Wind Tunnel Measurements of Windscreen Performance

2001 Meeting of the MSS Specialty Group on Battlefield Acoustic and Seismic Sensing, Magnetic and Electric Field Sensors

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ABSTRACT

Wind noise is recognized as one the primary environmental factors that limits the performance of battlefield acoustic sensors. Microphone windscreens are regularly used to reduce wind noise and the characterization of their performance is an important component of the acoustic sensor design. Textron Systems has extensive experience studying the performance of windscreens and have developed test methodology that allows for repeatable measurements in a controlled environment. Wind noise measurements are performed using a high-speed/laminar-flow, low-noise wind tunnel with an anechoic test section. A special test section is added to the wind tunnel to generate a turbulent flow. The turbulent wind velocity spectrum is measured using multi-axis hot-wire anemometers. Comparative performance measurements of several windscreen designs are presented.

INTRODUCTION

Textron Systems recently completed the construction of a new acoustic test facility at its Wilmington, MA plant. It consists of an open-circuit, laminar-flow, low-noise wind tunnel and an accompanying anechoic test chamber. One of the primary applications of this new test facility is the characterization of microphone windscreen performance.

Under all but the calmest conditions, the background noise level of a battlefield acoustic sensor is determined by wind noise picked up by the microphones. Increasing noise levels under windy conditions will result in reduced sensor performance, especially probability of target detection. As a result, the design of an effective windscreen and characterization of wind noise levels as a function of wind speed are essential factors in the design of acoustic sensors.

Outdoor wind noise measurements suffer from the variability of the weather and test site conditions. Additionally, field measurements by their nature are generally expensive and time consuming. The wind tunnel test facility provides both a laboratory environment with repeatable conditions as well as cost and time savings.

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Abstract

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HISTORY

While the addition of the acoustic test facility at Textron Systems is recent, the wind tunnel itself has a long and interesting history dating back to the late 1960's. It was designed and built at the Massachusetts Institute of Technology (MIT) Department of Mechanical Engineering by Carl E. Hanson and Professor Patrick Leehey. The original application was for studying aeroacoustic processes such as turbulent boundary layer noise and wall pressure fluctuations in the Noise and Vibration Laboratory.

By the late 1990's however, Textron Systems had become the only regular user of the wind tunnel, using it for the characterization of microphone windscreens. Due to this low level of utilization, in 1998 MIT decided the substantial lab space occupied by the wind tunnel would be better used as office space. As a result, the wind tunnel was disassembled, crated and delivered to Boston University (BU), whom had expressed an interest in it. It remained unassembled at BU for the next 18 months. In the summer of 2000, BU decided they no longer were interested in keeping the wind tunnel and were going to dispose of it.

Textron Systems purchased the wind tunnel in late 2000 and reconstruction of the tunnel was undertaken in 2001. Professor Leehey served as a consultant and was instrumental in successfully rebuilding the wind tunnel. Several significant improvements were made by Textron Systems to the original design. Foremost, the size of the acoustic test chamber was greatly enlarged and the anechoic performance now extends to a much lower frequency than before. The original DC motor driving the blower was replaced with an AC motor and new motor controller. In addition much of the original vibration damping material used throughout the tunnel is being replaced.

WIND TUNNEL SPECIFICATIONS

The Textron Systems wind tunnel facility has its own dedicated laboratory at the Wilmington, MA plant. The overall design of the original MIT wind tunnel is illustrated in Figure 1. Although, Textron Systems has made several significant modifications to the wind tunnel this drawing is still reflective of the basic design

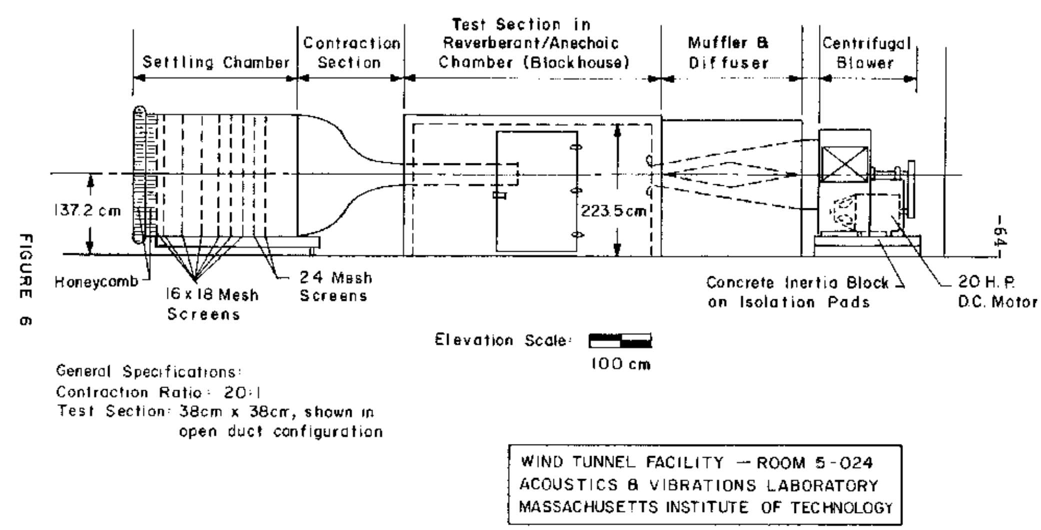

Figure 1: Original MIT Wind Tunnel Design

The wind tunnel is 50 feet in length, including the blower, and is designed to create flow velocities up to 200 ft/sec. Air is drawn through the tunnel and recirculated through the laboratory. To reduce noise from the blower and motor reaching the tunnel inlet the walls surrounding the blower, motor and inlet are covered with 20 inch deep foam wedges similar to those inside the acoustic test chamber.

The wind tunnel consists of several distinct specialized sections. The upstream half consists of the inlet, settling chamber and constriction sections while the downstream side includes the muffler/diffuser section and the centrifugal blower. The upstream and downstream sections connect within the acoustic test chamber. The wind tunnel can be configured either in a closed-duct or open-jet mode as the test chamber is sealed air tight

The inlet is a square opening 67 inches on a side with an 8 inch diameter collar around its periphery. It is filled with a honeycomb of 130,000 plastic soda straws, 3/16 inches in diameter and 10 1/2 inches long, stacked in a hexagonal close-packed configuration and held in place between two 18-mesh wire screens. The honeycomb serves as a flow straightening device, breaking up large scale eddies at the inlet entrance.

The settling or screening chamber further reduces turbulence in the flow through the use of several stages of fine mesh screens. These screens remove large eddies and create many small eddies which decay rapidly. Six 16 x 18 mesh screens and two additional 24 mesh screens are used to reduce the turbulent component of the flow to typically less than 0.05%. The combined inlet and settling chamber is 9 feet in length. Figure 2 is a photograph of the inlet & settling sections of the wind tunnel.

Figure 2: Wind Tunnel Inlet and Setting Chamber

The contraction section reflects a compromise between velocity requirements and practical size limitations. It reduces the cross sectional area of the tunnel by a factor of twenty, down to a 15 inch square duct and is 6 feet long. The shape of the contraction section is designed to prevent flow separation along the walls of the duct and is defined by a 9^{th}-order polynomial. It is constructed of a wooden skeleton overlaid with 1/8 inch thick plywood bent into shape. Figure 3 is a photograph of the constriction section of the wind tunnel.

Figure 3: The Wind Tunnel Constriction Section

The muffler/diffuser section sections isolates noise generated by the blower from the test section. The muffler consists of a large fiberglass filled box of reinforced plywood 8 feet long, 4 feet wide and 7.5 feet high. Partitions in the side walls form a series of quarter-wavelength resonators. The duct transitions from a 15 inch square cross section at the muffler inlet to a circular 40 ¼ inch cross section at the outlet to the blower. The transition is gradual over the length of the section. The walls of the duct are made of fiberglass cloth and wire screen. Centered in the duct is an 8 foot long cruciform wedge constructed of fiberglass over a masonite frame and covered with fiberglass cloth. It provides additional noise attenuation at high frequencies. Additionally, in the outlet to the blower is another honeycomb section of straws.

The blower is 39 3/8 inches in diameter with 12 blades and a single rectangular discharge. It is coupled to the muffler/diffuser section though an adjustable sliding coupling. The blower is driven via a rubberized belt by an AC motor. The blower and motor both rest on a concrete pad isolated from the floor to reduce the transmission of structural vibration to the test chamber.

The acoustic test chamber provides an isolated environment for testing. The external dimensions of the chamber are 20 feet long, 17 1/3 feet wide and 12 3/4 feet tall. It is built out of mortar-filled 7 1/2 inch wide cement blocks with a poured concrete ceiling. The walls are built on isolated footings. There is a single acoustic isolation door to the chamber and a pass though connector panel for cabling. The chamber features numerous electrical outlets for convenience and a sprinkler system for safety. The interior walls and ceiling are covered by absorptive acoustic foam panels consisting of a 4 inch thick base and 20 inch tall by 12 inch square triangular wedges. The floor is covered by removable 2 foot square sections of identical foam wedges. This allows the chamber to also be used as a hemi-anechoic room and facilitates equipment setup. The test chamber is designed to be anechoic down to 175 Hz. Figure 4 is a photograph of the interior of the acoustic test chamber. It shows the foam wedge lining and a small loudspeaker used as a sound source also wrapped in absorptive foam.

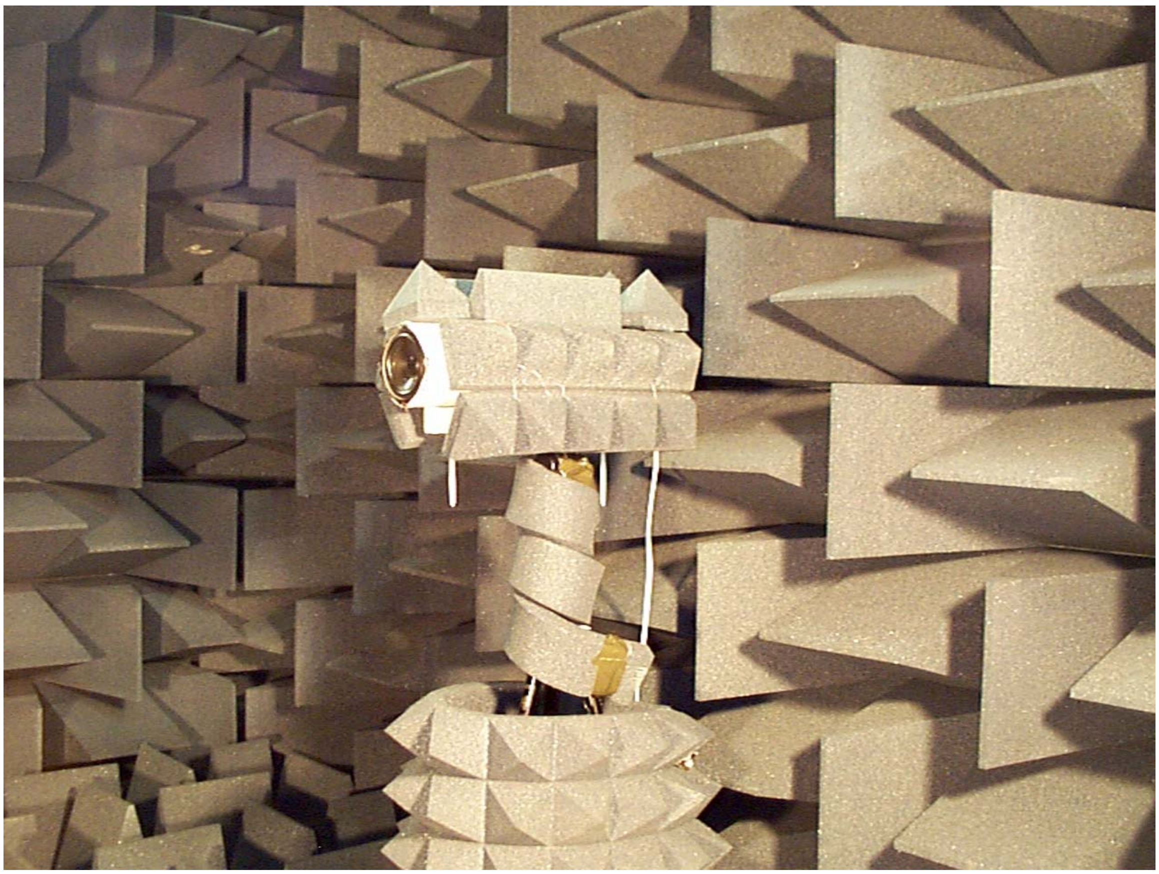

Figure 4: Interior of the Acoustic Test Chamber with Sound Source

The test sections of the wind tunnel which pass through the acoustic test chamber are designed for maximum flexibility. They can be completely removed to allow the chamber to be used as a normal anechoic room. They also allow the wind tunnel to be used in an open-jet mode. The wind tunnel duct passes through the chamber slightly off the center line due to the space restrictions of the Laboratory.

WINDSCREEN TESTING

Measurements of microphone windscreen performance are performed within the anechoic acoustic test chamber. A turbulent flow is generated by removing the side panel from the test section of the wind tunnel. The microphones and windscreens under test are then placed in this flow. A reference microphone is also placed inside the test chamber well outside of the turbulent flow to monitor the ambient noise level produced by the operation of the wind tunnel. Multi-axis hot-wire anemometers are used to measure the turbulent velocity spectrum of the flow. Although the wind tunnel cannot reproduce the longest turbulent length scales that exist in the atmosphere, good agreement with actual outdoor measurements has been generally observed.

The performance of a new windscreen design and that of a standard 3" diameter foam ball screen at two mean wind speeds is shown in Figure 5 and Figure 6. Good measurements are possible down to approximately 25 Hz. At both wind speeds the foam ball is clearly a more effective windscreen. Also shown is the ambient noise level in the test chamber. At 5 mph the ambient noise is just below the wind noise level observed by the microphone with the foam ball windscreen and several narrowband tones affect the measurement. These measurements were made in the wind tunnel at MIT in 1998. Improvements made to the rebuilt wind tunnel at Textron Systems will result in even lower ambient noise levels. Full characterization of the ambient noise levels will be performed later this year.

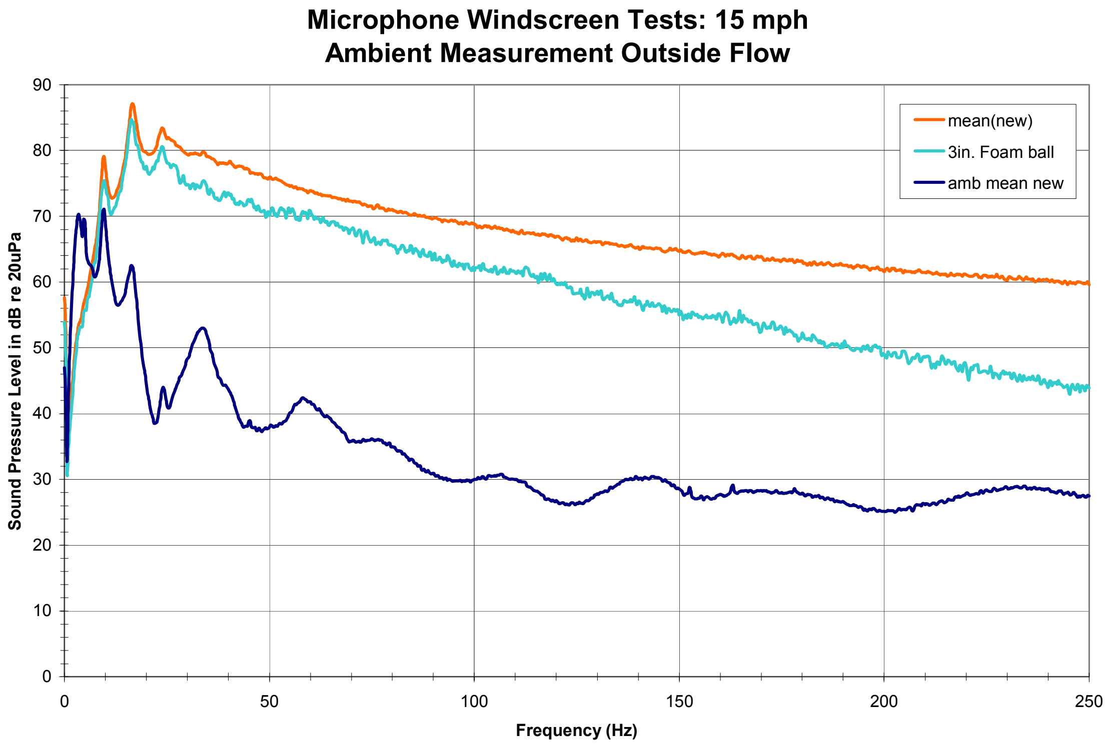

Figure 5: Windscreen performance at 15 mph

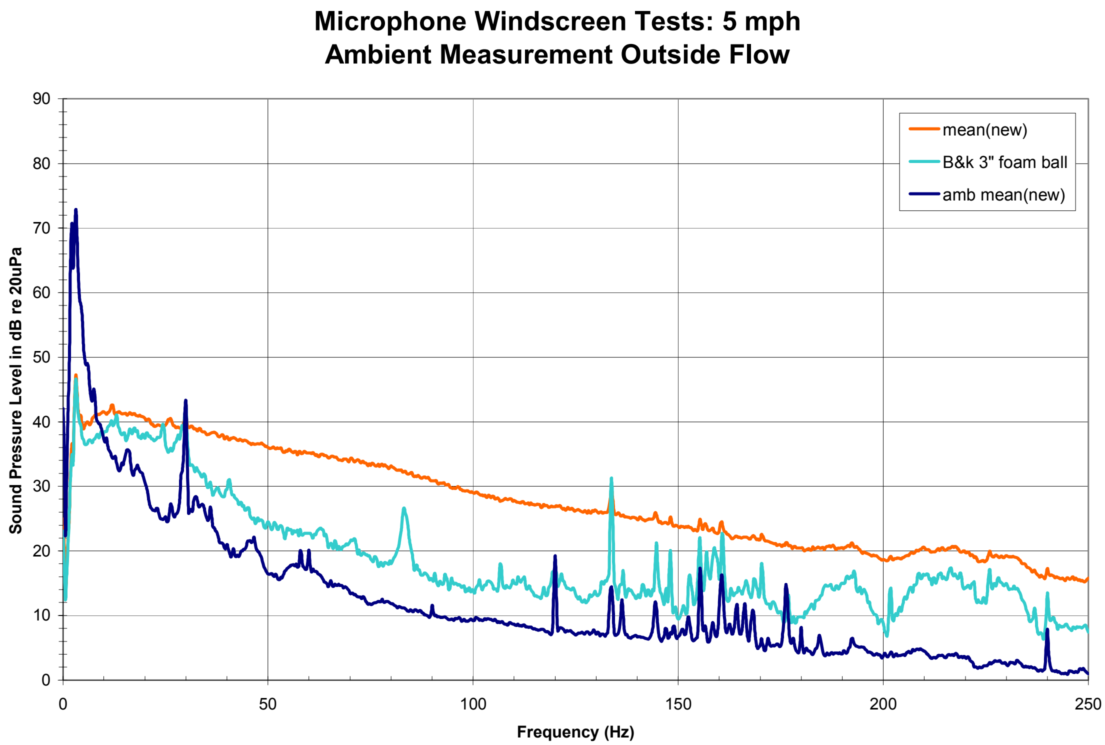

Figure 6: Windscreen performance at 5 mph

SUMMARY

The use of a low-noise wind tunnel for microphone windscreen characterization has been demonstrated. It provides a controlled laboratory environment for repeatable measurements which cannot be accomplished with outdoor testing. Full characterization of the wind tunnel performance will be accomplished in the coming months. Future work will also include research on active wind noise cancellation methods.

The new acoustic test facility at Textron Systems will be used for more than just wind noise measurements. The anechoic chamber by itself represents a significant new test facility and has already been utilized for a series of microphone calibration studies. The wind tunnel can be used for any number of aeroacoustic and aerodynamic studies. Additionally, Textron Systems is interested in partnering with other parties in related R&D efforts that can utilize the facility.

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