Device for Measuring Low Flow Speed in a Duct

Speed can be determined to within ±0.2 cm/s.

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A multiple-throat venturi system has been invented for measuring laminar flow of air or other gas at low speed (1 to 30 cm/s) in a duct while preserving the laminar nature of the flow and keeping the velocity profile across the duct as nearly flat as possible. While means for measuring flows at higher speeds are well established, heretofore, there have been no reliable means for making consistent, accurate measurements in this speed range. In the original application for which this system was invented, the duct leads into the test section of a low-speed wind tunnel wherein uniform, low-speed, laminar flow is required for scientific experiments. The system could also be used to monitor a slow flow of gas in an industrial process like chemical vapor deposition.

In the original application, the multiple-throat venturi system is mounted at the inlet end of the duct having a rectangular cross section of 19 by 14 cm, just upstream of an assembly of inlet screens and flow straighteners that help to suppress undesired flow fluctuations (see Figure 1). The basic venturi measurement principle is well established: One measures the difference in pressure between (1) a point just outside the inlet, where the pressure is highest and the kinetic energy lowest; and (2) the narrowest part (the throat) of the venturi passage, where the kinetic energy is highest and the pressure is lowest. Then by use of Bernoulli's equation for the relationship between pressure and kinetic energy, the volumetric flow speed in the duct can be calculated from the pressure difference and the inlet and throat widths.

The design of this system represents a compromise among length, pressure recovery, uniformity of flow, and complexity of assembly. Traditionally, venturis are used to measure faster flows in narrower cross sections, with longer upstream and downstream passages to maintain accuracy. The dimensions of the passages of the present venturi system are sized to provide a readily measurable pressure drop. Multiple throats are used to minimize the length needed to recover internal energy and enable the velocity profile to recover to near flatness. The venturi passages are defined by airfoil surfaces,

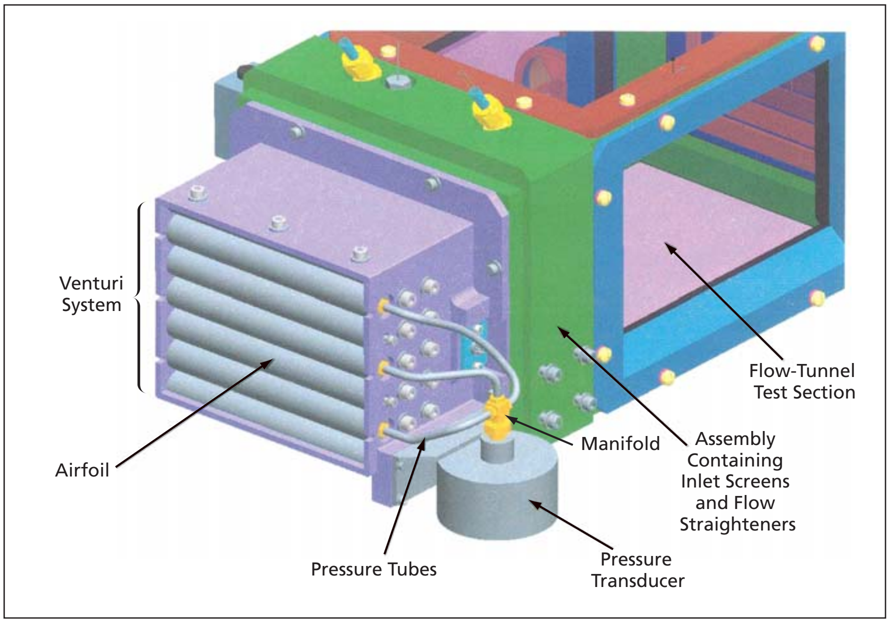

Figure 1. The **Multiple-Throat Venturi System** is mounted at the inlet end of a rectangular duct.

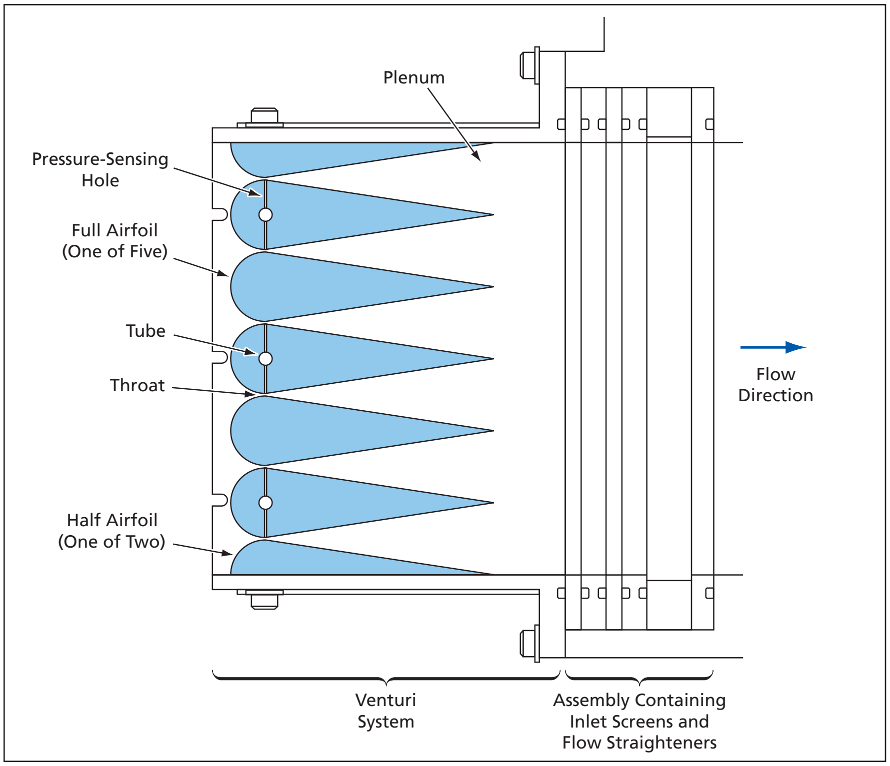

Figure 2. **Narrow Holes in Three of the Airfoils** connect pressure taps at the venturi throats with tubes, which, turn, connect the pressure taps to an input manifold of a differential-pressure sensor.

two-dimensional configuration of which is dictated by the need to match the rectangular duct cross section.

The flow into and out of the venturi passages is guided by the airfoil surfaces. There are two half airfoils at the top and bottom of the inlet, and there are five full airfoils between them. A plenum downstream of the trailing edges allows the flow to even out prior to entering the screens and flow straighteners. To enable measurement of pressure in all six throats, tubes in three of the airfoils are connected to a manifold, and narrow holes connecting the tubes with the throats are drilled in these airfoils. The pressures sensed at the six throat measurement locations become averaged together in the manifold, which is connected to one side of a sensitive differential-pressure transducer. The other side of the transducer is exposed to the pressure just upstream of the inlet. It has been found that the speed-vs.-pressure calibration curve is highly repeatable, enabling measurement of flow speed to within an error of ±0.2 cm/s.

This work was done by Frank Quinn and Kevin Magee of ZIN Technologies, Inc. for Glenn Research Center. Further information is contained in a TSP (see page 1).

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Innovative Partnerships Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-18021-1.

Measuring Thermal Conductivity of a Small Insulation Sample

Heat leakage is accounted for in design, operation, and calculation.

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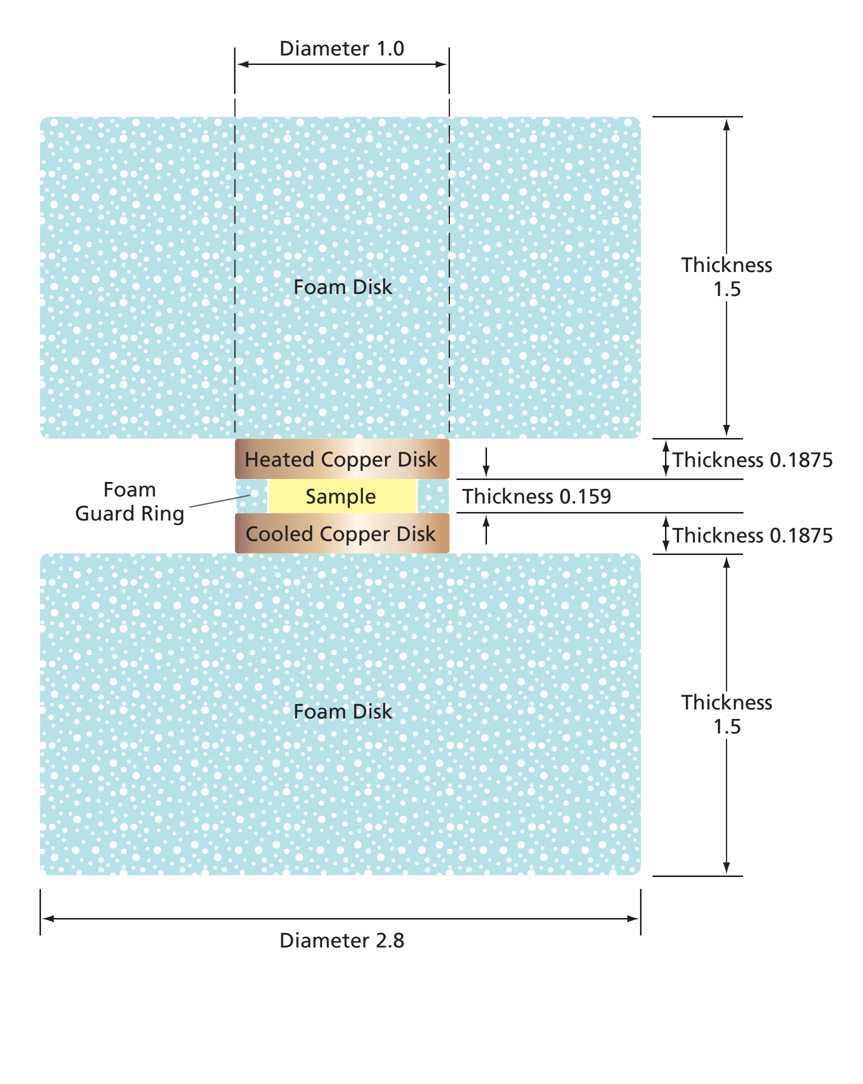
An instrumentation system for direct measurement of the thermal conductivity of a small sample of a highly insulating material has been devised. As used here, (1) "small" signifies having dimensions of the order of two centimeters — significantly less than the sizes of specimens for which prior devices for direct measurement of thermal conductivity have been designed; and (2) "highly insulating" signifies having thermal conductivity of the order of that of air.

The heart of the system is an assembly that includes two copper disks — one electrically heated, the other cooled with chilled water. The disks are separated by a guard ring made of strong, thermally insulating polymethacrylamide foam. The sample fits between the copper disks and within the ring (see figure). Matched thermocouples are used to measure the temperatures of the heated and cooled disks. The heated and cooled disks are affixed to larger foam disks, and the essentially still air in the gap between the larger disks insulates the sides of the specimen. This air gap region can be further divided by extending the foam ring into the gap region. The entire assembly as described thus far is lightly clamped together by means of nylon threaded rods and is placed inside a cylindrical chamber wherein the temperature is maintained at a set value (typically, 25 °C).

The electric power supplied to the heated disk is adjusted to maintain the temperature of this disk at a fixed value (for example, 35 °C) that exceeds the temperature in the chamber by a fixed amount. Similarly, the supply of chilled water to the cooled disk is regulated to maintain the temperature in this disk at a



This Assembly is Mounted in a constant-temperature chamber. The heated and cooled disks are maintained at temperatures $\Delta T/2$ above and $\Delta T/2$ below, respectively, the chamber temperature. The thermal conductivity of the sample is determined from the heater power needed to maintain the $\Delta T/2$ temperature differential of the heated disk. (Note: The dimensions are in inches.)