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16. Abstract This presentation shows methods to measure particulates in bleed air contamination using turbine engines on test stands and using test equipment and fixtures that were later used in the VIPR study. This effort was funded by the FAA via the RITE/ACER CoE.		
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Bleed Air Contaminant Particulate Measurements

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Presentation

NOTICE

This report was originally published in 2012 by the National Air Transportation Center of Excellence for Research in the Intermodal Transport Environment (RITE), Airliner Cabin Environment Research (ACER) Program, which is no longer active. It was republished through the National Transportation Library in 2026 in an accessible (Section 508) format. Typographical errors were corrected; the research content and findings are unchanged. Discrepancies identified during republication that could not be verified are noted in the Errata.

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Slide 3. Bleed Air Contaminant Particulate Measurements

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

Slide 4. BAS – Phase 1

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

Point #	Base: Temp, °C (°F)	Base: Press, kPa (psi)	Study 1: Temp, °C (°F)	Study 1: Press, kPa (psi)	Study 2: Temp, °C (°F)	Study 2: Press, kPa (psi)	Study 3: Temp, °C (°F)	Study 3: Press, kPa (psi)	Study 4: Temp, °C (°F)	Study 4: 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)								

Slide 5. 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 0.5 µm 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.

Slide 6. Particle Measuring

Optical Particle Counter

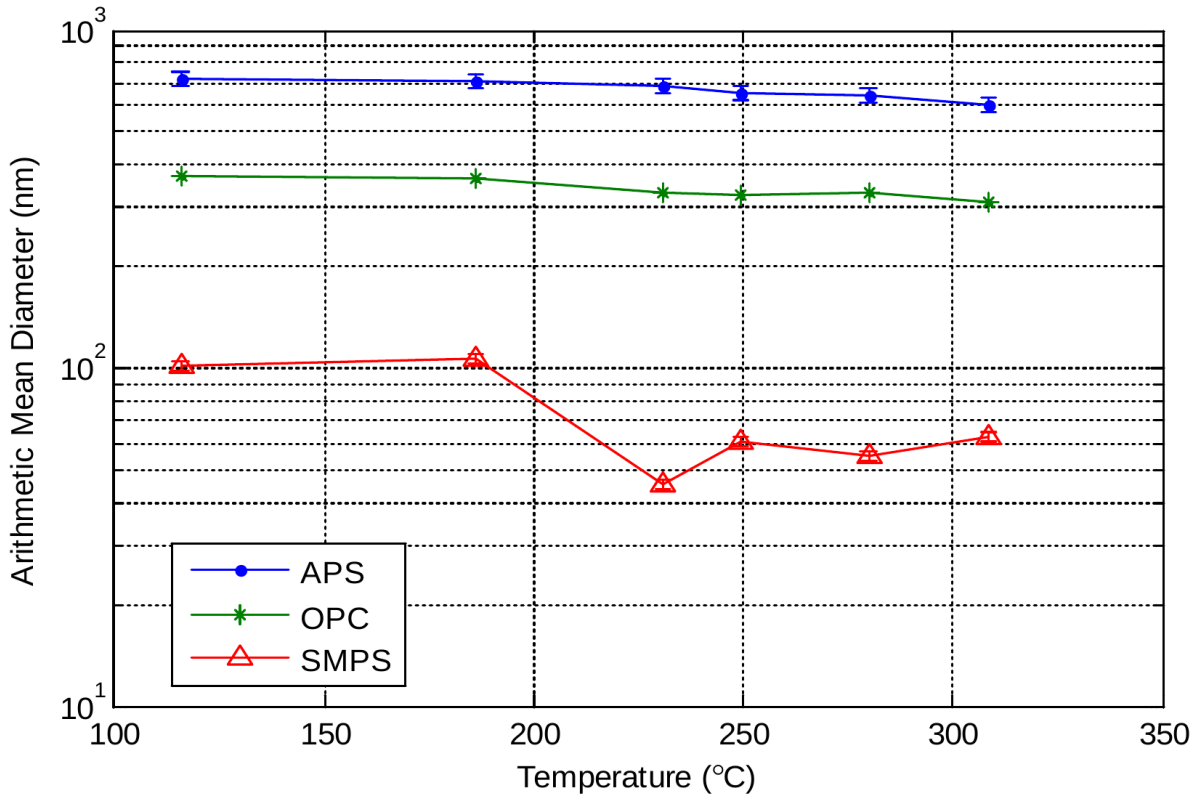
- Climet Spectro 0.3
- Calculates particle size and concentration by measuring the intensity of light scattered by the particles.
- Particle size is binned into 16 channels from 0.3 µm to 10 µm.

Scanning Mobility Particle Sizer

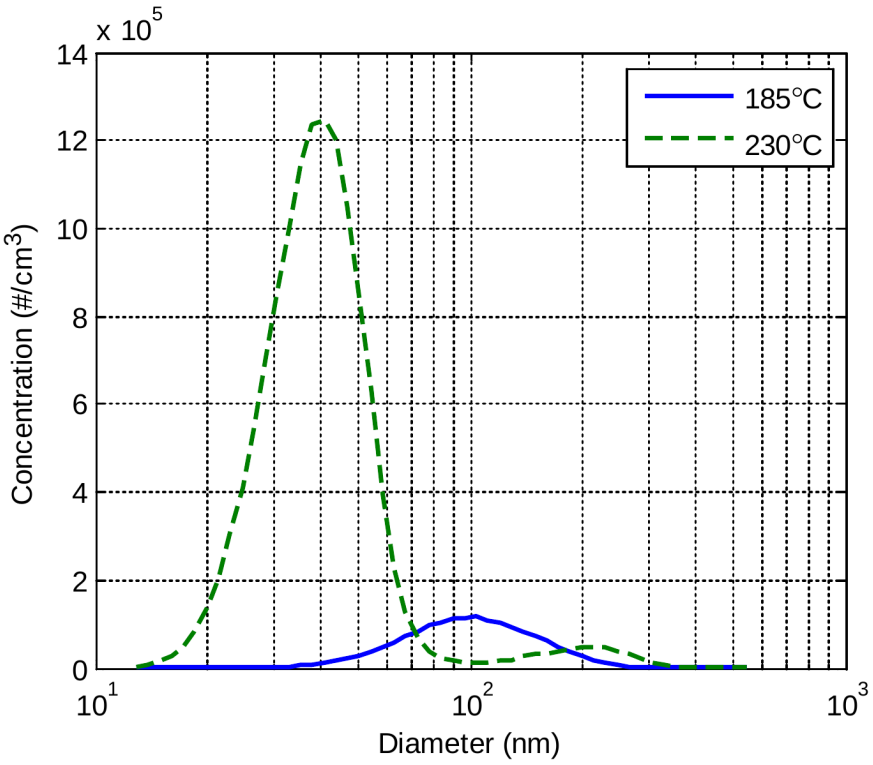
- TSI 3496
- Uses ionization with electric field to separate particles by mobility
- Uses a CPC to count different size bands
- Size range from 10 nm to 532 nm.

Slide 7. Results

Size distributions from base study



Slide 8. Results



Slide 9. BAS – Phase 2

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

Slide 10. 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 0.5 µm to 20 µm.

Scanning Mobility Particle Sizer

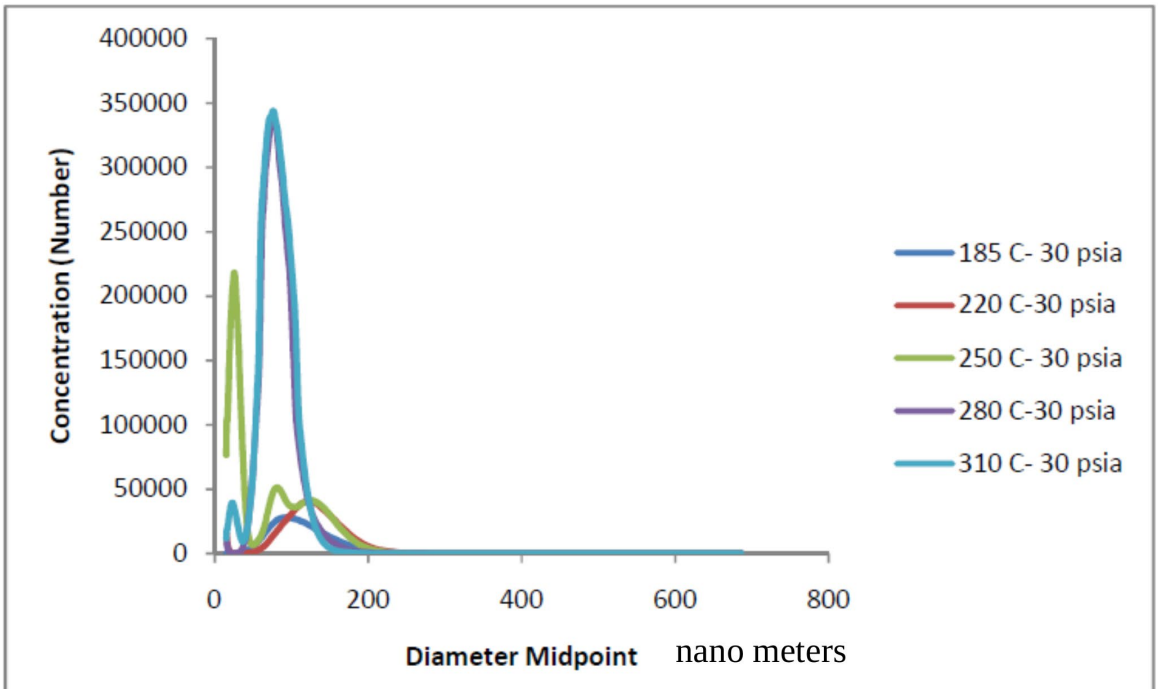
- TSI 3496
- Uses ionization with electric field to separate particles by mobility
- Uses a CPC to count different size bands
- Size range from 10 nm to 532 nm.

Slide 11. BAS Experimental Conditions

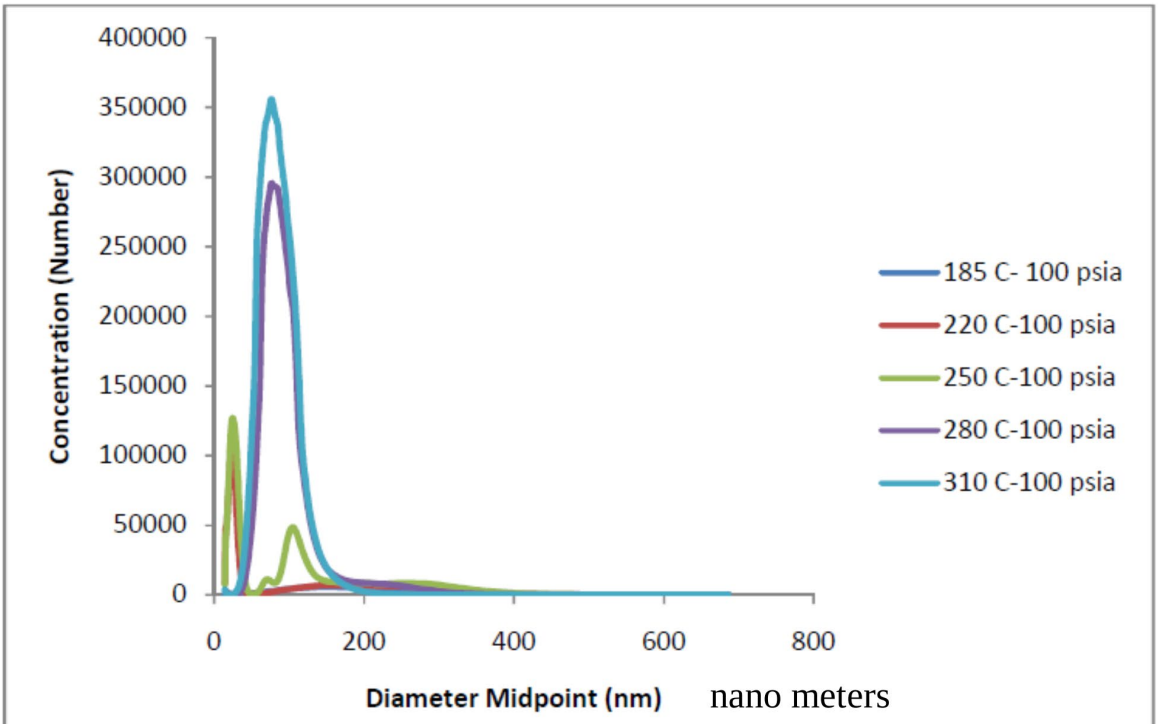
Planned test matrix: each temperature was to be run at each pressure (cells are blank in the original).

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

Slide 12. SMPS 30 psia

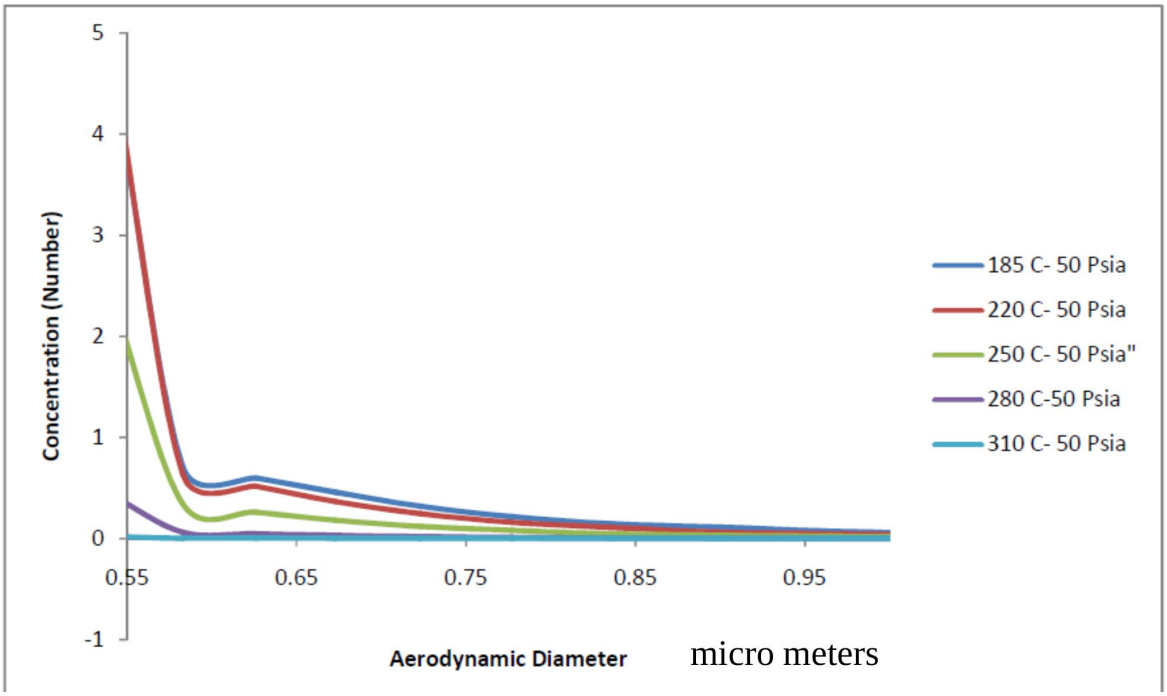


Slide 13. SMPS 100 psia



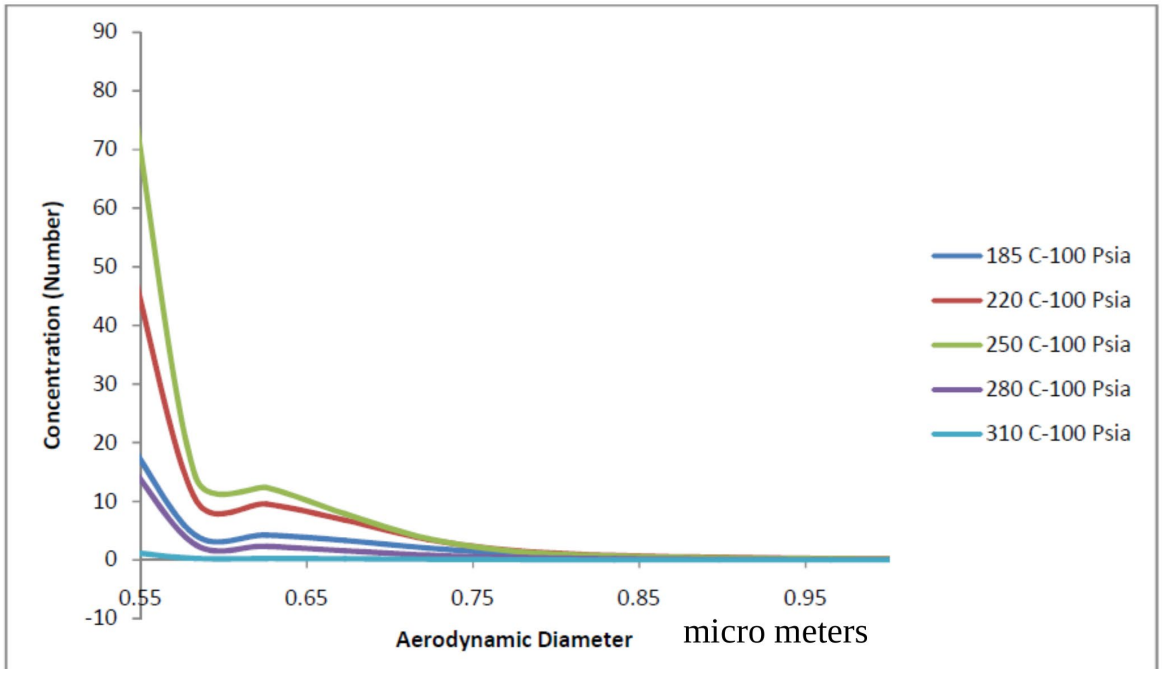
nano meters

Slide 14. APS 50 psia



micro meters

Slide 15. APS 100 psia



Slide 16. 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

Slide 17. Bleed air contamination detector?

Ionization smoke detectors work well for d<300 nm



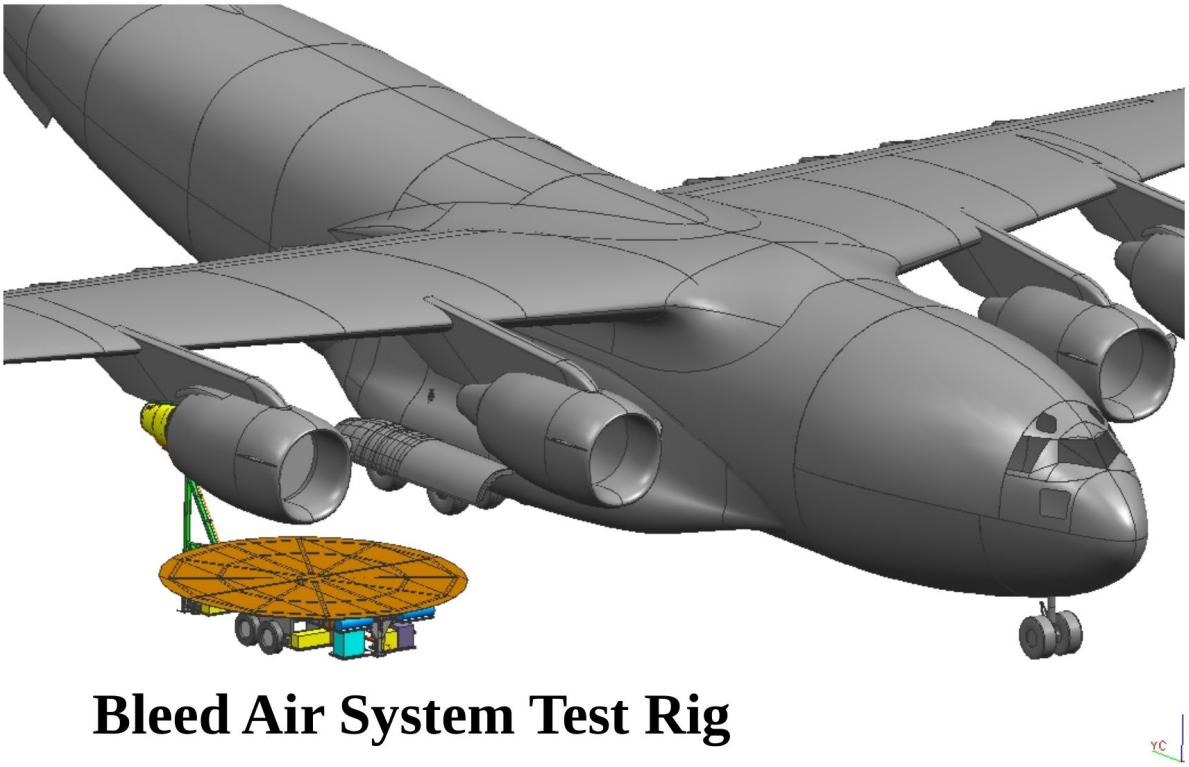
Slide 18. Vehicle Integrated Propulsion Research (VIPR)

- 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

Slide 19. VIPR Test Bed



Slide 20. VIPR Experimental Apparatus



Slide 21. VIPR Bleed Air Data

[In the original presentation, this slide shows only an empty black frame; the bleed air data it was intended to display did not carry into the published file.]

Slide 22. VIPR Plans

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

Slide 23. 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.

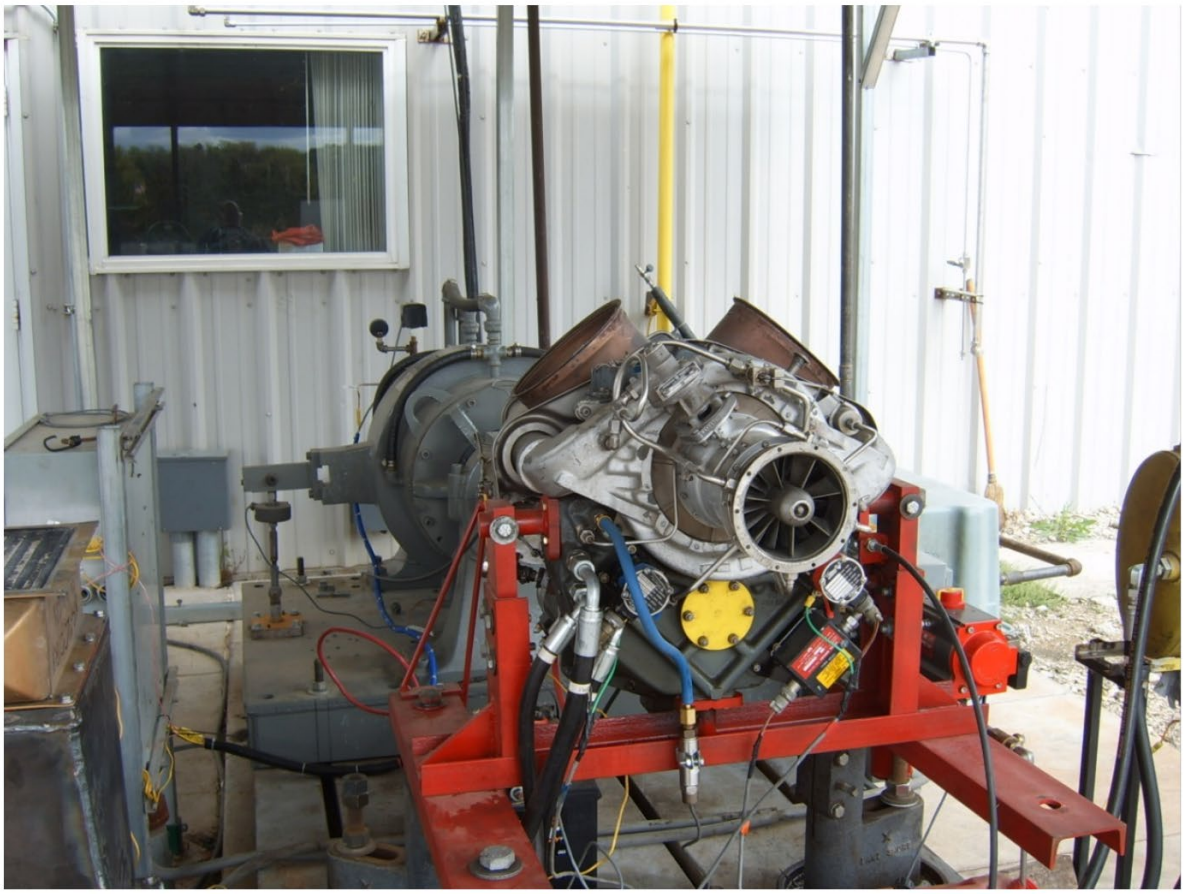
Slide 24. Test Stand Turbine Engine

- 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.

Slide 25. Allison T63



Slide 26. Allison T63



Slide 27. Measurement Equipment



Slide 28. Lots of work to do before August



ERRATA

The corrections and notes below were made when this report was prepared for republication through the National Transportation Library. Minor typographical, spelling, and punctuation errors were also corrected and are not listed individually.

Corrections Made in This Edition

1. Technical Report Documentation Page: author name “Shahin Amirir” corrected to “Shahin Amiri,” matching the title slide.
2. Slides 4 and 11: tables are presented as text tables with single-row headers.

Discrepancies Noted but Not Changed

3. Slide 21 (VIPR Bleed Air Data) contains only an empty black frame in the original; the data it was intended to show is not available. Retained with a note on the slide.