work. As mentioned in 6.2.6 the condition of the pig should be checked.

**6.4.3** At the start of flushing, a 'colorimetric and a gravimetric membrane filtration test' should be carried

out on the fuel immediately downstream of the into-hydrant filter water separator. This will establish a 'baseline' for the level of solids in the fuel against which results of tests carried out on the hydrant system may be measured.

**6.4.4** Colorimetric membrane filtration tests should be carried out on product from all risers, with random

gravimetric tests being performed on some risers. Satisfactory cleaning will have been achieved when colorimetric results are not more than two dry colour numbers between the fuel entering the system and the sample drawn from the risers, subject to a maximum colour rating of 4 dry, and gravimetric results are less than 0,2 mg/L.



**Figure 1: Schematic of a reverse flow nozzle device**

# 7

## METHODS TO BE FOLLOWED DURING CONSTRUCTION OF HYDRANT SYSTEMS TO AVOID INGRESS OF CONTAMINANTS AND TO PROVIDE FOR FUTURE CLEANING

**7.1** When designing a hydrant system or a large extension, consideration should be given to the provision of future pigging or other cleaning facilities. This may be done by using a suitable spool piece located in a convenient position (valve chamber etc.) which may be removed and a pig launcher/receiver installed when, and if, needed.

**7.2** Experienced and qualified site inspectors, supervisors, airport and/or hydrant operators, should pay strict attention to ensuring that water and solid materials are not left inside pipework when constructing the system. This is in addition to the inspection of welds and other construction features by appointed inspectors.

**7.3** Pipe lengths should always be capped or plugged at all times when they are not being worked on. The ends should be closed during all phases of construction, particularly during rainfall where flooding of the lines may occur, and at the end of any working period.

**7.4** Pipe end preparation produces grinding dust and flame cutting slag. Where it is necessary to carry out the pipe end preparation on site, pipe stoppers should be fitted to exclude debris. Any debris inside the installed

pipe should be completely removed before the next section is welded on.

**7.5** Heat affected lining material, weld slag or other debris that adheres to the pipe wall, should be removed as far as is practicable. After each main weld is completed, a pull-through stiff brush, pig or similar device can be used to dislodge such material and clean the section before the next length of pipe, (usually 11 m or less) is added. The reverse nozzle (mentioned in 6.3.5) using clean, dry and oil-free air may also be used for blowing the slag and other debris out through the open end of the pipe. It will be necessary to take precautions against personal injury from flying material.

**7.6** Before being lowered into the trench, the pipe should be cleaned thoroughly and care exercised to ensure that no foreign material enters the pipe string. If proper care has been exercised, most of the debris should be light material that has entered the pipe string through uncapped ends of the pipe. Blowing out with compressed air may be used to clear such matter but, as this is not always successful, other means of cleaning may need to be employed.

**7.7** If unlined, pipe fittings such as bends, tees and crosses should be thoroughly cleaned to remove any lacquers, chemicals and other preservatives. Equipment such as valves, pumps etc. may have been treated with an inhibitor or preservative before being delivered to site. All such materials must be meticulously removed before installing the equipment.

**7.8** If weldolets or similar are to be fitted to the pipe, the cutting of the hole should be followed by cleaning out any material which falls into the pipe by all means possible such as vacuuming, brushing, magnets, etc.

**7.9** When laying the pipes, care should be taken to ensure that no depressions that would form unwanted low points occur. Pipes should be well supported to

prevent sagging in service.

**7.10** Any opening into the pipework should be capped or blanked whenever access is not required, to prevent ingress of foreign matter.

**7.11** Foam pigging or pull-through devices should be used to clean sections as they are completed.

**7.12** Risers for hydrant pit valves and low or high points should be fitted with a blind flange or other reliable means of preventing water and debris from falling into the pipework before the pit valve is installed. Ensure that the pit box is dry before removing the flange prior to installing the pit valve.

## 8

# FUEL FILTRATION

**8.1** Adequate filtration, to ensure that product entering the airport depot is clean, should be installed in the receipt facilities. Depending on the method of supply to the hydrant depot tankage, this may require the installation of microfilters and filter/water separators.

**8.2** If experience shows that particulate in the incoming fuel is a problem, it may be beneficial to install a

microfilter fitted with elements with a nominal rating of 1,0  $\mu\text{m}$  upstream of the receipt filter/water separator. Such microfilters should use elements that comply with the requirements of API/EI 1590.

**8.3** Receipt and into-hydrant filtration should be provided by filter/water separators that comply with the requirements of API/EI 1581.



## 9

# HANDLING FUEL USED IN FLUSHING AND CLEANING

**9.1** Fuel that has been removed from the hydrant system as a result of cleaning and flushing should be returned to a dedicated tank, thoroughly settled and drained of any water and solids that may be present.

**9.2** On completion of all hydrant flushing, samples should be taken from the storage tank dedicated to receive the flushed product and submitted for test at an approved laboratory to establish its suitability for aviation use. If the fuel used in the flushing is from one identifiable batch, a re-certification test will suffice and the industry guidelines, limits of variation for test results should be used. If fuel from more than one batch is used, a full certification test should be carried out on the product. Fuel that fails to meet the requirements of

the test should be removed from airport storage and downgraded to non-aviation use.

**9.3** If necessary, the tank holding the product should be cleaned and inspected.

**9.4** Microbiological growth itself may be the 'dirt', or the cause of further 'dirt' being formed, in a system. If the presence of such material is detected, appropriate action must be taken, see Section 15.

**9.5** Since tank bottom water may encourage microbiological growth, it is essential that all tanks are checked frequently for bottom water and any found removed.



# 10

## COMMISSIONING NEW AND EXTENSIONS/ADDITIONS TO EXISTING HYDRANT SYSTEMS

### 10.1 GENERAL

**10.1.1** Commissioning plays a vital part in starting out with a clean hydrant system. If commissioning is not carried out correctly, debris left in the system will lead to problems in service. Debris and other detritus may provide an environment to trap moisture, which may lead to microbiological growth problems. Therefore, it is essential to ensure that the system is clean before placing it into service for fuelling aircraft.

It is also important to drain and dry the system completely after hydrotesting of the lines, if this is carried out with water. After draining from all the low points, further drying can be carried out by using dried, oil free, compressed air. The dew point of the exit air should be almost the same as the air entering. This exercise should be carried out immediately after the hydrotesting is completed, otherwise rusting may start at the weld points and the conditions required for microbiological growth could exist. Guidance on carrying out such an operation is given in API/EI 1594.

**10.1.2** If the system to be commissioned is an addition or extension to an existing system, it is essential to ensure that the existing 'old' part of the system is clean before putting the extension into service. It has been known for an 'old' system to contaminate a clean 'new' system once it is in service.

The fuel in the old system, that is to be connected to the new system, may have been stagnant near the

connection and dirt, and especially water, may have accumulated. It is important that special attention is paid to cleaning these sections when cleaning the old system. Cleaning should be done just before the connection is made.

A temporary mesh strainer inserted at the start of the new section may provide an indication of the condition of the old section of the hydrant. However, the means to easily remove the strainer should be provided to avoid further major drain-downs.

During the construction itself, stagnant sections of the old hydrant system should be flushed out periodically to prevent water accumulation and fungal growth. If the existing low points cannot achieve this, then alternate methods (covered elsewhere in this publication) will have to be adopted.

**10.1.3** CCTV cameras or endoscopes can be used once the commissioning procedures have been carried out and prior to placing the system in service. If adequate precautions are taken, and cleaning as suggested in Section 6 is carried out, the use of CCTV cameras or endoscopes should not be necessary.

**10.1.4** Flushing velocities should be as close as possible to those shown in Table C2 or better. Ideally, flushing should be made through a return loop to a tank. It is preferable to carry out the flushing without stopping the flow.

**10.1.5** Unless the hydrant is designed in the form of a loop, or temporary piping is installed, it will not be possible to flush fuel directly into a large capacity storage tank. In this case, flushing into vehicles or other temporary small capacity tanks will be required.

**10.1.6** For warnings regarding the generation of static electricity charges when flushing fuel that may contain particulate and/or water, see Section 13.

## 10.2 PROCEDURES

**10.2.1** Prior to commissioning, a detailed method plan should be developed. Such a plan should contain not only the operational features, but also set out the communications required and other details to ensure a safe operation. Pit valves should be removed during the pressure test and blind flanges with suitable venting means placed on the riser flanges. The direction of flushing on complex systems should be decided with flushing towards the chosen exit points being required.

**10.2.2** Before filling commences, low points should be checked for the presence of water. This may be done by using a dip rod such as a length of reinforcing bar, with suitable protection to avoid damaging the pipe internal lining where used. If more than a trace of water is present, it should be removed before commencing the filling operation. Ensure that any fittings, such as the low-point internal dip tube, that have been removed are properly replaced before filling commences.

**10.2.3** It is preferable to fill the system with fuel from a single batch. This makes the task of comparing pre- and post-soak fuel test results much easier. If it is not possible to fill with fuel from one batch, extra samples should be taken to establish a baseline quality of the fuel before soaking commences.

**10.2.4** Initial fill should be by gravity followed by venting of low points, pit valves and any other venting openings. It is important to vent the 15 cm (6 in.) riser as well as the inner sample line of low points so constructed. When filling, the initial movement of the fuel from a high to a low section of the pipe can be used to good effect to help 'push' any remaining debris to the next low point.

**10.2.5** After filling the lines, pressure testing and carrying out the soak test as in 5.8 of API/EI 1540, or other agreed practice, the system should be prepared for flushing.

**10.2.6** Guidance on the average flow velocities required for the various sections of the system can be determined from the tables in Annex C.

**10.2.7** Flushing back to a dedicated tank without filtration is the preferred method. (However, 'witches hat'-type strainers are useful in that they can be examined for the accumulation of debris between flushes.) If this is not possible, suitable fixed temporary tanks or tank vehicles, preferably road bridgers, need to be mobilised.

**10.2.8** To achieve the required velocity, it may be necessary to manufacture a manifold so that several hoses may be connected to pit valve risers at the end of the leg to be flushed. See 6.1.15 for recommendations on removing pit valves or leaving them in place. Ball valves, or similar fast acting valves should be used to control the flow into vehicles, even if pit valves are in place during the flush, but care should be taken not to create surge pressures when closing them.

**10.2.9** As a general guide, each section should be flushed with a quantity equal to two to three times the section capacity. Flushing must continue until satisfactory results on fuel samples are obtained.

**10.2.10** If a fast flush cannot be obtained, the fuel should be removed from the system, returned to a dedicated tank and replaced with fresh fuel. After due settling and checking for sediment and water, the fuel in the dedicated tank will be filtered out of storage and may be used in the hydrant system provided that it is established that it is fit for use in aircraft.

**10.2.11** It may be beneficial to install a pit valve on low point risers to assist in flushing. This may be of particular use in flushing spur type risers.

**10.2.12** On completion of flushing, membrane filtration testing as per 6.4.3, 6.4.4, and using the same criteria quoted therein, should be carried out.

# 11

## OPERATIONAL PRACTICES TO KEEP HYDRANT SYSTEMS CLEAN

### 11.1 GENERAL

**11.1.1** All measures to prevent the entry of water and solids into the hydrant system should be taken. These include the provision of efficient filtration, into and out of storage to acceptable industry standards and routine maintenance and quality control checks. Product in storage tanks should be subjected to strict quality control checks and tests in line with established industry practice. Low point and pit valve flushing, periodic sampling and testing should be meticulously carried out. CCTV survey, though relatively expensive and perhaps not universally available is, however, a useful method that should be considered to help determine the condition of the system. Periodic flushing should be carried out if fuel samples begin to show that it will be beneficial for product cleanliness.

**11.1.2** There should be good means of communication between the hydrant operator and the users of the system so that any signs of trouble can be investigated and action taken as swiftly as possible.

**11.1.3** If a dual supply and looped hydrant system design is used, when only one feeder is in use, the lines should be alternated on a routine basis to prevent stagnation of the line not in use.

### 11.2 FILTRATION

**11.2.1** Filtration as in Section 8 should be provided on both the inlet and outlet of the hydrant supply tanks.

**11.2.2** Routine product quality control tests and checks on the filtration equipment, in accordance with industry standards, are essential in monitoring the hydrant system cleanliness.

**11.2.3** After 12 months of immersed element life, internal inspection of filter vessels should be carried out. Particular attention should be given to detecting any signs of microbiological growth on the filter/coalescer elements and to the performance of the separator stage.

**11.2.4** If microbiological activity is detected, further investigation should be carried out to determine the cause and the extent of contamination downstream.

### 11.3 TANK INSPECTION AND CLEANING

**11.3.1** Regular (at least annual) inspection of tanks holding fuel to be used in the hydrant system should be carried out. Any signs of microbiological activity will require action similar to that in 11.2.4 to be carried out.

The tank should be cleaned and the necessary steps taken to eliminate any microbial activity.

**11.3.2** Regular draining of water should be carried out in accordance with industry standards.

### 11.4 LOW POINT FLUSHING

**11.4.1** Regular low point flushing should be carried out in such a manner that the flushings from the low

point sump are examined. A means to allow the inspection of the first flushings from the sump with, if necessary, adequate lighting, should be provided. See also 4.4.

**11.4.2** If sediment and/or water build-up is suspected it may be beneficial to temporarily replace the low-point 'dip-tube' with a hydrant pit valve on the low point riser to provide an extra flush. Refuelling of aircraft shall not be carried out through this valve.

**11.4.3** Changes in flow patterns or increases in flow rate may well cause sediment and water to be entrained and transported with the higher flow of fuel. Following any such change, or engineering works being carried out, more frequent low point flushing should be undertaken for at least several days after the event, even if initial samples do not give any indication of water or particulate. Into-plane operators should be advised to take extra samples during their operations and to closely monitor the differential pressure of dispenser filters. Records of such changes and the subsequent checks should be maintained.

**11.4.4** The recommendations of 11.4.3 also apply when re-commissioning if extra pumps have been used in flushing. Documentation of the commissioning flow rates for each hydrant section is required to determine whether further, higher flow flushing will be necessary.

## **11.5 HYDRANT PIT VALVE FLUSHING**

A regime similar to that appropriate for low points flushing should be established. Pit valve flushing, in addition to that routinely performed, should be carried out if conditions as in 11.4.3 exist.

## **11.6 MEMBRANE FILTRATION TESTING**

**11.6.1** Samples should be drawn from the downstream side of into-hydrant filters for colorimetric membrane filtration testing in accordance with industry practice.

**11.6.2** The results of these tests should be used as a 'base line' value for evaluation of other results obtained on samples drawn from various points on the system.

**11.6.3** If the colorimetric test results exceed the industry limits, further testing (including double membrane colorimetric and /or gravimetric membrane filtration testing) should be carried out. The cause and source of the contamination should be identified, recorded and remedied.

**11.6.4** Accurate records of membrane filtration testing should be established.

## 12

# HYDRANT SYSTEM DESIGN FOR CLEANING

**12.1** One of the greatest problems that the designer of a hydrant system faces is the sizing of the system for future growth. Larger diameter feeders in particular are installed to allow for future growth. These initially result in lower velocities which may lead to problems later as settled out particulate in the pipe may be moved as flows increase. However, proper initial cleaning and efficient into-hydrant filtration should overcome this problem.

**12.2** If double feeders are built, each one sized for initial volumes and short term increases, and which can be used singly in the early life of the system, higher flow velocities will ensure a measure of self-cleaning. As volumes increase and the velocity in one feeder becomes greater than is desirable, both feeders may be used.

**12.3** Such a design will allow greater flexibility in operations and provide for loop flushing but is more costly to build and may not always be feasible.

**12.4** If pigging is not possible and sampling shows the need to clean, high flow flushing should be considered. Return to a tank is the most desirable method, perhaps using a tank that is due for cleaning with appropriate consideration for the control of flow into the tank and the tank venting capacity (see also 6.1.7). If the fuel returned from the hydrant system can be directed through the receipt filter water separators, the removal of the elements and the installation of microfilter elements may be a consideration provided that this does not reduce the flow to a level where the fast flush is not possible.



# 13

## SAFETY CONSIDERATIONS

**13.1** In carrying out some of the operations/functions contained in this publication, certain non-standard conditions may prevail. These include higher than normal flow rates, rapidly filling refueller, bridger or road tanker tanks, entering confined spaces, using high pressure jetting and using inert gases. All practical precautions should be taken and work should be carried out under a 'Permit to Work' system based on detailed method statements and risk assessments.

**13.2** Fuel conductivity and the potential for generating static electrical charges at higher flow rates need to be considered. Moving jet fuel at higher than normal flow rates should not present a problem provided that the fuel is conductive (i.e. it has a conductivity level of at least 50 pS/m at the temperature at which it is being handled) and that there are no spark gaps present. Proper bonding of portable equipment used, including any temporary or vehicle tank receiving fuel, should be provided. See Annex B.

**13.3** If the conductivity of the fuel at the temperature at which it is entering the tank is less than 50 pS/m, the fuel is considered to be a static accumulator and velocity restrictions must be imposed. Even with conductive fuel, it is recommended that the velocity should not exceed 5 m/sec until the fill pipe into the tank is completely submerged. See Table B1.

**13.4** Whilst it is generally accepted that the maximum safe velocity, from an electrostatic charge generation point of view, is 7 m/sec for clean, dry and conductive fuel (>50 pS/m), flushed fuel may

**contain impurities such as water droplets and particulates. The presence of such impurities increases the risk of static charge build-up. Therefore, the velocity should be limited to 1 m/sec until the fill pipe is well submerged after which it may be increased to a maximum of 5 m/sec. See Table B1.**

For further information, refer to EI Model Code of Safe Practice Part 21 and other industry accepted publications.

**13.5** If it is necessary to break flanged joints or undertake other modification works on pipe sections that are under impressed current cathodic protection, (for example to remove a valve or fitting to gain entry to the system), either the current should be switched off or a bridging cable should be securely fixed across the points where the gap will be created before removing the valve or fitting.

**13.6** Standard procedures for entering confined spaces should be observed when entering valve chambers and other spaces where there may be an oxygen deficiency. If inspecting a large diameter pipe where even partial entry is contemplated, the pipe should be treated as being a confined space.

**13.7** If using an inert gas, such as nitrogen, a non life-supporting atmosphere will result if the gas is released in an uncontrolled manner. All due precautions should be taken to safeguard personnel involved.

**13.8** The use of personal protective equipment (PPE),

although of vital importance, protects only the user/wearer. Consideration should be given to providing, where necessary, protection to other personnel in the vicinity of the hazard and preparing adequate emergency procedures and provisions.

Measures such as cordoning off the work area, posting warning signs, providing screens against flying debris, adequate fire prevention measures and even the attendance of fire fighters and spill mitigation equipment should be considered as and when necessary.

# 14

## RECORDS

**14.1** Detailed written procedures (method statements) should be prepared to cover any flushing, cleaning and commissioning procedures to be carried out. These should specify areas to be included in the exercise; preparation details such as valve chambers to be opened and/or entered; sections to be worked on; clear sequence of operations to be performed; any limitations to be considered such as time constraints and samples and tests to be carried out prior to handing over the system to the users. A risk assessment should then be undertaken to determine if any further mitigation methods are necessary and these used to prepare the necessary Permit(s)-to-Work.

**14.2** Adequate records to show the carrying out of the operation with results of tests on samples drawn from various sections of the system should be maintained.

**14.3** Consideration should be given to recording the flow rate and velocity obtained in the various parts of

the system. Some companies establish Reynolds Numbers for the various sections flushed. Ideally drawings of the overall system should be annotated and used as a reference to sections of the hydrant and the locations involved in the exercise.

**14.4** Membrane filtration records for each hydrant pit valve sampled during flushing should be established. 'Base line' values should be obtained for samples taken from the downstream side of at least one of the into-hydrant filter vessels and these used for comparison with results obtained from the hydrant risers.

**14.5** Low point sampling records should also be established. Both the initial sample and final sample appearance should be established for each low point involved in the exercise.

**14.6** Examples of flushing, membrane filtration testing and low point sampling records are shown in Annex A.



# 15

## MICROBIOLOGICAL PROBLEMS

**15.1** One cause of 'dirt' in a system is microbiological activity. Whilst comprehensive guidance on this subject is beyond the scope of this publication, if it is not recognised and the appropriate action taken, a serious situation may develop.

**15.2** Micro-organisms are present in air, in water and in fuel. Microbiological activity may involve bacteria, yeasts and moulds. All can proliferate in water associated with fuels.

**15.3** Bacteria can produce biosurfactants that promote the formation of stable hazes and emulsions and encourage particulate dispersions. In addition, they may cause filter/coalescers to 'disarm' and malfunction. These may then act as a secondary breeding ground for microbes and can become festooned with microbial slimes.

**15.4** Most microbes, but particularly moulds, produce organic acids, which can cause corrosion, especially of aluminium and its alloys.

**15.5** Sulphate reducing bacteria (SRB) produce corrosive sulphides, which can dissolve in fuel and so cause problems for the end user. SRB stimulate local corrosion processes by direct sulphide attack on steel surfaces, which may lead to tank plate penetration.

**15.6** Fuel contaminated by microbes, but not sufficient to cause functional problems, may initiate microbial growth in equipment in the distribution chain.

**15.7** It can be seen from the above that strict quality control measures are necessary to prevent an infection of this nature. The single most effective measure is water draining. All of the micro-organisms above require water in which to reproduce. They may feed on nutrients that they find in fuel but they cannot multiply without water.

**15.8** Storage tanks and all other equipment containing fuel should be meticulously drained of water each day, even if the tank or equipment is not to be used that day. Water drawn off should be examined, as discoloured water may be an indication of microbiological activity. Pipework dead ends are a source of contamination unless they can be drained and such draining should be carried out periodically.

**15.9** Fuel samples that also contain free water should be closely examined at the interface. If there is not a clean cut between the water and the fuel, or there are signs of a silvery sheen on the surface of the water and/or particulate entrapped in a water bubble, microbiological activity may be present.

**15.10** Various pieces of field test equipment are available that may be used to confirm the presence of microbes and to monitor levels of contamination in water bottoms or in fuel. Some give an immediate answer; others require a few days to grow a culture. A list of suppliers of test kits is available from the API or EI.

**15.11** The condition of filter/coalescer elements in filter/water separators can be an indicator of a problem of this nature. Any staining, spotting or discolouration of the outer sock may be an indication of the presence of undesirable elements in the fuel. Filter vessels should be drained of water daily, as they can provide a suitable environment for microbe reproduction.

**15.12** Prevention is better than cure and good quality control and housekeeping will nearly always prevent an

infection. Infected systems may require mechanical and chemical treatment. If this becomes necessary, expert assistance should be sought and chemicals should only be used as a final resort and if there is no possibility that they can contaminate the fuels in any way. An infected tank should be thoroughly cleaned and the cause remedied if this is necessary. For instance, a tank bottom may not be draining properly and this needs to be rectified. Hydrant lines that are infected need to be cleaned and properly flushed.

# 16

## CCTV SURVEY

**16.1** Using suitable equipment, Closed-Circuit Television (CCTV) allows for internal inspection of pipelines that could not be inspected in the normal course of events.

**16.2** Only equipment that is certified for use in hazardous areas should be used in lines containing fuel or those that have contained fuel and may still constitute a hazardous environment. Its materials of construction should be suitable for use in aviation fuel.

**16.3** The camera should have a resolution sufficient to show the actual conditions in real time and be equipped with adequate lighting. The cable should be strong enough to be able to push the camera along the line but flexible enough to be inserted down a riser and allow bending to make the turn into the hydrant line.

**16.4** Viewing equipment should allow live monitoring of the operation and allow the video feed to be recorded

for later playback and examination. The equipment should allow the entry point, time, date and distance run inside the line to be displayed both on the live picture and on the recording.

**16.5** Care is needed to ensure that not only the camera but also the attached cables will not contaminate the fuel.

**16.6** It is prudent to survey small sections at a time. A first pass survey to see the general condition, followed by a more detailed survey if found necessary is recommended.

**16.7** Be prepared to take action on what is found and assess its effect on the hydrant system. Take care not to disturb sediment and debris unless equipped to deal with it immediately, especially if surveying a live system during a shutdown period such as at night.



# ANNEX A

This Annex contains examples of the following forms:

- Flushing Record.
- Membrane Filtration Sample Record.
- Low Point Sampling Record.
- Record Form.

Example Flushing Record

Date: .....

Source	Time Start	Time End	Flow Rate (m <sup>3</sup> /hr)	Qty Flushed (m <sup>3</sup> )	Section Flushed	Observations	Signature

Example Membrane Filtration Sampling Record

Date: .....

Location	Time	Type Col / Grav.	Membrane No.	Qty Flushed (L)	Result	Pit Valve Closure(secs)	Signature

Example Low Point Sampling Record

Date: .....

LP No.	Time	Qty Flushed (L)	Appearance Initial Sample	Appearance Final sample	Signature

**Example Record Form**

<b>Flushing Record</b>	<b>Millipore Filter Membrane Record</b>	<b>Low Point Sampling Record</b>
Date	Date	Date
Source	Location	LP No.
Start time	Time	Time
End time	Type (Colour or Gravimetric)	Quantity Flushed (L)
Flow rate (m <sup>3</sup> /hr)	Membrane no.	Appearance - Initial Sample
Quantity flushed (m <sup>3</sup> )	Quantity flushed (litres)	Appearance - Final Sample
Section flushed	Result	Signature
Observations	Pit valve closure (secs)	
Signature	Signature	



## ANNEX B

To control the build-up of static electricity, there are times when fuel flow velocity requires limiting to safe levels. Table B1 defines the various conditions that may be encountered in the operation of a hydrant system and the maximum recommended velocity to ensure a safe condition.

Fuel is considered to be a static accumulator when its electrical conductivity is less than 50 pS/m. At levels

of 50 pS/m and above, it may be considered as conductive but only if the tanks, vehicle, equipment etc. are correctly earthed and bonded.

Due attention to slow filling of empty filters until the vessel is full is essential as rapid filling has been the cause of internal fire in the vessel. Air eliminators should be properly checked and maintained.

**Table B1: Table of safe velocities**

Condition	Safe velocity, m/sec	Remarks
Fuel with conductivity of less than 50 pS/m (low conductivity) or where the conductivity is not known	1 m/sec initially then increase to 5 m/sec max.	The lower velocity should be maintained until the fill pipe or nozzle is well submerged, after which velocity may be increased to a maximum of 5 m/sec.
Clean, dry fuel with a known conductivity of 50 pS/m and above at the temperature at which it is being handled	7 m/sec	This velocity is often exceeded in refuelling of aircraft but should be regarded as a maximum in normal hydrant operations. However when filling a tank a slow fill shall be maintained as above until the inlet is well submerged.
Fuel which may contain water droplets and particulate	Treat as a low conductivity fuel	

Source: EI Model Code of Safe Practice, Part 21, *Guidelines for the control of hazards arising from static electricity*.



# ANNEX C

Note that the comma used in these tables denotes a decimal place.

**Table C1: Average velocities in pipes at given flow rates**

Nominal pipe diameter (in.)	Flow rate (m <sup>3</sup> /hr)	Average velocity (m/sec)
20	1 500	2,2
20	1 200	1,8
20	750	1,11
20	654	1,0
18	1 500	2,8
18	1 200	2,3
18	750	1,4
18	535	1,0
12	665	2,5
12	510	2,0
12	255	1,0
6	240	3,5

**Table C2: Minimum flow velocities and flow rates for alumina particles. See 6.1.1.**

Pipe Diameter (in.)	Particle size 10 µm		Particle size 100 µm		Particle size: 1 000 µm	
	Flow velocity (m/sec)	Flow rate (m <sup>3</sup> /min)	Flow velocity (m/sec)	Flow rate (m <sup>3</sup> /min)	Flow velocity (m/sec)	Flow rate (m <sup>3</sup> /min)
2	0,83	0,10	1,26	0,15	1,92	0,23
4	1,14	0,54	1,73	0,81	2,63	1,24
6	1,37	1,45	2,08	2,20	3,16	3,35
8	1,56	2,94	2,37	4,46	3,60	6,78
12	1,87	7,94	2,85	12,07	4,33	18,34
16	2,13	16,09	3,24	24,45	4,93	37,17
20	2,36	27,82	3,59	42,29	5,46	64,28
24	2,57	43,53	3,90	66,16	5,93	100,56
28	2,75	63,55	4,18	96,59	6,36	146,80
32	2,92	88,19	4,44	134,05	6,76	203,74
36	3,09	117,60	4,69	178,98	7,13	272,04
40	3,24	145,51	4,92	231,81	7,48	352,32

**Table C3: Determination of velocity**

Nominal Diameter		Outside Diameter	Wall Thickness	Nominal Bore	Flow Area
in.	mm	mm	mm	mm	m <sup>2</sup>
1	25	33,4	3,38	26,64	0,0006
1,5	40	48,3	3,68	40,94	0,0013
2	50	60,3	3,91	52,48	0,0022
3	75	88,9	5,49	77,92	0,0048
4	100	114,3	6,02	102,26	0,0082
6	150	168,3	7,11	154,08	0,0186
8	200	219,1	8,18	202,74	0,0323
10	250	273,0	9,27	254,46	0,0509
12	300	323,9	9,52	304,86	0,0730
14	350	355,6	9,52	336,56	0,0890
16	400	406,4	9,52	387,36	0,1178
18	450	457,2	9,52	438,16	0,1508
20	500	508,0	9,52	488,96	0,1878
22	550	558,8	9,52	539,76	0,2288
24	600	609,6	9,52	590,56	0,2739
26	650	660,4	9,52	641,36	0,3231
28	700	711,2	9,52	692,16	0,3763
30	750	762,0	9,52	742,96	0,4335
32	800	812,8	9,52	793,76	0,4948
34	850	863,6	9,52	844,56	0,5602
36	900	914,4	9,52	895,36	0,6296

**To calculate the average velocity in m/sec:**

Take the flow rate in m<sup>3</sup>/hr, divide by 3 600 and divide by the Flow Area in Table C3.

For example: 20 in. @ 1 500 m<sup>3</sup>/hr =  $1\,500 / 3\,600 / 0,1878 = 2,22$  m/sec.





1220 L Street Northwest  
Washington, D.C. 20005-4070  
202-682-8000

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## **Energy Institute**

61 New Cavendish Street  
London W1G 7AR, UK

t: +44 (0) 20 7467 7157

f: +44 (0) 20 7255 1472

e: **[pubs@energyinst.org.uk](mailto:pubs@energyinst.org.uk)**

**[www.energyinst.org.uk](http://www.energyinst.org.uk)**

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