Bleed Air Contaminant Particulate Measurements

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Bleed Air Contaminant Particulate Measurements

- Bleed air simulator measurement
  - Phase 1
  - Phase 2
- VIPR program
- Test stand turbine engine measurements

BAS – Phase 1

- Particle size distribution from the simulator for the following conditions:

Point #	Base		Study 1		Study 2		Study 3		Study 4	
	Temp, °C (°F)	Press, kPa (psi)	Temp, °C (°F)	Press, kPa (psi)	Temp, °C (°F)	Press, kPa (psi)	Temp, °C (°F)	Press, kPa (psi)	Temp, °C (°F)	Press, kPa (psi)
1	No Heat	200 (29)	100 (212)	200 (29)	230 (445)	690 (100)	230 (445)	200 (29)	280 (535)	200 (29)
2	185 (365)	200 (29)	200 (392)	200 (29)	250 (490)	690 (100)	—	—	280 (535)	340 (50)
3	230 (445)	460 (67)	240 (464)	200 (29)	280 (535)	690 (100)	230 (445)	480 (70)	280 (535)	480 (70)
4	250 (490)	690 (100)	275 (527)	200 (29)	310 (590)	690 (100)	230 (445)	690 (100)	280 (535)	690 (100)
5	280 (535)	480 (70)								
6	310 (590)	690 (100)								

Particle Measuring

Aerodynamic Particle Sizer

- TSI Model 3321
- Measures aerodynamic diameter by recording the time of flight of particles as they are accelerated through a nozzle.
- Particle size is binned into 52 channels from 0.5µm to 20 µm.

Condensation Particle Counter

- TSI Model 3781
- Measures particle concentration by optical counting.
- Water is deposited by condensation onto the particles to make them large enough to be detected optically.
- Particles as small as 6 nm are counted. There is no binning.

Particle Measuring

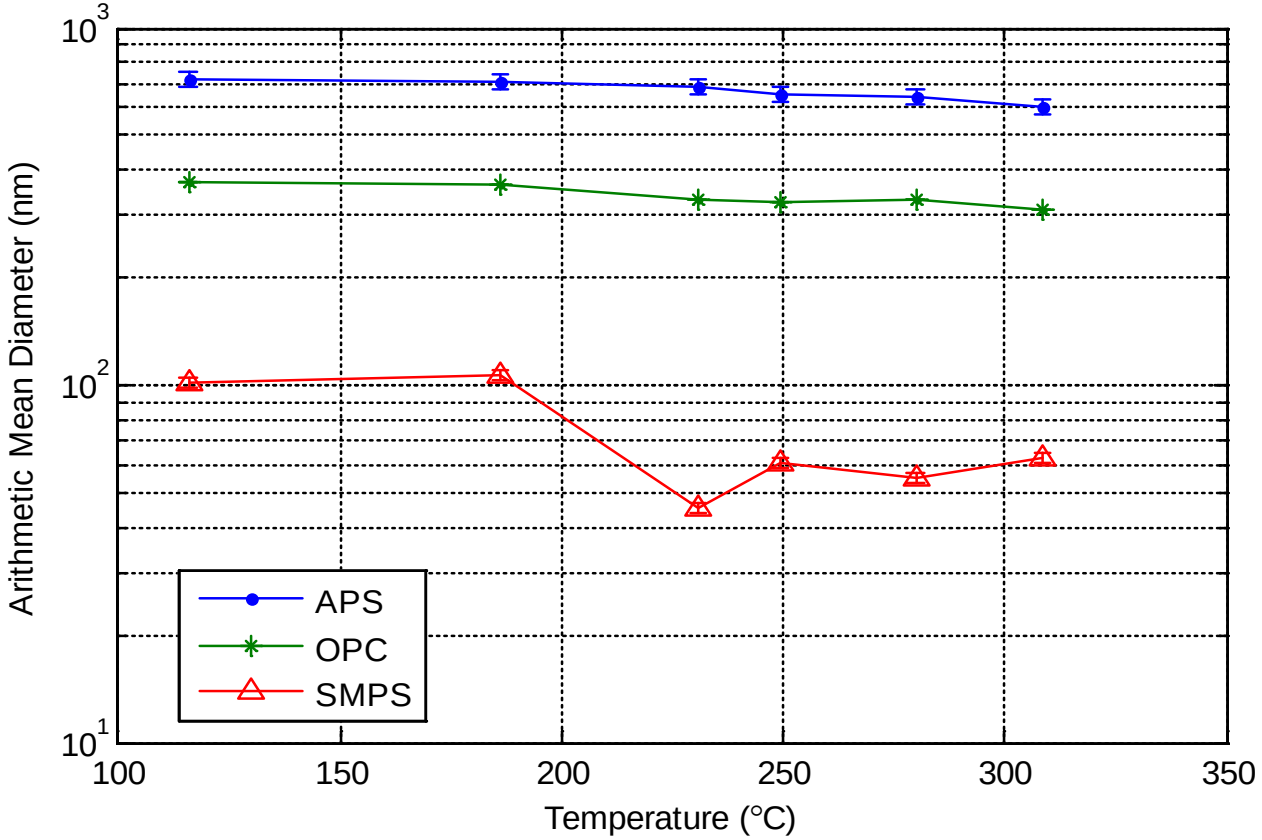
Optical Particle Counter

- Climet Spectro 0.3
- Calculates particle size and concentration by measuring the intensity of light scattered by the particles.
- Particle size is binned into 16 channels from 0.3µm to 10µm.

Scanning Mobility Particle Sizer

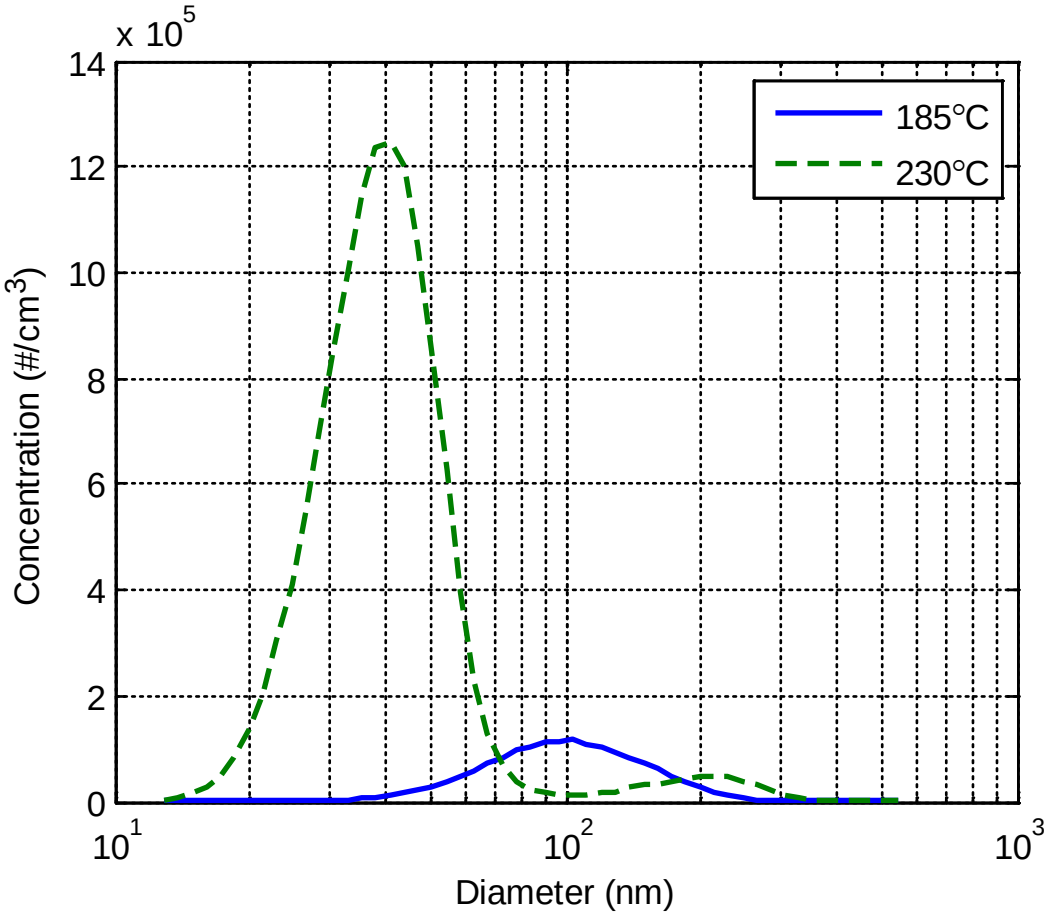
- TSI 3496
- Uses ionization with electric field to separate particles by mobility
- Uses a CPC to count different size bands
- Size range from 10nm to 532nm.

Results



Size distributions from base study

Results


x 10^5
14
12
10
8
6
4
2
0
Concentration (#/cm^3)
10^1
10^2
10^3
Diameter (nm)
185°C
230°C

BAS – Phase 2

- Particle Sizing
- FTIR analysis of gaseous contaminants
- Collection of contaminant samples with absorbent tubes

Particle Measuring

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Scanning Mobility Particle Sizer

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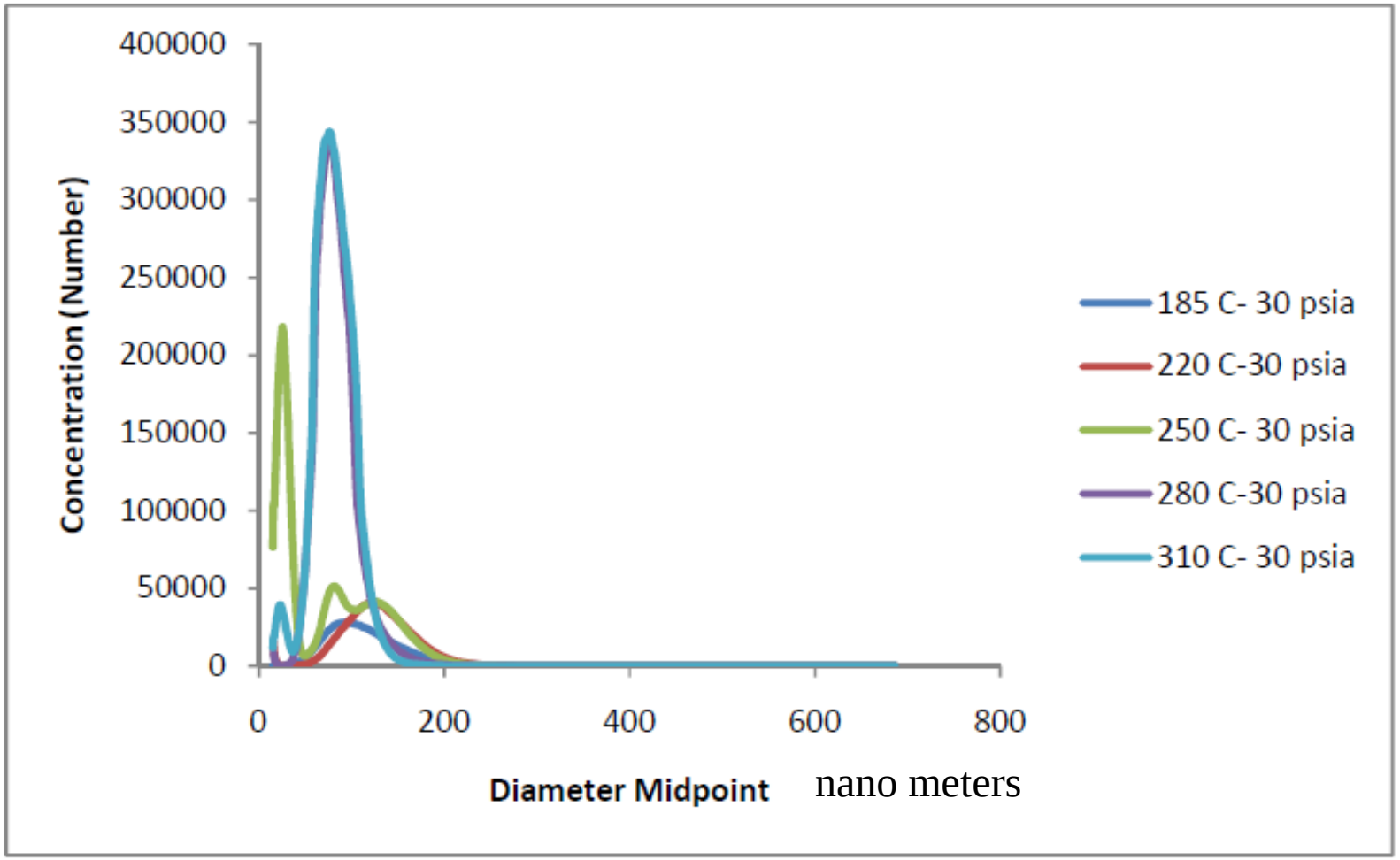
- Uses ionization with electric field to separate particles by mobility
- Uses a CPC to count different size bands
- Size range from 10nm to 532nm.

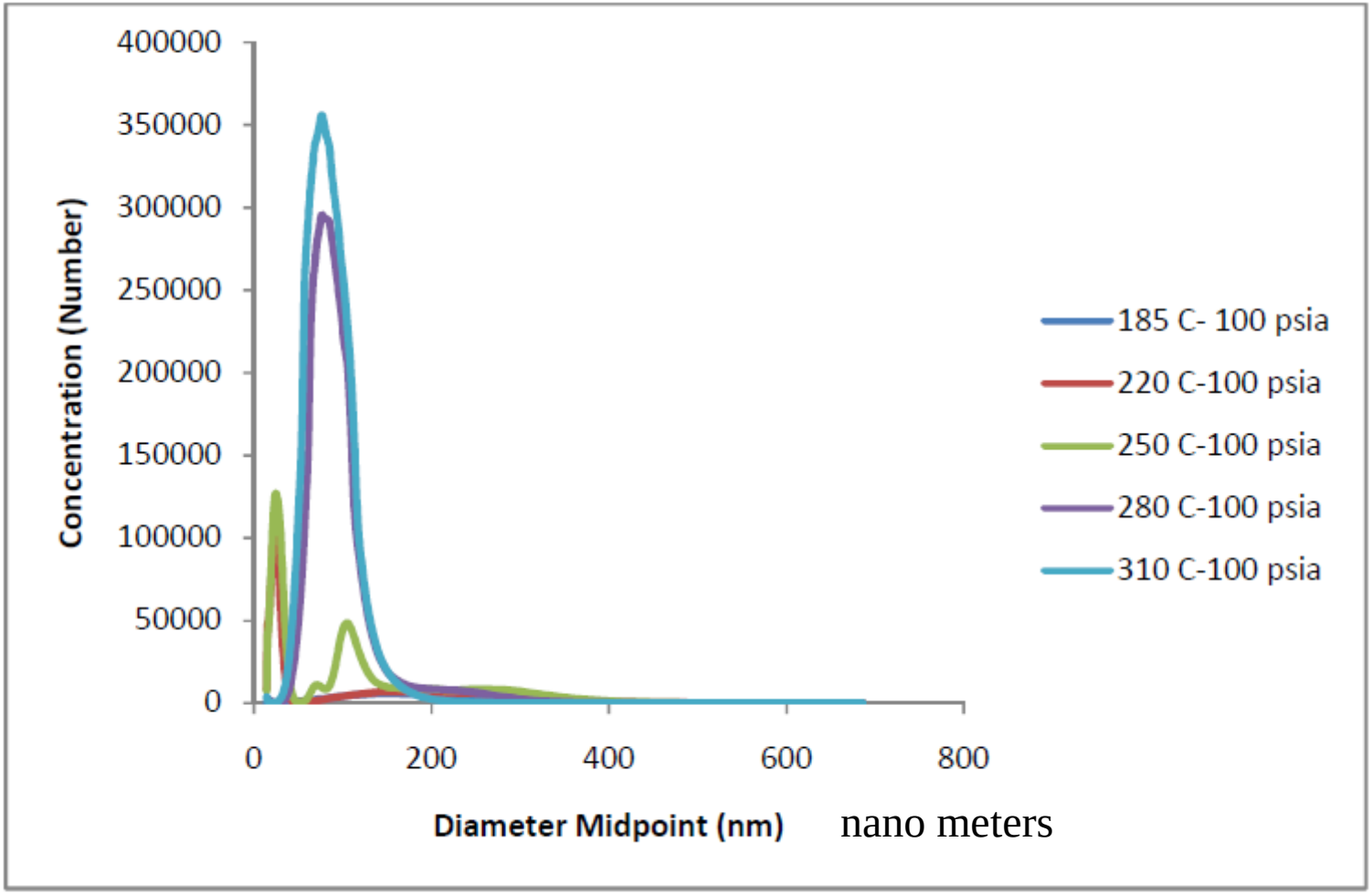
BAS Experimental Conditions

Temperature (C)	Pressure (psia)			
	30	50	70	100
185				
220				
250				
280				
310				

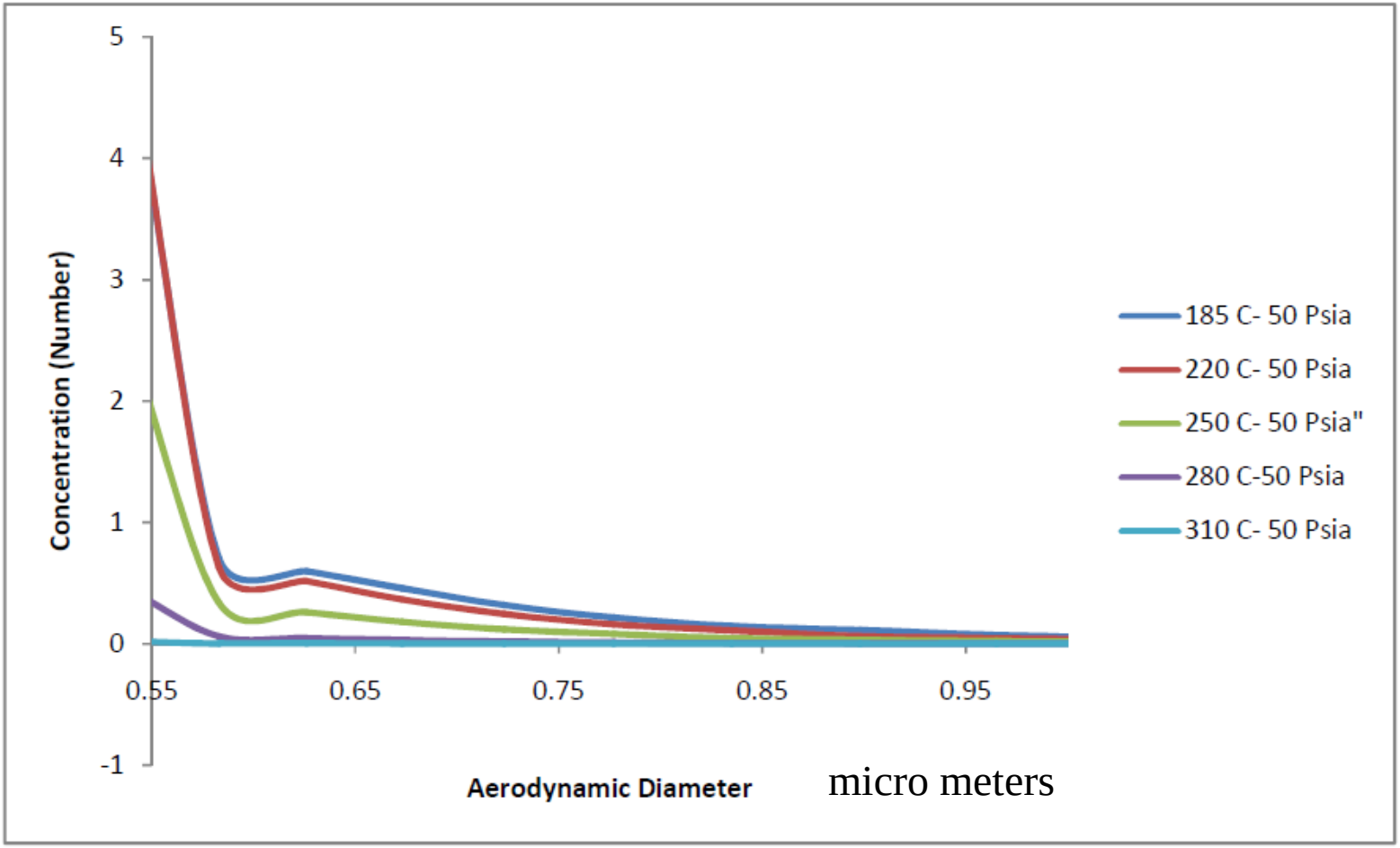
SMPS 30 psia


400000
350000
300000
250000
200000
150000
100000
50000
0
Concentration (Number)
0
200
400
600
800
Diameter Midpoint
nano meters
185 C- 30 psia
220 C-30 psia
250 C- 30 psia
280 C-30 psia
310 C- 30 psia

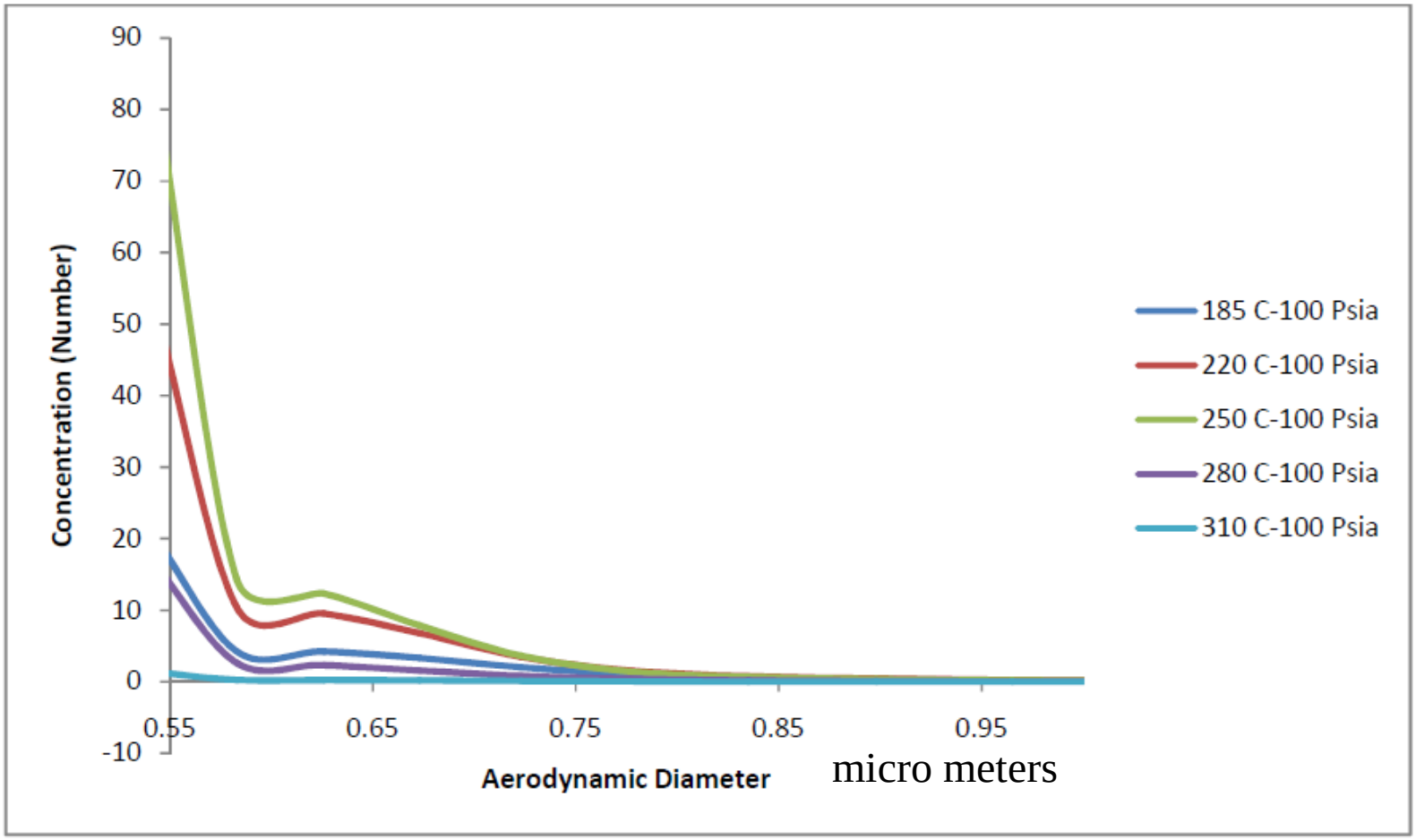
SMPS 100 psia



APS 50 psia


5
4
3
2
1
0
-1
Concentration (Number)
0.55
0.65
0.75
0.85
0.95
Aerodynamic Diameter
micro meters
185 C- 50 Psia
220 C- 50 Psia
250 C- 50 Psia"
280 C-50 Psia
310 C- 50 Psia

APS 100 psia


90
80
70
60
50
40
30
20
10
0
-10
Concentration (Number)
0.55
0.65
0.75
0.85
0.95
Aerodynamic Diameter
micro meters
185 C-100 Psia
220 C-100 Psia
250 C-100 Psia
280 C-100 Psia
310 C-100 Psia

Conclusions from BAS Measurements

- Bulk of particle counts below 300 nm
- Higher temperatures generate substantially more ultrafine particles, likely smoke generation
- Generation of increased ultrafine particles at elevated temperatures not likely tied to apparatus

Bleed air contamination detector?

Ionization smoke detectors work well for d<300 nm

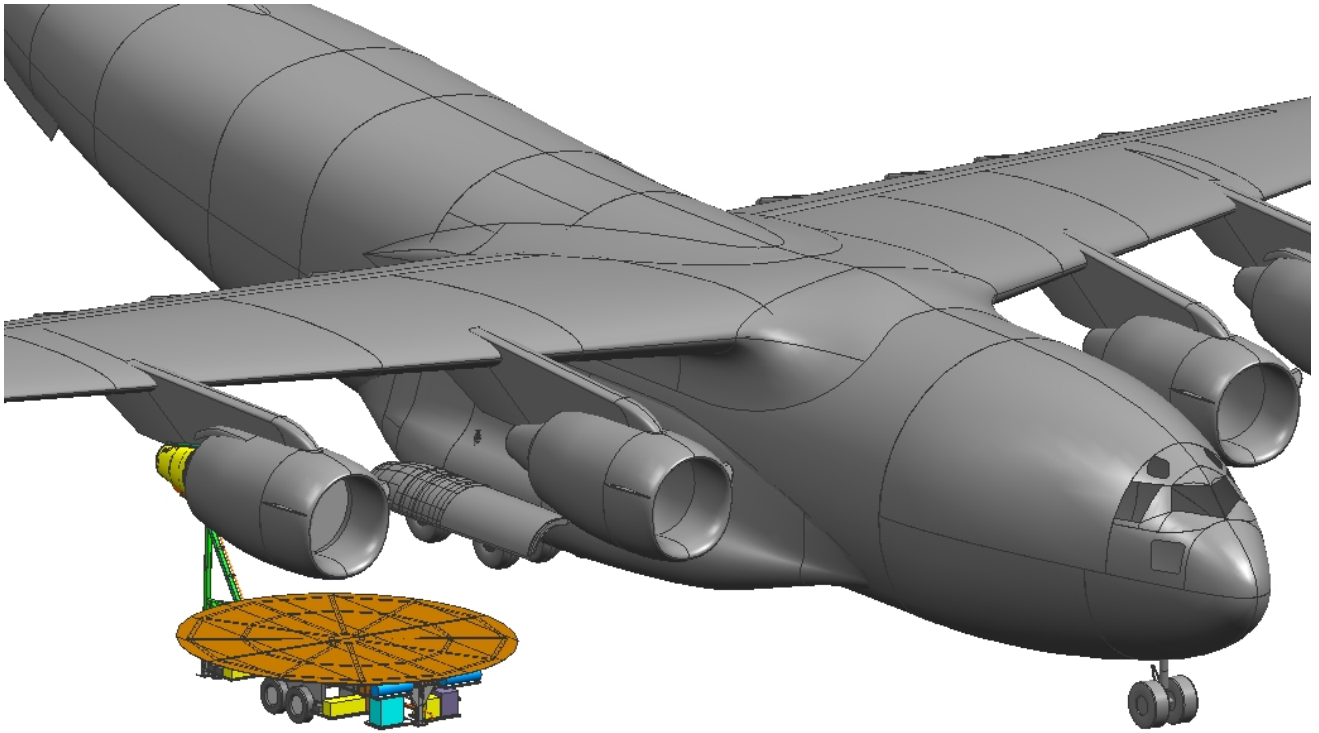
Vehicle Integrated Propulsion Research (VIPR)

- Multi-year, multi phase NASA program
- Other players include Air Force, Boeing, Pratt and Whitney, MAKEL, and the FAA
- Many objectives but overall focus is real time engine health monitoring
- Bleed air contaminant measurements a small, but important, piece of the program

VIPR Test Bed

Boeing C-17 Globemaster III

VIPR Experimental Apparatus



Bleed Air System Test Rig

VIPR Bleed Air Data

VIPR Plans

- Anticipate next phase of measurements in early 2015
- ACER Participation???

Test Stand Turbine Engine

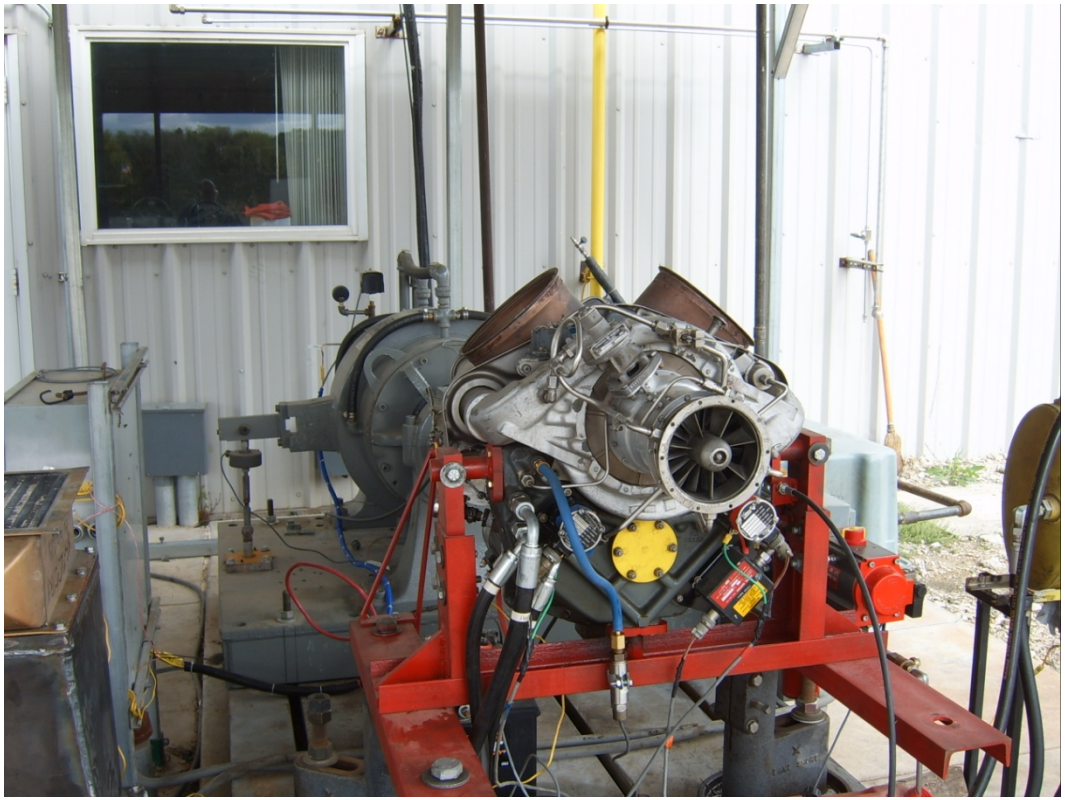
- BAS simulator can reproduce pressure and temperature but not the same environment
- Turbine engine compressor is nearly adiabatic with vanes and high speed blades. All heating is due to compression.
- BAS uses non-adiabatic reciprocating piston compressor with after-heater.

Test Stand Turbine Engine

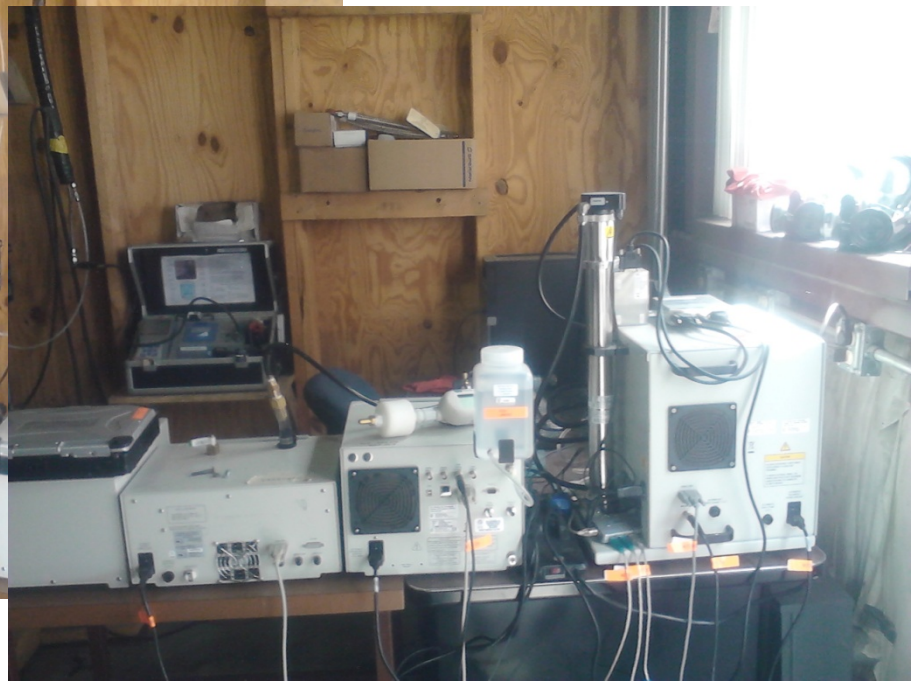
- Are particle characteristics universal or specific to the bleed air apparatus?
- Are particle characteristics dependent upon the nature of the aerosol introduction?
- Real aircraft engines (e.g. VIPR) are the ultimate answer but very expensive and difficult to run experiments.
- Small engine can answer most questions at fraction of the cost.

Allison T63

Allison T63



Measurement Equipment



Lots of work to do before August