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High Temperature Quiet-Flow Test Facility

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SUMMARY

Universal Silencer has developed a high temperature, quiet flow test facility for the testing and evaluation of exhaust silencers and silencer materials. This facility is driven by a rotary positive displacement blower delivering up to 110 m^3/min [4000 cfm] of airflow. This airflow is put through both a passive and active silencer to achieve minimal uncontrolled noise in the test stream. Controlled sound is injected into the airflow by a set of loudspeakers in a mixing/settling chamber. The airflow is heated up to 540C [1000F] by a 144Kw electric heater just prior to entering the test section. The test section is rated for a 10 cm [4 in] diameter flow path and up to 1.8 m [6 ft] long sample. The outlet of the test section exhausts outside the test building and a microphone measurement system measures the radiated sound level. This facility allows tests to be run with flow, sound level and temperature controls to obtain in situ measurements of silencer performance including insertion loss.

INTRODUCTION

The need for a high temperature test facility is based on the requirements of many applications that operate at high temperature but are too large or complex to be tested adequately in the laboratory and still obtain results that are representative of field performance. These applications include gas (combustion) turbines and large engines. Even for those applications which allow testing, it is often either impossible or extraordinarily difficult to measure the individual design attributes necessary for practical algorithm development. For example, recent tests on the performance of parallel baffles indicate that the lining material properties and wire screen have more acoustic effect that was previously assumed.

While this facility has a maximum test section diameter of 20 cm [8 in], it will allow the testing of materials at both high and ambient temperatures and with or without air flow for direct comparison of results without adjustments or correction factors. A series of tests are planned to verify the validity of using high acoustic flow resistivity pack at low temperatures to simulate the effect of temperature. Additionally, tests are planned for various combinations of pack material and temperatures to adequately map the effect of temperature on insertion loss and other material properties, such as acoustic resistance. This will allow algorithms to be developed for the high temperature performance of these materials and to either confirm or revise the current theories.

TEST STAND CONFIGURATION

This test stand consists of a variable speed rotary positive displacement blower (1,2), passive silencer (3), active silencing (4), mixing/noise injection chamber(5), heater (6), test section (7) and data collection microphone array (8) as shown schematically in the Figure 1. These components are labeled with numbers to assist in identifying them in the pictures in Figures 2-4.

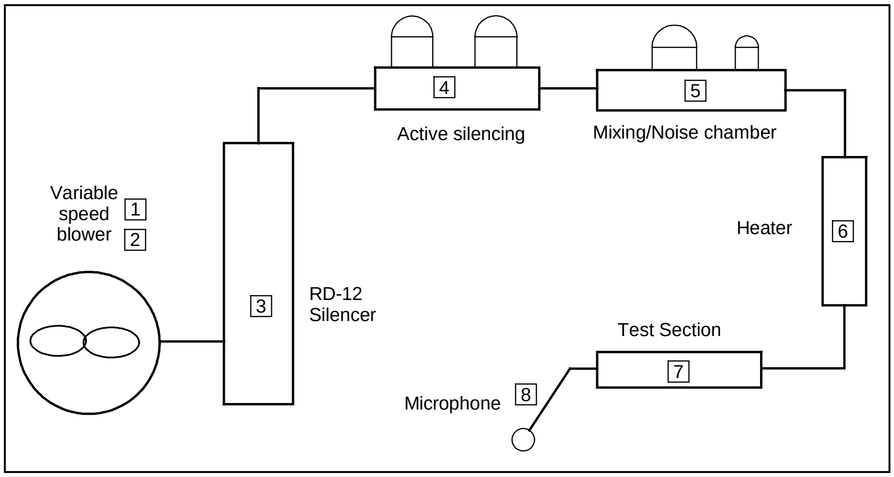

Figure 1 - Schematic representation of high temperature test stand

The 300 mm [12 in] rotary positive displacement (RPD) blower (2) is controlled by a variable frequency drive (1) and a 150 kW [200 hp] motor combination at speeds up to 1800 rpm and are shown in Figure 2. The motor is located under the platform on the left side and is unlabeled. The blower is capable of providing up to 110 m^3/min [4000 cfm] of air at approximately 70 kPa [10 psi] to the test stand; this will yield flow velocities of more than 60 m/sec [12,000 fpm] in the test section depending on the test section cross-section. A RD-12 passive silencer (3) shown in Figure 4 is used to substantially reduce the noise of the blower. The RD-12 is a critical grade combination reactive and absorptive silencer used in many RPD blower applications and is a standard product offering of Universal Silencer. After exiting the silencer the flow is discharged through the roof of the building into a diverter valve; the test stand can be used for other types of tests, such as inlet filters or silencer, and this provides an optional discharge to atmosphere. The degree of silencing is would adequate for most conditions but more reduction is needed for this application particularly at low frequencies. In addition to the passive silencer there is an active silencing section (4) with a special controller shown in Figure 3 to eliminate any remaining noise, primarily the blower fundamental of four times the operating speed. The active silencing section consists of four loudspeakers which provide the necessary power to cancel the sound. An error level microphone for the active silencer is located downstream of the speaker section (just after the vertical to horizontal elbow) and senses the amount of unsilenced noise. It then feeds back a

Figure 2 - View showing motor, controller and RPD blower

signal to the controller to adjust the speaker output. This yields a source of quiet air flow.

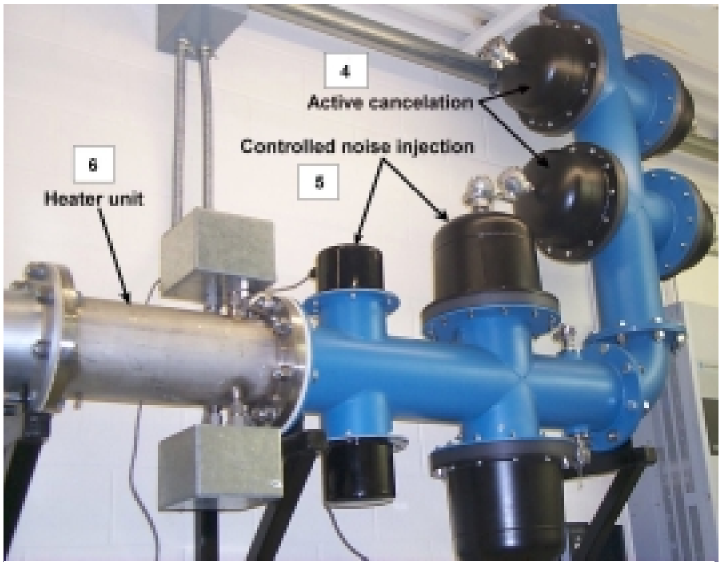

Figure 3 - View showing active control, mixing/sound injection chamber and heater

The next section of the test stand includes the mixing/noise injection chamber (5) where controlled noise may be added. This is an important section since it allows that repeatable results to be obtained for many different operating conditions. Depending on the particular test being performed an additional extension may be inserted between the mixing chamber and the heater unit (6) to obtain more uniform flow into the heater. The heater unit is a Sylvania, 480V, 3ϕ, 144 kW electric unit that can provide temperatures up to 540°C [1000°F]. The outlet temperature varies with flow and applied voltage with higher temperatures at lower flow rates and higher voltages. A temperature of 540°C [1000°F] can obtained with a flow velocity as high as 62 m/sec [13,600 fpm] while a temperature of 315°C [600°F] can be obtained velocities of 132 m/sec [25,900 fpm] in the 10 mm [4 in] test section. Flow uniformity is not a major consideration downstream of the heater as it has a very high pressure drop and the flow out of it is well distributed. Following the heater section is a transition to the test section (7) which is sized for a 10 cm [4 in] flow size. Other sizes up to 20 cm [8 in] can be accommodated with lower flow velocities in the test section. The straight pipe shown is replaced with the unit under test. To reduce the likelihood of injury from the hot pipe, the test section is only accessible from an elevated walkway. Downstream of the test section is an elbow and pipe discharge to the roof of the test building (8). On the roof a microphone array is mounted to the exit of the pipe.

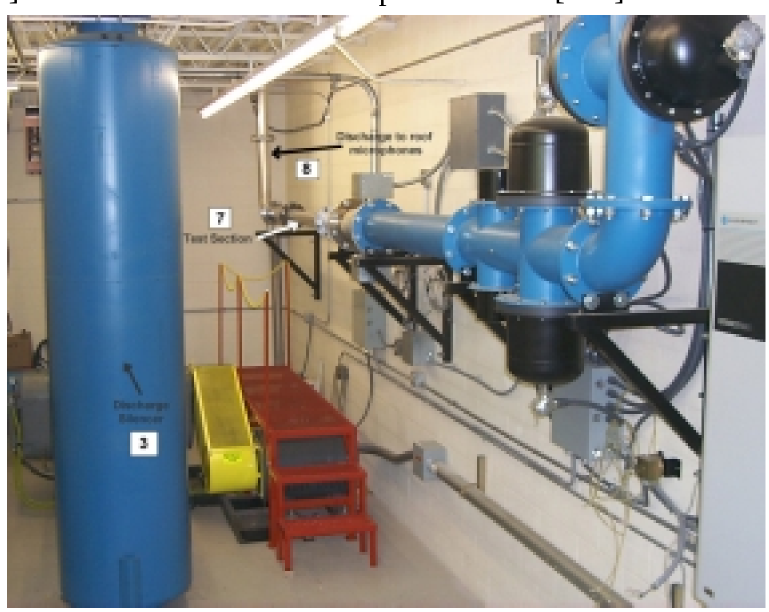

Figure 4 - View showing passive silencer, test section and discharge to microphone array

The microphone array consists of two microphones at 1 m from the outlet pipe, one 20° above and the other 20° below horizontal. This microphone boom is rotated using a stepper motor for precise position control. After testing and review it was found adequate to have four positions spaced 90° apart. The control system automatically moves and stops the microphones at the required locations.

Data taken to determine the degree to which we accomplished our goal of a quiet flow facility is shown in Figure 5. The average acoustic response of the test facility using the microphone array on the roof of the test building is shown. Ambient noise as sound pressure level is shown by the trace with the diamond (◆) symbol. The trace shown with a square symbol (■) is the noise level with flow through the system using a straight pipe in the test section. Also on Figure 5 is shown the sound level with the speaker noise injection as represented by the triangle symbol (▲). Ambient noise and flow noise above the 2 kHz limit of the graph are similar to that shown. Note that above 25 Hz the injected noise is at least 15 dB above the flow noise alone and is more than 30 dB at most frequencies; while not shown similar results are true above 2 kHz.

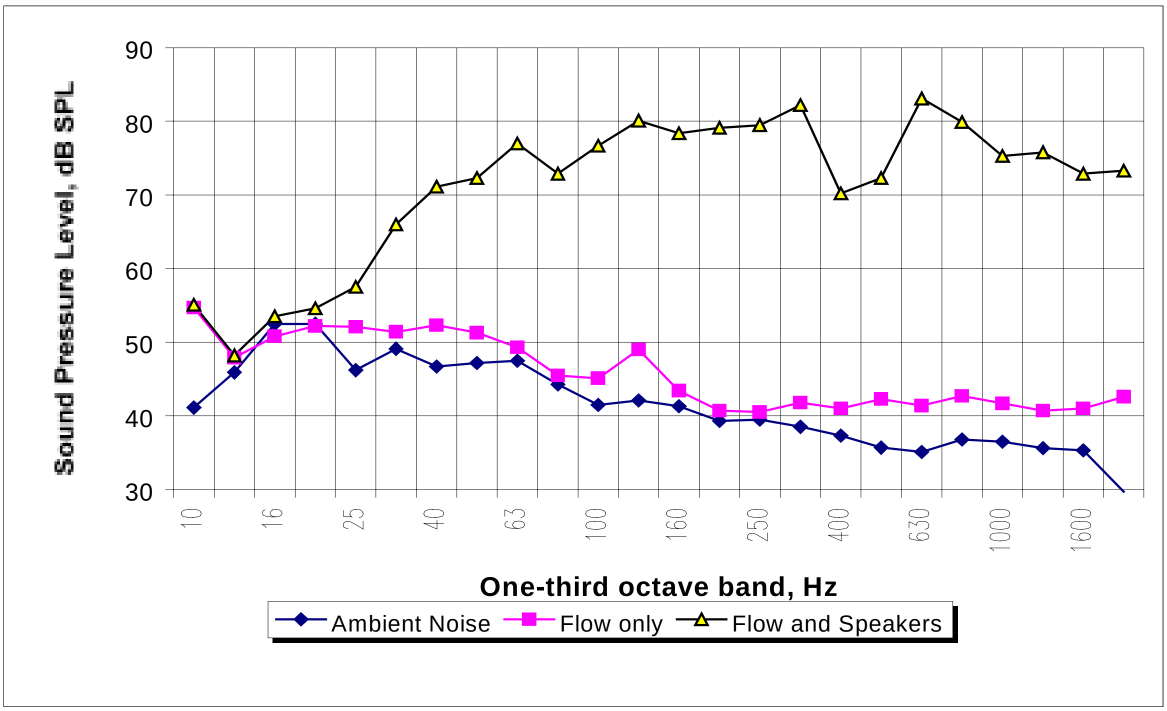

Figure 5 - Ambient and operational sound levels

CONCLUSION

A quiet high temperature flow facility has been constructed and initial verification completed. Testing indicates that the signal to background noise is greater then 20 dB at all frequencies above 25 Hz. The operational configuration will allow tests to be run that will provide substantial new information on the high temperature properties of acoustic materials and arrangements with in situ flow conditions. This information will allow the optimization of the acoustical and aerodynamic properties of new and existing products to provide cost effective solutions to our customers.