DEVELOPMENT OF A SMALL AREA SNIFFER

Laurie A. Meade

Dr. Jerome Kegelman

Research and Technology Group
Fluid Mechanics and Acoustics Division
Flow Modeling and Control Branch

Abstract:

The aim of this project is to develop and implement a sniffer that is capable of measuring the mass flow rate of air through a small area of pinholes whose diameters are on the magnitude of thousandths of an inch. The sniffer is used to scan a strip of a leading edge panel, which is being used in a hybrid laminar flow control experiment, in order to survey the variations in the amount of air that passes through the porous surface at different locations. Spanwise scans are taken at different chord locations by increasing the pressure in a control volume that is connected to the sniffer head, and recording the drop in pressure as the air is allowed to flow through the tiny holes. This information is used to obtain the mass flow through the structure. More importantly, the deviations from the mean flow rate are found and used to determine whether there are any significant variations in the flow rate from one area to the next. The preliminary results show little deviation in the spanwise direction. These results are important when dealing with the location and amount of suction that will be applied to the leading edge in the active laminar flow control experiment.

All information presented in this report is owned by industry and therefore no specific numerical results can be presented.

Introduction/ Background Information:

The intended application of this sniffer is to examine the variations in the flow rate through the tiny holes on the leading edge panel of a wing that is being used in a hybrid laminar flow control experiment. In hybrid laminar flow control, suction is applied to the leading edge. Thousands of minuscule electron-beam-drilled holes in the titanium skin of the leading edge act like tiny vacuum cleaners sucking away the turbulent air closest to the surface to create laminar flow. The size of the pinholes and the amount of suction applied through them are the keys to the success of the laminar flow control system. The location of the suction is also important and can be applied at different flutes. The flutes are the passage ways for the air to move through the structure. Each flute is one inch wide and contains thousands of holes.

Since the holes are drilled using a laser it is probable that there is some variation in the diameters of the holes and it is also possible that some holes may not be drilled all the way through to the flutes due to fluctuations in power. There is also the possibility that some holes may be clogged. Therefore, the suction that is thought to be applied may not be the actual suction that is taking place. This sniffer is able to determine the actual flow through different areas of each flute.

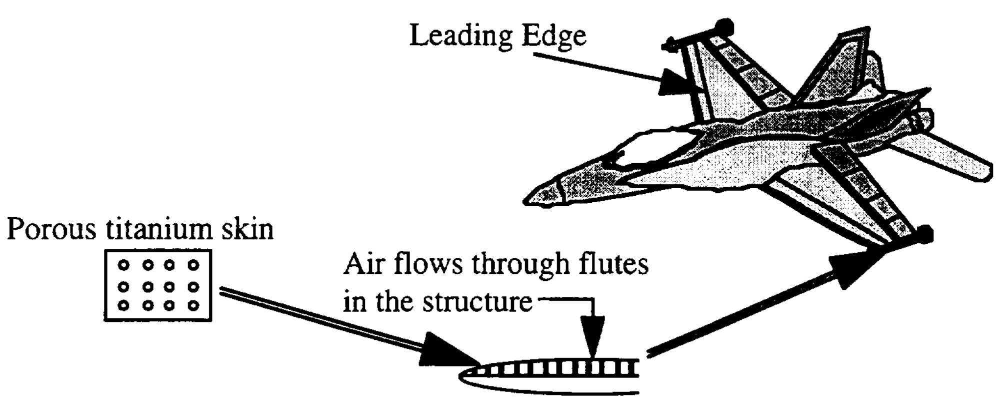

Figure 1

Apparatus and Procedure:

Figure 2 shows a schematic of the experimental setup. This setup is being used to survey a leading edge panel that was tested in the hybrid laminar flow control experiment that is currently taking place in the 8 ft Transonic Pressure Tunnel. The release valve is shut while air is allowed to flow through the fill valve until the pressure in the control volume has reached 5 psi. At this time, the fill valve is shut and the sniffer head is placed over the appropriate section of the leading edge. The release valve is then opened and the pressure drop is recorded. The pressure in the control volume is measured using a pressure tap and a digital pressure indicator. The analog voltage signal sent out by the pressure indicator passes through an analog-digital converter and the digital voltage is then read by the Macintosh computer and converted to psi. All data acquisition and analysis programs for this project were written using LabVIEW.

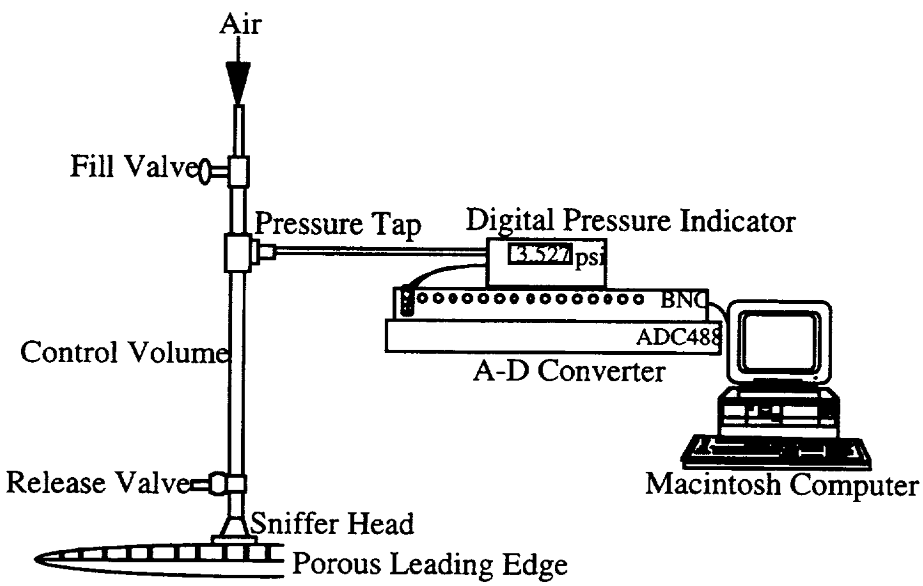

Figure 2

This procedure is repeated as the sniffer is moved along the flute that is being surveyed. The sniffer head was designed and constructed to cover an area of 1 inch x 1/8 inch in order to cover the width of a flute and only a small area in the spanwise direction. Each scan covers a distance of 2.0625 inches along a flute. The pressure drop of 32 areas is recorded by moving the sniffer by 1/16 inch each time, allowing for an overlap of 1/16 inch for each move. Once a scan is complete the derivative of the pressure versus time curve is computed for each location. This gives the corresponding mass flow at every pressure difference for each area. From here, the deviation in the flow rate at each area from the mean flow rate of the entire scanned area can be obtained for a single pressure difference.

Prior to surveying the actual leading edge of interest, experiments were done on a sample of the perforated titanium skin. It is evident by simple examination of this sample that several holes were not drilled completely through the surface. This gives reason to believe that the skin on the panel also has several holes that do not completely puncture the surface. All software was developed and tested on this sample before being used on the actual panel.

Results:

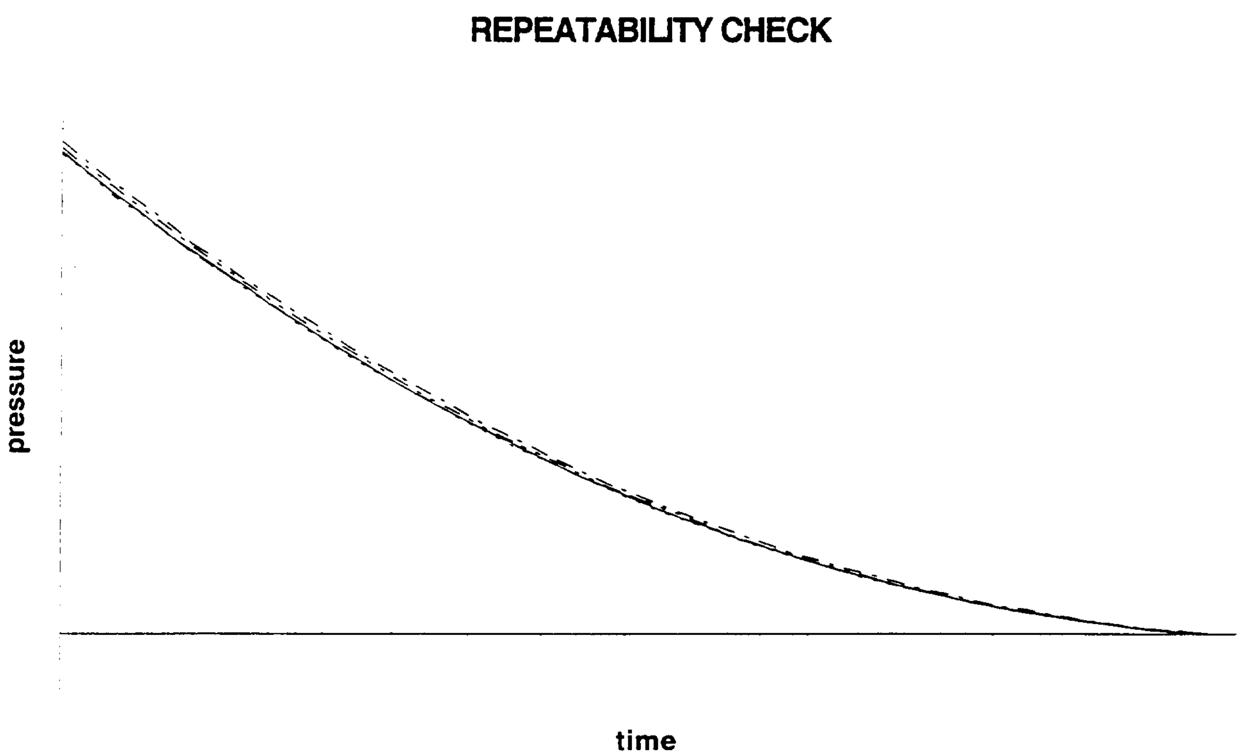

Figure 3

DEVIATION FROM THE MEAN FLOW RATE
scan taken on flute A

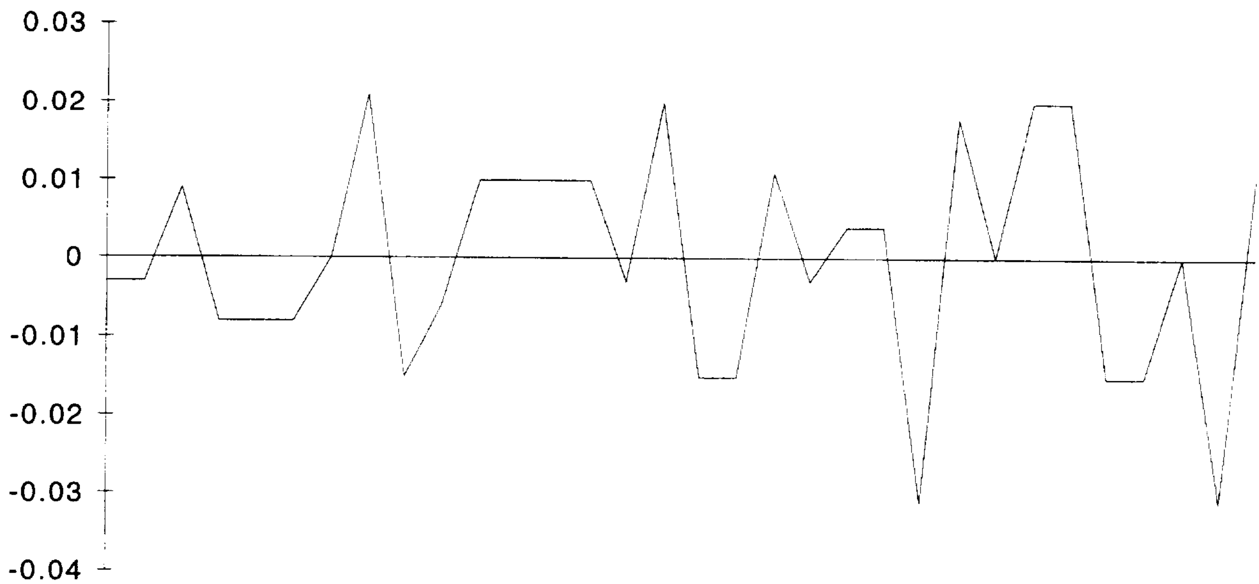

Figure 4

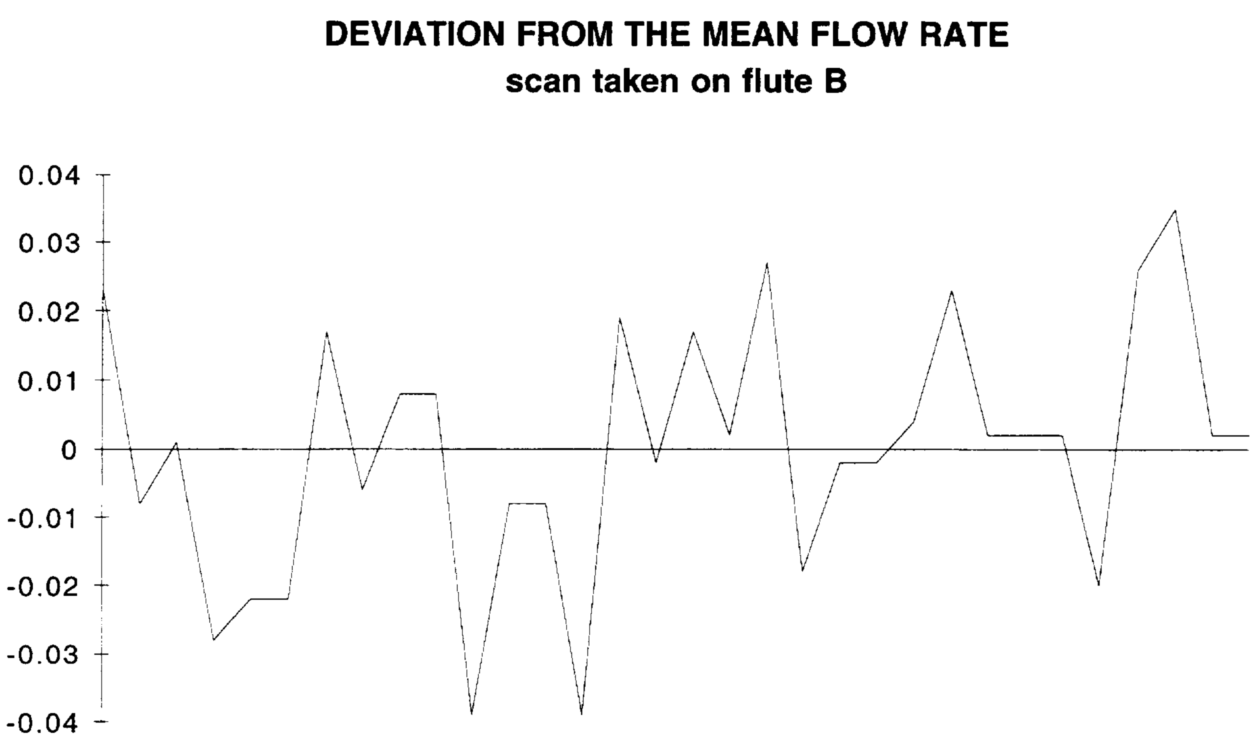
DEVIATION FROM THE MEAN FLOW RATE
scan taken on flute B
0.04
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
-0.04

Figure 5

COMPARING THE DEVIATIONS OF FLUTES A AND B OVER THE SAME SPANWISE SECTION

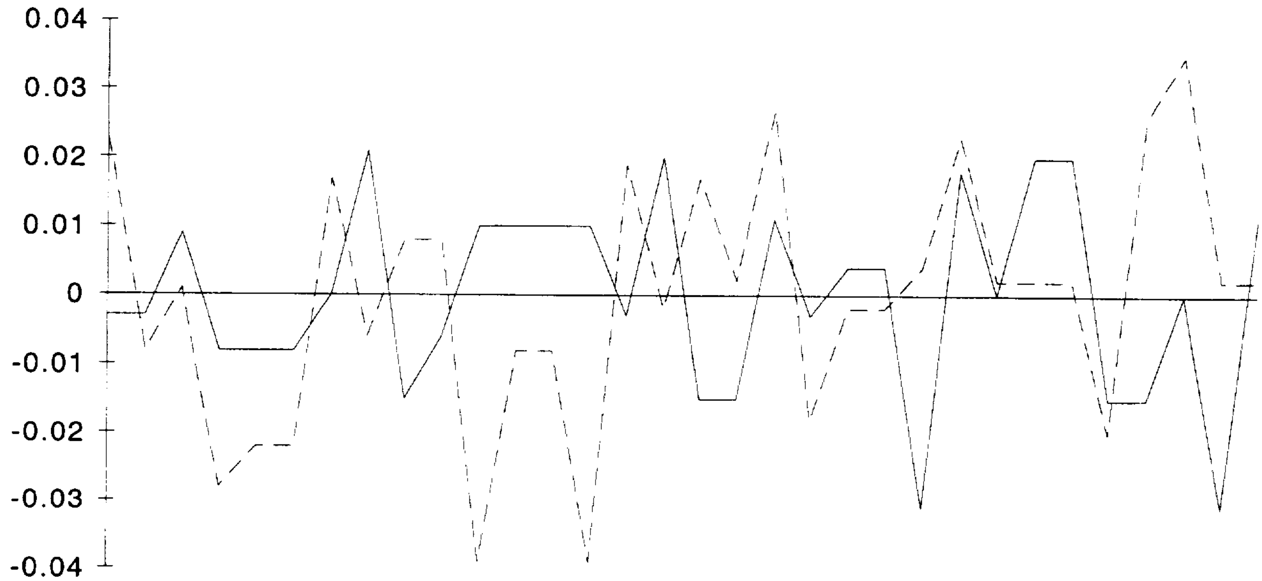

Figure 6

Discussion of Results:

As stated earlier, specific numerical results cannot be given in this report. The presented results show a sample of data that has been acquired and used to examine the flow rate through the surface. Figure 3 shows the repeatability of the setup for acquiring the pressure drop for several surveys at the same location on the surface. Once the setup was found to be repeatable at the same location, the spanwise scans were taken and a set of the results can be seen in figures 4-6. Figures 4 and 5 show plots of the deviation from the mean flow rate across flutes A and B. In figure 4 it can be seen that the maximum deviation is 3% and in figure 5 the maximum deviation is 4%. The deviation was expected to be much greater than this. The average deviation from the mean is 1% for each flute. The mean flow rate through flute A was found to be approximately 9% percent greater than the flow rate through flute B. The section of the skin at flute A is known to have more perforations, so this was expected. Figure 6 shows the deviation from the mean of both flutes at the same spanwise location. This was done to check for any trends in the deviations that may run in the direction in which the holes were drilled. From this plot there doesn't appear to be any relationship between the slight variations in flow and the spanwise location.

Conclusion:

The sniffer developed in this project is able to record the pressure drop as air flows through the perforated titanium skin. The programs that were developed can then use this information to calculate the mass flow and the deviations from the mean flow rate. These results can then be used to examine any variations in the flow rate at different locations on the leading edge panel. The sections that have been tested with this sniffer have not produced the results that were expected. It was expected that deviations up to 100% would occur, but to this point no significant deviations have been found in the results. There was also some speculation that a relationship might occur between the spanwise location and the variation. No trend has been found by the sniffer to indicate that this is true.