U.S. ARMY TANK AUTOMOTIVE RESEARCH, DEVELOPMENT AND ENGINEERING CENTER

2015 IASH Particle Count Limits Recommendation for Aviation Fuel

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Bagram Airfield

photo courtesy of Army Petroleum Center

Contamination

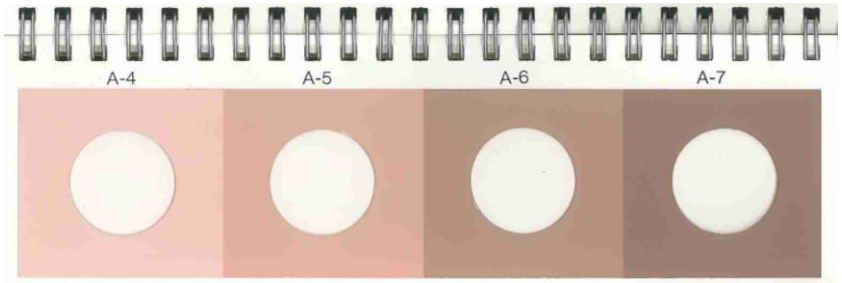
photos courtesy of Army Petroleum Center

Current Fuel Contamination Monitoring Methods

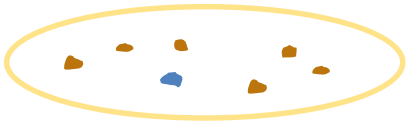
- ASTM D2276 – Particulate Contamination in Aviation Fuel by Line Sampling
  - gravimetric limit 1.0 mg/L (MIL-STD-3004, MIL-DTL-83133)
    - JP-4 and JP-5 (MIL-T-5624G - 5 NOV 1965)
  - color rating > 4 on any color scale (FM 10-67-1)
- ASTM D5452 – Particulate Contamination in Aviation Fuels by Laboratory 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

Current Fuel Contamination Monitoring Methods

- Drawbacks:
  - Operator subjectivity (ASTM D2276 color comparison)



  - Lack of detail (ASTM D2276 gravimetric)



  - Large sample volumes (500mL – 5 Liters)
  - Potential contamination
  - Time consuming

Electronic Contamination Monitoring

- Intent of DoD to publish particle count limit in MIL-STD-3004 for aviation turbine fuel and 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 4µm (c) /6µm (c)/14µm (c)/30µm (c)

Number of particles per millilitre		Scale number
More than	Up to and including	
2 500 000		>28
1 300 000	2 500 000	28
640 000	1 300 000	27
320 000	640 000	26
160 000	320 000	25
80 000	160 000	24
40 000	80 000	23
20 000	40 000	22
10 000	20 000	21
5 000	10 000	20
2 500	5 000	19
1 300	2 500	18
640	1 300	17
320	640	16
160	320	15
80	160	14
40	80	13
20	40	12
10	20	11
5	10	10
2,5	5	9
1,3	2,5	8
0,64	1,3	7
0,32	0,64	6
0,16	0,32	5
0,08	0,16	4
0,04	0,08	3
0,02	0,04	2
0,01	0,02	1
0,00	0,01	0

Proposed Limits

	Receipt	Vehicle Fuel Tank	Fuel Injector
Aviation Fuel			
DEF (AUST) 5695B		18/16/13	
Parker	18/16/13	14/10/7	
Pamas / Parker / Particle Solutions	19/17/12		
U.S. DOD	19/17/14/13*		
Diesel Fuel			
World Wide Fuel Charter 5th		18/16/13	
DEF (AUST) 5695B		18/16/13	
Caterpillar		18/16/13	
Detroit Diesel		18/16/13	
MTU		18/17/14	
Bosch/Cummins		18/16/13	
Donaldson	22/21/18	14/13/11	12/9/6
Pall	17/15/12	15/14/11	12/9/6 11/8/7

* 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
- 1614 samples analyzed

Army Petroleum Laboratory Sampling effort

- 1614 samples analyzed
- 1376 samples passed both gravimetric and particle count

- 238 samples failed particle count or gravimetric
  - 188 out of 238 samples failed particle count
  - 157 out of 238 samples failed gravimetric
  - 107 out of 238 samples failed both particle count and gravimetric

- 50 False negatives (fails gravimetric, passes particle count)

- 81 False positives (fails particle count, passes gravimetric)

Army Petroleum Laboratory Sampling effort

- 50 False negatives (fails gravimetric, passes particle count)
- ASTM D5452 repeatability (r) 0.0-0.6 mg/L
  - $r = 0.415x^{0.5}$
  - r at 1.0 mg/L = 0.415 mg/L
    - repeatability formula based on 5 liter sample
- 36 samples may be lower than 1.0 mg/L based on repeatability calculations.
- 14 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)

Army Petroleum Laboratory Sampling effort

- 81 False positives (fails particle count, passes gravimetric)
  - 36 samples gravimetric data may be greater than 1.0 mg/L based on repeatability calculations.
  - 2 diesel fuels high in 4µm (c) channel
  - 78 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 78 fuel samples confirmed >5 ppm free water contamination
    - 9 of 78 fuel samples with 1-5 ppm free water
    - 35 of 78 fuel samples confirmed to be absent of free water
    - 27 of 78 fuel samples untested

Air Force Petroleum Agency Sampling effort

- 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)

Air Force Petroleum Agency Sampling effort

- 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

Valero Benicia Refinery MIL-DTL-83133H

- 53 samples analyzed
- 49 samples passed both gravimetric and particle count

- 4 samples failed particle count
- 0 samples failed gravimetric
- 0 samples failed both particle count and gravimetric

- 4 False positives (high particle count not correlated to gravimetric)
- 0 False negatives (high gravimetric not correlated to particle count)

Valero Benicia Refinery MIL-DTL-83133H

- 4 False positives (fails particle count, passes gravimetric)
  - 1 sample had a gravimetric measurement of 0.8 mg/L which may be greater than 1.0 mg/L based on repeatability calculations.
  - All 4 fuels where high in 6µm (c),14µm (c), and/or 30µm (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

- Intent of DoD to publish particle count limit of 19/17/14/13 for the 4µm (c)/ 6µm (c)/ 14µm (c)/ 30µm (c) size channels in MIL-STD-3004 for aviation turbine fuel and MIL-DTL-83133 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.

- USA and USAF to start incorporating particle count values in samples submitted from field units for testing.

- Backup Slides

18/16/13 limits and 1.0 mg/L

- 1614 samples analyzed
- 1105 samples passed both gravimetric and particle count

- 509 samples failed particle count or gravimetric
  - 482 out of 509 samples failed particle count
  - 157 out of 509 samples failed gravimetric
  - 130 out of 509 samples failed both particle count and gravimetric

- 27 False negatives (fails gravimetric, passes particle count)
  - 46% reduction

- 352 False positives (fails particle count, passes gravimetric)
  - 335% increase

18/16/13 limits & 0.5 mg/L

- 1614 samples analyzed
- 865 samples passed both gravimetric and particle count

- 727 samples failed particle count or gravimetric
  - 482 out of 727 samples failed particle count
  - 559 out of 727 samples failed gravimetric
  - 314 out of 727 samples failed both particle count and gravimetric

- 245 False negatives (fails gravimetric, passes particle count)

- 168 False positives (fails particle count, passes gravimetric)

18/16/13 limits & 0.5 mg/L

- 245 False negatives (fails gravimetric, passes particle count)
- ASTM D5452 repeatability (r) 0.0-0.6 mg/L
  - $r = 0.415x^{0.5}$
  - r at 0.5 mg/L = 0.293 mg/L
    - repeatability formula based on 5 liter sample
- 205 samples may be lower than 0.5 mg/L based on repeatability calculations.
- 40 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)

18/16/13 limits & 0.5 mg/L

- 168 False positives (fails particle count, passes gravimetric)
  - 103 samples gravimetric data may be greater than 0.5 mg/L based on repeatability calculations.
  - 5 diesel fuels

18/16/13 discussion

- 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.