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An Automated System for the Acoustical and Aerodynamic Characterization of Small Air Moving Devices

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ABSTRACT

The measurement of the acoustic emissions of air moving devices used to cool electronic equipment under the actual aerodynamic conditions under which they operate is of significant interest. The Information Technology industry has standardized a plenum fixture for use in the measurement of acoustic emissions of these devices in the ISO 10302 and ANSI S12.11 test standards. This fixture has proven to be a valuable tool for use in the characterization of these devices. However, as many in industry have discovered, the construction of the plenum to the standardized specifications can be quite complex, and the use of the plenum to fully characterize air moving devices can be laborious and tedious.

Under contract to the NASA Glenn Research Center, who has a significant interest in the acoustic emissions of the air moving devices it uses to cool racks and payloads that are installed on the International Space Station, the authors have developed a fully automated fan test plenum that operates under software control. This plenum has been developed to facilitate rapid acoustic characterization of fans and other air moving devices, both independently and when operating into real world inlet conditions, obstructions, and aerodynamic loads. The plenum slider has been calibrated to allow development of fan curve data in parallel with acoustic emission data.

1. INTRODUCTION

Small air moving devices are used to cool a variety of electronic equipment and are a significant source of noise emissions from such equipment. Since the acoustic emissions of these devices depends heavily on the aerodynamic conditions into which the device operates, it is necessary to test these devices under the exact operating conditions under which they will be operated in practice in order for the data to be useful in predicting the overall noise emissions from a piece of equipment.

2. BACKGROUND

The need for a fixture to test air moving devices was recognized many years ago in the Information Technology industry. In the early 1960's, George Maling and his associates at IBM developed a plenum for the testing of such devices[1]. The plenum consisted of a polyester film-covered framework that was constructed of 5 cm by 5 cm wood (i.e. 2x2 lumber framing which was readily available). The polyester film provided an airtight yet acoustically transparent surface for the plenum. An adjustable exit port assembly allowed control of pressure drop across and flow rate through the plenum, allowing cooling fans and other air moving devices to be mounted to the plenum and exposed to the actual aerodynamic conditions under which they would be operated. Air moving devices were then operated in the plenum, and the sound power of the device was determined.

Details of the plenum design were revealed to the technical community via a special session on "Measurement of Noise from Fans for Cooling Electronics" at the Internoise 1982 Conference[2,3]. Then, through the efforts of the INCE Technical Committee on Information Technology Equipment Noise Emissions, the plenum was eventually standardized in ANSI S12.11[4] and ISO 10302[5].

While the plenum proved to be a valuable tool for the acoustic characterization of air moving devices, using the plenum for high volume production level testing of fans was very labor intensive and tedious. The need to constantly adjust operating conditions and read transducers meant numerous entries into the test chamber. Full characterization of a specific air moving device over its entire range of operating conditions required many hours of laboratory and test technician time. Advances in automated control and remote sensing technology since the inception of the plenum some 40 years ago, now made it possible to develop a fully automated plenum.

The NASA Glenn Research Center in Cleveland, Ohio, has many of the same interests in noise emissions from small air moving devices as does the Information Technology industry. Fans are used to cool equipment racks and experimental payloads that are destined for the International Space Station. The Acoustical Testing Laboratory (ATL) at NASA Glenn is charged with providing acoustic measurement and design services to support suppliers of such equipment. As one of the world's leading facilities in large fan technology, NASA Glenn is ideally suited to apply its analytical, design, and testing skills to the development of acoustically efficient solutions for cooling electronic equipment. It is with this as a background that the NASA Glenn ATL commissioned the development of a fully automated system for the acoustic and aerodynamic characterization of small air moving devices.

3. DESIGN GOALS FOR AUTOMATED PLENUM

A set of design goals for an automated plenum to support the needs of the NASA Glenn Research Center Acoustical Testing Laboratory was developed and are discussed below.

A. General Compliance with Industry Test Standards

The plenum should be generally compliant with the requirements outlined in ANSI S12.11 and ISO 10302, since this is an established industry standard for conducting such measurements.

B. Automated Exit Port Slider Control

The plenum shall include a linear actuator-based system for moving the exit port slider that can be controlled via a software control program. Multiple means of slider control shall be incorporated, allowing users to move the slider to a specific opening, move the slider slightly (bump) or move the slider to a specific aerodynamic operating point.

C. Remote Pressure Drop Sensing

The plenum shall include a transducer for measurement of the pressure drop across the plenum that is in accordance with the requirements outlined in ANSI S12.11 and ISO 10302. The pressure drop sensor shall have an output that can be read by a data acquisition card and displayed on the user interface of automated control software in the test chamber control room.

D. Remote Tachometer Sensing

The plenum shall include a transducer for the measurement of the rotational speed of the air moving device. The transducer shall provide an output that can be read by a data acquisition card and displayed on the user interface of automated control software in the test chamber control room. The transducer shall be flexible as to its position and orientation so as to accommodate a wide variety of fan speed monitoring needs.

E. Remote Fan Voltage Input Control

The plenum control software shall interface with a variable DC power supply allowing the user to adjust the input voltage to the air moving device from the software user interface in the test chamber control room. Air moving devices with input voltage requirements from 6V to 24V shall be accommodated.

F. Aerodynamic Calibration of Slider Exit Port

An aerodynamic model of the plenum exit port slider assembly shall be developed, allowing for the estimation of the volume flow rate provided by the air moving device from the slider position and measurement of pressure drop.

G. Robust Design for Automated or Manual Control

While the plenum is to be fully automated and controllable from a software interface located in the laboratory control room, it shall also be designed to be used as a manually operated plenum in the event of control hardware problems or for special needs testing. Therefore, all transducers shall have secondary readouts, and all controls shall be capable of being operated manually.

H. Compatibility with Existing Acoustic Data Acquisition Systems

The data acquisition systems and automation control hardware shall be compatible with the existing NASA Glenn Acoustic Testing Laboratory instrumentation systems, allowing for future integration of the plenum control software and the acoustic measurement system for fully automated fan characterization.

4. PLENUM CONSTRUCTION AND DESIGN VALIDATION

A prototype of the automated plenum was constructed and tested per the requirements of ANSI S12.11 and ISO 10302. Details of the plenum construction and resulting test data are discussed below.

A. Plenum Size and Construction

The industry standards related to this plenum define three sizes of plenum; full size, half size and quarter size. While the original plenum design was based around the full size plenum, which is appropriate for larger fans such as those used to cool large equipment racks, it was decided that a half size plenum, which is appropriate for fans such as those used to cool rack payloads and computer chassis, would best suit the current ATL needs. Therefore, a half size plenum with nominal dimensions of 0.6m x 0.6m x 0.5m (24” x 24” x 20”) was constructed.

The ANSI and ISO test standards suggest that the size of the material used to construct the plenum should be scaled in accordance with the plenum size. This implies a 2.5 cm x 2.5 cm (1" x 1") frame construction. Since the automated plenum would need to utilize the framework for mounting of the linear slider and various transducers, it was decided that a wood framework was not the optimal material for construction. Therefore, a design based on a 2.5 cm x 2.5 cm welded aluminum tube frame into which threaded inserts would be installed for component mounting purposes was selected for the plenum. While the use of aluminum materials for the plenum frame construction violated one of the "shall" provisions of the industry standards for the construction of the plenum, it was decided that as long as the plenum met the acoustical performance requirements of the standard, then it would meet the needs of the ATL.

Therefore, the insertion loss of the aluminum frame plenum was tested in accordance with the provisions of Section 5.5 of ISO 10302. The results are presented in Figure 1 below and indicate that the aluminum plenum meets the insertion loss requirements of the industry test standards.

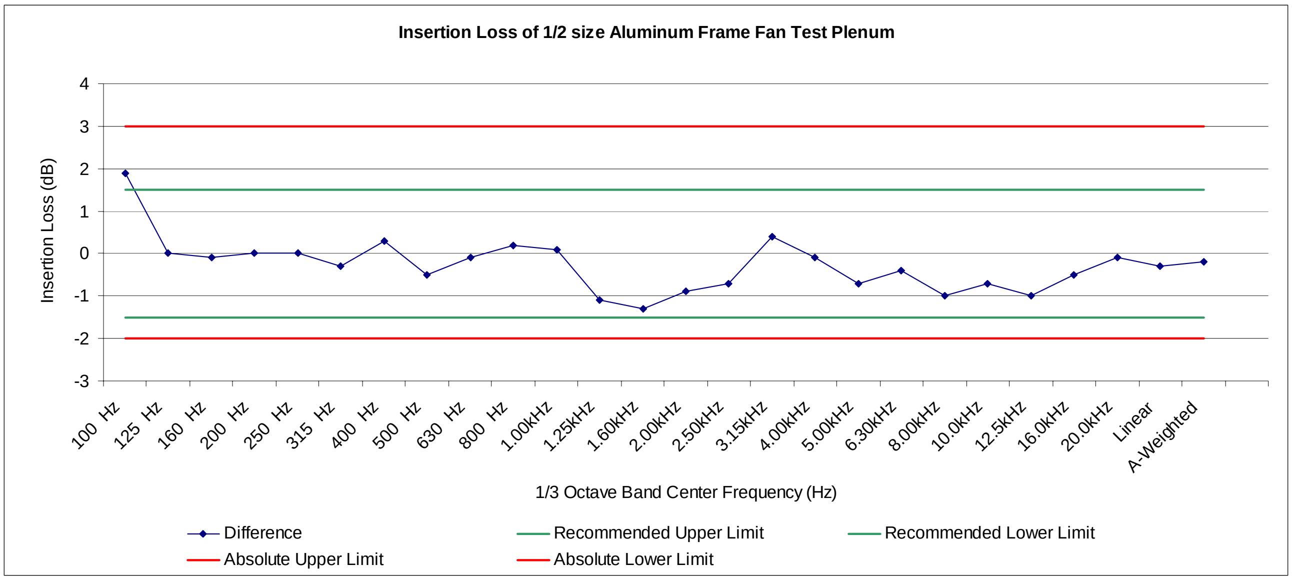

Figure 1: Insertion loss of ½ scale, aluminum framed plenum when tested in accordance with Section 5.5 of ISO 10302. Recommended and Absolute performance limits are also shown.

B. Automating the Exit Port Slider

A linear slide assembly with 400 mm of travel was selected for the one-half size plenum. The slider operated using 24 volt industrial logic and was easily controllable to within the one millimeter step size deemed to be adequate for the application. A National Instruments digital I/O board was used to provide control signals to the slider and read back the feedback signals from the slider. LabView based software was developed, allowing full control of the slider under the three defined operating scenarios (go to position, bump, go to operating point). John Phillips of Acoustic Systems developed the linkage mechanisms to transfer the motion of the linear slide to the exit port slider. Provisions for zeroing the slider were built into the linkage mechanism.

C. Remote Pressure Drop Sensing

The piezometric ring outlined in ANSI S12.11 and ISO 10302 was connected to a low pressure control transducer typically used for automated control of air systems in clean room spaces. The transducer provides NIST traceable pressure readings with 1% full scale accuracy (.01" H20 with 1" H20 full scale) to both a digital display and a DC voltage output that can be read by a data acquisition card. The transducer is mounted to the plenum, allowing it to be read manually when inside the chamber and remotely when operated under software control.

D. Remote Tachometer Sensing

A panel tachometer with digital readout and an optical sensor was selected for monitoring the fan RPM. The optical sensor is mounted to a gooseneck arm allowing the sensor to be aimed at the target at a distance and angle such that it does not interfere with the airflow to the fan. The tachometer provides 1 RPM accuracy over its 0-12000 RPM operating range. The tachometer can be read from its digital display which is located in the laboratory control room near the DC power supply or via its DC voltage output into a data acquisition card and into the user interface of the control software. Future versions of the automated plenum will support direct readout of RPM from fans with an integrated tachometer signal.

E. Remote Fan Voltage Input Control

A variable DC power supply with an RS-232 control interface was selected to provide input voltage to DC fans. The power supply is controllable in 0.1 volt steps either from the power supply controls or from the control software user interface. Future versions of the automated plenum will support pulse width modulated power supplies for fan speed control.

F. Aerodynamic Calibration of Slider Exit Port

An aerodynamic model of the fan exit port slider was developed by fitting actual pressure vs. flow data at various slider positions to a standardized aerodynamic model for flow through an orifice. Flow rates were estimated from averaging a number of hot wire flow velocity measurements across a duct connected to the inlet of the plenum. The data was then fit to the model, flow coefficients were developed and a mathematical model of the pressure vs. flow vs. slider position for the plenum was developed by David Nelson of Nelson Acoustics. The mean square error of the model used to estimate the flow rate when compared to the actual measured data is approximately 6%. This model allows the estimation of the flow rate from the air moving device from the pressure drop measurement and the known slider position. Future work on the plenum will include full characterization on a flow bench and a refinement of the model to further reduce errors, particularly at the model limits (high flow/low pressure and low flow/high pressure).

5. CONCLUSIONS

An automated plenum has been developed for use in conducting acoustic and aerodynamic testing of small air moving devices. A photograph of the ½ size plenum is shown in Figure 2. The plenum has been constructed in general accordance with the design requirements outlined in ISO 10302 and ANSI S12.11, with the exception that an aluminum framework has been used rather than the specified wood materials. Acoustic testing of the plenum fixture indicates that it meets all performance requirements of the test methods. As a result, recommendations will be made to the ANSI and ISO committees responsible for these test methods that the design requirements currently specified be modified to allow for alternative materials, provided the acoustic performance requirements of the method are met.

The plenum is currently being put into use in the NASA Glenn Research Center Acoustical Testing Laboratory and will be used to characterize both air moving device performance under aerodynamic load and the effect that inlet and outlet conditions have on noise emissions from these devices. Future work will include development of software to automatically move fans through a variety of operating conditions, and integration with the existing acoustic data acquisition system to create a system for fully automated fan characterization. Fan mounting plates consistent with the requirements of ANSI S12.11-Part 2[6] for vibration measurements are also being developed and will be integrated into the data acquisition system.

Figure 2: Photo of ½ size plenum prototype in Acoustic Systems hemi-anechoic chamber

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