Ion Wind Technologies for HVAC Applications

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Study Control Number: PN 99

Project Description

The objective of this project was to extend PNNL expertise in plasma science and engineering toward developing an accurate measurement technology for whole duct flowrate. The project focused on the transformation of an existing ion wind generator to a flow measurement instrument using ions as a gas tracer. The project scope for FY 99 was broken into three primary tasks: (i) complete a literature review and simple market assessment for similar device technology, (ii) develop a simple model of charge sheet to determine width of the ion plane, and (iii) develop a pulsed power supply and modify an existing apparatus for use as a prototype ion-tag flowmeter (ITF).

The ITF is based on a traverse-time measurement of ions down the duct. A 4-electrode configuration was used to form the ITF. Ions are generated in a plane using a corona discharge from small wires to larger diameter rods (Emitter). The ions flow downstream and are collected with a small bias potential across a separate array of rods (Collector). An electrometer is used to measure the charge collected. The time required for the ions to reach the detector is related to the gas flowrate by

$$T = LA/Q ,$$

where L is the distance between emitter and collector, T is the mean transit time, and Q and A are the flowrate and the cross-sectional area in the duct, respectively.

Technical Accomplishments

Prior Art

There has been considerable work in the past on ion-based flow sensors, but a product has not yet been marketed. All of the patents we obtained in this area are completely void of data supporting device operation. There are three basic designs: (i) corona/traverse time, (ii) corona/deflection, and (iii) electromagnetic (EM)/traverse time. The corona traverse time concept (US368106) is the closest to the design examined here. Deflection type devices (US3835705, US4953407) measure the degree of deflection perpendicular to flow, and EM devices (US 3688106, US5701009) employ an UV or X-ray source to ionize the gas rather than a corona discharge.

Electric Field Model

In order to develop reliable emitter systems, we developed a model to calculate the electric field around the emitting wires. The code, a modified version of PNNL's TEMPEST, solved Laplace's equation for the electric potential. An example of the output from this code is shown in Figure 1 where the magnitude of the electric field is contour plotted for a given emitter system. The dimension X is in meters, and the contour values are in V/m.

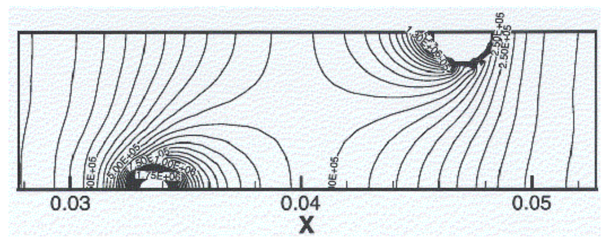

Figure 1. A sample output from the modified TEMPEST code.

Prototype Construction and Testing

A prototype ITF was constructed in a 6" test duct. A custom pulsed power supply was designed and constructed to drive the emitter section. Typical flowrates encountered in HVAC ducting are near 1000 ft/min, which corresponds to a 2 ms transit time (500 Hz) for a 1 cm gap. For the ITF to function, the pulse width should be much less than the transit time and the delay between pulses should be greater than the transit time. We therefore constructed a power supply capable of 20 kV pulses with 70 µs pulse widths and a repeat rate of 250Hz.

We examined the response of the ITF under numerous flowrates, and samples of the electrical waveforms for the collector current and emitter voltage and current are shown in Figure 2. We investigated several emitter configurations and emitter-collector separations with the same result. We did not observe any peak corresponding to the transit-time across the electrodes. We observed the same current response in the collector as in the emitter. The lower frequency response is undesirable and is due to the capacitive nature of the ITF air gap. The high frequency response is due to the corona discharge. In order for the flowrate to be obtained there must be a flowdependent phase lag between the emitter and collector current, and one was not observed here.

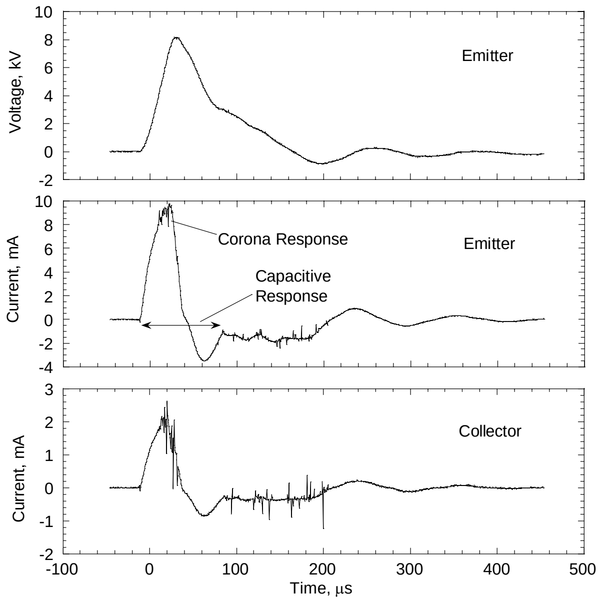

Figure 2. Waveforms Collected During ITF Testing.

The fact that the capacitive response is observed in the collector is also puzzling. Evidently the collector was not shielded adequately from the emitter grid. Increasing the separation between the two arrays reduced the interference, but this large background persisted. If there was a current pulse corresponding to flowrate, it may be a small signal sitting on top of this capacitive response. A shielding mesh could have been placed between the collector and emitter, but it would have consumed many of the ions available for detection.

The capacitive effect might be alleviated by using a high pass filter on the sampling line or by making changes to the pulsed power supply to reduce the capacitive response, but there was not sufficient time to explore these options.

Conclusions

Proof of concept of the ITF was not achieved in this study. We have offered several possible explanations why the signal was not observed. At this point, we believe that some electrical engineering of the drive and sampling circuitry will be required to reduce/filter out the large capacitive response of the emitter grid. Using electromagnetic radiation (UV or X-ray) to create the ion sheet would eliminate the capacitive response altogether. In addition, alternate technologies for whole duct flow measurement such as ultrasonic techniques should be examined as a better fit with existing platforms.

Acknowledgment

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