m+p Impedance Tube Solutions

Sound quality is becoming an important factor in product design, where acoustic materials serve to enhance the perceived acoustics of a product. Acoustic material testing enables engineers to assess crucial sound characteristics of sound absorbing materials. To this end, impedance tubes are utilized to identify sound characteristics of material samples in the laboratory under controlled conditions. The impedance test gives detailed information about the materials sound characteristics, including the absorption coefficient, reflection coefficient, acoustic impedance and sound transmission coefficient/loss.

The m+p impedance tube software package is available as a license option in m+p Analyzer. It includes a guided user interface to acquire measurements according to three international standards (ISO 10534-2, ASTM 1050-12, ASTM 2611-17), as well as automated report generation.

Sound quantities:

- Sound absorption
- Sound reflection
- Acoustic impedance
- Sound transmission coefficient/loss

Standards:

- ISO 10534-2
- ASTM 1050-12
- ASTM 2611-17

Turnkey solution incl.:

- Impedance tube
- Power amplifier
- Microphones
- Measurement front-end
- Software

Impedance tube setup

An impedance tube consists of a cylindrical metal tube with a loudspeaker on one end and a specimen holder on the opposite end. Behind the specimen, the tube is terminated by either a solid metal plug (2-mic-setup) or an extension tube with anechoic termination (4-mic setup). In either case, the sound waves generated by the loudspeaker travel through the tube towards the specimen where they get reflected, absorbed or pass through. Microphones measure the resulting sound field, from which the acoustic properties of the material sample are calculated.

The measurable frequency range of an impedance tube is constrained by the inner dimensions of the tube. m+p offers three tube diameters (30, 60, 100 mm).

Available tube types

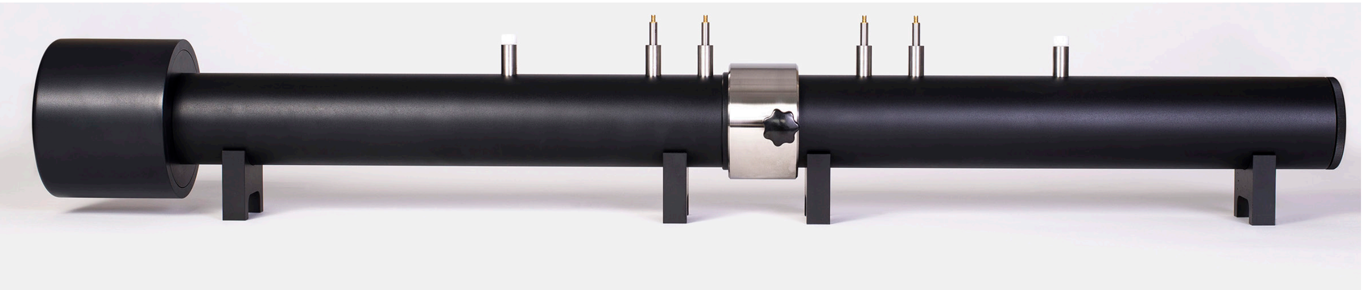
Type	Freq. range [Hz]	Tube diam. [mm]	Extension available
S	1800 - 6300	30	Yes
M	125 - 3150	60	Yes
L	63 - 1800	100	Yes

Two-microphone setup

In the 2-mic-setup, the tube is terminated behind the specimen, allowing for the sound to be either reflected or absorbed by the sample material. At two fixed positions the tube is equipped with microphones measuring sound pressures. The complex transfer functions between microphone readings are calculated by the software and used to derive the **absorption** and **reflection** coefficient as well as the **acoustic impedance** of the sample. This is commonly referred to as the “transfer-matrix method” described in **ISO 10534-2** and **ASTM 1050-12**.

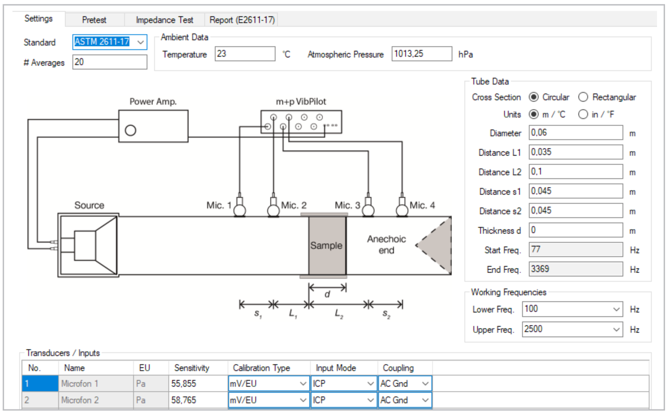
Four-microphone setup

Standard **ASTM 2611-17** defines a procedure to measure the **transmission loss** factor in addition to the absorption coefficient, reflection coefficient and acoustic impedance of a sample. In this setup, the tube is extended with a secondary cylinder behind the sample. Two additional microphones measure the sound that passes through the sample. Again, the “transfer-matrix method” is employed to evaluate the sound quality coefficients.



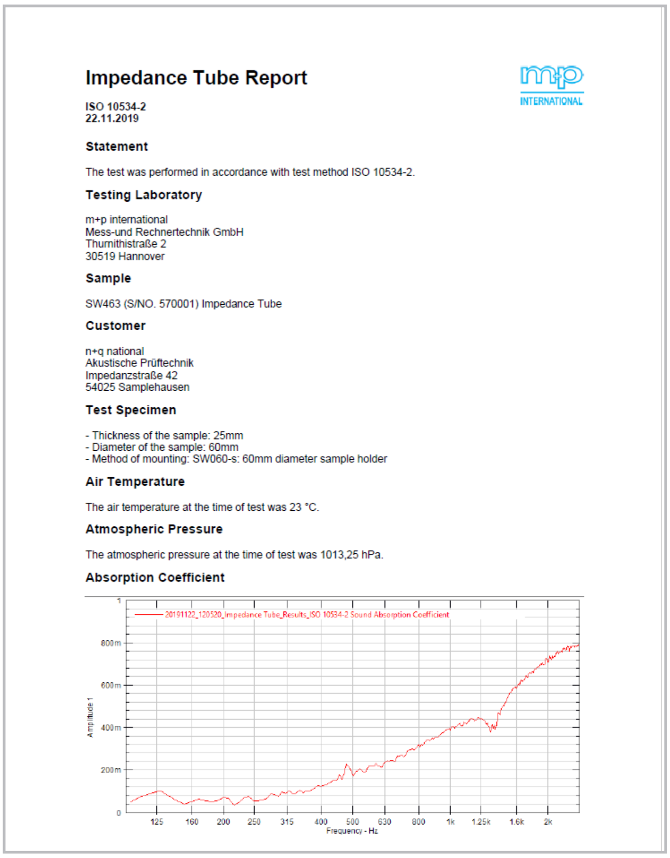
m+p Analyzer impedance tube software features

With m+p Analyzer, m+p international offers a complete NVH solution with features ranging from data acquisition to modal, rotational and acoustic analysis. As part of the acoustic package, we offer a dedicated “impedance tube” solution. The clean and easy-to-use interface guides the user through the setup, pretest and impedance measurements. All sound quality metrics are automatically calculated and ready to use in the built-in reporting tool. Reports are generated as Word or pdf files.



No.	Name	EU	Sensitivity	Calibration Type	Input Mode	Coupling
1	Microfon 1	Pa	55,855	mV/EU	ICP	AC Gnd
2	Microfon 2	Pa	58,765	mV/EU	ICP	AC Gnd

Fig. 1: Test setup



Impedance Tube Report

ISO 10534-2
22.11.2019

Statement

The test was performed in accordance with test method ISO 10534-2.

Testing Laboratory

m+p international
Mess-und Rechnertechnik GmbH
Thurnithistraße 2
30519 Hannover

Sample

SW463 (S/NO. 570001) Impedance Tube

Customer

n+q national
Akustische Prüftechnik
Impedanzstraße 42
54025 Samplehausen

Test Specimen

- Thickness of the sample: 25mm
- Diameter of the sample: 60mm
- Method of mounting: SW060-s: 60mm diameter sample holder

Air Temperature

The air temperature at the time of test was 23 °C.

Atmospheric Pressure

The atmospheric pressure at the time of test was 1013,25 hPa.

Absorption Coefficient

Fig. 2: Test report

Measurement principle

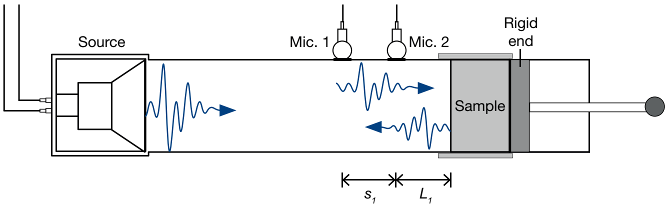


Fig. 3: Impedance tube illustration in two-microphone setup

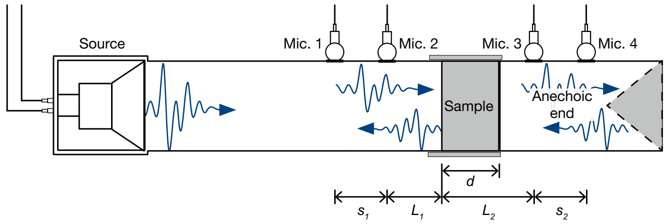


Fig. 4: Impedance tube illustration in four-microphone setup

m+p international’s impedance tube solution employs the “transfer-matrix method” for sound impedance measurements. Fig. 3 shows the 2-mic-setup. A loudspeaker generates a random stationary white noise sound wave that travels through the tube, passes the two microphones and is reflected on the material under test. After reflection, the sound wave travels back and again passes the microphones. Due to the random nature of the generated sound field, the sound pressure spectra at the microphone positions contain information in a wide frequency range.

A typical measurement runs for several seconds, while the measured sound pressures are linearly averaged for 10 to 50 blocks in order to reduce noise on the spectra. From the acquired sound pressure spectra, the transfer function H_{12} between the microphones is calculated using the auto- and crosspower spectral densities. Based on the measured transfer function, all acoustic parameters (r – reflection, α – absorption, Z – impedance) are calculated.

In the 4-mic-setup (Fig. 4) a second tube with two additional microphones is mounted behind the specimen, replacing the acoustic termination. Now, three transfer functions (H_{12}, H_{13}, H_{14}) are calculated from the respective sound pressure spectra. This allows for calculation of the transmission coefficient (as per ASTM 2611-17).

Tube calibration (error reduction)

Even after individual microphone calibration with a calibrator, small deviations in phase and amplitude between the microphones are common. A “tube calibration” accounts for these errors before the impedance measurement is taken. Measurements with the individual microphones in different locations are performed and transfer functions are calculated. From the resulting transfer functions, a spectral correction function is calculated, eliminating the influence of phase differences in the microphones.

Typical results

Fig. 5 shows a typical test result for the absorption and reflection coefficients of a specimen from a test with the two-microphone setup. Note that the sum of both functions adds up to be equal to one in the entire frequency range, as sound is either absorbed or reflected in each spectral line. This is an easy check to validate the test results. Also note the edge case, where an empty terminated impedance tube will result in a reflection of one (r = 1) and absorption of zero (α = 0) in the entire frequency range.

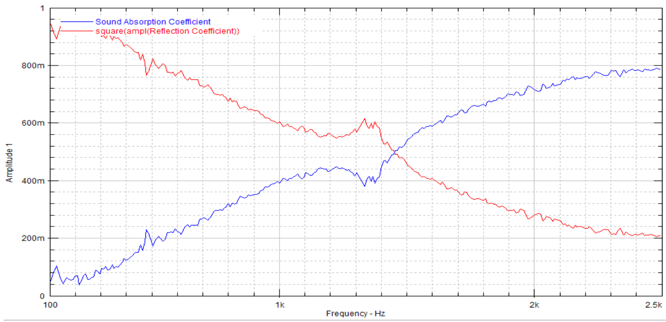


Fig. 5: Typical absorbtion and reflection coefficient of a sample

Scope of supply:

- Impedance tube (incl. loudspeaker, tube, sample holder, cables)
- Power amplifier
- 2 or 4 microphones and a sound calibrator
- Measurement front-end (e.g. 4-channel m+p VibPilot)
- m+p Analyzer DSAstd + impedance tube (AN-IMP)

Please contact your local sales representative to request a quote for a customized system.

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