Test Report

Aspirated Smoke Detectors (ASD) Performance and Reliability Testing in Dust Laden Environment

Vipac Reference: 30V-11-0424 -TRP- 264755-0
Date

Vipac Engineers & Scientists Ltd
Melbourne, Australia

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1. INTRODUCTION

VIPAC Engineers & Scientists Ltd. was commissioned by Xtralis to carry out performance and reliability testing on different models of Aspirated Smoke Detector (ASD) units in a dust-laden environment. Testing was conducted at VIPAC laboratory in Port Melbourne, Australia, between the 7th and 22nd February 2012.

2. SCOPE

The scope of the investigation was to compare the detection performance and reliability of ASD units when exposed to (sampling) dust-laden air. The most common physical effects on any ASD unit from dust sampling are:

- Contamination of optical components,
- Soiling of internal surfaces,
- Clogging of internal air filters and air paths,
- Abrasion/seizure of moving parts,
- Deterioration or failure of electrical components.

Sampling of dust is unavoidable in almost all environments and has the potential to compromise detection performance and reliability of an ASD unit resulting in increased demand for scheduled and unscheduled maintenance including replacement of components or detector itself after critical failures. Specifically this investigation measured, recorded and analysed:

- Reduction in sensitivity (detection performance),
- Smoke detection reliability (notification when sensitivity is compromised),
- Operational reliability (component failure),
- Fault reporting (notification of required service).

3. ASD UNITS UNDER TEST

Table 1 lists the ASD models and manufacturers used for this investigation. All ASD units under test were brand new.

No.	Manufacturer	Model	Serial Number
1	Xtralis	VLI-880	10811002
2	Securiton	Smoke Detector: SecuriRAS ASD 535-3	5000623.0103.010409 Securiton: 022.235636
		Smoke Sensor: SSD 535-2	5000613.0103.080808 Securiton: 022.235679
3	System Sensor	FAAST 8100	0026C800049F
4	Wagner	Smoke Detector: TITANUS PRO SENS (TP-1-SL)	308698
		Detector Module: DM-TP-01-L	384109

Table 1: ASD Units Under Test

4. TEST SETUP

The test setup comprised a Dust Chamber, Smoke Chamber, Smoke Generation Box and HEPA filtration arrangement as depicted in the schematic in Figure 1. All ASD units were connected to the Dust Chamber, Smoke Chamber and HEPA filtration arrangement through individual pipe networks (21mm ID) and valve arrangements to allow dust loading, smoke tests and clean air sampling independent of each other.

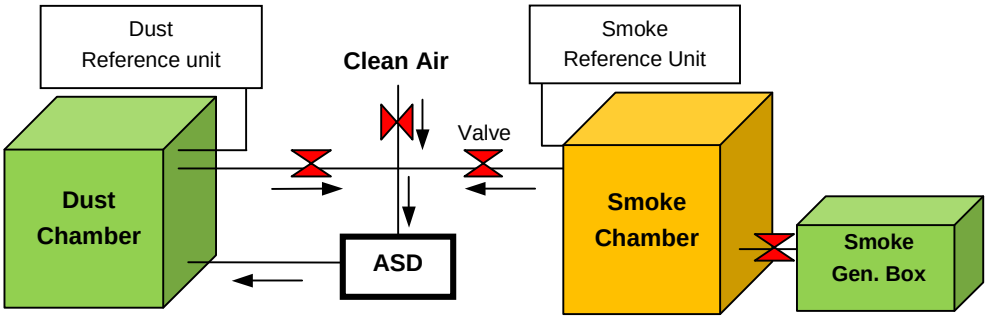


Figure 1: Test Setup – Schematic

4.1 Laboratory

- Ventilated space
- Temperature: 21-22˚C (70 – 72˚F)
- Humidity: 40-60%RH

4.2 Dust Chamber

- Dust Chamber (Figure 2) internal volume: 0.216m^3 (0.6 x 0.6 x 0.6)m [7.6ft^3 (1.97x1.97x1.97)ft]

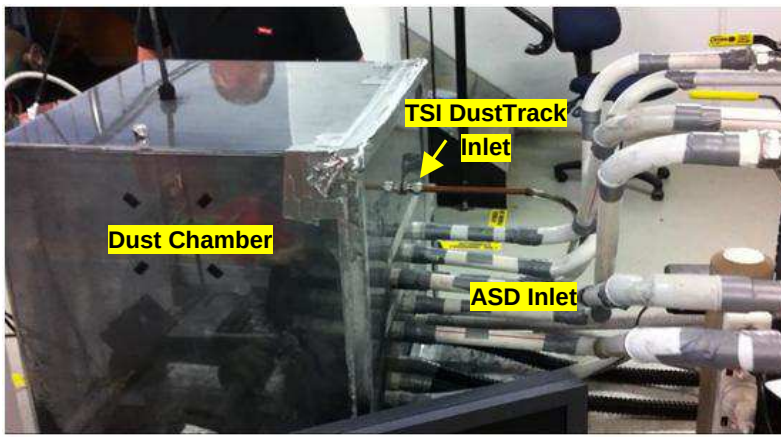


Figure 2: Dust Chamber

- ASD inlets were located in close proximity to each other and their exhausts were routed back to Dust Chamber for dust recirculation.
- Test dust: ASHRAE 52/76 standard test dust – see section 4.7 for details.

- Dust injection system: Dust placed in cylinder in center of Dust Chamber equipped with compressed air manifold and lid with holes for dust to escape through compressed air action. Mixing fans provided for turbulent airflow conditions for homogeneous dust level.
- Dust Chamber internal pressure equalised to ambient using a separate inlet.
- Dust reference unit: TSI DustTrak (PM_{10}) particulate measuring device. Sampling was arranged in parallel to and in close proximity to ASD inlets.
- To verify that all ASD units were subjected to similar dust loading rates a comparison was made between dust concentration levels inside the Dust Chamber and through each ASD inlet. Simultaneous readings were taken with two TSI DustTrak instruments; one for Dust Chamber and the other for ASD inlets. Table 2 shows minimal difference (%) in dust concentration levels between Dust Chamber and each ASD inlet indicating similar dust loading rates being applied for all detectors under test. Dust readings shown represent instantaneous readings where variations are expected inside the Dust Chamber.

ASD	Dust Concentration Dust Chamber (mg/m^3)	Dust Concentration ASD Inlet (mg/m^3)	% Difference
VLI-880	14.4	15.2	+5.55
SecuriRAS ASD 535-3	16.7	16.3	-2.39
FAAST 8100	20.5	20.2	-1.46
TITANUS PRO SENS	19.2	19.0	-1.04

Table 2: Dust Concentration (Dust Chamber / ASD Inlets)

- Dust chamber designed and assembled by VIPAC.

4.3 Smoke Generation Box and Smoke Chamber

- Internal volumes (Figure 3):
  - Smoke Generation Box: 0.043m^3 (0.35 x 0.35 x 0.35)m [1.52ft^3 (1.15 x 1.15 x 1.15)ft]
  - Smoke Chamber: 0.17m^3 (0.85 x 0.5 x 0.4)m [6ft^3 (2.78 x 1.64 x 1.31)ft]

Figure 3: Smoke Generation Box and Smoke Chamber

- Test smoke: smouldering cotton lamp wick (grey smoke) – see section 4.8 for details.
- Smoke generated in Smoke Generation Box and introduced to Smoke Chamber. ASD sampling occurred from Smoke Chamber with inlets placed in close proximity.
- Smoke Chamber internal pressure equalised to ambient using separate inlets. Mixing fans ensured homogeneous smoke level.

- Smoke reference unit: VESDA VLC-505. Sampling arranged in parallel to and in close proximity to ASD inlets. Reference unit provided ASDs' Response Threshold Value (RTV) – see section 5.2 for RTV explanation.
- Smoke Generation Box and Smoke Chamber designed and assembled by Xtralis.

4.4 Clean Air Sampling

All ASD units' pipe network included a separate branch for clean air sampling through a HEPA filter arrangement (Figure 4). This allowed ASDs to be purged with clean air to ascertain detector functionality in clean air conditions and remove residual dust after each dust exposure prior to smoke tests.

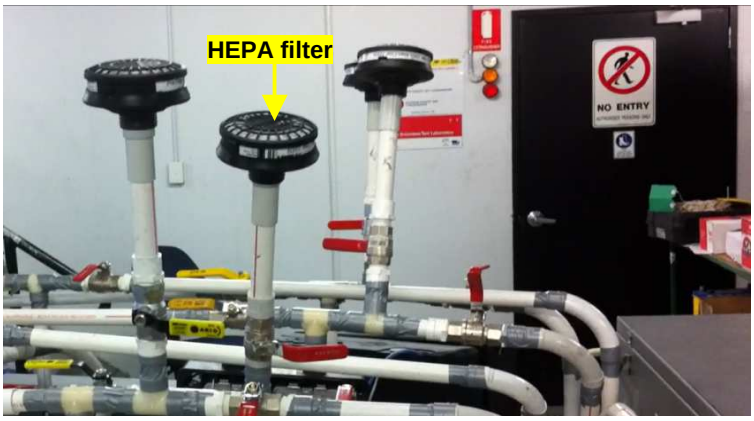


Figure 4: Clean Air Sampling Arrangement (HEPA filter)

4.5 ASD Units Setup

- All ASD units were brand new, fitted with new internal particulate filters (where applicable) – Table 3.

ASD	Particulate Filter Type
VLI-880	HEPA / Foam filter
SecuriRAS ASD 535-3	Metallic mesh (60x40)mm with (1x1)mm openings
FAAST 8100	Particle separator / Foam filter
TITANUS PRO SENS	No Filtration

Table 3: ASD Particulate Filter Types

- Baseline flow rate: 40L/min. Flow rate set by orifices on ASD inlets to Dust Chamber, Smoke Chamber and HEPA filter. Flow rates measured at each ASD exhaust with hot wire anemometer (TSI VelociCalc Plus) for each sampling phase (Table 4).

ASD	Aspirator Setting	Orifice Size (mm)	Flow rate (L/min)
VLI-880	4200rpm	7.5	43
SecuriRAS ASD 535-3	Level 5	7.0	43
FAAST 8100	Fixed	7.8	43
TITANUS PRO SENS	9V	9.0	41

Table 4: ASD Baseline Flow-rates

- Pipe networks designed short as possible to minimize transport times and dust deposition (loss) within pipe.

- Alarm delays: 0 sec.
- Alarms/Faults: latched.
- ASD RTV measured at 0.12%Obs/m (0.037%Obs/ft) alarm level.
- ASD units configured and flow rates validated with respective manufacturers' software tools (Table 5).

ASD	Configuration	Pipe Modelling
VLI-880	VSC 3.04.03 (S/W)	ASPIRE2 2.04
SecuriRAS ASD 535-3	ASD Config 01.01.00 (S/W)	ASD Pipeflow 2.0.4.3
FAAST 8100	PipeIQ 1.2.0 (S/W)	PipeIQ 1.2.0
TITANUS PRO SENS (detector module)	Switch settings (DIP) – Installation Instruction Manual	Not Available

Table 5: ASD Configuration / Pipe Modelling Tools

4.6 Test Instruments

Test instruments for the investigation are outlined in Table 6.

Instrument	Measurand	Model	Serial No.	Calibration
DustTrack	*Dust Chamber* dust concentration	8250	85201887	APPENDIX A
DustTrack	*ASD Inlet* dust concentration	8250	23390	Calibrated against Dust Chamber DustTrack (APPENDIX D)
VelociCalc Plus	Pipe airflow	8386A-M-GB	02080484	APPENDIX B
VESDA	Smoke concentration	VLC-505	8417637	Factory calibrated

Table 6: Test Instruments

4.7 Test Dust

- ASHRAE 52/76 test dust referenced in ANSI/ASHRAE Standard 52.2-2007 "Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size" – see APPENDIX C for calibration certificate. This type of dust was chosen as it is used for the loading of ventilation filters to simulate accumulation of particulate over service life and is representative of common dust types present in commercial and industrial environments.
- Dust concentration per loading: 10-40mg/m^3.

4.8 Test Smoke

- The test smoke was smouldering cotton lamp wick (grey smoke) referenced in UL268 Standard "Smoke Detectors for Fire Alarm Systems" (2009), Section 30 – Sensitivity Test.
- The smouldering of the cotton lamp wick occurred inside the Smoke Generation Box and smoke was gradually introduced to the Smoke Chamber.

5. TEST PROCEDURE

5.1 Test Cycle

A total of 14 test cycles were conducted. Each test cycle comprised dust loading of detectors, measurement of detectors sensitivity, functional checks and service/corrective actions (where required) according to the sequence in Figure 5.

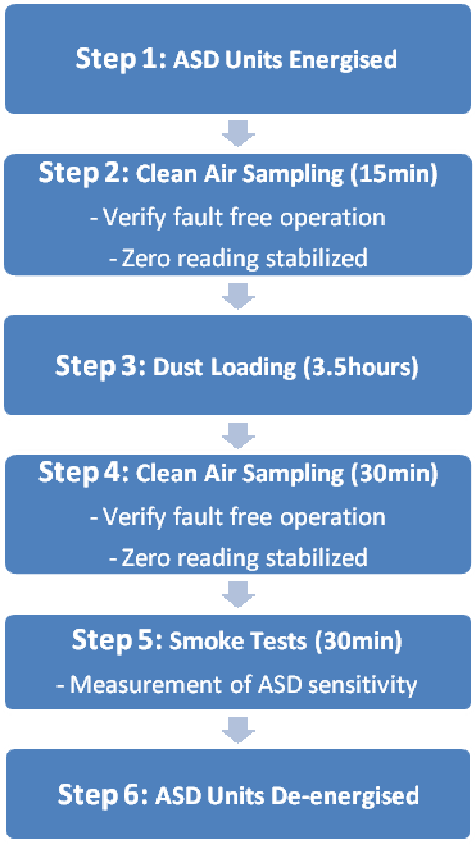


Figure 5: Test Cycle Steps

Note: An additional test cycle (#15) was conducted for the SecuriRAS ASD 535-3 unit to ascertain sensitivity improvement with internal filter replacement.

Dust loading parameters are included in APPENDIX D.
Throughout all steps a log was maintained of ASD faults / failures and corrective actions.
A replacement dust track was utilised for the

Maintenance schedule:

- At the end of each test cycle maintenance was performed on the DustTrack instrument (filter replaced, capillary cleaned, flow check, zero check).
- At end of each test cycle the Dust Chamber was cleaned and ASD pipe work purged with compressed air to clean orifices and remove dust deposits.
- Smoke reference unit (VESDA VLC-505) internal filter replaced at the end of test cycles 3, 7, 11.

5.2 Sensitivity (Detection Performance)

The impact of dust sampling on detectors sensitivity (detection performance) was determined by measuring each ASD unit Response Threshold Value (RTV) after each dust loading. The RTV is the amount of smoke concentration the ASD is subjected to in order to generate an alarm signal according to EN54 Standard “Fire Detection and Fire Alarm Systems – Part 20: Aspirating Smoke Detectors. A change in RTV therefore will entail a change in detector sensitivity. For example when the sensitivity of the ASD deteriorates its RTV will increase i.e. greater amount of smoke concentration will be required for the ASD to generate an alarm signal.

The initial baseline ASD sensitivity was determined (ASD out of box) and subsequent measurements after each dust load were normalised against this baseline to ascertain impact on detectors’ sensitivity (see APPENDIX E for calculation method).

For the RTV measurements, the ASD units were subjected to a slowly increasing smoke concentration at a rate that allowed an alarm to be issued between 2 to 10 min from start of test. The ASDs’ RTV was provided by the reference smoke detector (VESDA VLC-505) that was only operational during the smoke tests.

5.3 Pass/Fail Criteria

The following conditions constituted a failure:

- 50% reduction in ASD sensitivity. For a 50% reduction in sensitivity the ASD requires double the amount of smoke concentration to issue an alarm signal.
- ASD hardware faults and failures (non-field maintainable items).

6. RESULTS

6.1 ASD Sensitivity (Detection Performance)

Figure 6 depicts the trend lines of sensitivity (normalised) reduction for each ASD unit throughout the dust loading cycles along with the chronology of critical fault and maintenance indicators. Table 8 lists the details of the fults and maintenance indicators and detailed normalised sensitivity results are included in APPENDIX F.

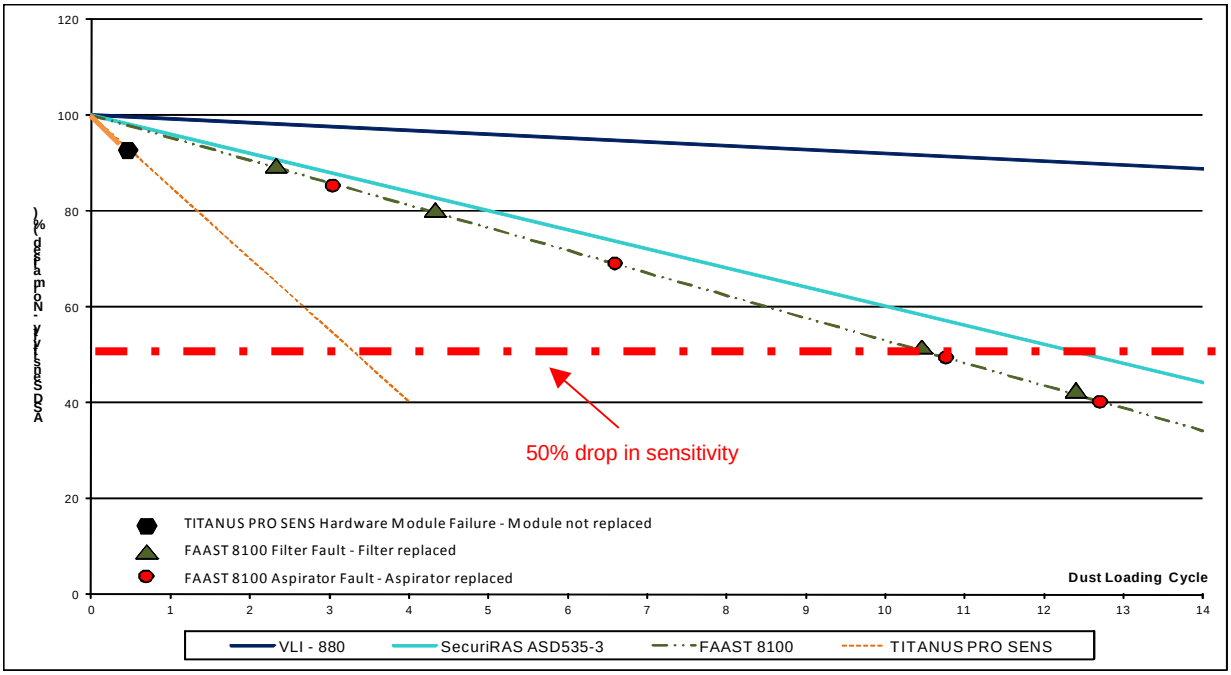


Figure 6: ASD sensitivity (normalised) trend lines with critical fault and maintenance indicators

The following are noted:

- All ASD units except the Xtralis VLI-800 recorded a 50% reduction in sensitivity. The Xtralis VLI-880 sensitivity for the same loading characteristics was reduced by approximately 10%.
- The TITANUS PRO SENSE issued a detector module failure during the first dust loading cycle.
- The FAAST 8100 unit issued multiple filter and aspirator faults.
- No notification was issued by the SecuriRAS ASD 535-3 unit for a 50% reduction in sensitivity.

6.2 ASD Hardware Faults and Failures

6.2.1 Filter Faults

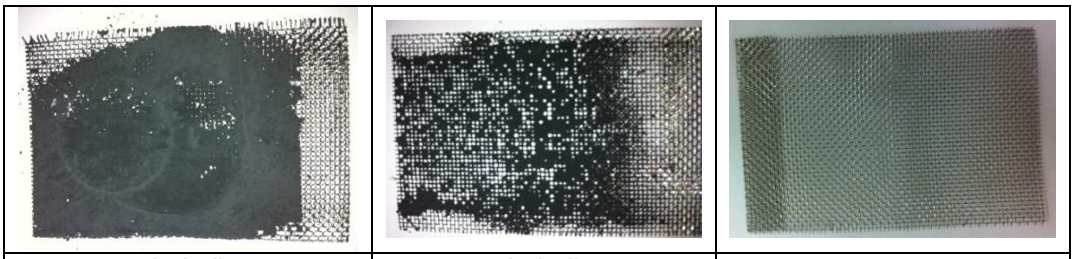
Where detectors exhibited field rectifiable faults, most commonly Filter Faults, the recommended field maintenance was carried out as per the manufacturer's instruction.

FAAST 8100:

From Figure 6 the FAAST 8100 unit issued four Filter Faults – fault conditions were not cleared with detector RESET. As per manufacturer's "Installation and Maintenance Instructions" document #I56-3630-000 (2010), this fault indicates the device filter is clogged and requires replacement. This is a field replacement items and in each fault condition the filter cartridge was replaced with new as per prescribed maintenance. This action did not restore the detector sensitivity.

SecuriRAS ASD 535-3:

Though the SecuriRAS ASD 535-3 has no filter status reporting function, the detector filters (metallic mesh before and after smoke sensor) were replaced with new to ascertain improvement in sensitivity. The detector was subject to an additional dust loading cycle (#15) and its sensitivity was ascertained both with the "loaded" and new filters (Figure 7). Replacement with new filters did not improve the detector sensitivity as seen from Table 7.



Loaded Filter – before smoke sensor	Loaded Filter – after smoke sensor	New Filter

Figure 7: SecuriRAS ASD 535-3 Filters (metallic mesh)

Dust Loading 15	Normalised Sensitivity (%)
Loaded Filters	50
New Filters	51

Table 7: SecuriRAS ASD 535-3 Sensitivity Change with Filter Replacement

6.2.2 Critical Failures

From Figure 6 two ASD units (TITANUS PRO SENS, FAAST 8100) exhibited critical failures that would require the unit to be replaced or returned for service.

1. TITANUS PRO SENS: Unit suffered "Detector Module Hardware Defect" during the first loading cycle – fault condition was not cleared with detector RESET. According to the manufacturer's technical manual "Air Sampling Smoke Detection System TITANUS PROSENS" doc #69-30-0226 (2009), the detector module requires immediate replacement. This is a field serviceable item. Since only one detector module was available, testing continued for 4 dust loading cycles (unit was able to detect smoke) despite manufacturer's recommendation to have the detector module replaced.

2. FAAST 8100: Unit suffered frequent “Aspirator Faults”. The aspirator ceased operation a total of 4 times in the course of testing which rendered it incapable of detecting smoke – all fault conditions were not cleared with detector RESET. According to the manufacturer’s “Installation and Maintenance Instructions” doc #I56-3630-000 (2010), this fault indicates the fan has stopped working and requires immediate attention. While this is not a field maintenance item for the purpose of this investigation the faulty aspirators were replaced with new. In practice, however, each failure would have necessitated the unit be replaced or returned for service.

ASD	Fault Type	Timeline	Comments	Corrective Actions
TITANUS PRO SENS	Detector Module Defect	2hr into dust loading #1	Detector module fault LED permanently lit	**Field maintenance item** Module not replaced. Fault condition maintained for remainder of test cycles
FAAST 8100	Filter Fault	Prior to dust loading #3	Filter fault LED permanently lit	**Field maintenance item** For every fault condition new filter inserted.
		Prior to dust loading #5		
		2hr into dust loading #11		
		End dust loading #13		
	Aspirator Fault	End of dust loading #3	Aspirator fault LED permanently lit. Aspirator ceased operation	**Non field maintenance item** For every fault condition faulty aspirator replaced.
		1.5hr into dust loading #7		
		2hr into dust loading #11		
		End dust loading #13		

Table 8: ASD Faults Timeline / Corrective Actions

7. CONCLUSIONS

Performance and reliability testing was conducted on four ASD units operating in a dust-laden environment.
For the purpose of this investigation all ASD units were installed and configured identically (flow rate, alarm threshold, alarm delay) and subject to identical dust loading conditions.

The findings and observations from this investigation are summarised below:

ASD Sensitivity (Detection Performance) Degradation:
Over the duration of testing significant trends were observed in ASDs' sensitivity. Notably:

- All ASD units except the Xtralis VLI-880 experienced sensitivity degradation of more than 50% (Table 9).
- The Xtralis VLI-880 sensitivity for the same loading characteristics was reduced by less than 10%.
- No notification was issued by the SecuriRAS ASD 535-3 unit for a 50% reduction in sensitivity.

ASD	Time to 50% sensitivity drop	Sensitivity drop at end of 14th dust cycle
VLI-880	Did not fail	10%
SecuriRAS ASD 535-3	14 cycles	50%
FAAST 8100	10 cycles	55%
TITANUS PRO SENS	4 cycles	55%*

Table 9: ASD Sensitivity Degradation

* TITANUS PRO SENS data presented for only 4 dust cycles since the detector sensitivity by that stage had reduced by more than 50%.

ASD Maintenance:

- The FAAST 8100 unit issued four filter maintenance notifications. When prescribed manufacturer's maintenance was performed the sensitivity of the unit was not restored.
- Though the SecuriRAS ASD 535-3 unit had no filter status reporting function, replacing the heavily soiled "loaded" filters with new showed no improvement of detector sensitivity.

ASD Critical Failures:
Two ASD units exhibited critical failures requiring repair:

- TITANUS PRO SENS – One "Detector Module" failure notification was issued during the first dust loading cycle. This is a field maintenance item.
- FAAST 8100 – Four "Aspirator Fault" failures occurred. The first fault occurred after the second dust loading cycle. This is not a field maintenance item and requires the unit to be replaced or returned to the manufacturer for service.

A critical attribute of fire detection systems is that the system performance be maintained within acceptable and expected bounds over the operational life of the product. While no specific comment is made on the design of any particular ASD product tested, the results presented can be considered significant and should be taken into consideration when selecting an ASD product for deployment in harsh (dust-laden) environments if reliable detector operation is to be maintained.

APPENDIX A

DustTrack (Dust Chamber) Calibration Certificate

Kenelec Scientific

TSI Dusttrak - Model 8520

Calibration Certificate

Report Number: DT105772

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Customer	VIPAC Engineers & Scientists
Address	279 Normanby Road
	Port Melbourne VIC 3207
Contact	Rob Davis
Equipment	TSI Dusttrak
Model	8520
Serial Number	85201887
Calibration Date	27/04/2011
Condition as Received	*As Left*

Measurement Variable	Model No.	Serial No.	Calibration Due
Photometer	8587A	71002264	12/05/2011
DC Voltage (Keithley)	2700	1260416	8/05/2011
Pressure	276140-SP	4146296	1/06/2011
Flow and Temperature	4140	41400951036	16/05/2011
Microbalance	DV215DC	1124010886	13/04/2011
1 um PSL		36795	Not Applicable
2.6 um PSL		580457	Not Applicable
10 um PSL		612530	Not Applicable

ENVIRONMENTAL CONDITIONS	
Ambient Temp	20°C
Humidity	38%RH
Barometric Pressure	1012hPa

Kenelec Scientific Pty Ltd Certifies That :-

All performance and acceptance tests required were successfully conducted according to required specifications. All test and calibration data supplied by Kenelec Scientific has been obtained using emery oil and has been nominally adjusted to respirable mass standard ISO 12103-1 A1 Test Dust (Arizona Dust)

Procedures Followed:	LABP1
Approved Signatory:	
Date:	27-4-2011

KENELEC SCIENTIFIC PTY LTD
ABN 88 084 373 717

23 Redland Drive
Mitcham Vic 3132

T 03 9873 1022
F 03 9873 0200

info@kenelec.com.au www.kenelec.com.au

Kenelec Scientific

TSI Dusttrak - Model 8520

Calibration Certificate

Report Number: DT105772

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CALIBRATION RESULTS				
As Found Verification Data				
Testing Number	Calibration Reference mg/m3	Instrument Output	Allowable Range +/-10%	
1	0.082	0.053	0.074	0.090
2	0.557	0.402	0.501	0.613
3	4.130	2.97	3.725	4.553
4	24.402	17.591	21.962	26.842

CALIBRATION RESULTS				
Calibration Verification Data				
Testing Number	Calibration Reference mg/m3	Instrument Output	Allowable Range +/-10%	
1	0.076	0.077	0.068	0.083
2	0.574	0.629	0.517	0.631
3	4.157	4.544	3.741	4.573
4	24.848	24.333	22.363	27.333

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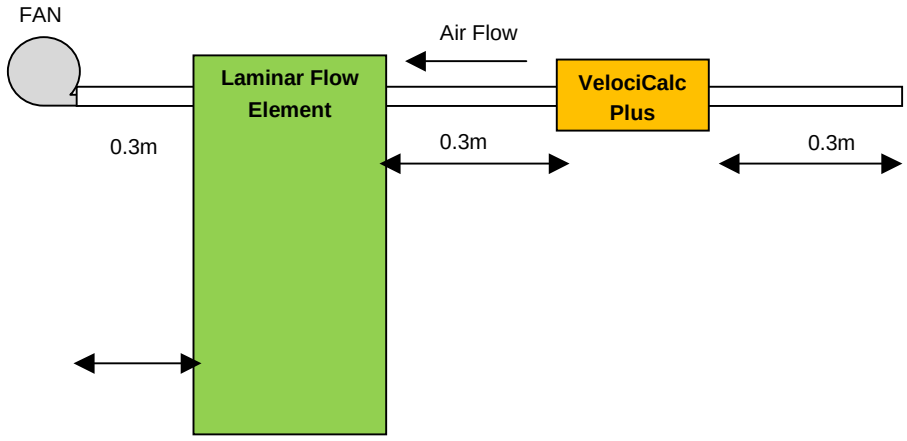
Z:\Calibration\Certificates\all TSI\Dusttrak\DT105772-8520-88901087

APPENDIX B

VelociCalc Plus Air Velocity Meter (TSI) Calibration

Methodology

The VelociCalc Plus air velocity hot anemometer meter was calibrated in-series with the Laminar Flow Element (below schematic).



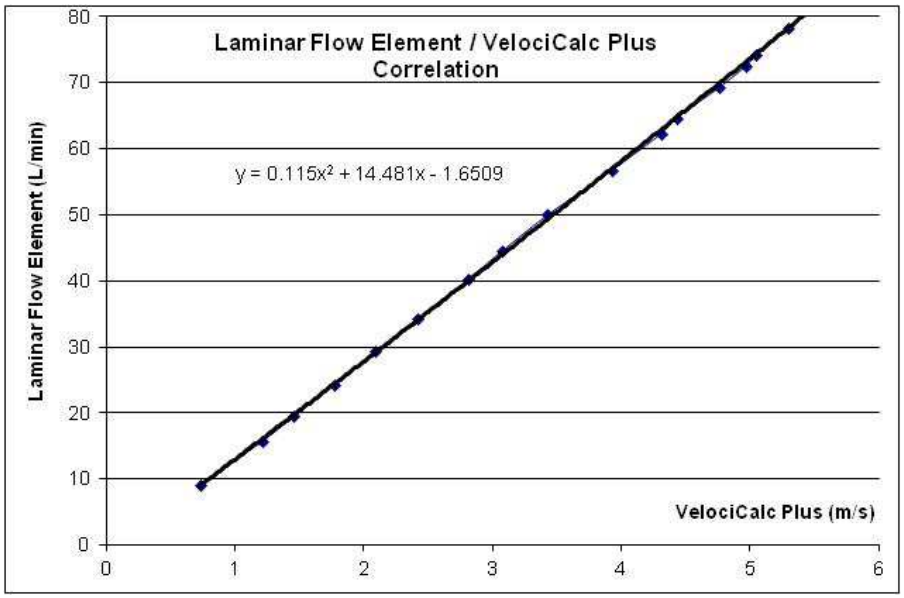
Instruments

- Laminar Flow Meter: FC0318 DP Transmitter + Flow Element (Furness Controls Ltd). UKAS Accredited Calibration Laboratory No.0580, Calibration Certificate No. 06632.
    - Flow Element Serial Number: 1007175
    - Transmitter Serial Number: 1007173
- VelociCalc Plus Air Velocity Meter (TSI): Model: 8386A-M-GB, Serial Number: 02080484

Test Ambient Conditions

- Ambient Temperature: 20°C (68°F)
- Relative Humidity: 40-60%RH

Comparison Results



Furness Controls Limited

Beeching Road, Bexhill-on-sea, East Sussex, England, TN39 3LJ

0580

Certificate of Calibration

Calibration Certificate No: 06632

Issued by: Furness Controls Limited

Date of Issue: 19 August 2010

Customer	:	ICAM Limited UK, Focus 31, Mark Road, Hemel Hempstead, Hertfordshire, HP2 7BW.
Via	:	N/A
FCL Reference Nos	:	55353
Customer Order No	:	401240
Date calibrated	:	19 August 2010
Instrument	:	FCO318 DP Transmitter + Flow Element
Manufacturer	:	Furness Controls Limited
Flow Range		0 to 200 l/min
LFE DP	:	84.28 Pa
Transmitter Ser No	:	1007173
Transducer No	:	FC80281
Flow Element Ser No	:	1007175
Firmware version	:	E300A07

I Clarke

Approved:

Approved Signatories
I Clarke
A Legget
G Markham
G Thorogood
DB Walker

Furness Controls Ltd
Beeching Road
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e-mail : calibration@furness-controls.com

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Furness Controls Limited

UKAS Accredited Calibration Laboratory No. 0580

Calibration Certificate No. 06632

Flow Range: 0 to 200 l/min Signal O/P: 0 to 10 V

Reference Flow l/min	Flow meter being calibrated Output V	Error % of Rdg	Display l/min	Error % of Rdg
0.00	0.00266	N/A	0.0	N/A
2.0219	0.10138	0.28	2.0	-1.08
3.9993	0.19852	-0.72	3.9	-2.48
6.002	0.30130	0.40	6.0	-0.03
8.051	0.40071	-0.46	8.0	-0.63
10.224	0.51119	0.00	10.2	-0.23
15.017	0.75099	0.02	15.0	-0.11
20.022	1.00453	0.34	20.0	-0.11
25.106	1.25465	-0.05	25.1	-0.02
30.114	1.51230	0.44	30.2	0.29
40.64	2.02699	-0.25	40.5	-0.34
50.22	2.49766	-0.53	50.0	-0.44
75.84	3.78073	-0.30	75.6	-0.32
100.90	5.03775	-0.14	100.7	-0.20
125.74	6.28398	-0.05	125.6	-0.11
150.26	7.51849	0.07	150.3	0.03
175.07	8.76665	0.15	175.2	0.07
199.61	10.01386	0.33	200.2	0.30

Each result is the average of 20 readings taken.

Test Engineer : Geoff Thorogood Signature :

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Furness Controls Limited

UKAS Accredited Calibration Laboratory No. 0580

Calibration Certificate No. 06632

Procedure:

The instrument provides a digital indication and an electrical output corresponding to the flow through the laminar flow element.
The instrument was calibrated against a standard laminar flow element.
Differential pressure was measured using a digital micromanometer.
The output was measured using an Agilent 34401A digital multimeter.
The readings of the reference standards and of the instrument under test were taken either manually or via RS232 when available to a PC running a calibration program.
The calibration medium was dry air.
The ambient temperature was 20 ± 2 °C and the relative humidity was < 70 %.
Reference flow readings were corrected to the working conditions of the instrument.
The working conditions were: 1014 mbar and 20.2 °C.

Standards & Uncertainties

The reported expanded uncertainty is based on a standard uncertainty multiplied by a coverage factor k=2, providing a level of confidence of approximately 95%. The uncertainty evaluation has been carried out in accordance with UKAS requirements.
The estimated uncertainty associated with the measurement of the applied flow is ± 0.5 % of reading.
The uncertainty of flow calibration is the uncertainty of the measured flow + 1 lsd.
The estimated uncertainty of the indicated current is ± 0.01 % of reading + 3 uA + 1 lsd.

Standards used:

FCO96 WS374 (2 l/min)
FCO96 WS227 (30 l/min)
FCO96 WS266 (500 l/min)
Agilent 34401a RS42
FCO510 WS366 (0 to 2 kPa)

All measuring standards are traceable to national or international standards.

Program & version: CS043: V2.3.3.300 Series + LFE.34

Comments:

The instrument is within the manufacturer's specification for accuracy.

Test Engineer : Geoff Thorogood Signature : SJT

---------- End of calibration certificate ----------

APPENDIX C

ASHRAE 52/76 Calibration Certificate

Station Yard Industrial Estate, Hatton
Derbyshire, UK, DE65 5DU
Telephone: +44 (0) 1283 520306
Fax: +44 (0) 1283 520412
Email: sales@powdertechnology.com
Website: www.powdertechnology.com
Registered in England No. 3407393

CERTIFICATE OF CONFORMANCE
STANDARD TEST DUST
TYPE – ASHRAE 52/76

BATCH NUMBER 7681 DATE 1-4-11

MOLACCO BLACK 23%
Carbon Black C177266
Specific gravity 1.7 2.1

SAE J 726 FINE test dust 72%
Mineral dust predominantly silica with other oxides present.
Particle size up to approximately 80 microns.
Specific gravity 2.6 – 2.7 gms/cm^3

COTTON LINTERS STAPLE BELOW ? 5%

MOISTURE CONTENT < 1.0% by weight

Batch Number 7681 of Standard Test Dust type
ASHRAE 52/76 meets the requirements of that specification

Signed .....
N Samuel
1-4-11

Note: Standard Test Dusts may be prone to segregation of the particles during transport and handling and should therefore be used as a complete jar at a time or samples removed for use as required by a recognised sampling method.

APPENDIX D

DustTrack Loading Analysis

Data logging Interval	Averaging time for data points	Data points per Loading (3.5 hrs)
1 minute	10 seconds	210

Table 10: DustTrak Settings

Dust Loading Cycle	Min (mg/m^3)	Mean (mg/m^3)	Max (mg/m^3)	SDEV (σ)
1	0.123	18.951	27.517	3.757
2	7.529	18.516	29.022	2.947
3	0.028	15.923	22.467	2.646
4	6.054	16.589	24.172	2.637
5	2.047	16.084	22.675	2.737
6	10.308	15.206	23.014	2.644
7	3.787	15.446	29.873	3.579
8	6.074	16.031	25.495	2.574
9	3.441	16.031	23.368	2.817
10	6.006	14.788	23.974	3.048
11	12.66	19.882	27.855	3.119
12	0.303	20.296	20.296	6.879
13	8.854	23.658	30.967	3.301
14	14.199	35.684	94.167	8.858
15	7.164	33.291	62.737	7.569

Table 11: Dust Loading Analysis

DustTrack 85201887 Average concentration (mg/m^3)	DustTrack 23390 Average concentration (mg/m^3)
22.84	22.79

Table 12: DustTrack Comparison Average Reading

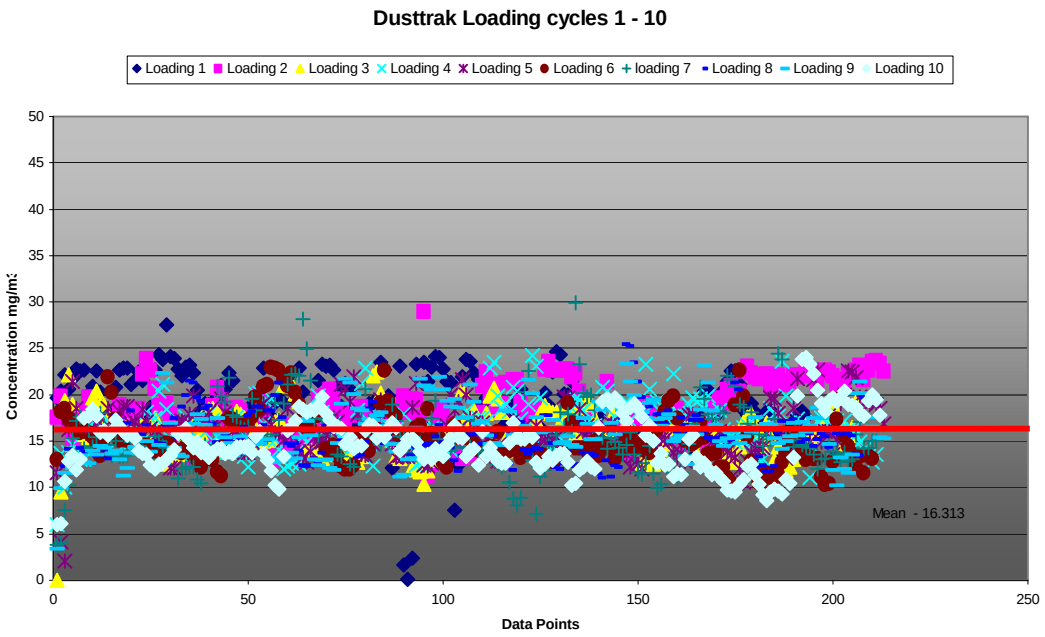

Figure 8: Summary Graph Dust Loading 1 - 10

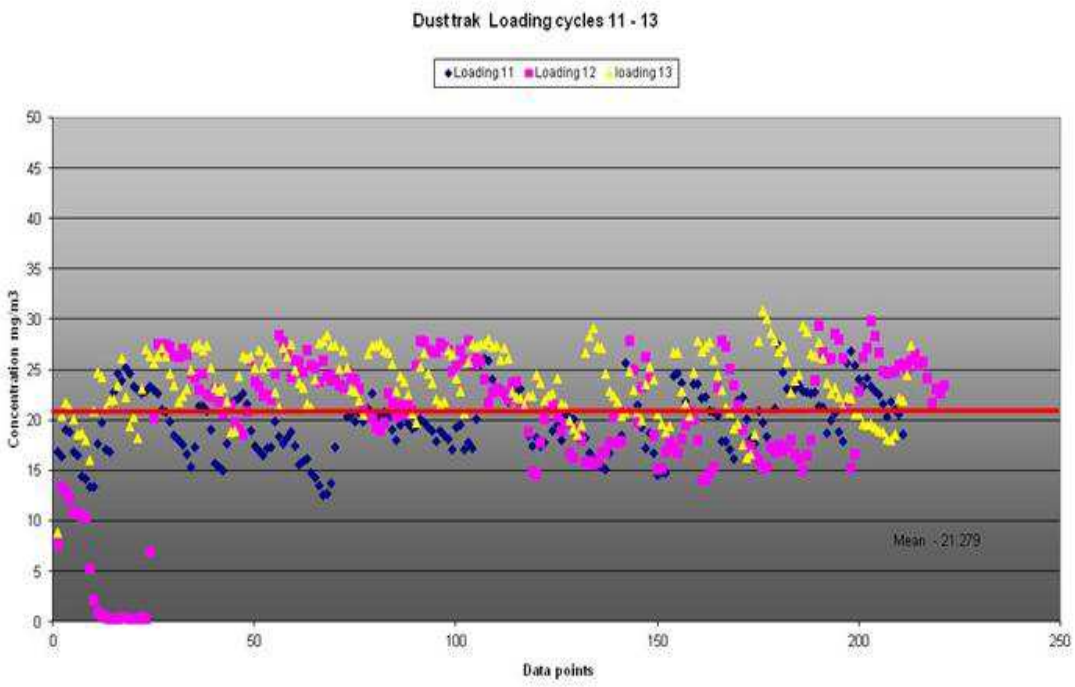

Figure 9: Summary Graph Dust Loading 11 - 13

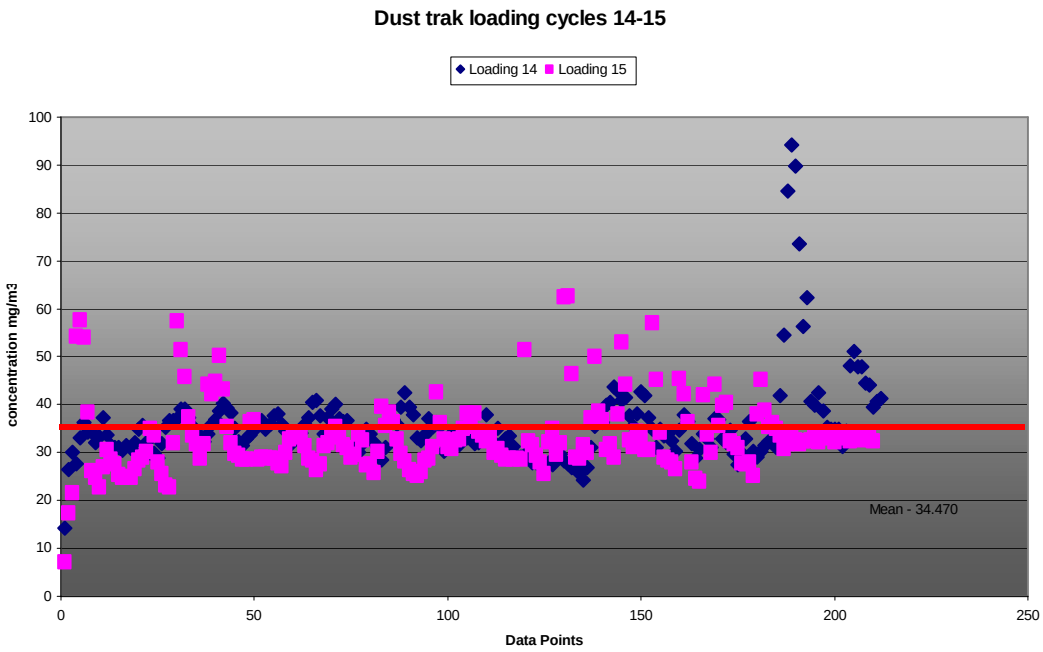

Figure 10: Summary Graph Dust Loading 14 - 15

APPENDIX E

Sensitivity (Normalised) Calculation

The normalized sensitivity after each dust loading was calculated as follows:

$$RTV_N = \frac{RTV_0}{RTV_n} \times 100$$

RTV_N: Normalised sensitivity
RTV_0: Baseline. Average of two RTV measurements (%Obs/m) taken for ASD out of box
RTV_n: Average of two RTV measurements (%Obs/m) following dust loading

Example:

- RTV_N = 100 → Baseline (ASD out of box)
- RTV_N = 67 → 33% reduction in sensitivity → ASD requires x1.5 the amount of smoke concentration compared to baseline for alarm condition
- RTV_N = 50 → 50% reduction in sensitivity → ASD requires x2 the amount of smoke concentration compared to baseline for alarm condition

APPENDIX F

Detailed Test Results – Individual ASD Units

	VLI - 880	FAAST 8100	SecuriRAS ASD535	TITANIUS PRO SENS
Baseline (ASD out of box)				
Smoke Test 1 (%/m)	0.211	0.460	0.318	0.297
Smoke Test 2 (%/m)	0.195	0.490	0.332	0.280
Average RTV_0 (%/m)	0.203	0.475	0.325	0.289
RTV_N (%)	100	100	100	100
Dust Loading 1				
Smoke Test 1 (%/m)	0.249	0.560	0.366	0.366
Smoke Test 2 (%/m)	0.170	0.556	0.388	0.417
Average RTV_1 (%/m)	0.210	0.558	0.377	0.392
RTV_N (%)	97	85	86	74
Dust Loading 2				
Smoke Test 1 (%/m)	0.213	0.671	0.37	0.448
Smoke Test 2 (%/m)	0.210	0.666	0.392	0.494
Average RTV_2 (%/m)	0.212	0.669	0.381	0.471
RTV_N (%)	96	71	85	61
Dust Loading 3				
Smoke Test 1 (%/m)	0.187	0.648	0.386	0.520
Smoke Test 2 (%/m)	0.195	0.702	0.424	0.484
Average RTV_3 (%/m)	0.191	0.680	0.405	0.502
RTV_N (%)	106	70	80	57
Dust Loading 4				
Smoke Test 1 (%/m)	0.199	0.722	0.471	0.595
Smoke Test 2 (%/m)	0.227	0.603	0.468	0.663
Average RTV_4 (%/m)	0.213	0.663	0.470	0.629
RTV_N (%)	95	72	69	46
Dust Loading 5				
Smoke Test 1 (%/m)	0.197	0.631	0.450	NT*
Smoke Test 2 (%/m)	0.189	0.722	0.458	NT
Average RTV_5 (%/m)	0.193	0.677	0.454	
RTV_N (%)	105	70	72	
Dust Loading 6				
Smoke Test 1 (%/m)	0.249	0.814	0.470	NT
Smoke Test 2 (%/m)	0.190	0.716	0.476	NT
Average RTV_6 (%/m)	0.220	0.765	0.473	
RTV_N (%)	92	62	69	

	VLI - 880	FAAST 8100	SecuriRAS ASD535	TITANIUS PRO SENS
Dust Loading 7				
Smoke Test 1 (%/m)	0.198	0.738	0.510	NT
Smoke Test 2 (%/m)	0.245	0.852	0.503	NT
Average RTV_7 (%/m)	0.222	0.795	0.507	
RTV_N (%)	92	60	64	
Dust Loading 8				
Smoke Test 1 (%/m)	0.248	1.008	0.514	NT
Smoke Test 2 (%/m)	0.231	0.817	0.513	NT
Average RTV_8 (%/m)	0.240	0.913	0.514	
RTV_N (%)	85	52	63	
Dust Loading 9				
Smoke Test 1 (%/m)	0.219	0.765	0.608	NT
Smoke Test 2 (%/m)	0.208	0.830	0.575	NT
Average RTV_9 (%/m)	0.214	0.798	0.592	
RTV_N (%)	95	60	55	
Dust Loading 10				
Smoke Test 1 (%/m)	0.199	1.015	0.508	NT
Smoke Test 2 (%/m)	0.262	0.965	0.498	NT
Average RTV_{10} (%/m)	0.231	0.990	0.503	
RTV_N (%)	88	48	65	
Dust Loading 11				
Smoke Test 1 (%/m)	0.257	1.008	0.549	NT
Smoke Test 2 (%/m)	0.263	0.982	0.605	NT
Average RTV_{11} (%/m)	0.260	0.995	0.577	
RTV_N (%)	78	48	56	
Dust Loading 12				
Smoke Test 1 (%/m)	0.213	0.838	0.593	NT
Smoke Test 2 (%/m)	0.229	0.907	0.59	NT
Average RTV_{12} (%/m)	0.221	0.873	0.592	
RTV_N (%)	92	54	55	
Dust Loading 13				
Smoke Test 1 (%/m)	0.219	0.999	0.606	NT
Smoke Test 2 (%/m)	0.214	1.000	0.590	NT
Average RTV_{13} (%/m)	0.217	1.000	0.598	
RTV_N (%)	94	48	54	
Dust Loading 14				
Smoke Test 1 (%/m)	0.200	1.090	0.678	NT
Smoke Test 2 (%/m)	0.212	1.024	0.642	NT
Average RTV_{14} (%/m)	0.206	1.057	0.660	
RTV_N (%)	99	45	49	

	VLI - 880	FAAST 8100	SecuriRAS ASD535	TITANIUS PRO SENS
Dust Loading 15 – *Loaded Filters*				
Smoke Test 1 (%/m)	NT	NT	0.651	NT
Smoke Test 2 (%/m)	NT	NT	0.650	NT
Average RTV_{15} (%/m)			0.651	
RTV_N (%)			50	
Dust Loading 15 – *New Filters*				
Smoke Test 1 (%/m)	NT	NT	0.625	NT
Smoke Test 2 (%/m)	NT	NT	0.650	NT
Average RTV_{15} (%/m)			0.638	
RTV_N (%)			51	

NT: Not Tested

Table 13: Detailed Results: Smoke Tests / Normalised Sensitivity