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IATA Super-absorbent Polymer (SAP) Special Interest Group – Data summary and proposed roadmap

On 14 November 2017 the IATA SAP Special Interest Group released the statement shown in Appendix A. This paper provides a summary of the information on which the statement is based and the roadmap that is proposed by the group for adoption by all stakeholders.

Background

A Special Interest Group was established at the May 2014 IATA Aviation Fuel Forum to investigate whether there was a correlation between fuel control unit (FCU) and/or hydro-mechanical unit (HMU) operability issues and the presence of super-absorbent polymer (SAP) and to determine whether there was a causal link.

Participants in the group since then have included representatives from airframe and engine OEMs (Airbus, Boeing, GE, Honeywell, Pratt & Whitney, Rolls-Royce), aviation fuel filter manufacturers (FAUDI Aviation, PECOFacet, Parker Velcon), airlines (Air Berlin, American Airlines, Austrian Airlines, British Airways, Delta Air Lines, KLM, Lufthansa, Swiss International, Thomson Airways, South African Airways, United Airlines) airline associations (A4A, IATA) and the Energy Institute (including representatives from Shell Aviation, Shell Global Solutions and VITOL).

Data summary – aircraft events

The Special Interest Group has been made aware of eight aircraft events where SAP has been confirmed by those involved as having been the cause of operability issues for the aircraft operator. Details of the events are shown in Table 1.

Table 1: Aircraft events

Date	Departure Location*	Aircraft type	Engine type	Issue
May 2017	Rangoon (RGN)	B757	RB211-535E4	Series of uncommanded thrust variations, failed starts and long shutdown times on one engine, then a dual engine failed start.
June 2016	Dhaka (DAC)	B777	GE90-115B	Aborted take-off due to ENG FAIL message and high vibration.
Dec 2015	Lagos (LOS)	A330	Trent 700	Engine surge and engine pressure ratio fluctuations in flight.
Mar 2015	Lagos (LOS)	A330	Trent 700	Engine anomalies and then failed start found during standard pre-start checks on the ground.
Oct 2014	Bogota (BOG)	3x A330	Trent 700	Three aircraft impacted. Each experienced engine control system anomalies and failed starts during standard pre-start checks on the ground.
Mar 2014	Port Harcourt (PHC)	A330	Trent 700	Engine anomalies and failed start found during standard pre-start checks on the ground.
Dec 2010	Lisbon (LIS)	B777	GE90-94B	One engine sustained heavy damage in flight (high vibration during climb) and was shutdown. The sister engine (on same aircraft) also sustained heavy damage on the next flight (same issues) and was shutdown.
Apr 2010	Surabaya (SUB)	A330	Trent 700	Dual engine loss of thrust control.

*Special Interest Group participants have been involved in reviewing some of the ground handling facilities at the locations cited in Table 1. In only one case could the cause of SAP migration from filter monitor elements be explained. At all other locations it was not possible to identify any significant fuel handling irregularities that could offer an explanation of SAP migration mechanisms.

Further, two locations did not use filter monitors when fuelling the flight in question; the Special Interest Group believes this supports a conclusion that SAP may accumulate in airframe/engine fuel systems during multiple flights from multiple locations.

Details of two particularly well researched incidents have been shared within the Special Interest Group, showing cause and effect in relation to the presence of SAP in hydro-mechanical units. **OEMs consider the presence of SAP in fuel to be a potential flight safety issue and cannot endorse a level of SAP that is acceptable in fuel.**

Data summary – potential mechanisms for SAP migration from filter monitor elements
It is known that element manufacturing processes can generate SAP particles that may be flushed downstream of elements when exposed to fuel flow for the first time. Filter manufacturers have implemented measures to minimise this.

EI 1583 *Laboratory tests and minimum performance levels for aviation fuel filter monitors* includes the mandatory requirement that during two of the first-article/qualification tests, all fuel that passes through the filter monitor element is also passed through a bag filter, which is then analysed for the presence of SAP. The 7th edition of 1583 has introduced the mandatory requirement that no SAP shall be detectable in any of the effluent during those two tests.

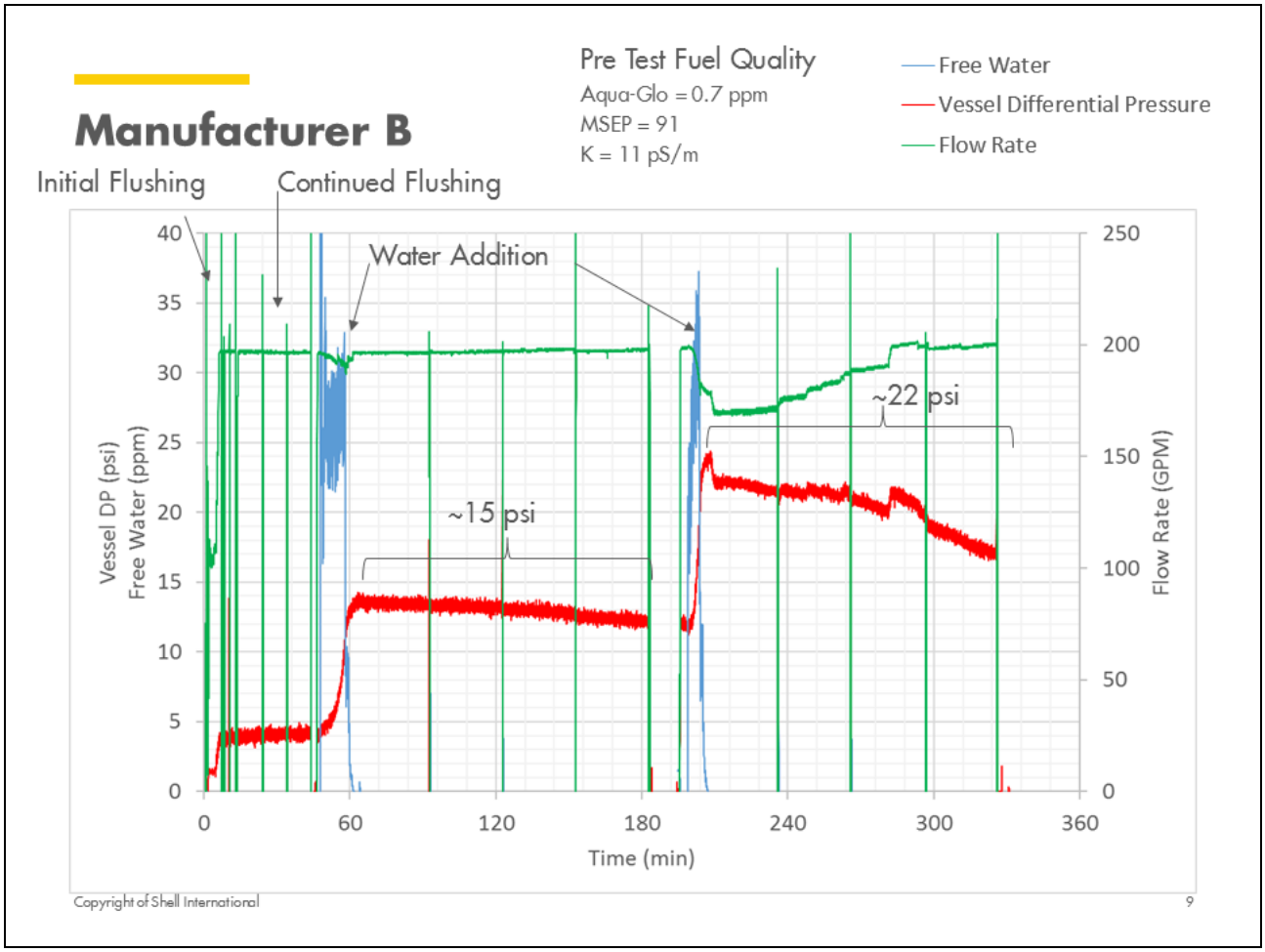
Assessing the presence of manufacturing debris cannot be undertaken on every production element, hence manufacturer recommendations to flush filter monitor systems during their commissioning.

Filter monitor manufacturers have confirmed that it is not possible to guarantee that no SAP will pass downstream of filter monitor elements when in service.

Data summary – confirmation of SAP extrusion from filter monitor elements at elevated differential pressure
Work was undertaken by Shell Global Solutions utilising the filtration qualification test facility at Southwest Research Institute and a hydrant cart as the filter 'test bench'. Details of the equipment set-up and testing can be summarised as follows:

- The hydrant cart was connected to the qualification test rig and the fuel directed via a standard hydrant pit valve. After passing through the filter monitor vessel the fuel was returned to the qualification rig via a standard aircraft refuelling nozzle, incorporating a 100 mesh hose end strainer.
- The filter monitor vessel housed ten 2 in. x 20 in. long filter elements and was operated between 70-100% rated flow (up to 200 GPM).
- All fuel flowing through the hydrant cart was passed through bag filters to capture SAP downstream of the unit. The bag filters were analysed for the presence of SAP following the method described in EI 1583.
- Each set of elements was exposed to the following test regime (all of which is within the normal operating envelope), shown graphically in Figure 1:
  - an initial 5-minute duration exposure to fuel flow with three deadman-induced stop/starts;
  - a further 35-minute period of fuel flow with three deadman-induced stop/starts;
  - an injection of 25 ppm water to increase the differential pressure across the filter monitor vessel to c15 psi and fuel flow for 2 hours, with four deadman-induced stop/starts;
  - a further injection of free water (or in one case an increase in flow rate, still below rated flow) to increase the differential pressure across the filter monitor vessel to c22 psi and fuel flow for 2 hours, with four deadman-induced stop/starts;
- Bag filters were removed and analysed for the presence of SAP after each step in the test regime.

Figure 1 – Graphic representation of test regime that ten 2 in. filter monitor elements were exposed to (each commercially available model tested in separately)



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Results showed that:

- SAP from initial flushing of new elements with fuel produced levels of SAP around the limit of detection of the method, which was mainly caught in the 100 mesh hose end strainer.
- There was gross SAP migration from the elements from Manufacturer A at vessel differential pressures of 15 psi and 22 psi (c4 mg SAP/in and c11 mg SAP/in respectively), see Figure 2 and 3.
- Elements from Manufacturers B and C showed SAP migration increasing to above the limit of detection of the method at 15 psi and 22 psi, see Figure 4 (noting different Y-axis scale to Figure 2).

These test data demonstrate the likelihood that all filter monitor elements, including those qualified to EI 1583 (6th or 7th editions), may shed some SAP when operating normally. The study demonstrates a previously unknown vulnerability of filter monitor technology at elevated differential pressure (caused by the absorption of free water from fuel and extrusion of SAP as a water-activated gel).

EI 1583 7th edition does not include testing to detect SAP downstream of elements at elevated differential pressure (caused by free water injection in flowing fuel) with multiple stop/starts. **The EI will not be maintaining or updating EI 1583 beyond its current 7th edition and will withdraw the specification by no later than 31st December 2020.** Until then, only modifications to existing qualified elements that reduce the level of SAP migration will be eligible for an EI qualification test witness.

Figure 2 – Quantification of SAP migration from the elements from Manufacturer A

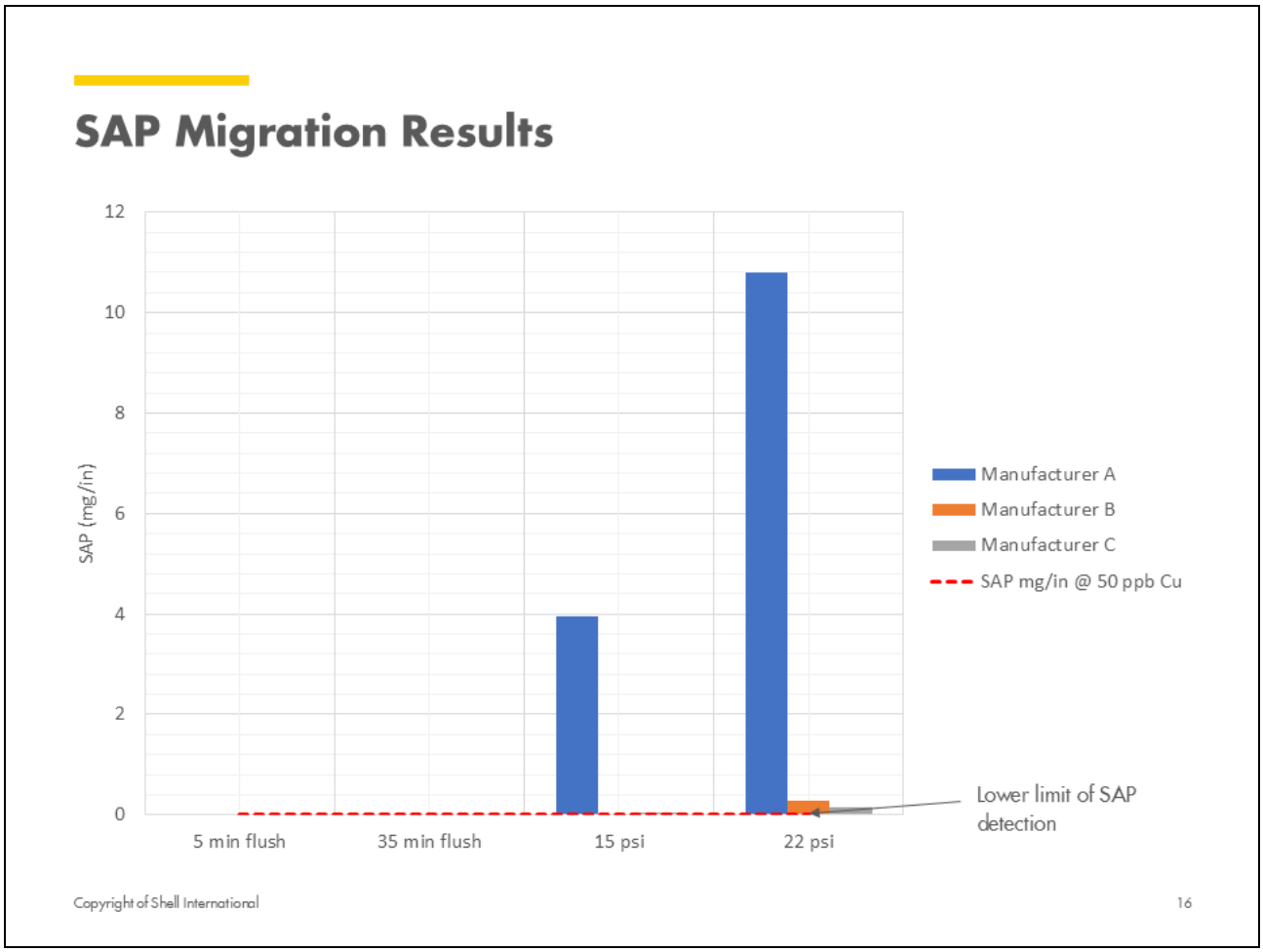

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Figure 3 – Visual indication of quantity of SAP migration from the elements from Manufacturer A (SAP particles/gel dyed blue, collected in bag filters from test rig)

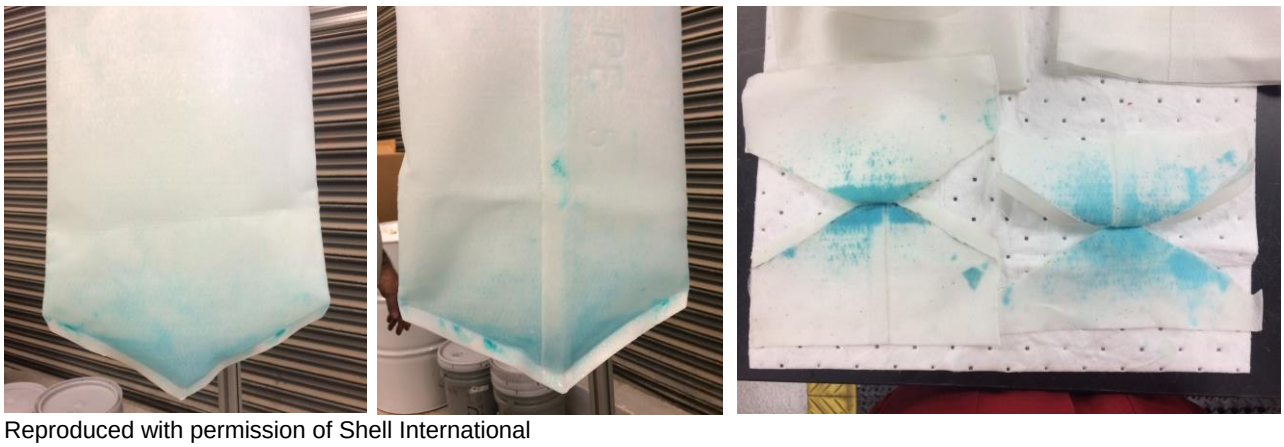

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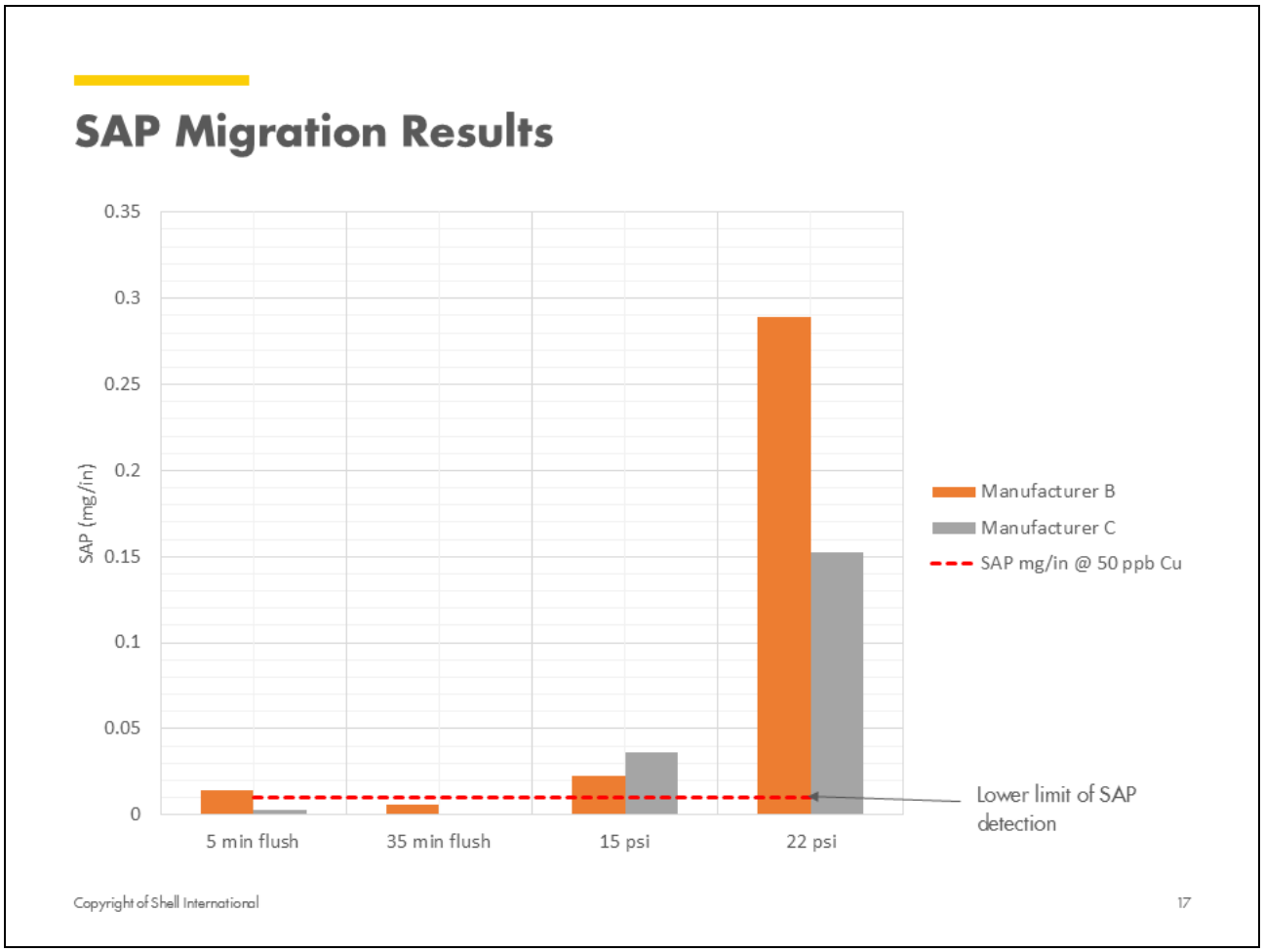
Figure 4 – Quantification of SAP migration from the elements from Manufacturers B and C



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Special Interest Group Conclusions

- There have been eight aircraft events where SAP has been confirmed by those involved as having been the cause of operability issues for the aircraft operator.
- Engine and airframe OEMs consider the presence of SAP in fuel to be a potential flight safety issue and cannot endorse a level of SAP that is acceptable in fuel.
- Filter monitor manufacturers and SAP manufacturers have confirmed that it is not possible to guarantee that no SAP will pass downstream of filter monitor elements when in service.
- Testing of 50 mm (2 in.) nominal diameter filter monitor elements (all three commercially available models) has shown that they can release super-absorbent polymer, particularly at differential pressures above 15 psi (caused by water injection into fuel; at or below their rated flow).

It is the collective opinion of the Special Interest Group that the continued use of filter monitor filtration systems in aviation fuel handling is incapable of reliably meeting the aircraft and engine operating requirements.

It is the position of the Special Interest Group that filter monitors shall be phased out of all aviation fuel handling systems.

Roadmap

The following proposals are offered by the Special Interest Group for industry adoption:

Proposed industry actions for immediate implementation

1. Disseminate warning message to all users of Filter Monitors (including via IATA Portal, A4A, EI and JIG)
2. Present a summary position and proposed roadmap to a following Working Group who will be tasked with implementing the recommendations of this Special Interest Group.
3. Filter monitor users to replace all elements operating at or above 15 psi at maximum achievable flow, regardless of the length of time they have been in service or their fuel throughput.
4. Filter monitor users to limit all filter monitor operational differential pressure to a maximum of 15 psi
5. Filter monitor users to clean hose end strainers as part of filter monitor commissioning and routine hose end strainer checks
6. Filter monitor users to implement EI 1583 7th edition.
7. Industry stakeholders to scope out EI 1599 dirt defence filter and EI 1588 water barrier filter + sensor ruggedness trial protocol and timing

Proposals for 0-6 month timeframe

1. Replace all 60 mesh hose end strainers in use with filter monitor systems to 100 mesh.
2. Reset all Filter Monitor DP switches to 15 psi max
3. EI to finalise EI 1588 specification for water barrier filters
4. Gain Industry acceptance that assurance of 30ppm water is the limit for into-wing, regardless of technology. Sensor measurement rather than water removal is acceptable.
5. Start a 6 month(?) trial of EI 1599 / EI 1588 elements in conjunction with sensor technology (multiple locations and climates).
6. Filter Manufacturers to demonstrate 6” diameter EI 1583 elements are not a concern under water wetted conditions.

Proposals for 6-12 month timeframe

1. Implement DP switches on all Filter Monitors regardless of truck or hydrant (set to 15 psi)
   - Consideration needs to be given to ensuring global reach.
2. New filtration technology maturity and performance assessment.
   - Includes any new specification development requirements, initial qualification witnessing etc.

Proposals for 12-18 month timeframe

1. Report out on EI 1599 and EI 1588 field trials
2. Agree on all acceptable future filtration options, impact on vessels and vehicles
3. Roadmap is to be reassessed if simple retrofit elements are not feasible or acceptable.

Proposals for 18-36 month timeframe

1. All vehicles retro-fitted with non-EI1583 elements (and sensors) if existing vessels can be used.
   - Consideration needs to be given to ensuring global reach.

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Appendix A - IATA SAP Special Interest Group communication to all users of filter monitor filtration systems

Representatives of airlines, engine and airframe manufacturers, aviation fuel filter manufacturers and the EI have been meeting as an IATA Special Interest Group to share information relating to the presence of super-absorbent polymer (SAP) in engine/fuel system components.

The Special Interest Group is aware of eight incidents since April 2010, where the presence of SAP in engine/airframe fuel system components has been confirmed by those involved. More than one engine manufacturer, airframe manufacturer and location have been affected.

The SAP involved in these events can only come from filter monitors, qualified to the industry specification, EI 1583.

It has not been possible for these events to be investigated sufficiently to explain SAP migration mechanisms. To date, the Special Interest Group has been unable to identify any significant fuel handling irregularities at the locations implicated in the events. However, work undertaken by the Special Interest Group has identified SAP migration mechanisms within normal operating parameters, that were previously unknown.

Engine and airframe OEMs have not identified a level of SAP that is acceptable in aviation fuel. Filter monitor manufacturers and SAP manufacturers have confirmed that it is not possible to guarantee that no SAP will pass downstream of filter monitor elements when in service.

It is the collective opinion of the Special Interest Group that the continued use of filter monitor filtration systems in aviation fuel handling is incapable of reliably meeting the aircraft and engine operating requirements.

It is the position of the Special Interest Group that filter monitors shall be phased out of all aviation fuel handling systems.

The Special Interest Group activity will be concluded with the issue of a data summary and proposed roadmap for adoption by the industry.