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THE LABORATORY OF BUILDING PHYSICS IN 2016

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ABSTRACT

The laboratory of building physics (LBP) was gradually established in 70's of 20th century. From the very origin, by several changes it has undergone. The laboratory participated on support and development of number specific constructions and building structures in the past. This paper shows the short overview of laboratory history and its present state as well. It points to the current equipment and its application in practice and research. Brand new Multichannel Measurement System for airborne sound insulation measurements, Acoustic Camera, 3D printer, The Environmental Climatic Chamber with Guarded Hot Box, Water Spray Test Chamber are presented here.

INTRODUCTION

The science and research are the basic preconditions for prosperous country economy. The ambition of European Union is increasing of research and education level in each countries. Aim is to increase the economic growth of EU by international competitiveness. The preconditions are higher focusing on applied research, creating an environment for personal growth of excellent researchers and creating national and international research teams. The way how to integrate universities into this process is through functional laboratories and creative excellence teams. Therefore University laboratory should fulfill the conditions of international level in field of applied projects, research projects and as a tool for education of students and young potential researchers.

HISTORY

The laboratory was gradually established in 70's of 20th century in the space of carpentry workshop. This workshop was used mainly by students for buildings scaled models creation in the past. The initiator of the idea of laboratory was prof. M. Bielek. In cooperation with university development workshops, the first version of Big Pressure Chamber designed for research in air infiltration of envelope building structures was constructed. Other devices were: two Small Pressure Chambers for sealing profile properties measurements, big Water Spray Testing Chamber for water penetration by envelope constructions measurement and the device for research in field of durability of building materials (author of design prof. F. Ohrablo). Also the laboratory of building acoustics was constructed in this period (prof. J. Zajac).

LABORATORY EQUIPMENTS

The LBP is part of the Department of Building Constructions (DBC). The laboratory can be divided in accordance to field of application of individual facilities:

- ***The Laboratory of Thermal Physics;***
- ***The Laboratory of Building Acoustics;***
- ***The Laboratory of Building- and Environmental Aerodynamics;***
- ***The Roof Testing Laboratory (is not discussed in this publication);***

Equipment and buildings of LBP has been renovated (years 2014-2015) thanks to University Science Park project (USP) on Slovak University of Technology in Bratislava (STUBA) [1]. Working Package WP 2.1.5.1 named „The system for environmental quality increasing of buildings“ was responsible for this process. In the following sections the overview of most interesting devices in laboratory are presented.

THE LABORATORY OF THERMAL PHYSICS

The Environmental Climatic Chamber with Guarded Hot Box

The concept of Environmental Climatic Chamber with Guarded Hot Box (ECCGHB) was developed already in 60ties of last century [2-4]. The idea of environmental chamber which models physical phenomenos affecting on the cladding structures gradually undergone by several changes. The Hot Box system was introduced in 1974 by Mumaw [5] and in 1991 began to be as standardized method of determination steady propagation of heat expressed by thermal resistance R (m^2.K/W). Based on the work by Burch et al. (1987) and Stephenson (1988) et al. wider usage of devices has been designed [6]. The Revolution in Environmental Chambers development was application in measuring of dynamic heat transmission characteristics of wall [7]. The Environmental Chambers were made in different sizes, types and have become a part of the building structures testing equipments during the years [8-12]. Current topic of maybe all laboratory equipments is in increasing accuracy of measurements and verified interpretation of measured data [13]. Environmental Climatic Chamber of LBP was built up in 1987 and after 28 years was completely reconstructed in year 2015. Chamber has been used in wide range of research and engineering projects as well (usually about PVC, Al and wooden windows and doors testing) [14, 15].

ECCGHB allows to modeling of synergic phenomena of heat transfer, vapor diffusivity and air filtration under steady and dynamic boundary conditions. A Guarded Hot Box is used to test the thermal performance of homogenous and non-homogenous specimens, such as windows, complex wall assemblies, cavity walls, ventilated shaded wall assembly or walls with phase change materials (PCM). It determines the amount of heat transfer through a given material or assembly of various materials. The device is used to determine the building structures thermal properties (transmission heat loss coefficient U(W/m^2.K) of windows, doors and building cladding, thermal resistance R(m^2.K/W), surface temperature θ_s(ºC) and thermal field θ(ºC)) in range - 35 ºC to + 60 ºC. Also is used for the experimental testing of constructions with multidimensional heat flow and Determination of thermal conductivity coefficient of building materials. It includes different heating and cooling circuits, 140 measuring and recording points of different physical quantities. Regulated and measured quantities are: temperature θ (ºC), air velocity v (m/s), pressure p (Pa), relative air humidity φ *or R.H.* (%), heat flow rate Φ (W), solar radiance E_e (W/m^2) (Figure 1). Devices and measurements are driven by LabView software interface with online driving possibility. Measurements are also evaluated by thermo vision camera with resolution 640x480 pixels. Devices fully meet the criteria required in the current standards [16-20].

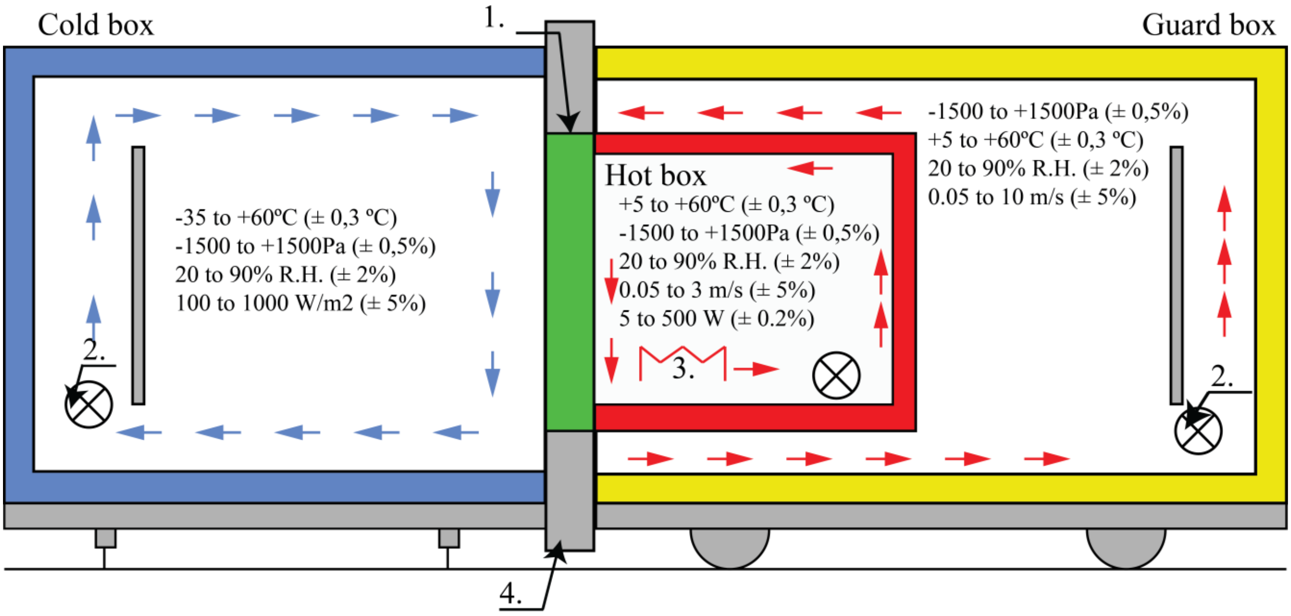

Figure 1. Schematic cross section of the Environmental Chamber. 1. Default testing specimen 1230 x 1480 mm; 2. Conducting unit; 3. Heat input**;** 4. Masking panel 2640 x 2640 x 200 (500) mm $\lambda \leq 0.04 \mathrm{W m^{-1} K^{-1}}$.

THE LABORATORY OF BUILDING ACOUSTICS

Multichannel Measurement System for airborne sound insulation measurements

Specifically, the multi-channel building and room acoustic measurement system is presented in this section. The measuring system meets the requirements of accuracy class 1 in compliance with current legislation [21, 22]. It is a compact measuring systems with centralized control and data collecting. The measuring device operates in real time at a one third octave resolution (0.4 Hz to 20 kHz). Allows parallel measurement of all standard acoustic parameters of the field of building acoustics (Figure 2) in accordance with standards [23-29], multispectral recording in time domain with time averaging 25 ms, sound recording (*Fs*= 44.8 kHz, 24 bit, *.wav). One of the biggest advantages of the device is its compactness, and usage even on in situ measurements.

The new equipment in laboratory is also omnidirectional sound source with amplifier capable of ensuring the sound output of 120 dB in the range of 50 Hz to 5 kHz, fulfilling the standardized requirements [23, 27]. This set is extended of tapping machine (normalized impact noise source) with built-in battery operated by wireless controller. The tapping machine is equipped with a stalling speed weights laser control.

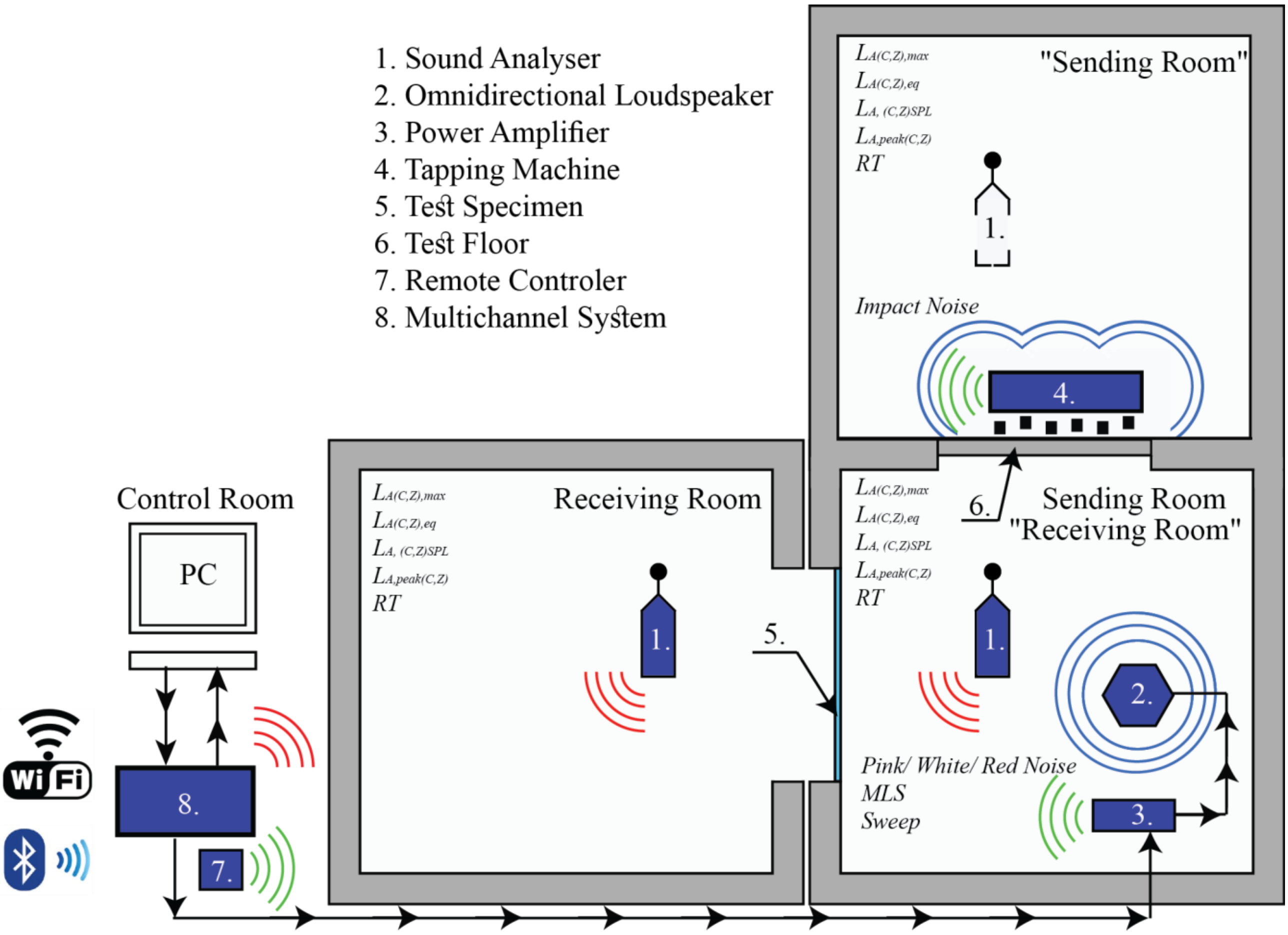

Figure 2. Building acoustics measurement setup.

Acoustic Camera

The acoustic camera is equipment which is used for localization and imaging noise sources. The term of acoustic camera, has been used for different devices with different purposes of use in past. Already at the end of 19th century was as acoustic camera signed equipment based on special mechanical principle of Lamb waves visualization on excited specimen surface [30]. Another type was, device for visualization of field under water based on sonometry (sonar) [31-33]. Also in medicine was acoustic camera used (later called sonography) [34]. Another device works on principle of laser scanning for visualization of sound sources underwater [35]. The current form of acoustic camera extended by name *„microphone array system“* was established based work from 1973 [36]. The first acoustic camera was launched in 1999. Acoustic camera works by evaluating the delay and phase shift of the incoming sound to the receiver array. Depending on the size and shape (2D or 3D) each camera system has different accuracy, the frequency range and is appropriate for different types of sound field and the distance from the source.

Acoustic cameras are used in mechanical engineering [37-39], mechatronic engineering [40], for low-flying airborne targets localization [41], wind turbines research [42], aero acoustic research [43] and last but not least in building and environmental acoustics [44-47]. Research in acoustic camera development is still in process. Aim is get as much as possible accuracy and find a cheaper way how to build sound imaging system as well [48, 49].

Acoustic camera instrumentation of LBP, is the complex measuring system consisting from camera and microphone array intended to sound sources visualization in steady or dynamic mode (images or movies Figure 3). The spherical 80 channel microphone array is primarily designed for applications in enclosed spaces. The microphone array allows to locate the various sound sources and display the analyzed space in 2D or 3D (visualization). Allows displaying the measured object to localize sound sources in real time. Recommended distance from the source is from 0.3 to 5 m. Measurement setup consists also from software interface for data visualization and post processing data includes also psychoacoustics model.

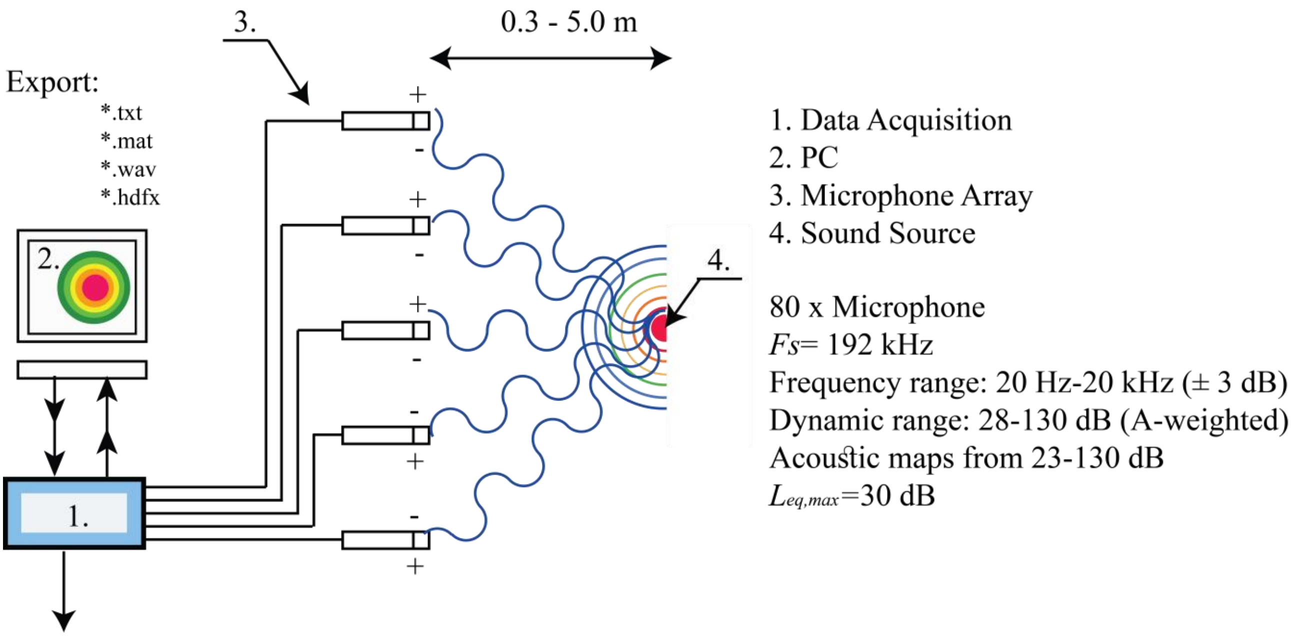

Figure 3. Principle of Acoustic camera.

THE LABORATORY OF BUILDING AND ENVIRONMENTAL AERODYNAMICS

Water Spray Test Chamber

It is generally used for the window frame water tightness and wind pressure resistance testing. There are well known more kinds of external doors, windows and façades testing methods. Each country has specific requirements on building envelope in accordance to the location and weather conditions. Nowadays, research is focused on development of measurement technique with extreme weather conditions of coast areas simulation [50]. Ongoing research extended water tightness measurements from steady pressure to dynamic boundary condition with fluctuating pressure created in special chamber [51]. The use of light wooden frame resp. ventilated cladding in building design led to testing the whole facade elements as well as testing in situ. [52, 53]. Therefore, in addition to monitoring the spread moisture over leakage path along the glazing stop to the interior, leakage path around the operable unit to the interior and leakage path through the joint of frame members in the time will be extended of leakage path through the window to wall interface to the interior, through the window assembly into the adjacent wall assembly, through the window to wall interface into the adjacent wall assembly. Also wide research in driving rain and dependence waterproofing and air tightness of structures was investigated [54]. It has also been demonstrated that the estimated standard waterproof relates to the bending stiffness structure [55]. It is already quite common to have possibility to built in pressure sensors inside of cavity specimen and have possibility of dynamic pressure driving during measurement. [56, 57].

The newly renovated facility meets all the standard requirements for the implementation of accredited tests. Water Spray Testing Chamber of STUBA is designed for testing of specimen with size 2400 x 1800 x (20-200 mm). Two rails with jets are installed in the chamber. Fixed rail ensures a steady stream of water on the sample with a flow rate of 0.24m^3/h. Driven rain slat equipped with a 14 high-pressure jet is controlled and moves in vertical direction (v_{max}= 0.15m/s). The samples are clamped by 20 pneumatic clamping cylinders into the test opening. Deflection of specimen under test, can be measured by 12 laser sensors. (Figure 4). The test device can thus be used for the categorization of window in water tightness and resistance to wind load [58-62]. The categorization process is supplemented by sound insulation and heat transfer coefficient measurements.

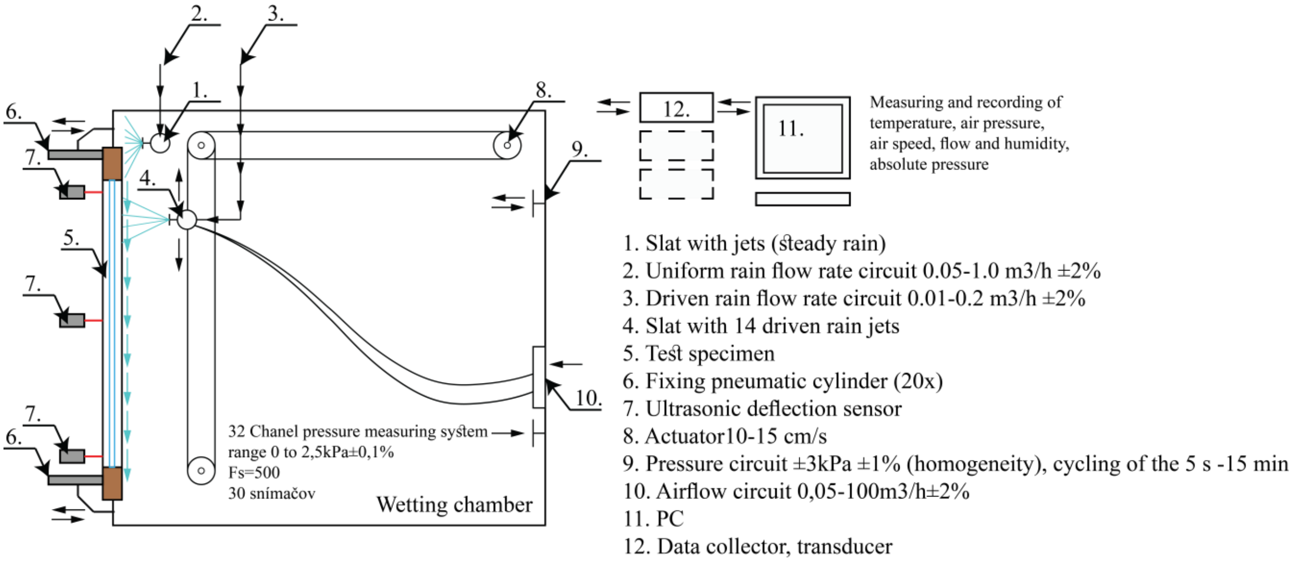

Figure 4. Wetting chamber measurement setup.

3D printer

The Laboratory of Building and Environmental Aerodynamics is equipped also by color 3D printer (Project 260C). Is an innovative complement to traditional methods of preparation and production of laboratory model by students and department employees. Is applicable in the 3D model printing of buildings, urban area as well as construction elements. Greater appreciation and interesting application 3D printer finds in research, not only in the building physics field. Opens space for cooperation in wide range of fields (construction, architecture and urban planning, design and art, model building, film industry, marketing, advertising and sales, archeology and museology, medicine, pharmaceutical industry, automotive industry, electrical industry, food industry etc.). 3D printer of LBP is primarily used for the model production, components and individual parts used in laboratory measurements determined in the wind tunnel.

CONCLUSION

This publication presented the proportions of new equipments in laboratories LBP. The aim was the lab advertising and overview of research fields where laboratories finds its application. As was mentioned, in LBP the majority of standard tests from building acoustics, aero-acoustics and thermal physics can be performed there. The scope of the article description does not fit the roof testing laboratory. The laboratory is equipped with devices as Climatic Test Cabinet, QUV Accelerated Weathering Tester, Strength Testing Machine. This part of the laboratories will be published in one of the future publications. The laboratory ambition is to increase the level of laboratory research on domestic as well as international level and contribute to increase the level of knowledge in practice field.

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