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Army's Evaluation of Aviation Fuel Contaminants Using Electronic Sensors

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14. ABSTRACT
This publication primarily applies to electronic sensors that could be used on mobile into-plane fuelling equipment, in conjunction with filtration equipment. In addition to the design and functional requirements that apply to every sensor produced by a manufacturer, it also includes standardized laboratory testing protocols for the ?first article testing? of a make/model/version of a sensor. These cover performance verification in response to dirt and free water contamination challenges, testing of mechanical integrity in response to pressure and material compatibility.

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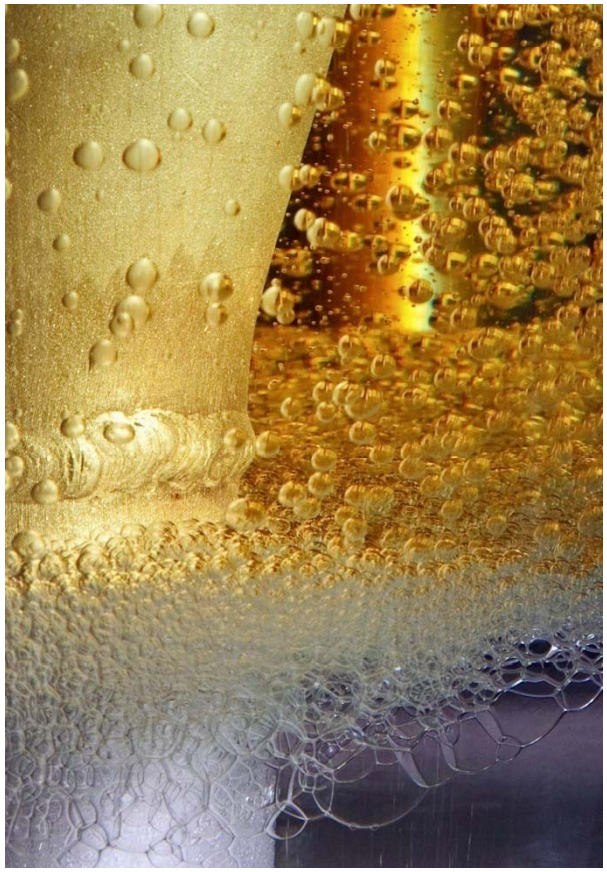
Roadmap

- History
- Industry looking for a better way to determine fuel cleanliness
- Energy Institute (EI) documentation
- Army data review
  - Using a modified EI 1598 protocol
  - EI 1581 testing incorporating electronic sensor analysis
- Proposed limits
- Summary
- Acknowledgements



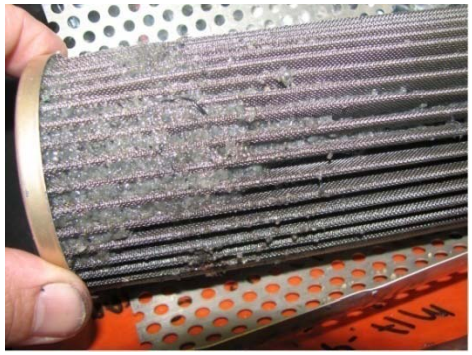
Electronic Sensor History

- Particle counting is not a new science
- Hydraulic industry has utilized this technology for decades and created a mature process
- Hydraulic industry has developed recognized calibration methodologies and standardized cleanliness code ratings
  - ISO 11171
  - ISO 4406
- Turbidity/photometers used in beer/wine industry
- Challenge – Being able to determine both particulate and water contamination

ISO/Range Code	Min. particles /mL	Max particles /mL
1	0	0.02
2	0.02	0.04
3	0.04	0.08
4	0.08	0.15
5	0.15	0.3
6	0.3	0.6
7	0.6	1.3
8	1.3	2.5
9	2.5	5
10	5	10
11	10	20
12	20	40
13	40	80
14	80	160
15	160	320
16	320	640
17	640	1,300
18	1,300	2,500
19	2,500	5,000
20	5,000	10,000
21	10,000	20,000
22	20,000	40,000
23	40,000	80,000
24	80,000	160,000
25	160,000	320,000
26	320,000	640,000
27	640,000	1,300,000
28	1,300,000	2,500,000
29	2,500,000	5,000,000
30	5,000,000	10,000,000

Need for Improved Methods for Determining Fuel Cleanliness

- With the problems with SAP migration, aviation industry started looking at real-time methods for determining fuel cleanliness
- Some “re-inventing of the wheel” occurred
- Products went to the field without proper qualifications or requirement documents
- Energy Institute (EI), in cooperation with the aviation industry, developed the required documentation

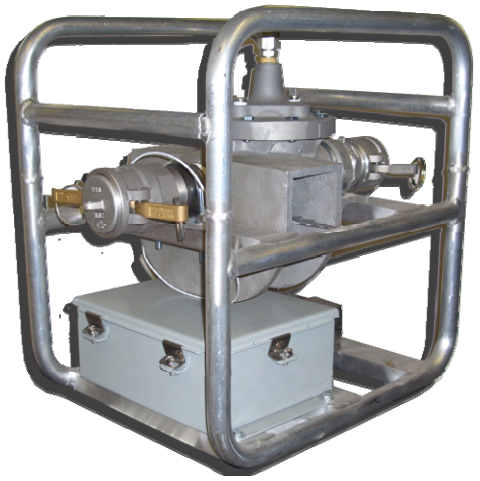


New Standards

- **EI 1570 – Handbook on electronic sensors for the detection of particulate and/or free water during aircraft refueling**
  - Intended to be a source of information on the technologies that might be viable for use in electronic sensors for the detection of particulate and/or free water during aviation fuelling.
  - Stakeholder review has been completed.
- **EI 1598 – Design, functional requirements and laboratory testing protocols for electronic sensors to monitor free water and/or particulate matter in aviation fuel**
  - This publication primarily applies to electronic sensors that could be used on mobile into-plane fuelling equipment, in conjunction with filtration equipment. In addition to the design and functional requirements that apply to every sensor produced by a manufacturer, it also includes standardized laboratory testing protocols for the 'first article testing' of a make/model/version of a sensor. These cover performance verification in response to dirt and free water contamination challenges, testing of mechanical integrity in response to pressure and material compatibility.

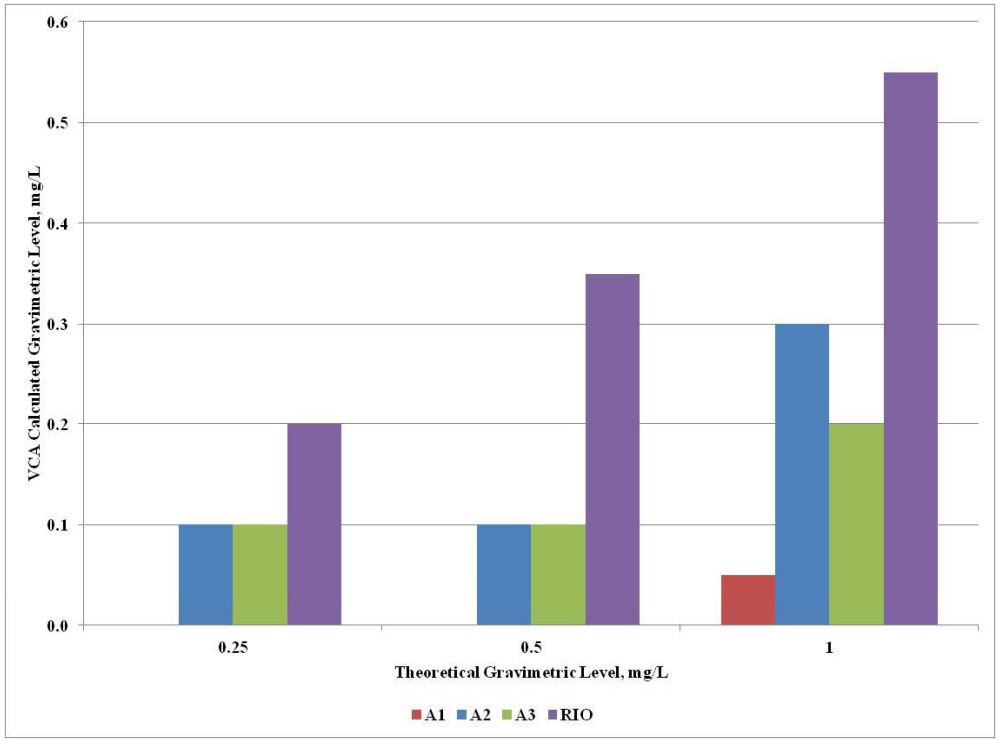
Army Evaluations

- Main objective was to evaluate Velcon VCA
  - VCA
  - VCA-CV (portable unit)
- Other sensors already installed so included in evaluations
- Modified EI 1598 test protocol
  - Included ISO 12103-1 ultra fine, fine, and medium test dusts
  - Red Iron oxide (RIO)
  - Water challenges
  - RIO and water



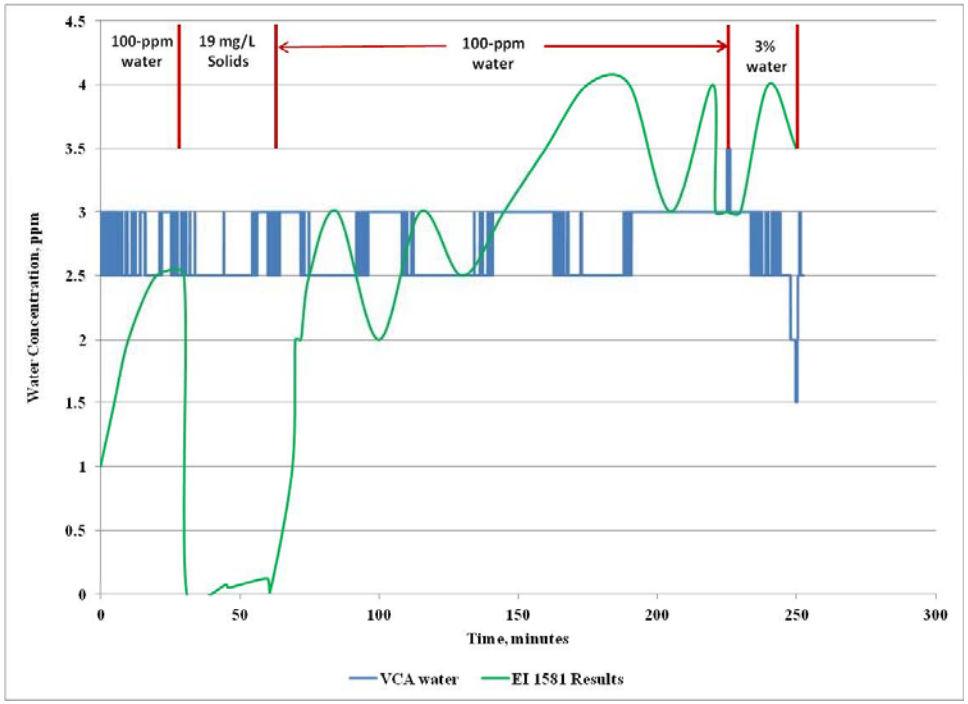
VCA Summary - Solids

- Evaluated various test dusts and multiple concentrations
  - 0.25 mg/L to 1 mg/L
- Sensor did not detect ultra fine test dust until 1 mg/L concentration
- Output the same for 0.25 and 0.5 mg/L with fine and medium test dust
- Red iron oxide consistently had higher readings



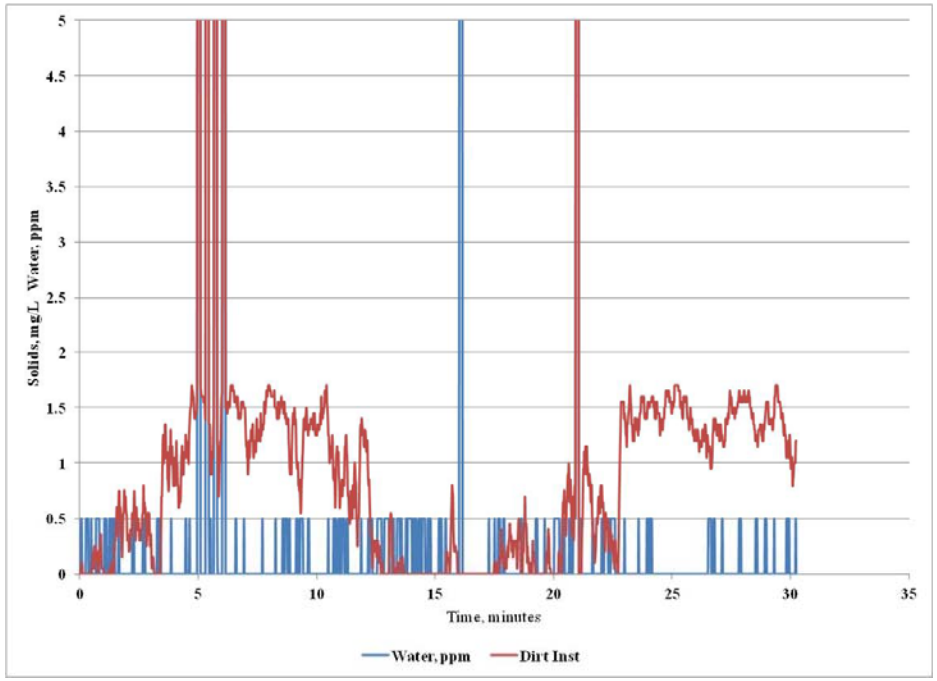
VCA Summary - Water

- Evaluation of VCA during EI 1581 evaluation
- Water results typically the same for all concentrations from 0 to 4 ppm



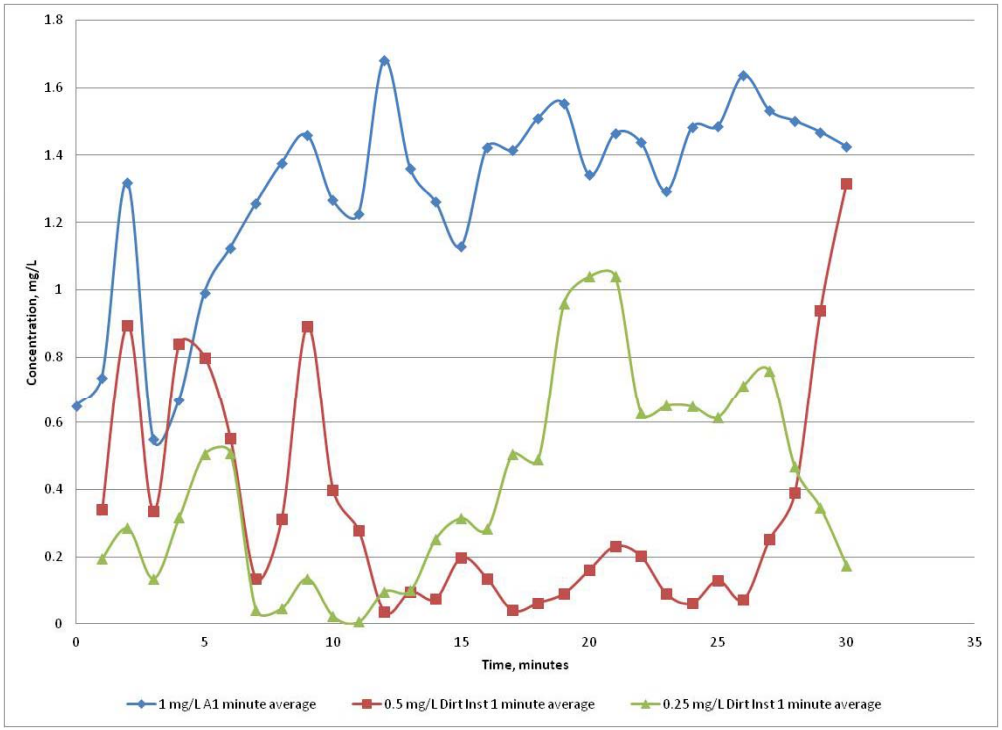
VCA-CV Summary - Dirt

- Calculated data as reported on VCA-CV using 0.25 mg/L ISO 12103-1 A1 ultrafine test dust
- Continually reading high with significant spikes in the data



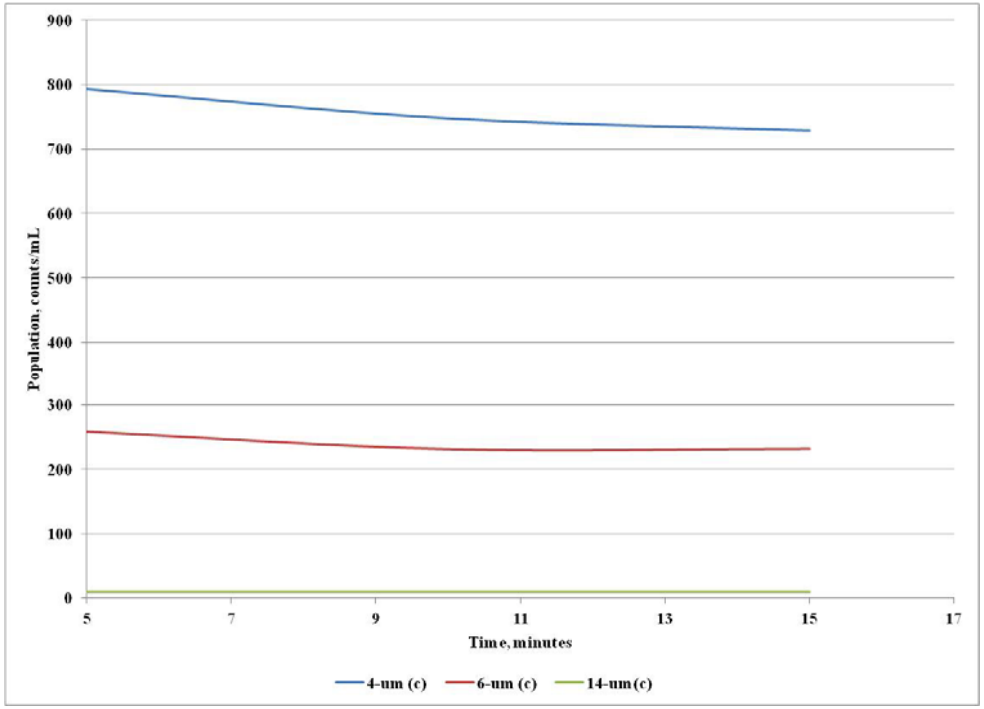
VCA-CV Summary – Dirt

- Same data as previously presented, ISO 12103-1 A1 ultrafine test dust
- Data reduced over 1 minute periods
- Still significant variation in results



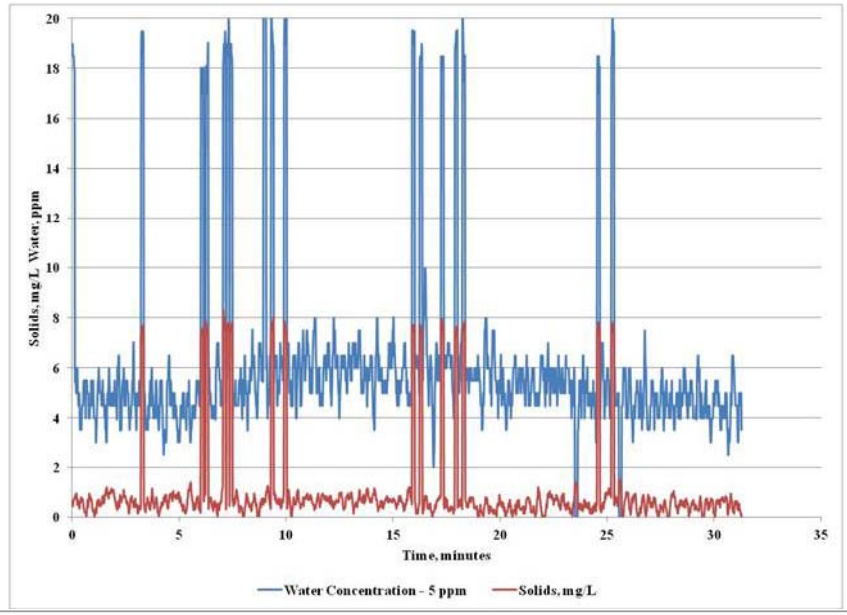
Parker ACM 20 - Solids

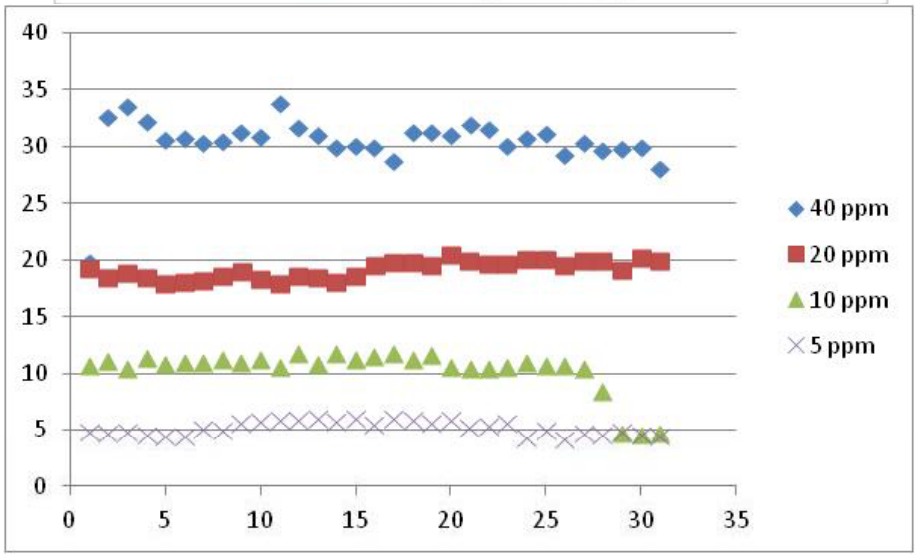
- Particle counting results for 0.25 mg/L ISO 12103-1 A3 medium test dust
- Results stable without spikes



VCA-CV Water

- Water challenge at 5 ppm free water
- Raw data noisy
- One minute averages show good results up to 20 ppm

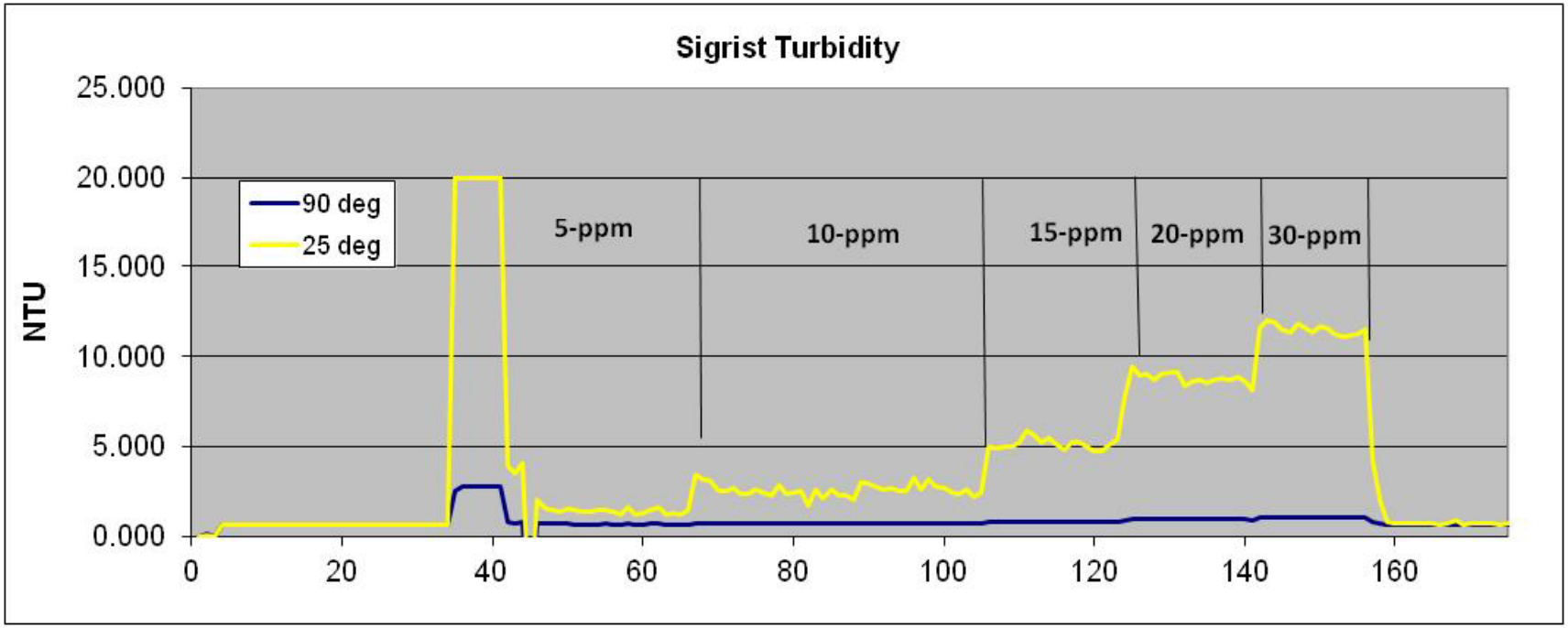




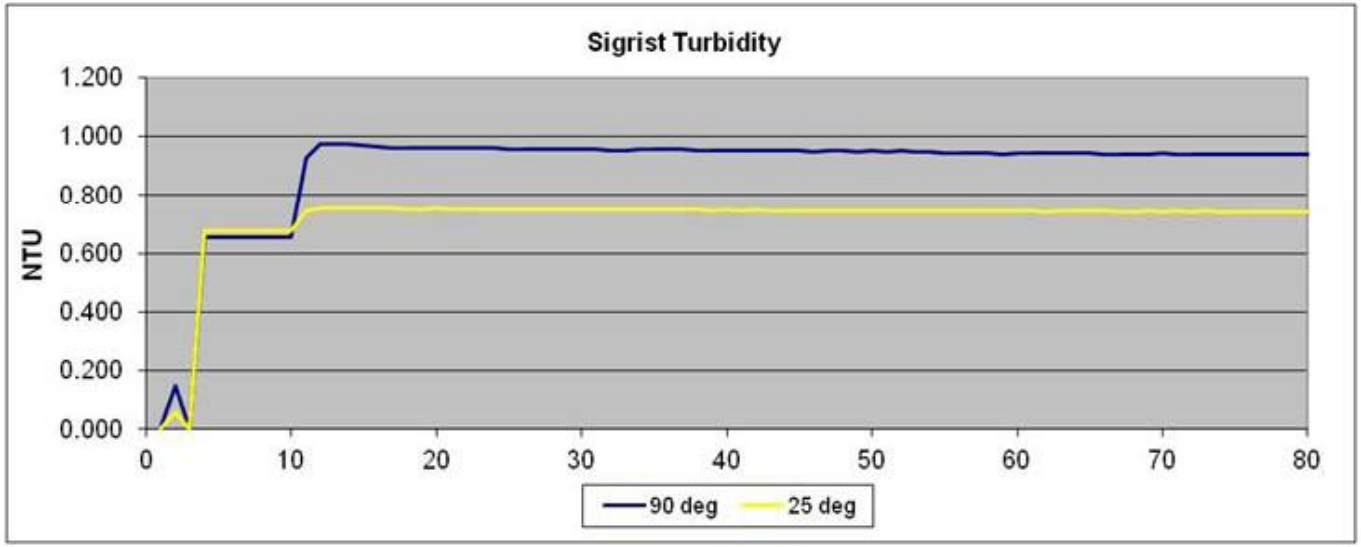
Sigrist Photometer

- Sigrist photometer only generates raw data
  - 25º
  - 90º
- Conventional wisdom
  - 25º - water contamination
  - 90º - dirt contamination

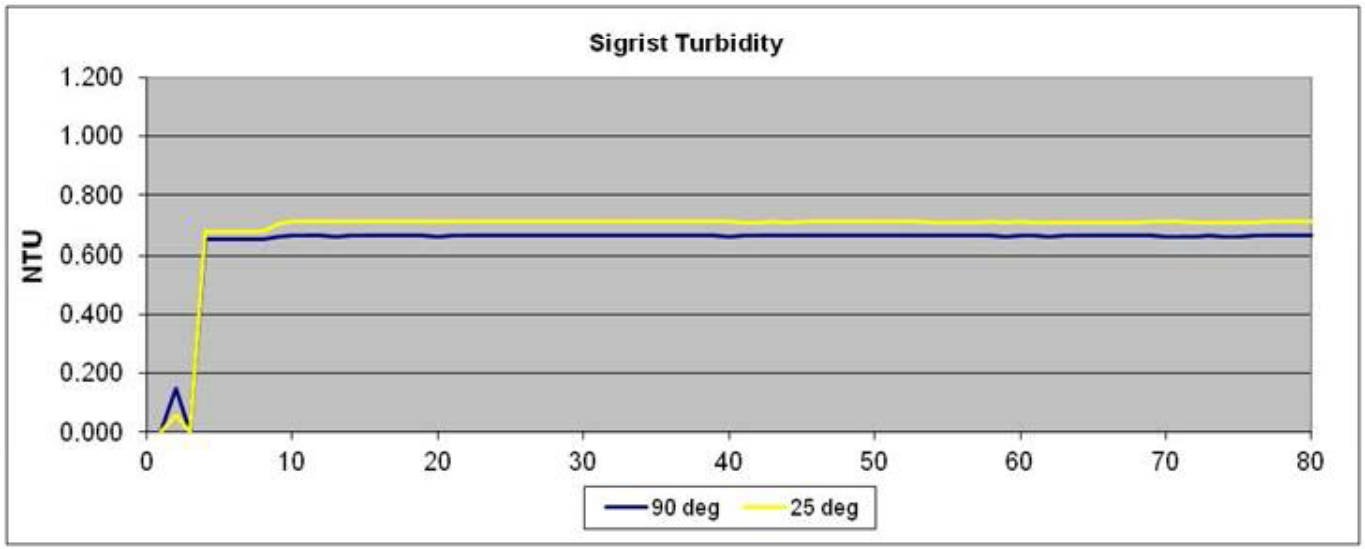
Sigrist – Water Challenges



Sigrist – Dirt Challenges

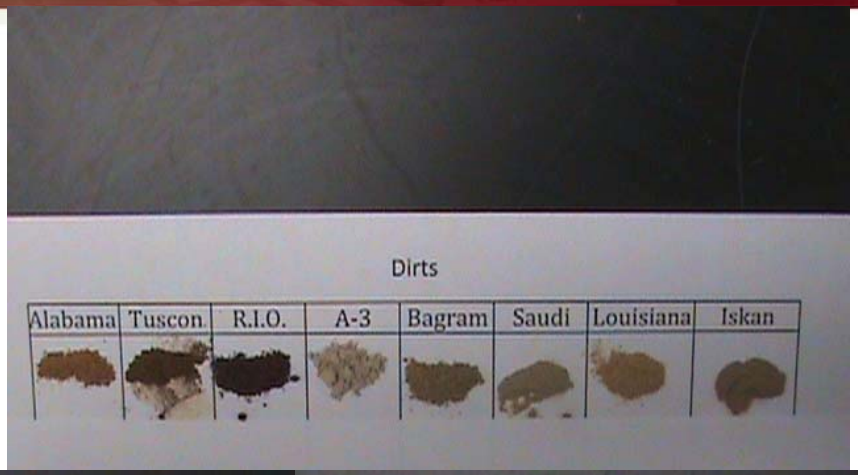


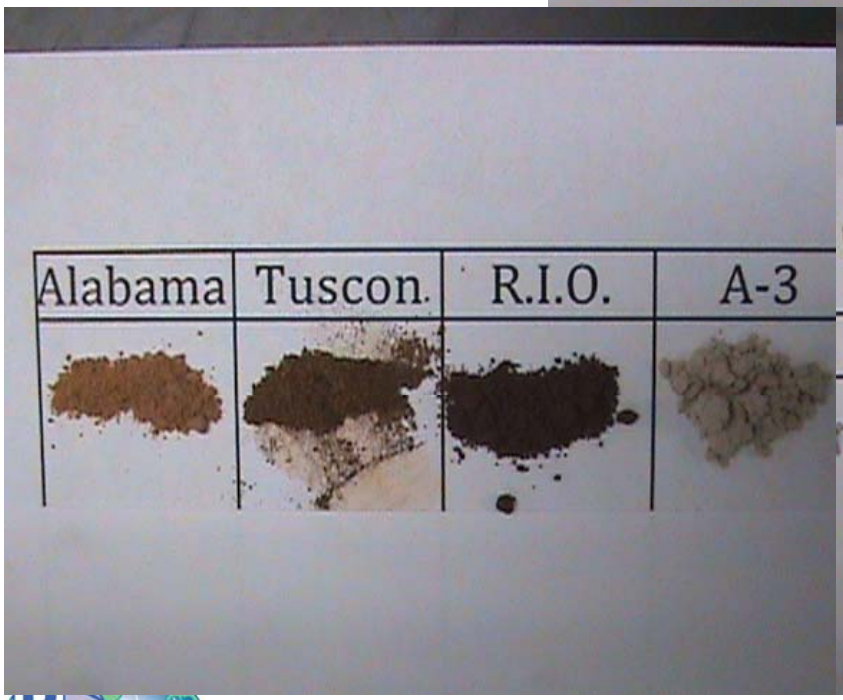
0.25 mg/L Red Iron Oxide



0.25 mg/L ISO 12103-1 A1 Ultrafine Test Dust

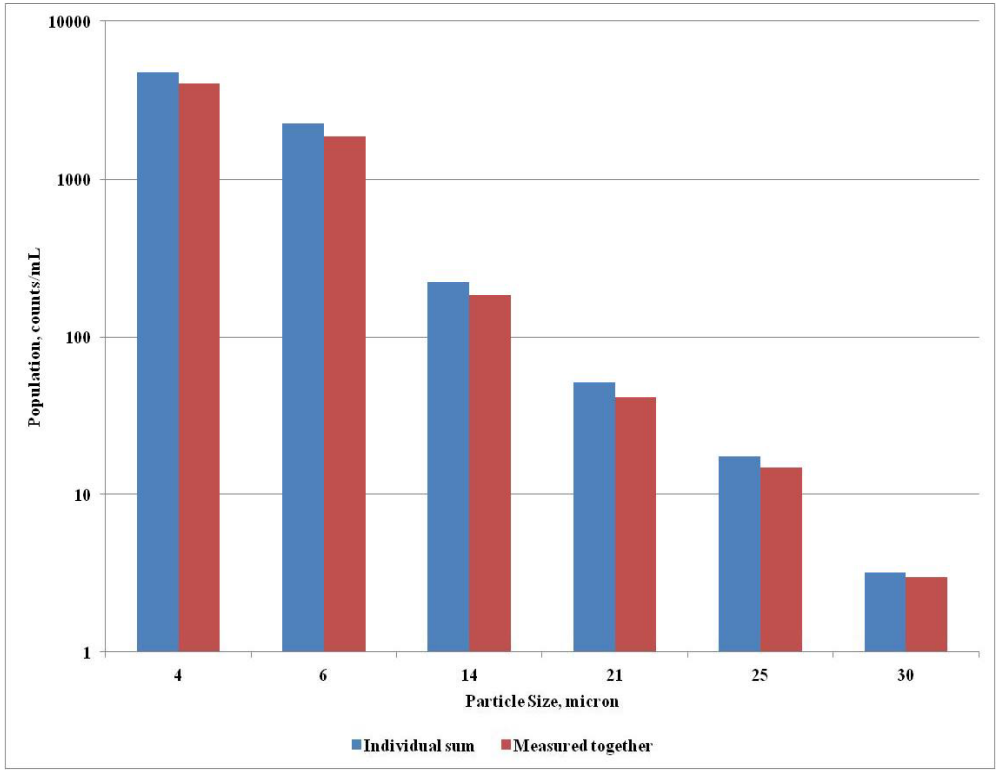
Dirts from Around Various Parts of the World





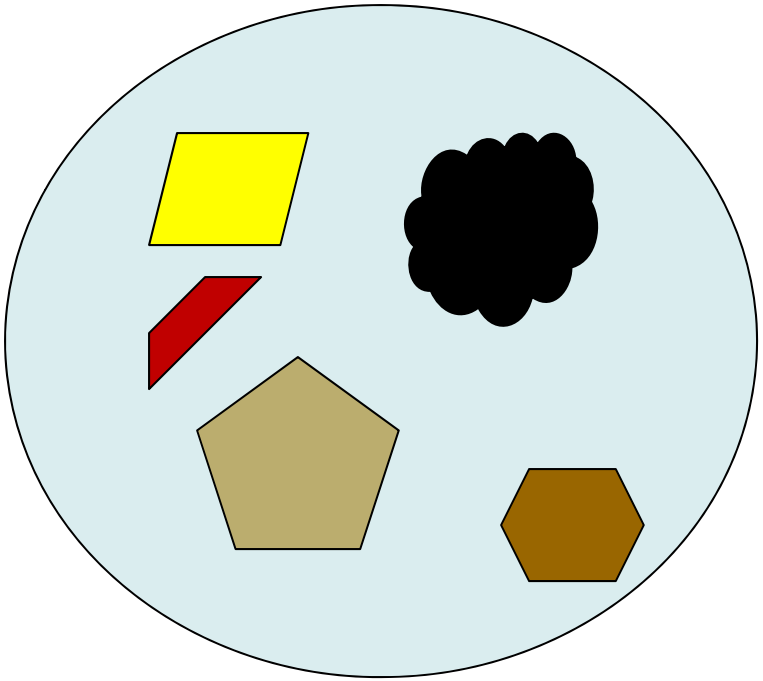
Dirt/water Contamination

- Why doesn't the water values and dirt values add up?
- We make an assumption both the water and dirt remain as individual particles
- Bad assumption!
- Cause for differences
  - Water coated particles
  - Multiple particles in water droplets

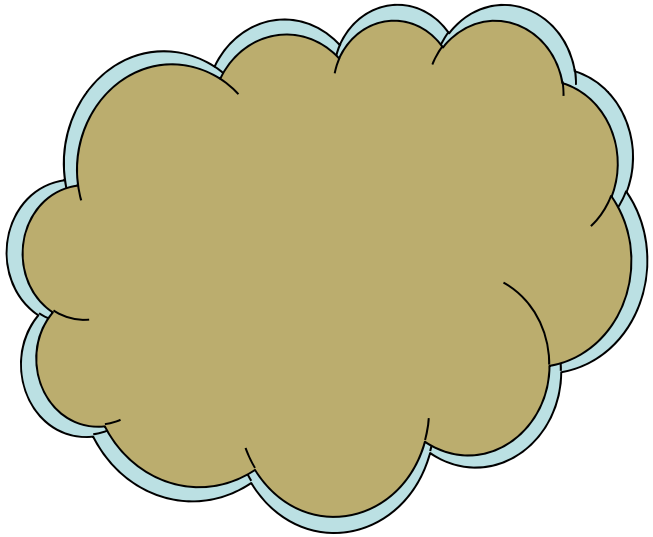


How Does Light Scatter Devices Measure These Contaminants?

Solids in Water



Water Film on Solid Particle



Determination of ISO 4406 Cleanliness Levels

- EI 1598 good for determination of instrument response to different contaminants using controlled conditions and contaminants
- Contamination distributions significantly different in the field after fuel is filtered
- Particle contamination
  - Small particles – Typically less than 6-µm (c)
- Water Contamination
  - If the fuel water separator fails, droplets will be 21-µm (c) and greater
- Propose adding 4th particle size to monitor excessive water
  - Not a new idea
    - 4-µm (c) added to ISO 4406
    - Vic Hughes proposed 30-µm (c) as part of ISO 4406 cleanliness code
  - Not part of ISO 4406

ISO 4406 Cleanliness Codes

ISO 4406 Cleanliness Codes for the
API/IP 1581 5th Edition Evaluations

Test No.	ISO Cleanliness Code at End of Test	Maxmium Water Content, ppm
1	21/19/14/11	5.9
2	21/19/14/13	40
3	22/20/17/14	18
4	22/21/19/16	40
5	23/22/18/15	41
6	22/21/17/14	42
7	17/16/14/13	1
8	23/22/19/16	42
9	16/15/12/9	1
10	20/18/16/14	45

Other EI1581 Particle Count Results - Water

Test No.	ISO Cleanliness Code at End of Test	Maximum Water Content, ppm
11	17/16/13/9	1
12	18/16/14/10	1
13	15/15/13/10	1.5
14	17/16/13/9	2.5
15	17/16/15/13	4
16	15/15/14/11	5
17	18/17/15/12	5
18	18/17/14/12	5
19	17/17/15/13	5
20	18/17/15/12	8

Other EI1581 Particle Count Results - Water

Test No.	ISO Cleanliness Code at End of Test	Maximum Water Content, ppm
21	19/18/16/14	10
22	18/18/17/14	10
23	18/17/15/13	10
24	18/17/16/14	10
25	19/19/17/15	10
26	19/17/17/15	10
27	20/19/17/15	10
28	19/18/17/15	10
29	18/17/16/14	12.5
30	19/18/17/14	13

Other EI1581 Particle Count Results - Water

Test No.	ISO Cleanliness Code at End of Test	Maximum Water Content, ppm
31	18/18/16/14	13
32	19/18/17/15	13
33	19/17/16/14	14
34	18/18/16/13	14
35	18/17/16/14	15
36	18/17/16/15	15
37	19/18/17/15	15
38	19/18/17/15	16
39	19/18/16/14	18
40	19/19/17/15	18

Other EI1581 Particle Count Results - Dirt

Test No.	ISO Cleanliness Code at End of Test	Maximum Dirt Content, mg/L
1	18/15/7/0	0.25 RIO
2	16/14/7/0	0.25 ISO A1
3	16/14/8/0	0.025
4	13/10/7/4	0.075
5	18/12/9/6	0.125
6	17/9/6/5	0.125
7	17/10/7/4	0.125
8	17/11/10/8	0.15
9	17/15/13/10	0.15
10	15/14/13/11	0.175

Other EI1581 Particle Count Results - Dirt

Test No.	ISO Cleanliness Code at End of Test	Maximum Dirt Content, mg/L
11	18/17/14/10	0.2
12	22/20/15/10	2.0
13	22/20/15/10	2.8
14	22/21/17/10	2.9
15	22/21/17/11	3.1

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. Army	19/17/14/13*		
Diesel Fuel			
World Wide Fuel Charter 4th		18/16/13	
DEF (AUST) 5695B		18/16/13	
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)

Conclusions

- Particle counters have the better overall capability for determination of water and dirt contamination particularly at low levels required to meet EI 1581 specifications
- Turbidity meters/ photometers/light scattering devices better for measuring only water contamination
- Proposed ISO 4406 Cleanliness level
  - 19/17/14/13

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