# Muffler Performance Measurement Test Rig

Mufflers are widely used to reduce the exhaust and intake noise of fluid machines for different applications. Every muffler has to be tailored carefully to the engine to which it is connected. One very important tool of muffler design is the measurement of its properties, acoustic performance and pressure drop. Introduction of flow is a key issue as it simulates a real engine situation. The two-source technique has been proven to be the most stable and most efficient technique to characterize the full scattering matrix of the muffler. At several companies and research institutes, this has become a standard measurement which is repeated frequently throughout the design process. This is a new platform to measure the passive (e.g. Transmission Loss) and active (flow-generated noise) properties of mufflers. Stepped sine excitation is used with simultaneous excitations from both sides of the muffler. The stepped sine excitation is optimized to reduce the needed time without jeopardizing the quality of the measurement. Measurement of flow background noise, microphone coherence, and pressure drop are also performed. This platform is based on a combined JAVA/NI software and National Instruments Data Acquisition cards, to automate the measurement accounting for different theoretical and practical considerations.

**Our solution for the measurement of muffler acoustic performance includes the following standard components:**

1. *SIDLAB Measurement Rig.*
2. *SIDLAB Acquisition Software.*
3. *SIDLAB Data Acquisition System.*
4. *SIDLAB Flow Measurement Kit.*
5. *Acoustic Sensors.*
6. *Commissioning: Installation and training.*

## 1. SIDLAB Measurement Rig

This is the test rig for the measurement of the acoustic properties of mufflers for different exhaust/intake and HVAC applications. We offer 3 standard inner diameter sizes of 25, 50, and 100 mm. Other pipe sizes are available upon request. The rig can handle flow up to 100 m/s and air temperature up to 100°C. It can be further modified for higher flows, higher temperatures, and specific gases.

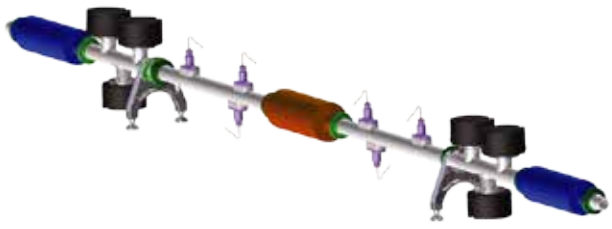

*Figure 1 Views of the two-port test rig, showing the test object, microphones, loudspeakers, and end mufflers.*

**The SIDLAB Acquisition Rig solution consists of:**

1. 2x Measurement pipes, holding the microphones.
2. 2x Loudspeaker pipes, holding the loudspeakers.
3. 2x Termination mufflers, one on each end of the rig, to reduce reflections and increase measurement quality.
4. 4x Rig supports, either table support or floor support.
5. 6x Microphone holders, designed for ¼ inch microphones.
6. 6x loudspeakers, high power and metallic diaphragm.
7. 1x Two-channel Amplifier.
8. Two adaptors for the connections to the test objects. More adaptors can be manufactured by the user based on different sizes.

**Optional add-on:** Fan to provide the flow, and a frequency inverter to change the fan speed.

## 2. SIDLAB Acquisition Software

SIDLAB Acquisition is used to acquire the measurement data needed to characterize the passive acoustic properties (e.g. Transmission Loss) of two-port elements (e.g. exhaust or intake mufflers). SIDLAB Acquisition is provided together with a Data Acquisition System and the measurement microphones. It automates the measurement procedures accounting for different theoretical and practical considerations. Different excitations (random or stepped sine) can be used. The results are stored in different formats compatible to SIDLAB Acoustics and can be used to simulate a complete system.

SIDLAB Acquisition is very useful for companies and research institutes, who perform this measurement as a standard measurement which is repeated frequently throughout the design process. SIDLAB Acquisition uses the two-source location technique which has been proven to be the most stable and most efficient technique to measure transmission loss.

**SIDLAB Acquisition interface guides the user through the measurement procedure:**

1. Properly connect the cables.
2. Set the rig dimensions.
3. Perform the absolute and/or relative calibration.
4. Conduct the upstream and downstream measurements.
5. Calculate the transmission loss and the transfer matrix for the measured object.
6. Optional add-on: Measure the pressure drop across the muffler at different flow speeds and calculate the muffler loss coefficients.
7. Optional add-on: Measure the flow generated noise inside the muffler (radiated sound power).

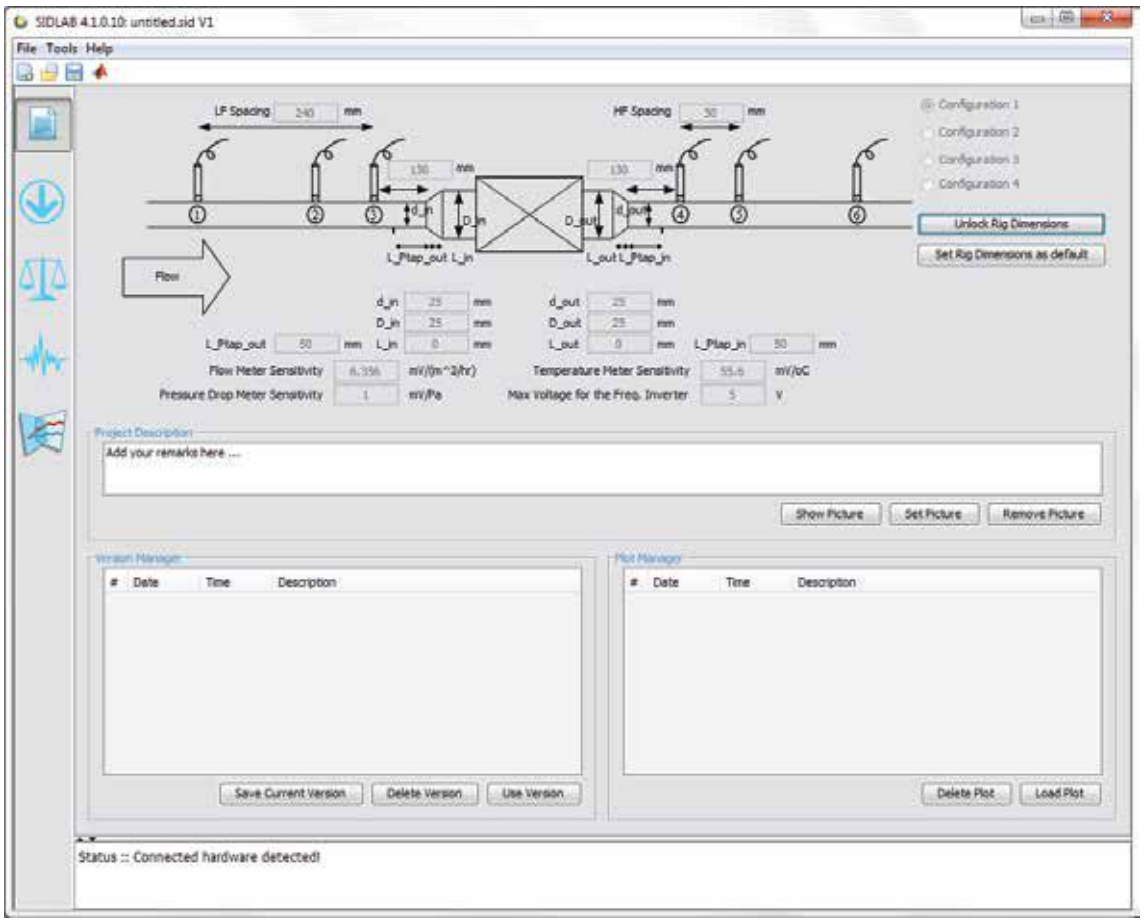


*Figure 2 SIDLAB Acquisition Interface for the Input Data.*

It is very common to perform this test with flow through the pipe. SIDLAB Acquisition has an optional add-on to control the fan speed (providing the flow) through the same interface. Flow speed and temperature are also measured automatically and used in the calculation.

**SIDLAB Acquisition has the following advantages over other Data Acquisition systems:**

1. It supports stepped sine capabilities which provide better results, especially with flow. High Signal to Noise Ratio, easier to extract the loudspeaker signal from the flow noise.
2. It is easier to use and faster to do repeated measurements.
3. It has all functionalities integrated in one place.

**The results that are provided by SIDLAB Acquisition Software are:**

1. Transmission Loss in downstream (exhaust) and upstream (intake) directions.
2. Noise Reduction.
3. Components of the Transfer and Scattering Matrices.
4. Acoustic Pressure at all the microphones and the coherence to the reference signal.
5. Background Noise and Flow Generated Sound Power.
6. Pressure drop – flow curve, and loss coefficient.

The software supports a variety of post-processing functions. It also supports the export of the raw data for further post-processing in another software. Different versions of the measurement can be saved in one project file with several functionalities to compare with other versions in other project files.

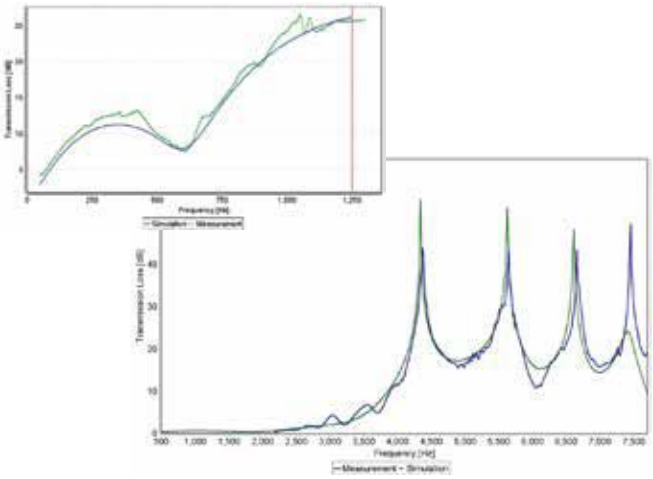

*Figure 3 Samples of TL data and comparison with Simulation.*

## 3. SIDLAB Data Acquisition System

We provide the necessary Data Acquisition System from National Instruments (NI) to be able to conduct the measurement. The Data Acquisition System consists of 8 inputs, 4 outputs and the interface with the computer via USB port. The system is supplied with all necessary cabling to the microphones, amplifier and loudspeakers, all fitted in a carrying case.

If you have your own National Instruments Data Acquisition System, we can use it. However, this is the subject to the specifications of the current Data Acquisition System that you have.

**The components provided with the SIDLAB Data Acquisition System are:**

1. Data Acquisition frame (National Instruments) with USB interface and all necessary 8 ICP inputs and 4 output modules.
2. Carrying Case.
3. All necessary cabling.
4. Optional add-on: Necessary cards for Fan control and Measurement of mass flow, gas temperature, and pressure drop across the muffler. The details are described in the SIDLAB Acquisition Flow kit part.

*Figure 3 The NI Data Acquisition System is connected via USB cable to a computer. The SIDLAB Acquisition software is programmed using LABVIEW. (The computer is not included in the offer).*

If it is required to measure the muffler performance at high frequencies, beyond the plane wave range, 1 extra microphone can be installed at several cross sections to be able to resolve the first higher order mode and measure the Transmission Loss of the least attenuated mode.

## 4. SIDLAB Acquisition Flow kit

To facilitate the measurement with flow, the rig is equipped with extra sensors that are connected to the same data acquisition system. The rig is connected to a fan to provide the flow, and a frequency inverter to change the fan speed. The fan speed can be controlled from the SIDLAB Acquisition Software, and all the sensor readings are fed automatically into the software.

It is also required to measure the pressure drop across the test objects and plot the pressure drop curve at different speeds. This can be done by varying the fan speed, and measuring the differential pressure between the inlet and outlet of the test object. The loss coefficient of the muffler can be calculated by the software.

**This item includes:**

1. Mass Flow measurement sensor measuring the flow rate at the inlet of the rig.
2. Temperature measurement sensor of the flow temperature at the inlet of the rig.
3. Differential pressure measurement sensor measuring the pressure drop across the test object.
4. Control the speed of the fan producing the flow into the rig in order to provide different flow speeds.
5. All necessary cabling.

## 5. Acoustic Sensors

Six microphones are normally used for this measurement to cover a wide frequency range within the plane wave range of the measurement pipes. Two microphone spacing on each side of the muffler are used to cover low and high frequencies. Special microphones are used, that are designed for the in-duct measurement of sound fields. ¼ inch microphones to provide good accuracy for the wave decomposition using the two-microphone technique. The microphones are calibrated with Class 1 microphone calibrator.

If the frequency range of interest is rather narrow, then it can be enough to use 4 microphones. If there is an interest to measure beyond the plane wave range, then 10 microphones can be used to measure the higher order modes.

**This item includes:**

1. 6x ¼ inch microphones.
2. 1x Class 1 microphone calibrator + adaptor for ¼ inch microphones.
3. All necessary cabling.

## 6. Commissioning

The commissioning includes Packaging, Shipping, Installation, and 2 days onsite hands-on **training will be offered by one of cover the following topics:**

1. Installation and assembly of the rig
2. Installation and assembly of the data system.
3. Installation of the acquisition software designated computer.
4. Perform test measurements on the company's mufflers.
5. Training of company engineer through the whole process.
6. Theoretical training on the background of the measurement process.
7. Overview of what can be done with the measurement results.

The whole system will be packaged inside a wooden box, made of plywood, for transportation. The box is equipped with custom designed internal structure for secure fastening of the test rig components.

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