2015 CRC Aviation Meetings
Particle Count Limits
Recommendation for Aviation Fuel

Joel Schmitigal
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<table>
<thead>
<tr>
<th>a REPORT</th>
<th>b ABSTRACT</th>
<th>c THIS PAGE</th>
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17. LIMITATION OF ABSTRACT

Same as Report (SAR)

18. NUMBER OF PAGES

22

19a. NAME OF RESPONSIBLE PERSON
Bagram Airfield

photo courtesy of Army Petroleum Center
Current Fuel Contamination Monitoring Methods

- ASTM D2276 – Particulate Contamination in Aviation Fuel by Line Sampling
  - gravimetric limit 1.0 mg/L (MIL-STD-3004, MIL-DTL-83133)
    - color rating > 4 on any color scale (FM 10-67-1)

- ASTM D5452 – Particulate Contamination in Aviation Fuels by Laboratory Filtration
  - gravimetric limit 1.0 mg/L (MIL-STD-3004)

- ASTM D3240 – Undissolved Water in Aviation Turbine Fuels
  - 10 PPM (MIL-STD-3004, ATP 4-43)

- ASTM D4176 – Free Water and Particulate Contamination in Distillate Fuels (Visual Inspection Procedures)
  - Clear and Bright
• Drawbacks:
  – Operator subjectivity (ASTM D2276 color comparison)
  – Lack of detail (ASTM D2276 gravimetric)
  – Large sample volumes (500mL – 5 Liters)
  – Potential contamination
  – Time consuming
MIL-DTL-83133, MIL-DTL-5624, and DEF STAN 91-91 include a requirement to only report particle counting measurements.

- IP 564 – Parker ACM20
- IP 565/ASTM D7619 – Stanhope-Seta AvCount
- IP 577 – Pamas S40
Particle Counter Methodology

- Particle counts are taken utilizing calibration methodologies and standardized cleanliness code ratings
  - ISO 11171
  - ISO 4406

- Particle Count ISO 4406 code 19/17/14/13 limits of 4\(\mu\)m (c)/6\(\mu\)m (c)/14\(\mu\)m (c)/30\(\mu\)m (c)

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## Proposed Limits

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* 4μm (c)/ 6μm (c)/ 14μm (c)/ 30μm (c)
Army Petroleum Laboratory Sampling effort

- September 2012 – March 2015
- ASTM D5452 Laboratory filtration
- IP 564 – Parker ACM20 (59 samples only)
- IP 565/ASTM D7619 – Stanhope-Seta AvCount
- 1414 samples analyzed
1414 samples analyzed
1209 samples passed both gravimetric and particle count

205 samples failed particle count or gravimetric
  161 out of 205 samples failed particle count
  135 out of 205 samples failed gravimetric
  91 out of 205 samples failed both particle count and gravimetric

44 False negatives (fails gravimetric, passes particle count)
70 False positives (fails particle count, passes gravimetric)
44 False negatives (fails gravimetric, passes particle count)

ASTM D5452 repeatability (r) 0.0-0.6 mg/L
- \[ r = 0.415x^{0.5} \]
- \[ r \text{ at } 1.0 \text{ mg/L} = 0.415 \text{ mg/L} \]
  - repeatability formula based on 5 liter sample

33 samples may be lower than 1.0 mg/L based on repeatability calculations.

11 samples have high gravimetric reading that is not accounted for by particle count data.

Particles not seen by particle counter
- Particle greater than 70\(\mu\)m (c) (Stanhope Seta) - 200\(\mu\)m (c) (Parker)
- Particles less than 4\(\mu\)m (c)
70 False positives (fails particle count, passes gravimetric)

- 28 samples gravimetric data may be greater than 1.0 mg/L based on repeatability calculations.
- 2 diesel fuels high in 4μm (c) channel
- 66 aviation fuels high in 6μm (c), 14μm (c), and/or 30μm (c) channels indicating free water contamination
- Analyzed to determine if free water contributed to the high particle counts
  - 6 of 66 fuel samples confirmed >5 ppm free water contamination
  - 8 of 66 fuel samples with 1-5 ppm free water
  - 25 of 66 fuel samples confirmed to be absent of free water
  - 27 of 66 fuel samples untested
110 samples analyzed
105 samples passed both gravimetric and particle count
3 samples failed particle count
3 samples failed gravimetric
1 samples failed both particle count and gravimetric
2 False positives (high particle count not correlated to gravimetric)
2 False negatives (high gravimetric not correlated to particle count)
2 False negatives (fails gravimetric, passes particle count)
- 1 samples may be lower than 1.0 mg/L based on repeatability calculations.
- 1 sample had high gravimetric reading that is not accounted for by particle count data.

2 False positives (fails particle count, passes gravimetric)
- 1 aviation fuels high in 14μm (c) channels indicating free water contamination
Conclusions and Further Testing

- Proposed limits for particle counting in agreement with existing fuel specification limits 92% of the time (96% USAF data).

- Free water measurements need to be taken to account for false positives.

- Duplicate gravimetric measurements need to be taken to determine if poor measurement repeatability accounts for false negatives.

- Photograph failed gravimetric filter pads for visual inspection.
Recommendations

- Tri-Service POL Technical Steering Committee recommends the 19/17/14/13 limits for the 4µm (c)/ 6µm (c)/ 14µm (c)/ 30µm (c) size channels as an acceptable method for particulate matter with the stipulation (requirement) to perform follow on testing for particulate matter via ASTM D5452 and water via ASTM D3240 for product exceeding the limits.
• Backup Slides
18/16/13 limits and 1.0 mg/L

- 1414 samples analyzed
- 982 samples passed both gravimetric and particle count

- 432 samples failed particle count or gravimetric
  - 407 out of 432 samples failed particle count
  - 135 out of 432 samples failed gravimetric
  - 110 out of 432 samples failed both particle count and gravimetric

- 25 False negatives (fails gravimetric, passes particle count)
  - 43% reduction

- 297 False positives (fails particle count, passes gravimetric)
  - 324% increase
1414 samples analyzed
806 samples passed both gravimetric and particle count

608 samples failed particle count or gravimetric
- 407 out of 608 samples failed particle count
- 459 out of 608 samples failed gravimetric
- 258 out of 608 samples failed both particle count and gravimetric

201 False negatives (fails gravimetric, passes particle count)

149 False positives (fails particle count, passes gravimetric)
201 False negatives (fails gravimetric, passes particle count)

ASTM D5452 repeatability (r) 0.0-0.6 mg/L
- \[ r = 0.415x^{0.5} \]
- \[ r \text{ at } 0.5 \text{ mg/L} = 0.293 \text{ mg/L} \]
  - repeatability formula based on 5 liter sample

165 samples may be lower than 0.5 mg/L based on repeatability calculations.

36 samples have high gravimetric reading that is not accounted for by particle count data.

Particles not seen by particle counter
- Particle greater than 70μm (c) (Stanhope Seta) - 200μm (c) (Parker)
- Particles less than 4μm (c)
149 False positives (fails particle count, passes gravimetric)

- 91 samples gravimetric data may be greater than 0.5 mg/L based on repeatability calculations.
- 5 diesel fuels
• Low levels of free water can have a large impact in particle count readings, this may account for an unknown number of the false positive readings.