耶鲁大学–南京信息工程大学大气环境中心

Yale-NUIST Center on Atmospheric Environment

A discussion of "Novel Aerosol/Gas Inlet for Aircraft-Based Measurements".

Suresh Dhaniyala et al.,2003

Aerosol Science and Technology

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Outline

1 Introduction

2 Theory

3 Design

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1 Introduction

- Polar stratospheric clouds (PSCs) are comprised of gas phase nitric acid and particles containing solid and liquid phase HNO_3 , H_2SO_4 , and H_2O.
- This particles and gas work for a catalytic in the springtime destruction of polar ozone.
- In the past,Concentrations of aerosol constituents that can be measured with forward-facing probes,and to sample gas have used back-facing inlets.
- A new inlet that has been designed to sample both aerosols and the gas phase with a single detection technique.The inlet was flown on the NASA ER-2 aircraft during the SOLVE 2000 campaign.

2 Theory

2.1 Stokes Number

The tendency of a particle to deviate from the gas flow is determined by the ratio of inertial forces to viscous forces actingon the particle.This dimensionless ratio, known as the Stokes number , is given by:

$$St = \frac{\rho_p C_c D_p^2 U}{18 \mu W}$$

where ρ_{p} :the particle density, C_C : The slip correction, D_{p} :the particle diameter, U :the characteristic flow velocity, μ :the gas viscosity, and W:characteristic dimension of the flow.

2.2 Flow Modeling

- A computational fluid dynamics (CFD) program, FLUENT was used to optimize the design.
- FLUENT has been used extensively in modeling of particle trajectories in compressible, transonic, and even supersonic flows , and is well suited for the present calculations.

3 Design

3.1 The Different Components of Inlet

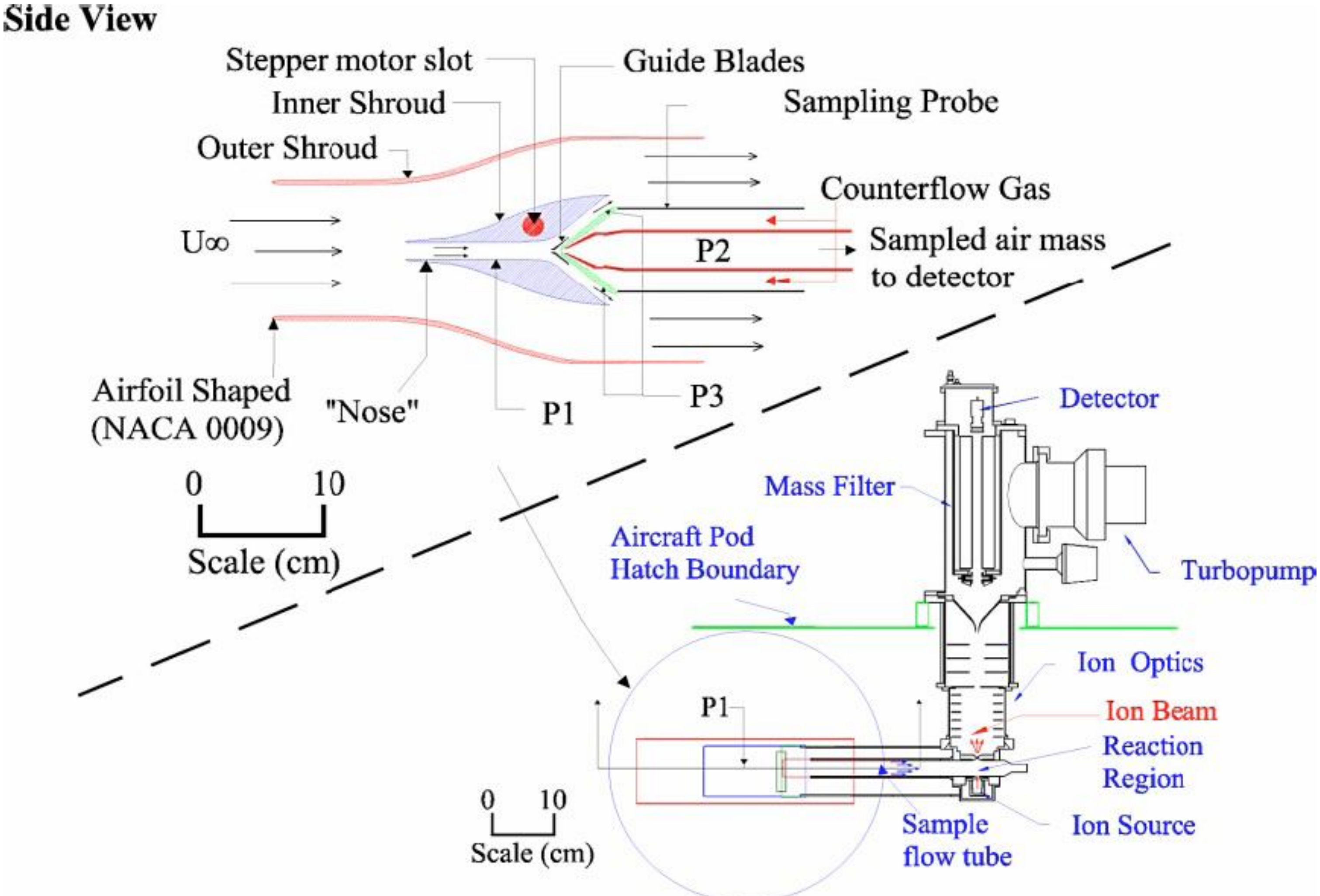
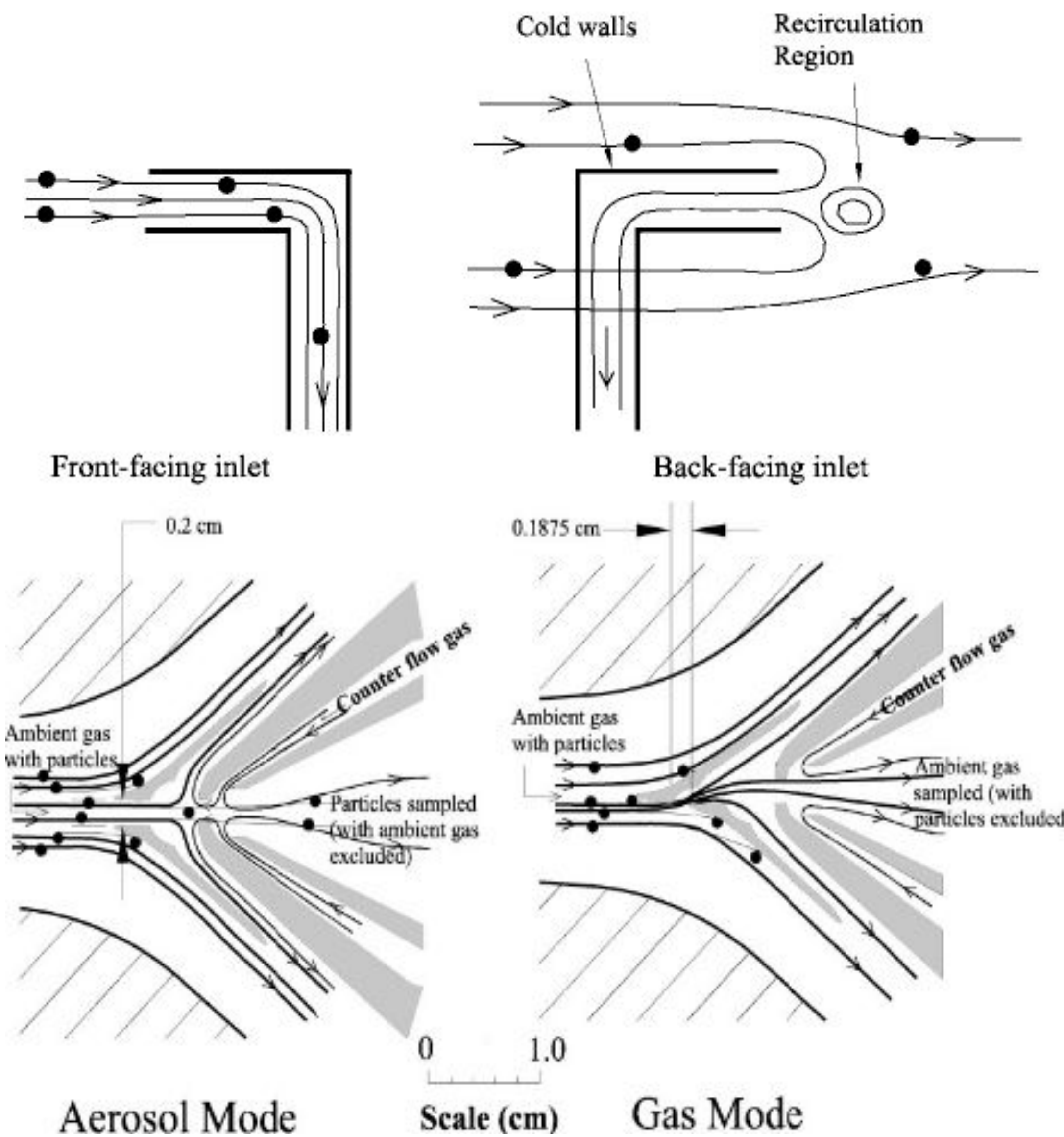


Figure1. Schematic diagram of the inlet showing the different components.

3.2 Compare of the old and new inlet



- Front-facing and back-facing inlets.
- A counterflow virtual impactor (CVI)

Figure 2. Schematic diagram illustrating compare of the old and new inlet.

3.3 Outer Shroud Design

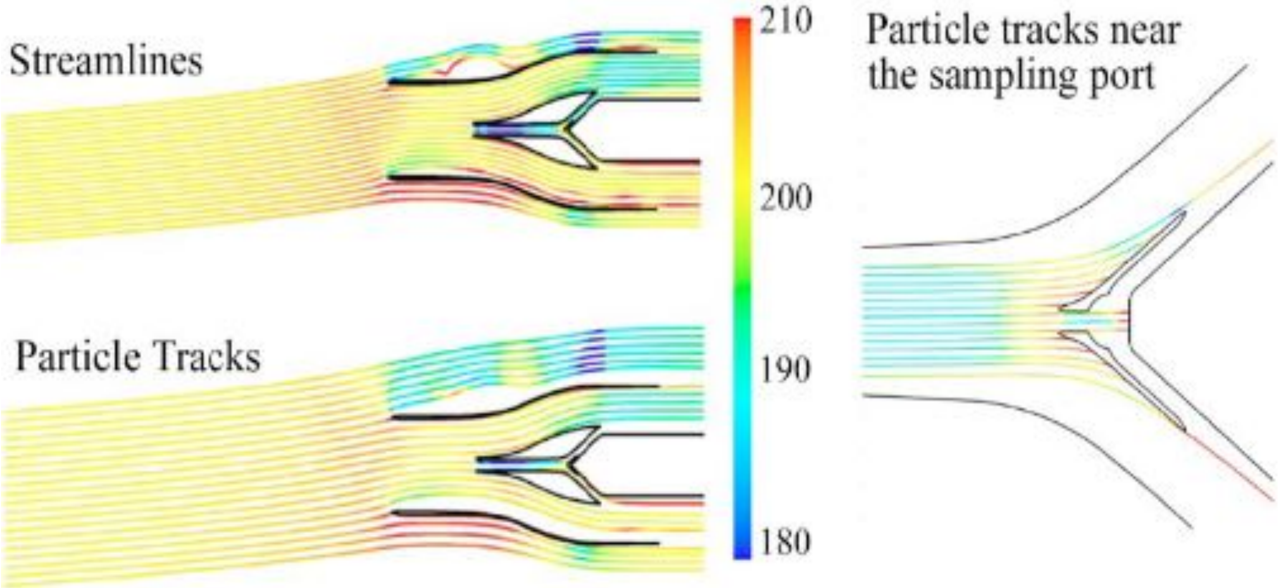


Figure 3. The simulated particle trajectories (1 μm) and gas pathlines for ambient pressure of 5000 Pa and flow directed at an angle of 2 degrees.

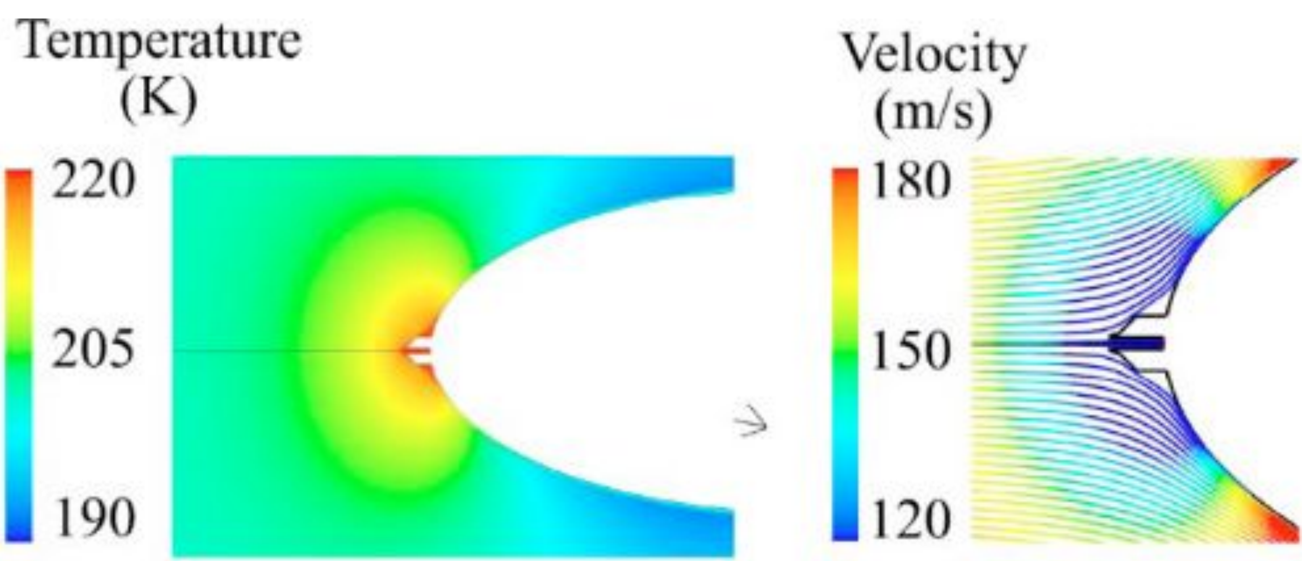


Figure 4.Flow features near a typical blunt sampler are shown to illustrate the particle sampling artifacts likely with such inlets.

3. 4 Inner Shroud Design

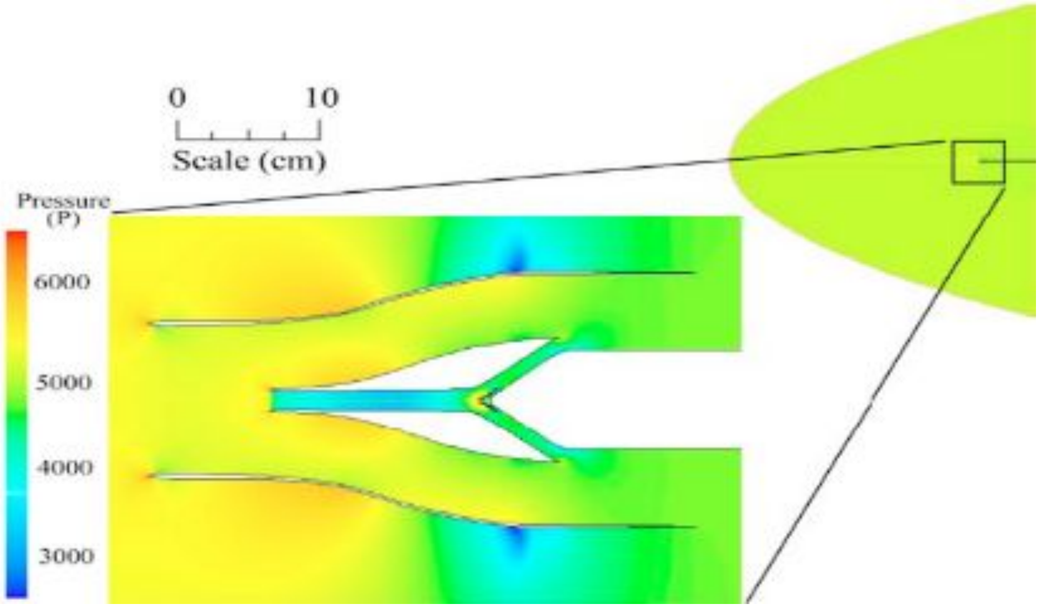


Figure 5. Simulation results showing the calculated pressure field in the large domain for ambient conditions of 50 mb pressure and free stream velocity of Mach 0.7.

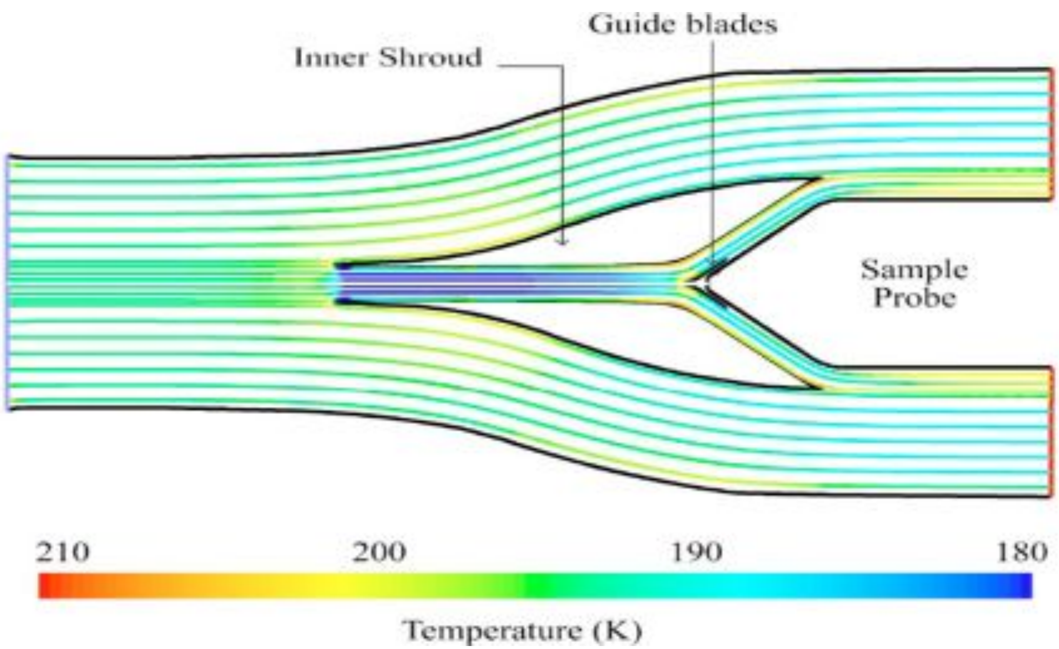


Figure 6. Gas pathlines inside the outer shroud, colored by flow temperature (ambient pressure of 50 mb), show the absence of any significant compressional heating along the flow path towards the sampler.

3. 5 Guide Blade Design

Inside the inner shroud and directly in front of the sample slit, there are two small flow directors called “guide blades”. The adjustable positioning of these two guide blades enables selective aerosol or gas sampling with the required particle separation characteristics.

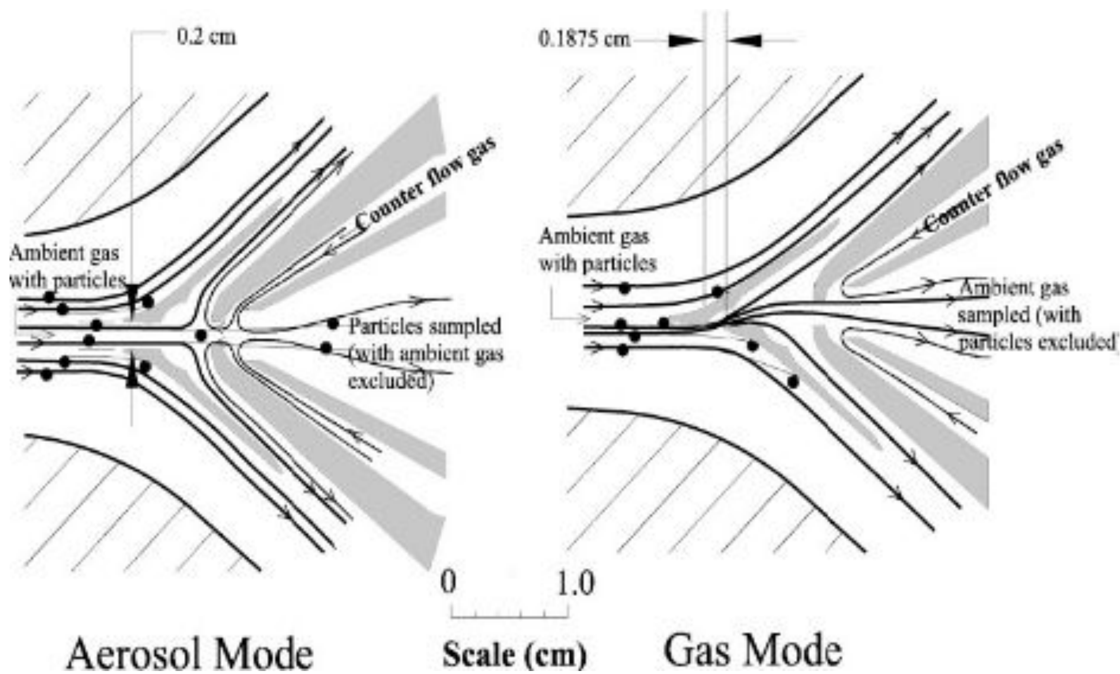


Figure 7. Schematic diagram illustrating the configuration of the guide blades and operation of the inlet in the two sampling modes—gas and aerosol.

3.5.1 Aerosol Mode and Gas Mode

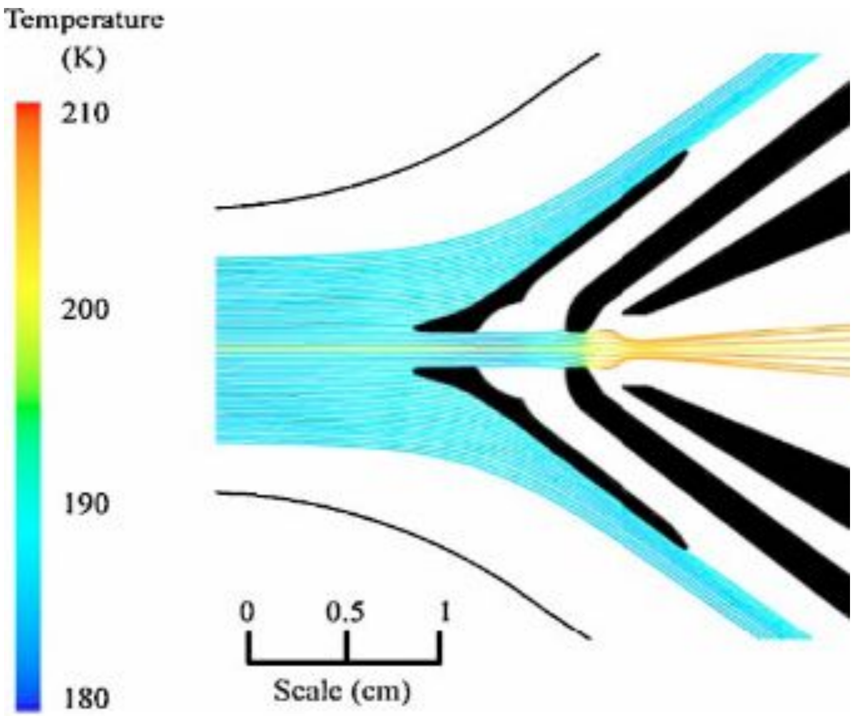


Figure 8.Trajectories of 0.7μm diameter particles are shown for guide blades.

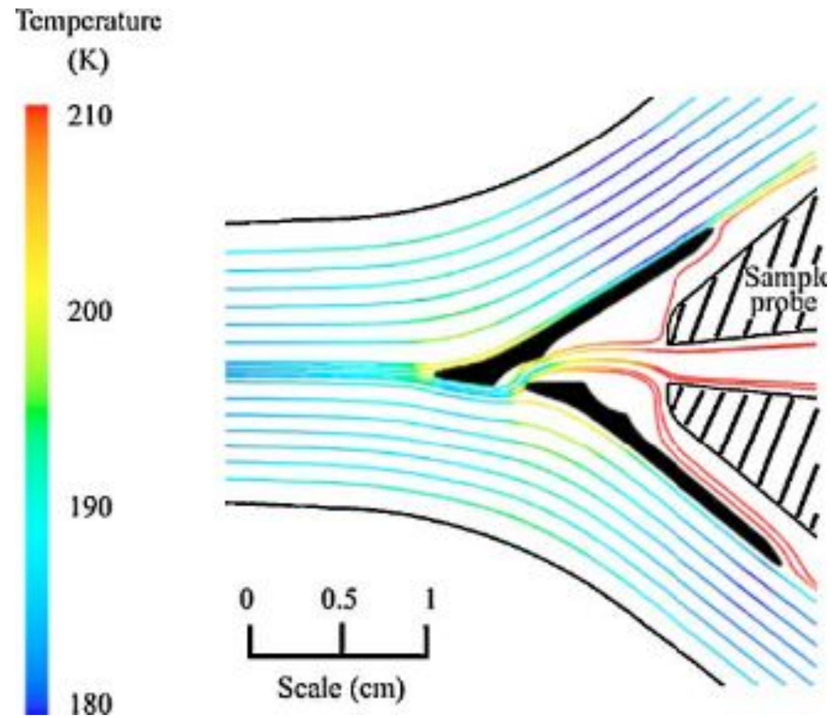


Figure 9. Gas pathlines near the sample probe.

3.6 Particle Collection Efficiency

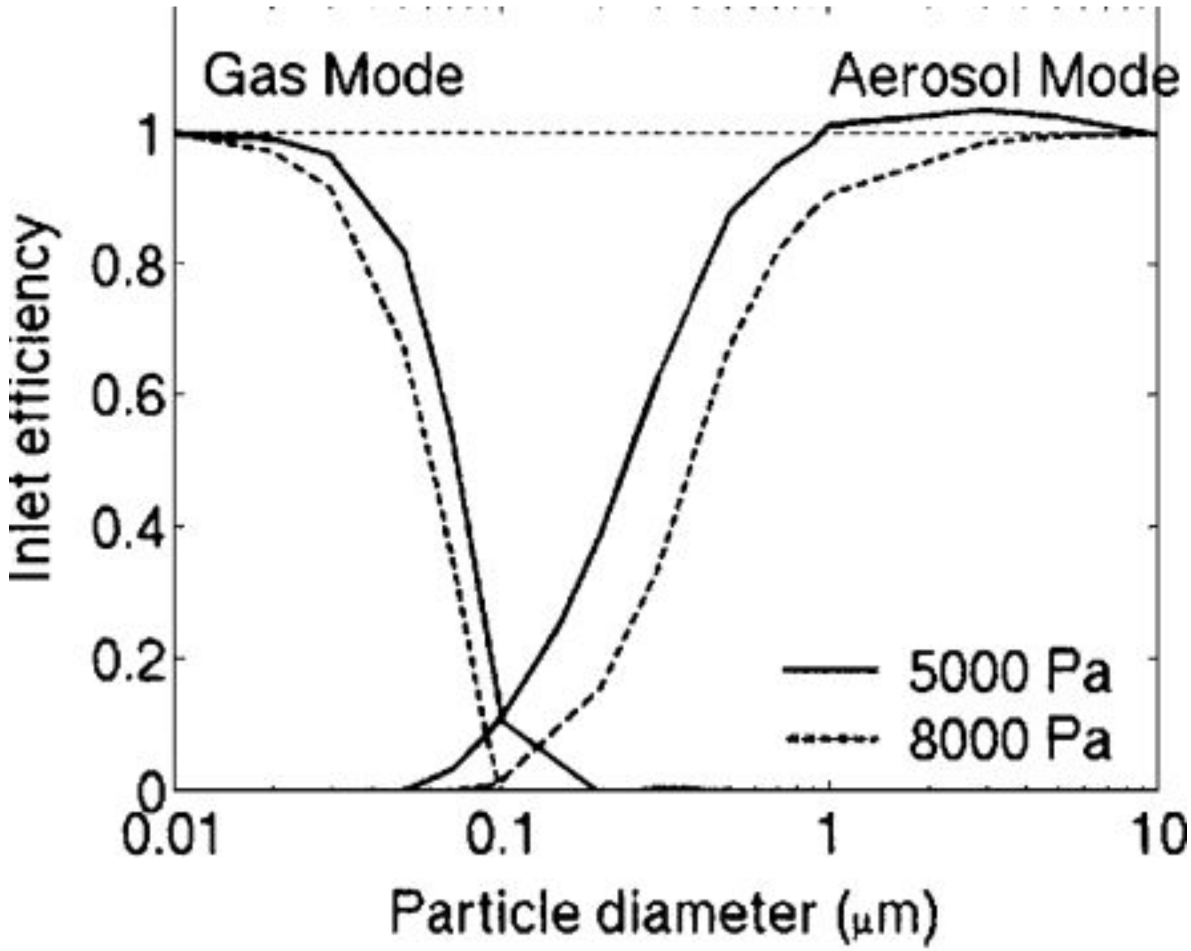


Figure 10. Collection efficiency curves for the inlet operating in the two modes—gas and aerosol—at two different ambient pressures.

4 Results and Discussions

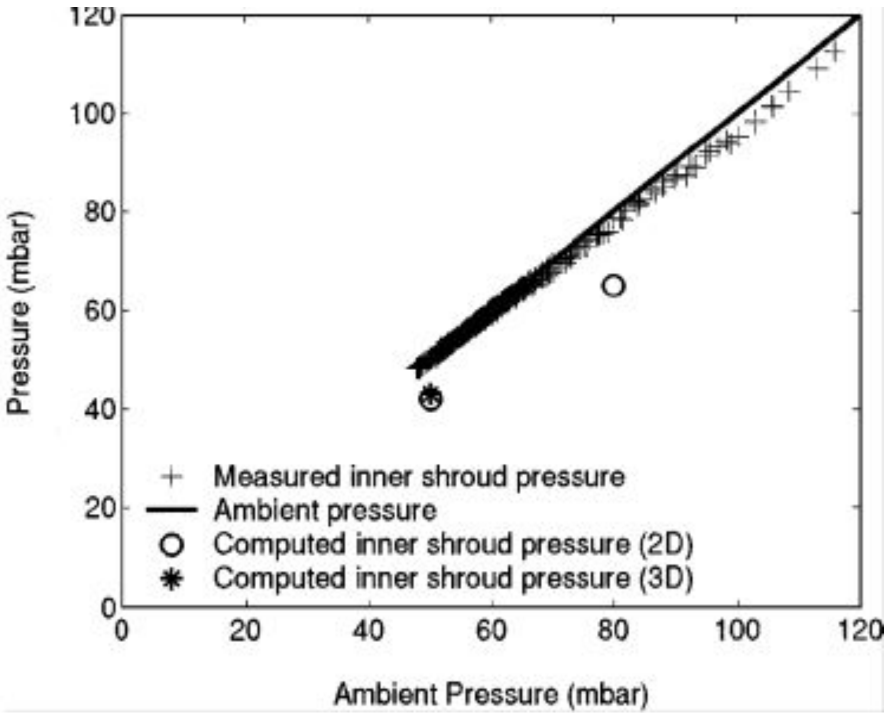


Figure 11. Comparison of the measured inner shroud channel pressure (P1) with CFD calculations for varying ambient static pressures.

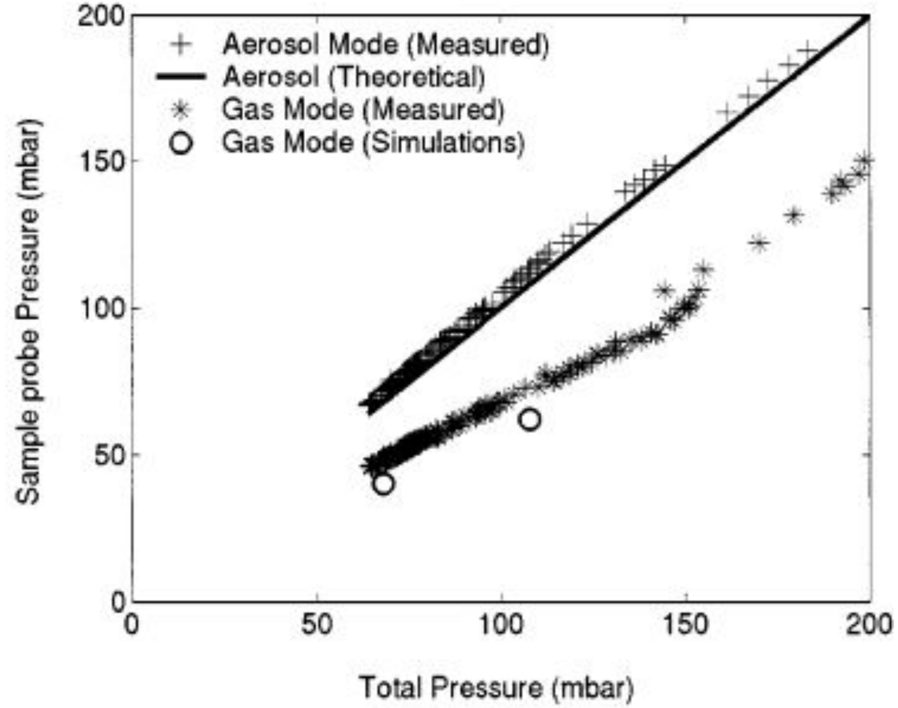


Figure 12. Comparison of the measured sample probe pressures(P2) with the CFD calculations for varying aircraft measured total pressures.

5 Conclusions

- A novel multistage inlet design for selective gas and particulate phase measurement of volatile species from high-speed.
- This inlet represents one of the first efforts to sample gas without wall contact.
- The inlet pressure measurements agree to within ~10% with the CFD predictions , indicating that the inlet performance is likely similar to that predicted by the model.

Thank you for your attention!