Fast Particle Size Distribution Measurements with SMPS utilizing a Novel Classifier

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Presented at Cambridge Particle Meeting.
27th June 2014

UNDERSTANDING, ACCELERATED

Content

+ Model 3082 classifier
  - Ease of use
  - Performance,
    - Sheath flow
    - Voltage
    - Size and concentration testing ISO 15900
  - Scan time
    - Fast Scanning
    - Considerations and Trade offs
  - Summary

BACKGROUND & MOTIVATION

+ Differential mobility (DMPS Fissan *et al* 1983; SEMS, Wang & Flagan 1990) is the measurement principle of choice for making size distribution measurements
+ TSI 3071 Electrostatic Classifier introduced in 1972
+ TSI 3080 Electrostatic Classifier in wide use since introduction in 1999
+ Motivation for 2013 redesign
  - Desire for portability and ease of use
  - Desire for operation without PC for field use
  - 3080 Classifier limited to 30 sec scans; take advantage of fast response of today's CPCs
+ 3080 performance is well-proven. Refreshed device should do no harm. Must be as good or better.

TSI Model 3071

TSI Model 3080

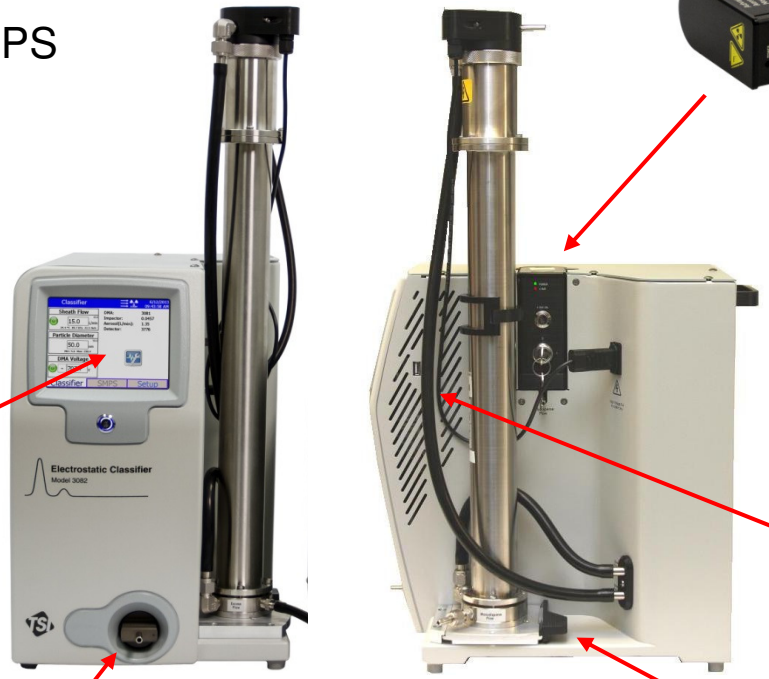
TSI MODEL 3082 ELECTROSTATIC CLASSIFIER

Ease-of-Use Improvements

- Auto-recognition of SMPS hardware
  - DMA
  - CPC
  - Neutralizer
  - Impactor

Integrated, removable bi-polar x-ray neutralizer

TSI Model 3088



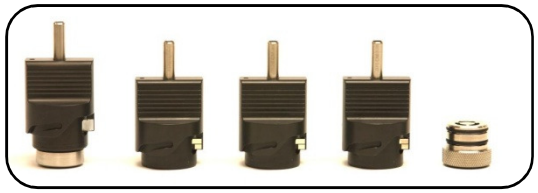
Touchscreen display

Now supports stand-alone scanning (no PC) in addition to software

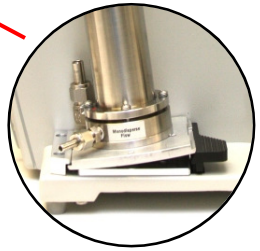
Data download via USB Flash

25% weight and width reduction compared to TSI Model 3080

Inlet and impactor kit



Tool-free installation of DMAs and impactor set

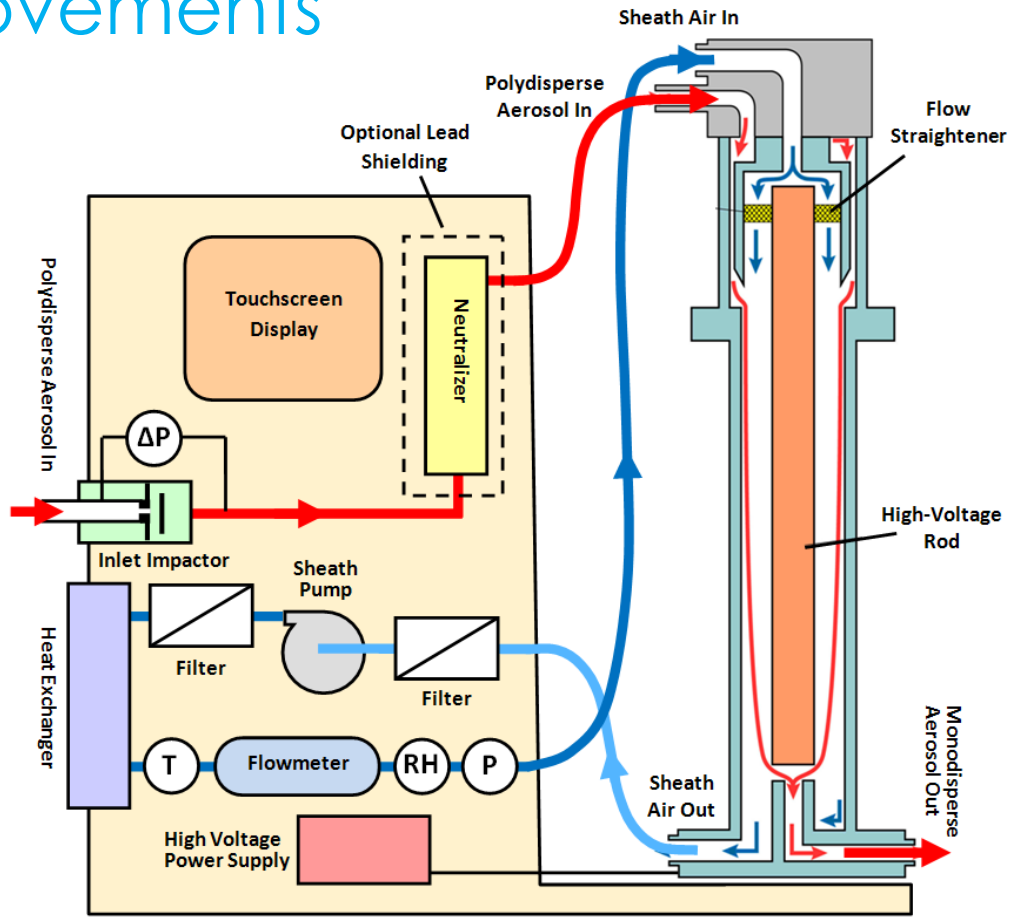


DMA quick-connect mount

TSI MODEL 3082 ELECTROSTATIC CLASSIFIER

Performance Improvements

- 2-30 L/min sheath flow
- 50 Hz data sampling for higher time resolution
- Optional Dual polarity high voltage control for DMA with 50 ms response time for fast scanning
- Well-characterized CPC response time
- Single blower, removed bypass flow connections
- No change to DMAs



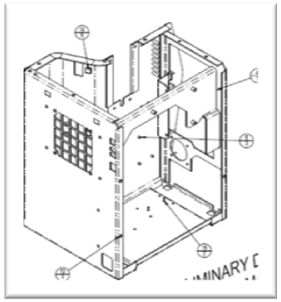
TSI MODEL 3082 ELECTROSTATIC CLASSIFIER

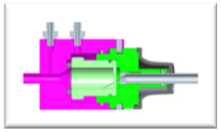
Extensive Verification Testing

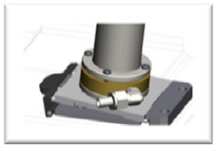
Development: 18 months, 15 engineers, 5 prototype cycles, 17 total prototypes, 150+ development tests, 55 validation tests

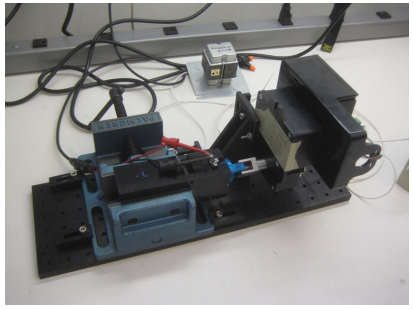
Subsystem verification – test BEYOND product specifications

- Sheath flow
- High voltage
- Dual polarity
- Response time
- Algorithms
- Communication
- Mechanical interfaces
- Accelerated life testing







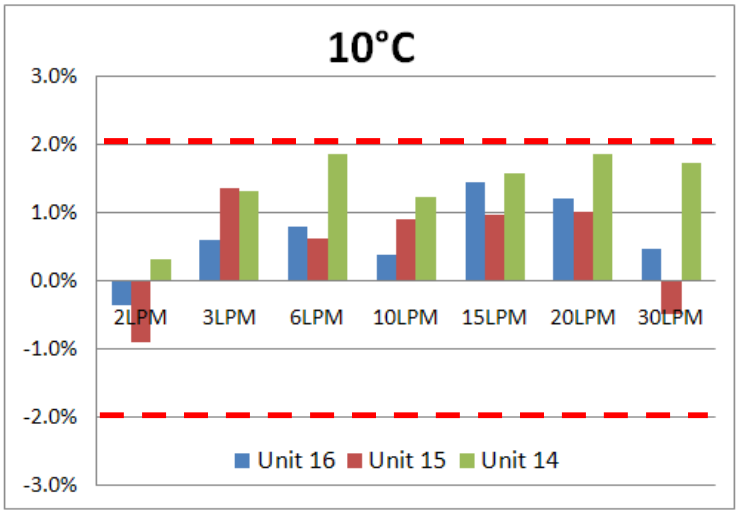


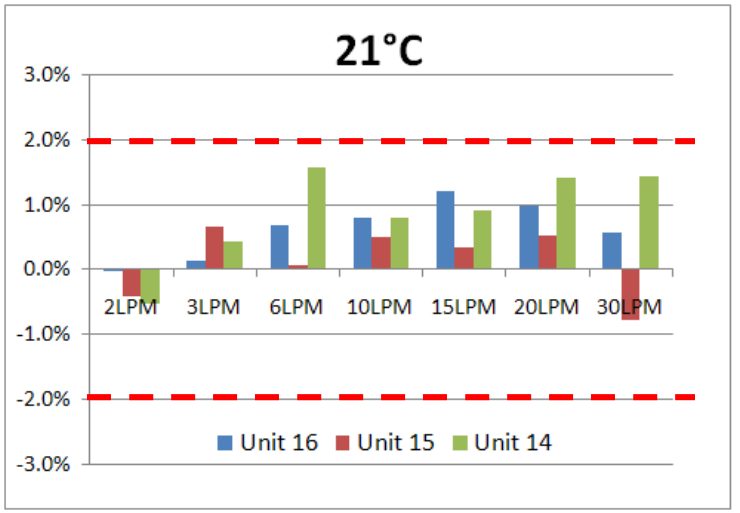
System validation – test to product specifications

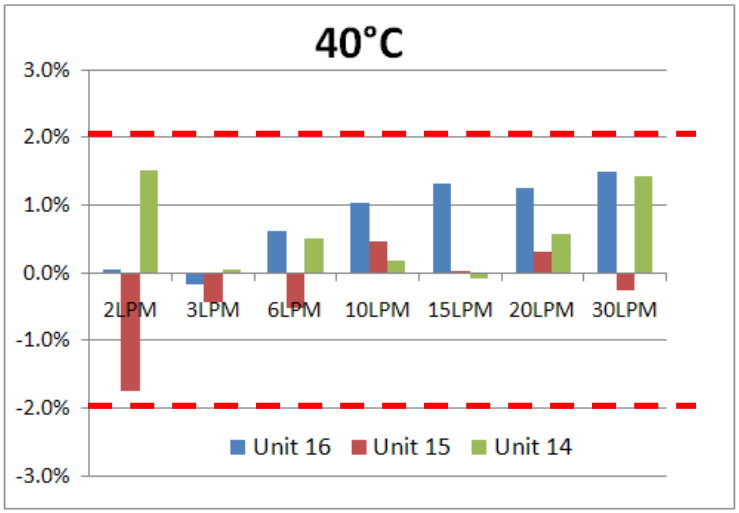
- Size accuracy
- Concentration accuracy
- Size resolution
- Fast scanning
- Reliability/repeatability
- Shipping/vibration

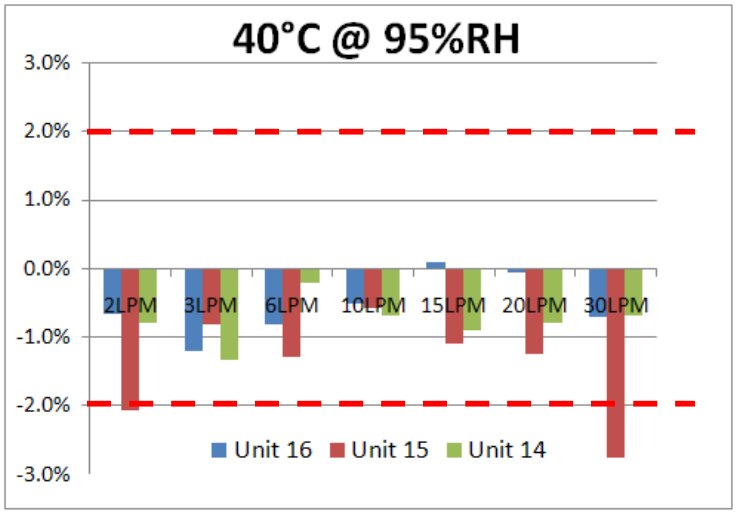
3082 SHEATH FLOW ACCURACY

Target Accuracy: ±2% over 10-40°C range

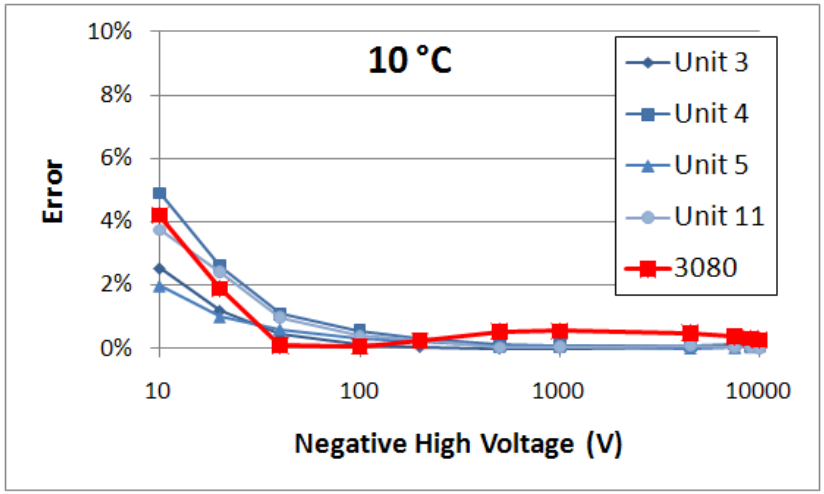


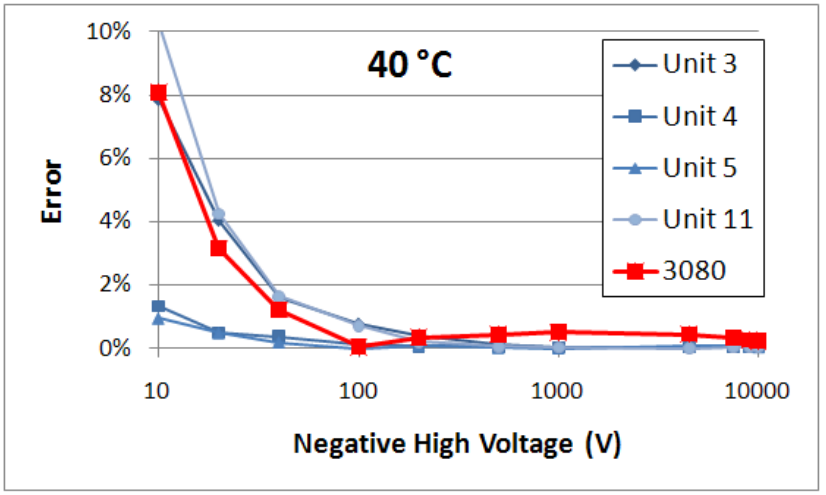


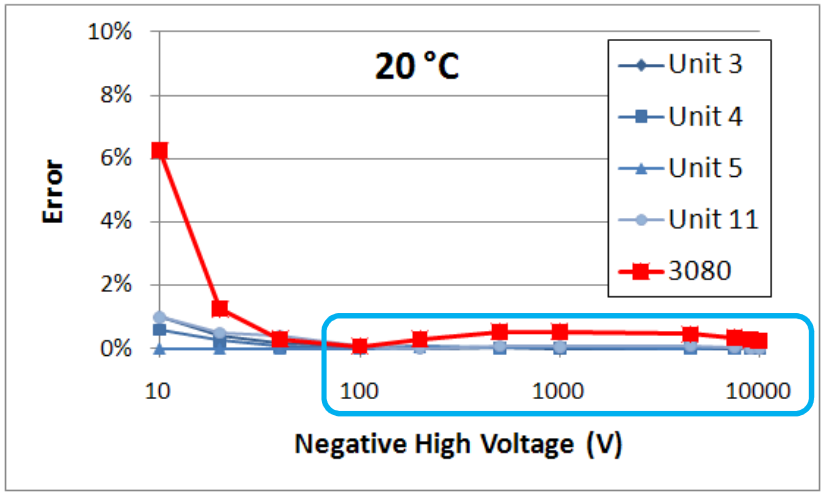




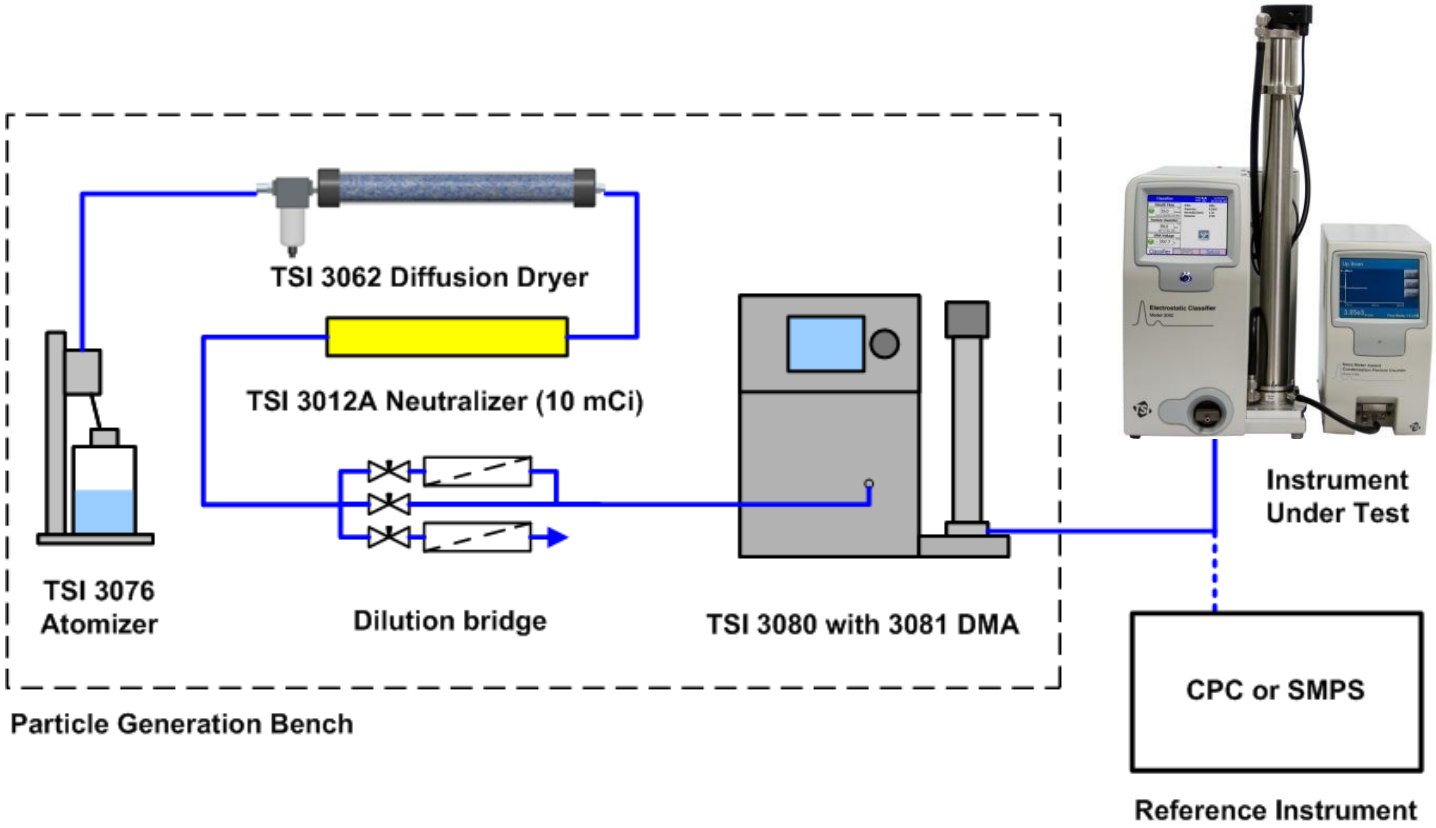
3082 HIGH VOLTAGE ACCURACY







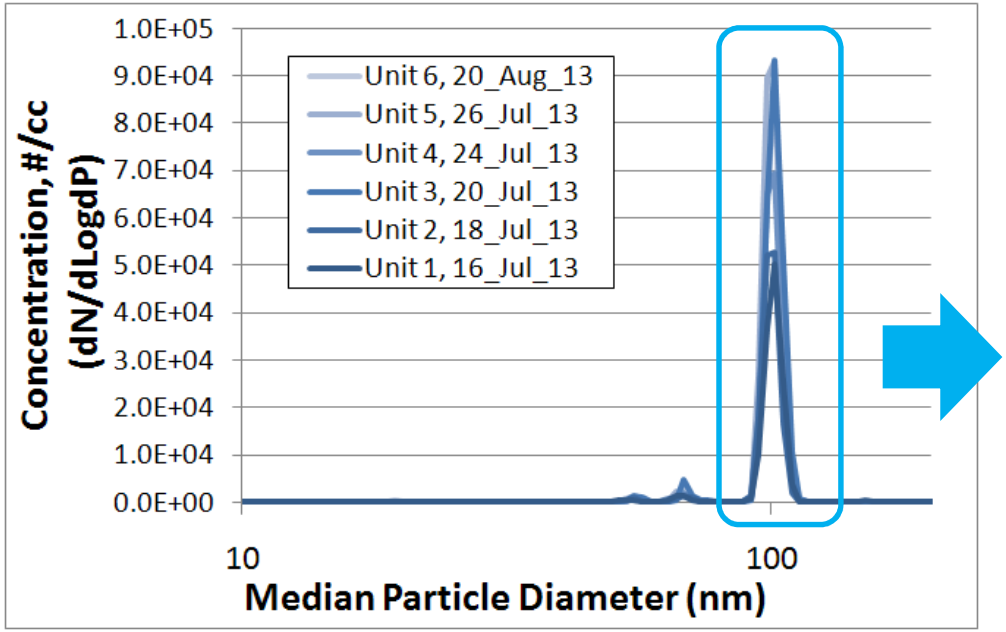
PARTICLE TEST SETUP



- Flexible setup for majority of tests
  - Different materials (NaCl, PSL)
  - Number concentration accuracy
  - Size accuracy
  - Polarity comparisons
  - 3080 Comparisons

3082 100nm SIZE ACCURACY

Methods per ISO 15900 Sections 7.7, 7.8



Test (n=5)	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	Unit 6
Mean Diameter (nm)	101.0 ±0.2	100.0 ±0.2	99.8 ±0.9	99.5 ±0.8	100.0 ±0.2	100.4 ±0.8
Size Resolution	1.0%	1.0%	1.1%	1.1%	1.0%	1.1%

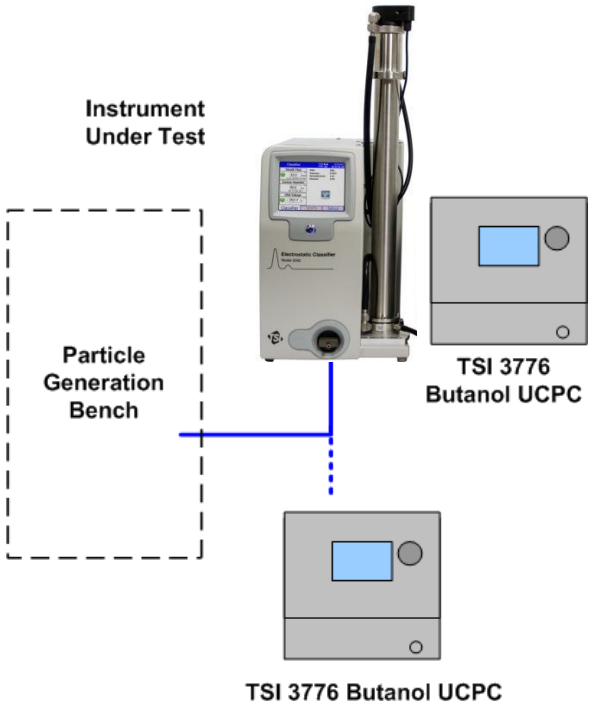
Configuration:
3776 CPC high flow, 3081A DMA, 60s scan time, 10:1 sheath to aerosol flow ratio, avg. of 5 scans

3082 CONCENTRATION ACCURACY

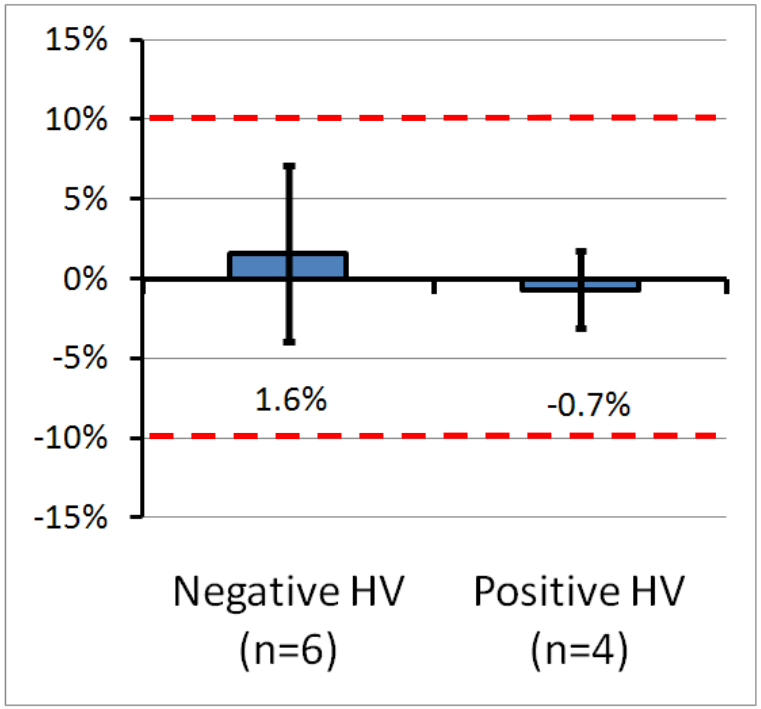
Methods per ISO 15900 Section 7.9

Test conducted in instrument calibration

- Monodisperse 100nm PSL at >1000 #/cc
- 60s scan time x 5 samples
- CPC concentration recorded before/after SMPS scan, averaged



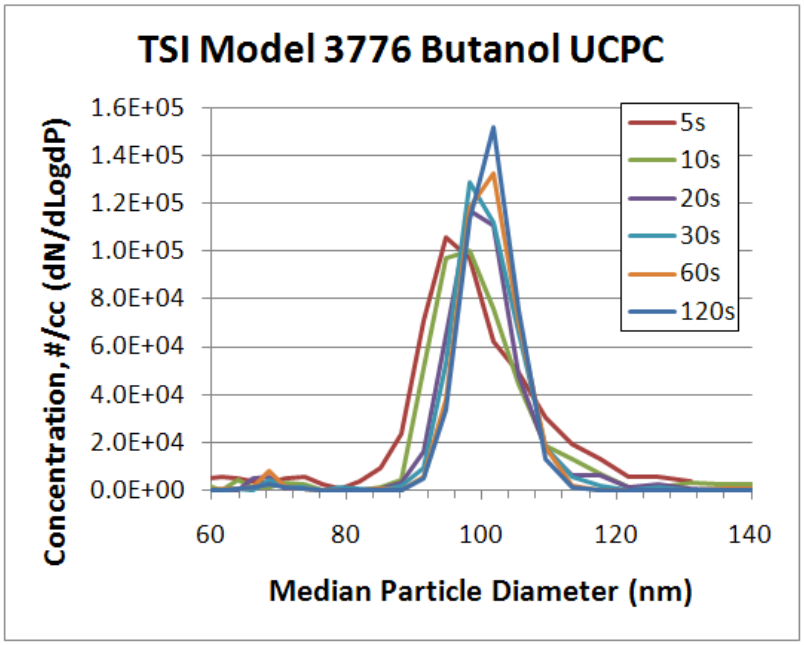
Experimental Setup

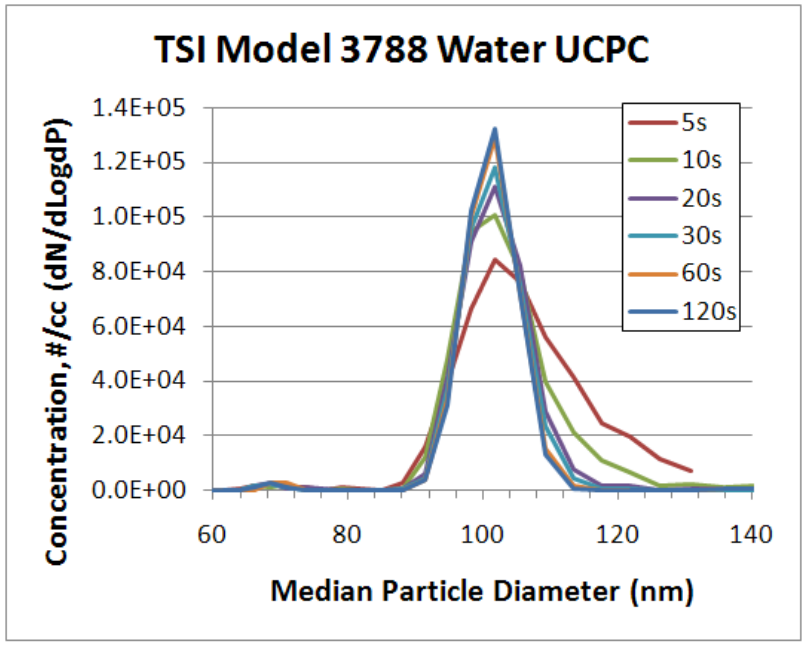


Test Results

3082 SCAN TIME COMPARISON

100nm PSL, using scan times 5-120s





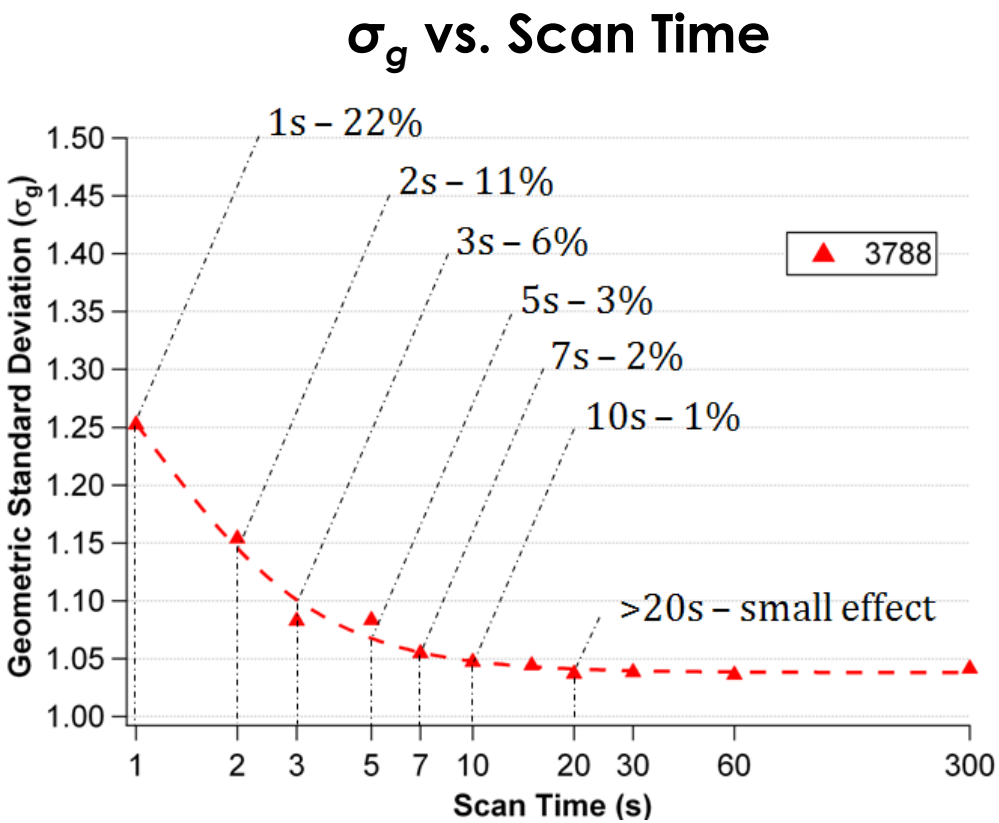
Configuration

- 3081A DMA
- 10:1 sheath to aerosol flow ratio
- 1.5 l/min CPC flow rate
- 25.4 cm tube length
- avg. of 3 scans

FAST SCANNING

Considerations and Tradeoffs

+ Fast scanning ideal for polydisperse distributions at high concentrations, non-ideal for monodisperse aerosols
+ Trade-off between resolution and scan time due to basic physical principles (see figure)
+ For best results…
  - Use CPCs with fast response time (3776, 3788) for best resolution
  - Use short tube length (<25cm) to reduce broadening
  - Time delay can be adjusted for your specific setup to improve accuracy



From Erickson *et al.* (2012) Investigation of Fast Scanning SMPS Measurements: 16s and Below. Presented at EAC 2012, WG08S3O5

SUMMARY

UNDERSTANDING, ACCELERATED

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+ Fast scanning sizer and classifier has been developed
  - Enhanced usability (auto-recognition and tool-free install of hardware, size/weight reduction, touch screen display)
  - Enhanced performance (dual polarity, fast-scanning for measuring moderate transients, higher resolution from increased sheath flow)
+ Calibration methods comply with international standards
  - ISO 15900:2009 for size accuracy, resolution, etc
  - ACTRIS/EUSAAR for data reporting
+ Performance has been verified against 3080 Classifier
  - Extensive verification and validation testing to ensure reliability over time, temperature, RH, vibration
  - Fast scanning advantages/trade-offs investigated

