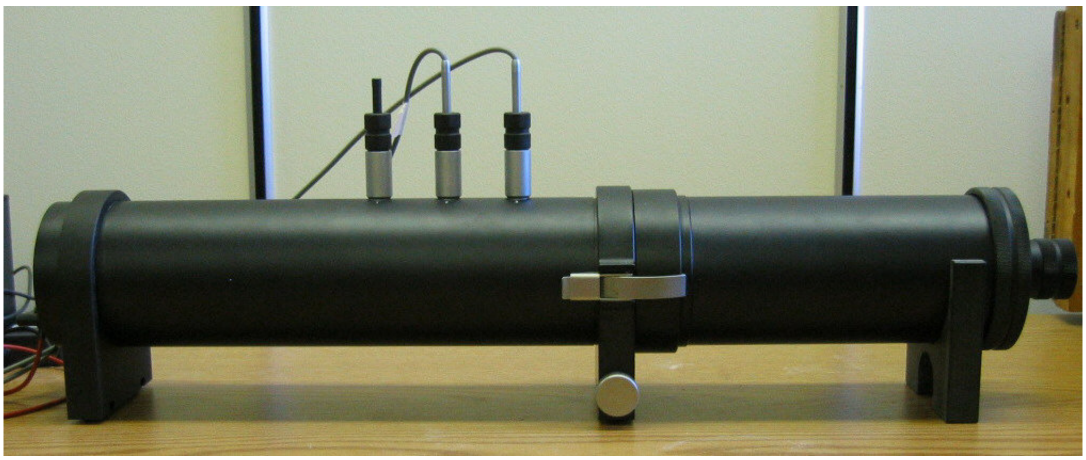
Acoustic Property Measurements using the B&K Type 4206 Impedance Tube (ASTM E 1050 90)



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Acoustics and Noise Control
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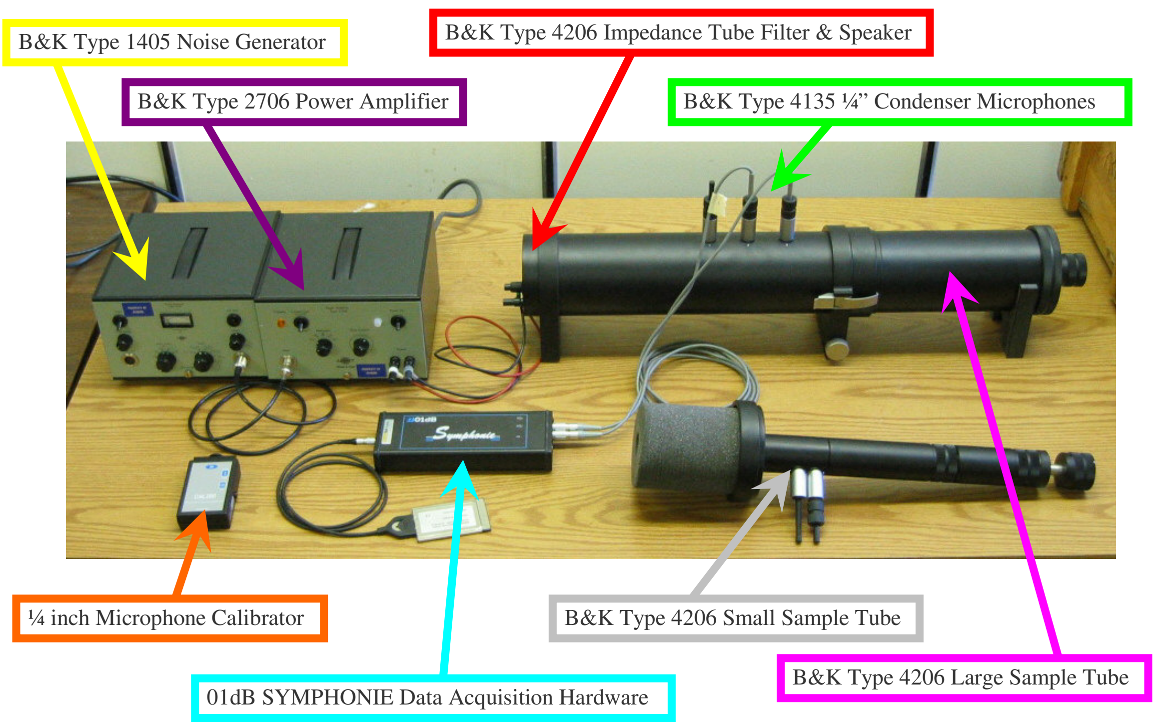
Purpose:

The acoustic properties that can be computed from the impedance tube are listed below.

- Complex Acoustic Frequency Response Function
- Complex Reflection Coefficient
- Normal Incidence Sound Absorption Coefficient
- Normal Specific Acoustic Impedance Ratio
- Normal Specific Acoustic Resistance Ratio
- Normal Specific Acoustic Reactance Ratio
- Normal Specific Acoustic Admittance Ratio
- Normal Specific Acoustic Conductance Ratio
- Normal Specific Acoustic Susceptance Ratio

The most critical property here is normal incidence sound absorption coefficient which is a function of frequency valued between zero and one. Sound absorption is the percent of sound energy being absorbed by the material sample. This is the primary indicator to the way any barrier material will react in any given environment.

Instrumentation:



B&K Type 1405 Noise Generator:

This device outputs a broadband signal, 0-20 kHz. The gain setting is positioned at 50% causing a peak to peak value of the signal of about 10 volts.

B&K Type 2206 Power Amplifier:

This device receives as an input a signal created by the noise generator. The signal is attenuated through the amplifier. The current limit is set to 1.8 amps rms. The attenuator is set to 40, decreasing the incoming signal by 40 dB. The gain dial is then set to about 66%, increasing the signal. The output from the amplifier produces a sound pressure level of about 105 dB in the tube (~55 dB above background).

B&K Type 4206 Impedance Tube:

The impedance tube consists of an adjustable filter, speaker, propagation tube, microphone holders, large sample tube (80 mm diameter), and a small sample tube (25 mm diameter). Each sample tube contains an adjustable plunger for positioning the sample and creating air gaps behind the sample if desired.

Filter Characteristics:

The adjustable filter has three settings: low pass, high pass, and linear. The low pass filter is used to collect high resolution acoustic data in the frequency range of 50-100 Hz. The linear filter is used in general for the large tube. The high pass filter is used for data collection in the small tube.

Speaker Characteristics:

The speaker diameter is 80 mm. The maximum rated input signal to the speaker is 10 watts max average power. The maximum pulsed power allowed by the speaker is 50 watts for 2 seconds. It has an impedance of 4 ohms. As a general rule of thumb, the input to the speaker should be less than 6 volts peak to peak to prevent damage.

Large Sample Tube Characteristics:

The large sample tube has an inner diameter of 80 mm. It is rated for a frequency range of 50 to 1600 Hz

Small Sample Tube Characteristics:

The small sample tube has an inner diameter of 25 mm. It is rated for a frequency range of 500 to 6400 Hz.

B&K Type 4135 Condenser Microphones (2) and B&K Type 2670 Preamps (2):

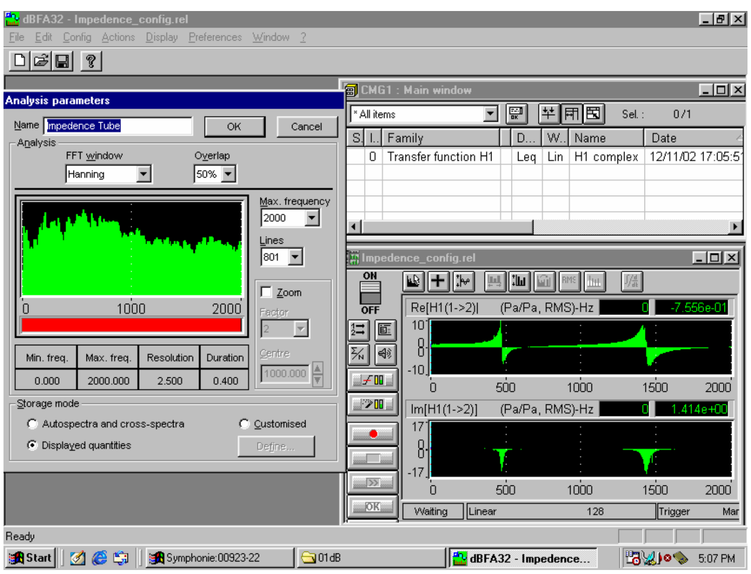
200 V Polarization
B&K Type 2670 Preamps
    Serial #: 2003924, 2003925
    Preamps have integrated cables with 7 pin LEMO connectors
Microphone 1:
    Serial # -- 1488287   Sensitivity – 3.67 mV/Pa
Microphone 2:
    Serial # -- 1488205   Sensitivity – 3.72 mV/Pa

01dB Symphonie Data Acquisition Hardware:

18 bit resolution
51.2 kHz max sampling rate
Anti-Aliasing Filter
    Butterworth Windowed
    120 dB/octave
1 MΩ Impedance
2 -- 7 pin LEMO inputs
1 -- 4 pin LEMO output (not used for impedance testing)
1 -- Tach input (not used for impedance testing)

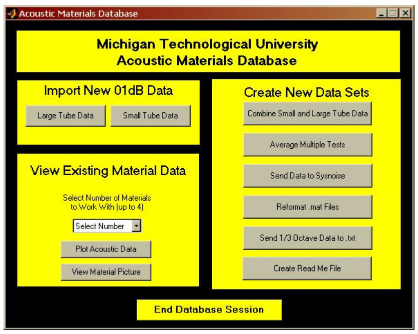
Procedure:

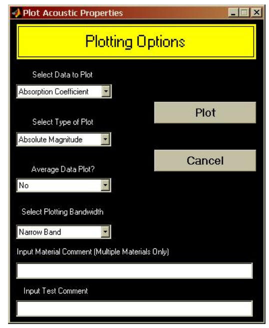
1. Set up measurement chain as follows:
    a. Connect noise generator to the amplifier using special B&K cables provided
    b. Connect amplifier to impedance tube filter using 2 banana plugs
    c. Set noise generator, amplifier, and filter characteristics to specifications previously listed
    d. Screw microphones onto preamps
    e. Connect preamps to Symphonie box
    f. Insert sample into tube properly aligned with the tube flange
    g. Connect sample tube (large or small) to propagation tube and lock into place
    h. Insert microphones into proper holders and secure
    i. Insert dummy microphones into remaining holders to seal tube
    j. Connect Symphonie pc card to data acquisition box and laptop computer
2. Set up 01dB Symphonie software as follows:
    a. Open dBFA32 application (used for collecting sound pressure data)
    b. Configure microphones
    c. Calibrate microphones to 94 dB using Larson Davis CAL200 94dB 1000Hz calibrator
    d. Define measurement setup as follows:
        i. Hanning Window with 50% Overlap
        ii. 128 Averages (<1% random normalized error) based on FRF coherence
        iii. 801 Lines of resolution
        iv. Large Tube
            1. Max Frequency = 2000 Hz
            2. Resolution = 2.5 Hz
        v. Small Tube
            1. Max Frequency = 10000 Hz
            2. Resolution = 12.5 Hz
    e. Define displayed curves as complex H1 frequency response function (shown below is the correct setup for the software using the large tube)

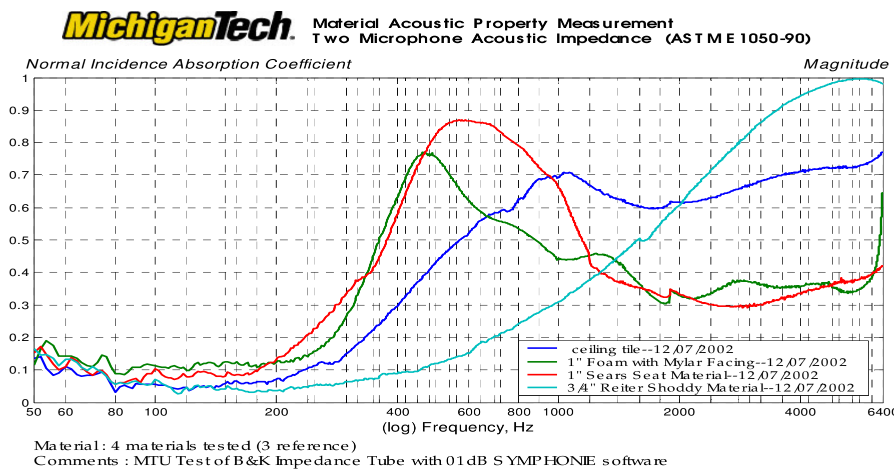


3. Turn on noise generator and amplifier
4. Obtain the frequency response functions to phase calibrate the microphones
    a. Insert provided calibration sample into tube (large or small)
    b. Obtain the frequency response function between the mics in normal positions (A)
    c. Switch mic positions
    d. Obtain the frequency response function between the mics in this configuration (B)

    e. Return mics to original position
5. Copy 01dB calibration data into MS Excel spreadsheet
6. Delete header lines and save data as comma separated variable (.csv) file
7. Insert material sample for testing into appropriate tube (large or small)
8. Obtain the frequency response function between the microphones
9. Copy 01dB data into MS Excel spreadsheet
10. Delete header lines and save data as comma separated variable (.csv) file
11. Repeat steps 7 thru 10 for all material samples of one tube type
12. Switch tubes and repeat steps 4 thru 11
13. Import .csv data into the Acoustic Materials Database for saving and plotting







Equations used in Acoustic Materials Database to compute acoustic property data are shown below.

Calibration Function

$|H_c| = \sqrt{(H_A * H_B)}$ -- (A and B are FRFs from phase calibration)

$\Phi_c = ½ (\Phi_A + \Phi_B)$

Calibrated H1 Frequency Response Function

$|H| = |H_{measured}| / |H_c|$

$\Phi = \Phi_{measured} - \Phi_c$

Complex Reflection Coefficient

$R = [\{H - e^{(-j*k*s)}\} / \{e^{(j*k*s)} - H\}] * e^{(2*j*k(L+s))}$

L is the distance between the sample and the closest microphone

s is the distance between the two microphones

k is the wave number = $2*\pi*f / c$

Normal Specific Acoustic Impedance Ratio

$Z = [\{1+R\} / \{1-R\}] * \rho*c$

Normal Incidence Sound Absorption Coefficient

$\alpha = 1-|R|^2$