ARCHITECTURE CIVIL ENGINEERING ENVIRONMENT
The Silesian University of Technology
No. 2/2017

ON-SITE DIAGNOSTICS OF THE MECHANICAL VENTILATION IN OFFICE BUILDINGS

Monika BLASZCZOK [a*], Małgorzata KRÓL [a], Maria HURNIK [a]

[a] PhD Eng.; Department of Heating, Ventilation and Dust Removal Technology, Faculty of Energy and Environmental Engineering, Silesian University of Technology, Konarskiego 20, 44-100 Gliwice, Poland
*E-mail address: *monika.blaszczok@polsl.pl*

Received: 6.04.2017; Revised: 25.04.2017; Accepted: 8.05.2017

Abstract
The methodology for inspecting the ventilation system and on-site measurements for office buildings has been proposed under the project "Development of thermal diagnostics of buildings". The inspections of the ventilation system in two office buildings were conducted. The design documentations were compared with the existing state of the installations. The measurements of the air flow volume, of the temperature of ventilation air and of the volume flow of the heating medium and its temperature were performed. The measurements allowed to determine the power of the heater referring to the heating medium and to the air. On the basis of the inspection and measurements performed, the technical condition of the ventilation system was determined and its utilization in each of the buildings.

Streszczenie
W ramach projektu „Rozwój diagnostyki cieplnej budynków" zaproponowano metodykę przeprowadzania inspekcji sytemu wentylacji oraz pomiary *in-situ* dla budynków biurowych. W artykule przedstawiono dwa budynki biurowe, dla których przeprowadzono inspekcję instalacji wentylacji. Porównano dokumentację projektową ze stanem istniejącym oraz przeprowadzono pomiary strumienia objętości powietrza wentylacyjnego, temperatury powietrza wentylacyjnego oraz pomiary strumienia objętości czynnika grzewczego i jego temperatury. Pomiary pozwoliły wyznaczyć moc nagrzewnicy od strony wody i od strony powietrza. Na podstawie przeprowadzonej inspekcji oraz wykonanych pomiarów określono stan techniczny instalacji wentylacji oraz jej wykorzystanie w każdym z budynków.

Keywords: **Office building; Thermal diagnosis; Inspection of ventilation.**

1. INTRODUCTION

The paper presents a part of project entitled "Development of thermal diagnostics of buildings", which related to reduced of energy consumption in the buildings. The detailed scope of the project is described in [1]. As part of the research task, a method of a rapid diagnosis of heating system [2], cooling sources [3] and air-conditioning systems was developed as well as a method of calculate building energy performance certificates based on measurements [4].

This paper presents the research done in two office buildings. The obtained results were referenced to the design documentation. The results of the inspections and measurements on the mechanical ventilation system were discussed. Attention was paid to the divergence between the documentation and the installation status of both buildings. The problems encountered during the measurements were discussed.

2. THERMAL DIAGNOSIS AND MEASUREMENT METHODS FOR THE INSTALLATION OF MECHANICAL VENTILATION

In developed countries, almost 40% of the consumed energy is used in the buildings. There have been repeated attempts to reduce this energy consumption because of the costs as well as the pollution. At the same time, buildings are expected to meet high expectations regarding thermal, air quality or lighting conditions. The search for a solution to this situation has resulted in new energy-saving buildings and thermo-modernization of old buildings. It takes into account energy consumption and profitability of investments [5]. The numerical analyses are used in many cases to predict energy consumption of building [6, 7, 8]. In the numerical analysis assumed input conditions are very important [9] thus the detailed information about installation are needed. In addition to using numerical methods to determine the consumption of energy the on-site diagnosis could be used, therefore different inspection schemes for existing installations exist [10, 11, 12]. It is pointed out that this should be the first step towards reducing energy consumption. The experience shows huge divergences between a designer's intentions, installation and everyday practical operation [13]. This is why the first step in evaluating installation should be to analyze the design documentation. The next step is to inspect the installation, that is to check the documentation with the actual state. The final step should be diagnostic measurements what will allow to evaluate the installation work in real conditions [14, 15]. This research stage often reveals major abnormalities in the operation of the installation [14, 16, 17].

Since the ventilation installation will be considered, diagnostic measurements will include:

- measurement of the flow of the heating medium,
- measurement of the temperature of the heating medium,
- measurements of the ventilation air volume flow,
- measurements of the air temperature,
- measurements of the air humidity,
- measurements of the absolute pressure,
- measurements of the power taken by electrical appliances.

Each of these measurements involves the use of appropriate measuring equipment and a number of preparatory activities.

For measuring the volume flow of heating medium in ventilation systems, non-invasive measurement methods using ultrasonic flow meters are proposed. The preparation of the measurements involves removing the insulation from the pipes and sometimes even the paint or rust.

Measurement of the temperature of the heating medium is most appropriate in the pipelines supplying the media to the ventilation heaters. An approximate measurement of the surface temperature of the pipelines using (adhesive) thermometer sensors is proposed. The use of this method also involves the proper preparation of the pipeline.

The measurement of the volume flow in the ventilation ducts and measuring sections of some devices can be carried out using the Prandtl tube. The first step should be to determine the points of the measuring grid according to [18] and then drill the holes in the previously designated points in the measuring sections.

Air temperature measurement can be made using thermocouples. Thermocouples transmit the signal to units that allow reading and temperature recording. Multi-channel thermometers are suggested to be used for diagnostic purposes, as they allow for simultaneous measurement and recording of multiple temperatures.

The basic way of measuring air humidity in ventilation ducts is by use of a wet thermometer and a dry thermometer. The device consisting of both thermometers is called a psychrometer [19].

3. DESCRIPTION OF THE ANALYZED BUILDINGS

Both buildings are located in Gliwice.

3.1. Office building I

The office building I is a five- storey one with a partly used attic. The building is L-shaped. During the study, only part of the building was used. The rest of the area was under renovation. The building has office, service and commercial functions. The total usable area of the building for rent is 3041.1 m^2. During the study the areas used were: on the ground floor 370.9 m^2, on the second floor 383 m^2 and on the third floor 322.7 m^2.

According to the project design, mechanical ventilation is used to provide hygienic conditions in the offices, when they are in use. The installation of the mechanical ventilation cooperates with the central heating and the cooling installation [3]. Two supply and exhaust air systems were designed, the configuration of which is shown in Table 1.

Table 1.
Configuration of air systems – building I

Ventilation installation 1		Ventilation installation 2	
supply V_N = 7880 m^3/h, Δp=375Pa	exhaust V_W = 7340 m^3/h, Δp=365Pa	supply V_N = 7065 m^3/h, Δp=445Pa	exhaust V_W = 5540 m^3/h, Δp=420Pa
damper	damper	damper	damper
filter class F-5	filter class G-4	filter class F-5	filter class G-4
rotary heat exchanger	rotary heat exchanger	rotary heat exchanger	rotary heat exchanger
air heater for water power 25 kW		air heater for water power 29 kW	
supply air fan electrical power 4.0 kW	exhaust air fan electrical power 4.0 kW	supply air fan electrical power 4.0 kW	exhaust air fan electrical power 4.0 kW

Both air handling units are located in the basement. The joint outdoor wall air intake and wall air exhaust was designed. The air ducts, circular and rectangular are insulated. The air was assumed to be supplied to the rooms through wall and ceiling diffusers, and in the attic by floor diffusers. Ceiling diffusers were placed in the suspended ceiling. Depending on the purpose of the individual rooms, exhaust air is provided through wall or ceiling diffusers. The project assumed the use of supply and exhaust elements grille diffusers, round and rectangular diffusers as well as swirl floor diffusers.

The ventilation installation was made according to the documentation. Only one difference is observed. There aren't exhaust air terminal device, because the extract air is exhausted directly into the engine room. The pressure balance inside air handling units is adjusted by pressure adjusting plates mounted at exhausts [20].

3.2. Office building II

Office building II is an administrative and office building for one company. It has three storeys. The building's area is 1025.6 m^2. There are a lobby with a reception desk, a lecture room, a kitchen and three small rooms on the ground floor of the building.

According to the project there are two Daikin units, which operate with the VAM heat exchanger, one serving a lecture room, the other – the first floor office and the director's office with additional rooms. There is only one VTS Clima air-conditioning unit equipped with a filter, heater, cooler and a fan. It supports the lecture room and is located in the suspended ceiling of the utility room located on the ground floor of the building. The exhaust unit serving this room contains only the exhaust fan section which was located in the ceiling above the kitchen room on the ground floor. The following will describe inspection and performance measurements for the lecture room only [20].

4. INSPECTION OF VENTILATION INSTALLATION

4.1. Office building I

The ventilation installation 1 and 2 are operated by two GOLD RX-30 air handling units from SWEGON. Air conditioning units are in good condition, without mechanical damage, tight, located in the engine room in the basement. The air handling units can work with nominal capacity:

- Supply 1- 8200 m^3/h, exhaust 1 - 7200 m^3/h,
- Supply 2 - 7100 m^3/h, exhaust 2 - 5200 m^3/h,

or with reduced capacity:

- Supply 1 - 4100 m^3/h, exhaust 1 - 3750 m^3/h,
- Supply 2 - 3600 m^3/h, exhaust 2 - 2600 m^3/h.

The installation works with reduced capacity in the winter, and in the summer with nominal capacity. In the winter the air is heated first in a rotary heat exchanger, then in water heater, in the summer the air is only filtered, heat recovery section is turned off. Air handling units work periodically according to the schedule (Table 2).

Table 2.
Air handling unit air schedule.

Air handling unit 1		Air handling unit 2	
Day	Work hours	Day	Work hours
Mon-Fri	6:00-20:00	Mon-Fri	6:00-20:00
Saturday	6:00-17:00	Saturday	6:00-14:00
Sunday	-	Sunday	-

Figure 1.
Insulation of ventilation ducts: in the engine room (left), in the suspended ceiling (right)

Figure 2.
The pressure adjusting plates on exhaust opening of air handling units: view from the outside (left), view from the inside (right)

According to the project, the ventilation ducts from the air intake to the air handling unit are insulated, other ducts were also insulated (Fig.1). The condition of the insulation is good.

Inlets and outlets are correctly positioned and do not cause acoustic and thermal discomfort. The joint outdoor air intake is placed in the wall of the building at a height of approx. 5 m pursuant to Journal of Laws Dz. U. No. 75 [21]. The outdoor air is transported by one duct, which is divided in the engine room into two ducts supplying outdoor air to the air handling units.

The exhausted air is extracted directly into the engine room, the pressure adjusting plates are installed at the outlets of the air handling units to control the pressure balance (Fig. 2).

The air handling units are equipped with air dampers: at the inlet of the outdoor air. Filters were regenerated just before the inspection. The rotary heat exchangers were functional without major mechanical damage.

Both heaters TBLA-4-120-050-2-2 from SWEGON are installed outside of the air handling units, they are clean and free of mechanical damage (Fig. 3).

Figure 3.
The water heater: view from the outside (left), view from the inside (right)

The air handling units are equipped with four identical fans (supply and exhaust fan) of power of 4 kW, rotation speed of 1445 1/min, voltage of 400 V and frequency of 50 Hz (Fig. 3).

4.2. Office building II

The air supplied into the lecture room is treated in the suspended compact VTS Clima supply unit of the yield of 1500 m^3/h. The unit is placed in the suspended ceiling of the utility room on the ground floor of the building. The exhaust unit contains only the section of an exhaust fan and is placed in the ceiling above the kitchen room on the ground floor.

The configuration of this installation is shown in Table 3.

Table 3.
Configuration of air systems – building II, the lecture room

The lecture room's ventilation	
supply	exhaust
damper	
filter class EU4	
water heater 60/40°C power of 25 kW	
water cooler 7/12°C, cooling power of 14 kW	
supply air fan	exhaust air fan

The unit is insulated, leak proof, free of damages and deformations. There is an air damper mounted at the inlet of the unit. The access to the unit is very difficult, so it was not possible to approach it from inside.

The heater is supplied with hot water prepared in the boiler room located in the basement of the office building.

The air supply and air exhaust ducts of rectangular cross-section are insulated, connections to the diffusers and extractors are made with elastic ducts of circular cross-section (Fig. 4).

The treated air is supplied into the room through two swirl diffusers of type RL produced by Krantz company. The same kinds of diffusers are used as the exhaust devices.

The air is drawn through a wall intake, whose inlet is not covered. The exhaust air terminal device is located on the roof of the building.

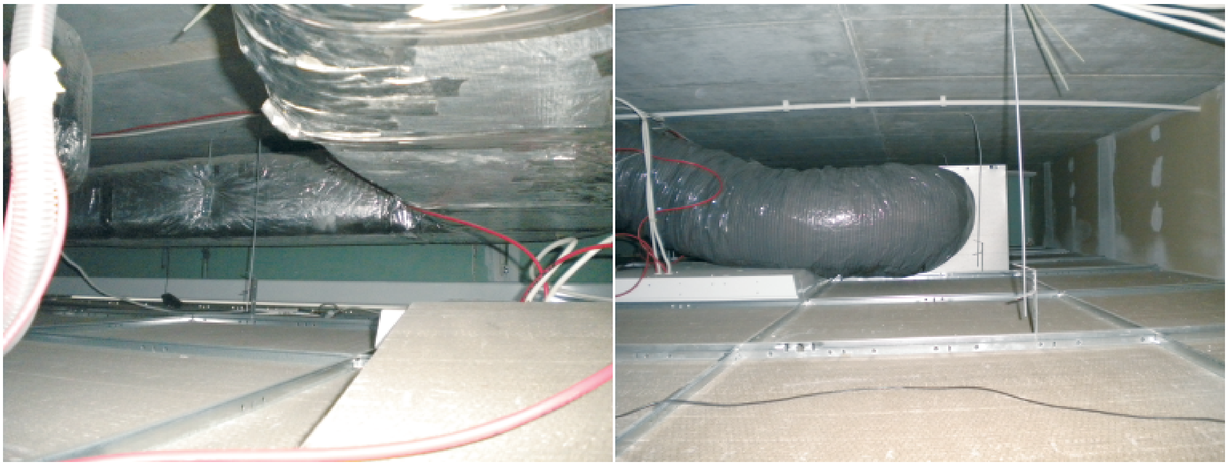

Figure 4.
Supply and exhaust pipes in suspended ceilings

There is a connection between supply and exhaust centrals. The exhaust duct has an offshoot joined directly into the outer air duct supplying the air treatment unit. There is no mixing section here.

The air conditioning system of the lecture room was assumed to be switched on just for the periods of courses. But the interview with the users proved that even then the air conditioning system was not in use due to noise generated by the air conditioning unit.

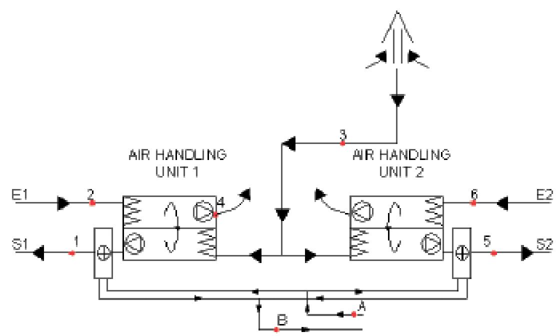

Figure 5.
Diagram of location of measurement points in a mechanical ventilation system

5. DIAGNOSTIC MEASUREMENTS

5.1. Office building I

In order to determine the instantaneous power of the water heaters in the installation 1 and 2, the following measurements were made:

- Measurement of the air volume flow in points 1-4 with the use of a Prandtl tube type L,
- Measurement of air temperature in points 1-6 with the use of thermocouple and multichannel thermometer,
- Measurement of relative humidity and absolute pressure in points 1-4
- Measurement of the volume flow of the heating water in point A with the use of an ultrasonic flow meter,
- Measurement of the temperature of heating water at points A and B using thermometer sensors.

The measurement points are shown in diagram in Fig. 5.

Measurement of the dynamic pressure distribution with the use of Prandtl tube (Fig. 6) was made once for reduced flow in the winter and for nominal flow in the summer, since this is a constant flow system. The dynamic pressure measurements were performed in a uniform measurement grid of 15 points in ventilation ducts, and 21 points at the outlet of air handling unit. On the basis of this measurement, a volume air flow was determined. In the same point the air temperature was measured. The temperature distribution of 2-week registration was used to determine the average value.

Measurement of the dynamic pressure distribution at the outlet of air handling unit (Fig. 7) showed local air extraction from the engine room, these flow disturbances make it impossible to determine exhaust air flow volume. The 2-week measurements of temperature of exhaust air were performed in point of maximum dynamic pressure.

At the same time, the relative humidity of the air and

Figure 6.
Measurement of pressure distribution in the ventilation duct using a Prandtl tube

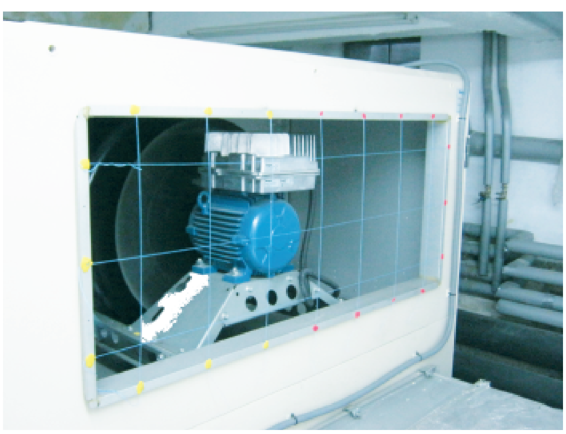

Figure 7.
A grid of dynamic pressure measurement points at the outlet of the air handling unit

the atmospheric pressure were measured to determine the density of the air.

Measurement cross sections are located as far as possible from disturbances of airflow and flow of heating water. Unfortunately, the lack of a rectilinear sections of the supply air and extract air ducts that would be long enough in installation 2 prevented the dynamic pressure distribution from being measured, therefore the values of the volume air flow were determined from the balance.

Table 4 shows the air flow volume measured at the point of installation according to Fig. 5.

Table 4.
Air flow volumes in installation 1 and 2 determined on the basis of measurements by a Prandtl tube

Winter		
Measurement point		**Air flow volume, m³/s**
No	**Location**	
1	Supply S1, beyond air handling unit	1.31
2	Extract E1, in front of air handling unit	1.13
3	Supply S1+S2, beyond outdoor wall air intake	2.34
5	Supply S2, beyond air handling unit	1.03
6	Extract E2, in front of air handling unit	0.74
Summer		
Measurement point		**Air flow volume, m³/s**
No	**Location**	
1	Supply S1, beyond air handling unit	2.29
2	Extract E1, in front of air handling unit	2.32
3	Supply S1+S2, beyond outdoor wall air intake	4.29
5	Supply S2, beyond air handling unit	2.00
6	Extract E2, in front of air handling unit	1.46

To determine the instantaneous power of the heater, it was necessary to know the efficiency of the rotary heat exchangers, which was determined according to formula (1):

$$\Phi_1 = \frac{t_1^{``} - t_1^{`}}{t_2^{`} - t_1^{`}} \cdot \frac{\dot{V}_{out}}{\dot{V}_{ex}} \qquad (1)$$

where:

Φ_1 – the heat recovery coefficient,

$t_1^{``}$ – outdoor air temperature beyond rotary heat exchanger, °C,

$t_1^{`}$ – outdoor air temperature in front of rotary heat exchanger, °C,

$t_2^{`}$ – extract air temperature in front of rotary heat exchanger, °C

V_{out} – outdoor air flow volume, m^3/s

V_{ex} – extract air flow volume, m^3/s

Due to the inability to measure the temperature of the ventilation air directly in front of the heater to determine the heat recovery efficiency, the heater has been switched off. Then the outdoor air temperature, supply and extract air temperature has been measured. Based on these temperature values and the knowledge of the supply and extract air volume, the heat recovery coefficient in installation 1 and 2 was determined to be 69% and 63%, respectively.

In order to correctly determine the instantaneous heater power of the air heater the following formula was used:

$$Q = \frac{\dot{V}}{3600} \cdot \rho_a \cdot c_p \cdot (t_{2a} - t_{1a}) \qquad (2)$$

where:

Q – instantaneous heater power, kW

V – ventilation air flow volume, m^3/h

ρ_a – air density, kg/m^3

c_p – specific heat of dry air, kJ/kgK

t_{1a} – air temperature in front of the heater, °C

t_{2a} – air temperature behind the heater, °C

It was also necessary to take into account the heating of the ventilation air in the fan, which was determined according to the formula (3):

$$\Delta t = \frac{N}{\dot{V} \cdot \rho \cdot c_p} \qquad (3)$$

where:

Δt – temperature difference, K

N – fan power, kW

V – air flow volume, m^3/h

ρ_p – air density, kg/m^3

c_p – specific heat of dry air, kJ/kg K

On the basis of the 2-week temperature record and the knowledge of the ventilation air flow volume and taking into account the heat recovery coefficient and the heating of the air in the fans (installation 1 - heating in the fan is equal to 2.5 K, installation 2 - 3.2 K) the instantaneous power values of the heaters of both installations were determined according to formula (2). This allowed to determine the amount of energy consumed by the heaters during the recording of the parameters. Hence, in the period from 12 March 17:25 to 17 April 13:15 the heaters of both installations used 15496 kWh of energy – determined with the use of ventilation air flow measurements The heater power is also determined on the water side by means of the water volume flow and water temperature in front of and beyond heaters (Fig. 8) according to formula (4):

$$Q = m_w \cdot c_w \cdot (t_{w1} - t_{w2}) \qquad (4)$$

where:

Q – instantaneous heater power, kW

m_w – water volume, kg/s

c_w – specific heat of water, kJ/kg

t_{1w} – water temperature in front of the heater °C

t_{2w} – water temperature behind the heater, °C

Figure 8.
Measurement of the flow volume of heating water by the use of an ultrasonic flow meter and the flow temperature of the heater by the use of an adhesive thermometer

A good accordance was obtained between the instantaneous power heater on the air side and water side, as can be seen in the example graph (Fig. 9). Also, the energy consumed by the heaters of both installations determined from the water side during the recording of parameters amounted to 15806 kWh. It is very close to the energy value determined on the air side.

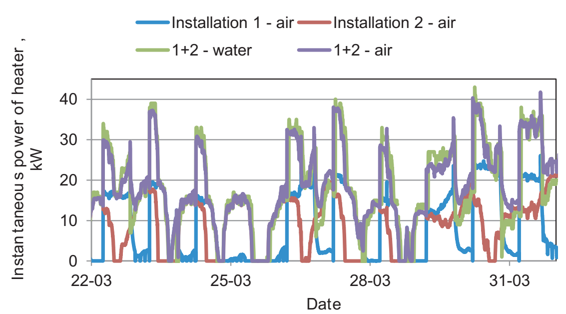

Figure 9.
Comparison of instantaneous power of heater determined from the air and water side for the selected registration period

5.2. Office building II

There were the following diagnostic measurements done on air-conditioning system of the lecture room:

- Measurement of the air volume flow in points 1–4 with the use of a Prandtl tube,
- Measurement of air temperature in points 1, 2, 4 with the use of thermocouple and multichannel thermometer,
- Measurement of relative humidity and absolute pressure in points 1, 2 ,4
- Measurement of volume and temperature of inflowing and exhausted air in points 5-8 with the use of a bolometer,
- Measurement of the volume flow of the heating water in point A with the use an ultrasonic flow meter,
- Measurement of the temperature of heating water at points A and B using thermometer sensors.

The scheme of the system with the marked measurement points is shown in Fig. 10. The measurement cross-sections were localized far from any obstacles disturbing the flow of air or heating water. The measurement points were determined according to the Makowiecki method [22].

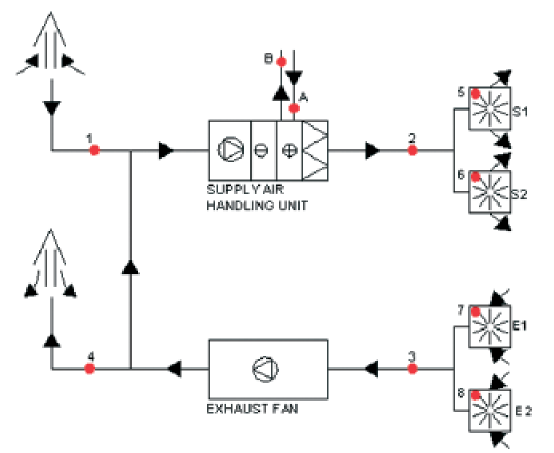

Figure 10.
Diagram of location of measurement points in the mechanical ventilation system of the lecture room

The air-conditioning system of the lecture room is a system of constant volume of ventilation air, thus the measurements to determine the volume of ventilation air were taken just once. The values of volume of ventilation air measured with the use of a piling tube at individual points of the system according to Figure 10 are presented below (Table 5).

The volume of recirculating air was determined based on measured with the use of a Prandtl tube volumes of ventilation air. According to the balance of inflowing air the recirculating air flux is 0.13 m^3/s, what gives 30% of inflowing air. In turn, the flux of the recirculating air calculated basing on exhaust air volume is 0.11 m^3/s (26% of inflowing air). This little difference could be the result of the measurement inaccuracy. The lack of access to the return air duct made it impossible to directly measure the volume of recirculating air flux.

Table 5.
Air flow volumes in lecture room basis of measurements in site

Measurement point		**Air flow volume, m^3/s**
No	**Location**	
1	Supply, beyond the air intake	0.3
2	Supply, beyond air handling unit	0.43
3	Extract, in front of air handling unit	0.38
5	Extract, beyond air handling unit	0.27
6	Supply (Diffuser) 1	0.22
7	Supply (Diffuser) 2	0.19
8	Exhaust 1	0.15

Figure 11.
Measurement in the supply channel by means of a Prandtl tube and measurement of ventilation air volume flow using a balometer

The measurements of the volume of inflowing and exhausted air fluxes with the use of a balometer capture hood were performed as well. (Fig. 11).

While summing the volumes of air supplied by two diffusers the value of 0.41 m^3/s was obtained, in turn the volume flux of exhausted air is 0.31 m^3/s. These values differ from the values determined on basis of measurements with the use of a piling tube (respectively 0.43 m^3/s and 0.38 m^3/s). A balometer is a very sensitive device, a quite big inertia is typical for such a device and keeping it long enough in a position ensuring the adjacency to the ceiling with diffusers and extractors mounted was difficult (Fig. 11). This might have caused the discussed differences of the obtained results.

The temperature was recorded for the period of 2 hours with time step of 1 min and averaging time of 10 s to determine the average instantaneous power. The recording period of 2 hours resulted from the working time of the air-conditioning system that was used most often. It was switched on just for the period of lectures ongoing in the room. The measurements took place in the winter, when the ambient temperature was 3°C. The instantaneous power of the heater determined by the measurements of air fluxes was 12.9 kW for 30% of recirculating air and 13.4 kW for 26% of recirculating air.

At the same time the measurements of the temperature of supplied and returned heating medium were carried out with the use of thermometer sensors and the volumes of both heating medium fluxes were measured with the use of an ultrasonic flow meter. The determined power of the heater was 6.6 kW, which significantly differs in case of the value determined on the basis of measurements of air fluxes. In this situation the power of the heater was determined based on nominative values of ambient temperature and heater power (from the rating plate). The obtained value of 14.4 kW indicates that the value determined on the basis of measurements of air fluxes is correct. The incorrect value of the instantaneous power of the heater based on the measurements of heating medium fluxes were due to the structure of pipes which transported the heating water – the pipes were double welded.

6. DISCUSSION

6.1. Office building I

Based on its analysis and on-site inspection of the installation, slight differences from the design specification can be noted [23]. The ventilation installation was made according to the documentation. Only one difference was observed. There were not exhaust air terminal device and the air was exhausted directly into the engine room. An interview with the person responsible for maintaining the installation has provided information on how the system works. No major problems were encountered during diagnostic measurements, the location of ventilation units in large room and the wide extent of installations made it possible to find the appropriate measurement distances away from the disturbance. Only in the installation 2 no appropriate cross-section for measurement of air flow volume it could be found, therefore the flow was determined by balancing the measured air flow volumes. Determining instantaneous power measurements in two ways: from the water side and from the air side and comparing the variation of its values, allowed to confirm the correctness of the measurements. In the case of the analyzed installation a high similarity of measurement results was obtained.

6.2. Office building II

The inspection and diagnostic measurements in the office building II revealed many problems which arise commonly at on-site research [23]. Major difficulties arouse at the inspection stage when one air-conditioning unit failed to be located. That unit had never been installed. There are some other components of the installation that remained in the design phase and were never installed. This applies to window diffusers or heat exchanger in the existing unit. The designer's intentions regarding the use of the designed installation do not correlate completely with the current state of its use. Ventilation in the lecture room is not used because of the loud operation.

In the course of the measurements, problems were also encountered regarding the difficulty of reaching the conduit, for example due to the lack of space. One should note the measurement of the volume flow of the heating medium to determine the power of the heater. The results obtained from the ultrasonic flow meter were falsified because of the construction of the conduit. It turned out that the duct transporting the heating medium was double welded, which makes it impossible to use the flow meter. The errors came to light when determining the heater power by referring the air volume. It shows that one must always treat the results with great caution and try to conduct a study to confirm the results

7. CONCLUSIONS

The first step in evaluating installation should be to analyze the design documentation. Large differences could be observed at this first stage. The office building II missed some parts of the installation that were in the project design. When inspecting and diagnosing the mechanical ventilation in real buildings, some difficulties could arise. The most common problem in conducting inspection is the lack of technical documentation or the incompatibility between the documentation and installation as well as the absence of the person responsible for maintaining the installation, who may provide information on how the system operates. Also during diagnostic tests, there are problems encountered – most often lack of a suitable measurement cross-section located far from obstacles that might cause flow disturbances. Then measurements inside are very often difficult, but not impossible. It is very important to analyze the results of the research carefully and if possible to make additional measurements that will verify the obtained results.

ACKNOWLEDGMENTS

The work was performed within:

1. Research task No. 4: “The development of thermal diagnostics of buildings” No. SP/B/4/77113/10 within the Strategic Research Project funded by the National Centre for Research and Development: “Integrated system for reducing energy consumption in the maintenance of buildings”.
2. Statutory works No. 08/010/BK_17/0024 and 08/010/BK_16/0015, funded by the Ministry of Science and Higher Education

REFERENCES

[1] Popiołek Z., Kateusz P. (2017). Comprehensive thermal diagnostics on-site of buildings – polish practical experience. *Architecture Civil Engineering Environment, 10(*2).

[2] Specjał A., Ciuman H. (2017). On-site thermal diagnostics of heating and DHW installations. *Architecture Civil Engineering Environment, 10(*2).

[3] Hurnik M., Blaszczok M., Król M. (2017). On-site thermal diagnostics of cooling sources for air conditioning systems in office buildings. *Architecture Civil Engineering Environment, 10(*2).

[4] Bartosz D., Specjał A. (2017). Estimation of the seasonal demand for cooling based on the short-term data. *Architecture Civil Engineering Environment, 10(*2).

[5] Ferdyn-Grygierek J., Blaszczok M. (2010). Energy Consumption in School Buildings Before and After Thermomodernization, 2nd International Conference on Advanced Construction Location: Kaunas Univ Technol, Kaunas, LITHUANIA NOV 11–12, Book Series: Advanced Construction.

[6] Ferdyn-Grygierek J., Baranowski A. (2009). Energy-saving solutions for the cooling of the office buildings. *Rynek Energii, 1*, 46–52.

[7] Baranowski A., Ferdyn-Grygierek J. (2011). Numerical analysis of the energy consumption in the office building. *Rynek Energii,* 2.

[8] Ferdyn-Grygierek J., Baranowski A. (2011). Energy demand in the office buildings for various internal heat gains. *Architecture Civil Engineering Environment, 4(*2).

[9] Ferdyn-Grygierek J., Baranowski A. (2011). Impact of the internal heat gains on the prediction of the seasonal heat consumption in building, Rynek Energii, 6.

[10] Haberl J. (Chair) (2017). Performance Measurement Protocols for Commercial Buildings, ASHRAE, Atlanta, 2010. ISBN 978-1-933742-79-3.

[11] Yana R., Maa Z., Zhaob Y., KokogiannakisaaG. (2016). A decision tree based data-driven diagnostic strategy for air handling units, Energy and Buildings, 133.

[12] Zhao Y., Wen J., Xiao Y., Yang X., Wang S. (2017). Diagnostic Bayesian networks for diagnosing air handling units faults – part I: Faults in dampers, fans, filters and sensors, Applied Thermal Engineering, 111.

[13] Cohen R., Standeven B., Bordass B., Leaman A. (2001). Assessing building performance in Use 1: The Probe process, Building Research & Information 29.

[14] PN-EN 15239:2007 Wentylacja budynków – Charakterystyka energetyczna budynków – Wytyczne dotyczące kontroli instalacji wentylacji (Ventilation of buildings – Energy performance of buildings – Guidelines for inspection of ventilation systems).

[15] Ai Z.T., Mak C.M. (2016). Short-term mechanical ventilation of air-conditioned residential buildings: A general design framework and guidelines. Building and Environment, 108.

[16] Yua Y., Woradechjumroena D., Yub D. (2014). A review of fault detection and diagnosis methodologies on air-handling units. Energy and Buildings, *82*.

[17] PN-EN 12599:2002/AC:2004 Wentylacja budynków – Procedury badań i metody pomiarowe dotyczące odbioru wykonanych instalacji wentylacji i klimatyzacji (Ventilation of buildings – Test procedures and measurement methods for the reception of ventilation and air conditioning systems).

[18] PN-EN 12599:2013-04 Wentylacja budynków – Procedury badań i metody pomiarowe dotyczące odbioru wykonanych instalacji wentylacji i klimatyzacji (Ventilation for buildings – Test procedures and measurement methods to hand over air conditioning and ventilation systems).

[19] Trzeciakiewicz Z. editor, (2013). On-site diagnostics of cooling sources and ventilation and air-conditioning systems, Vol. 3 of the Guidebook of thermal diagnostics of buildings, (Diagnostyka in situ źródeł chłodu oraz instalacji wentylacyjnych i klimatyzacyjnych Tom 3 Poradnika diagnostyki cieplnej budynków), Gliwice, Politechnika Slaska. Wydzial Inzynierii Srodowiska i Energetyki.

[20] Popiolek Z. editor, (2013). Comprehensive on-site thermal diagnostics of buildings in practice, Vol. 5 of the Guidebook of thermal diagnostics of buildings, (Kompleksowa diagnostyka cieplna budynków in situ w praktyce Tom 5 Poradnik diagnostyki cieplnej budynków), Gliwice, Politechnika Slaska. Wydzial Inzynierii Srodowiska i Energetyki.

[21] Dz. U. 75 Rozporządzenie Ministra Infrastruktury, z dnia 12 kwietnia 2002 r. w sprawie warunków technicznych, jakim powinny odpowiadać budynki i ich usytuowanie, (Regulation of the Minister of Infrastructure on the technical conditions to be met by buildings and their location) of 12 April 2002 (Journal of Laws 2015, item 1422)

[22] Makowiecki J., Rosiński M. (2002). Procedura badawcza instalacji wentylacyjnych i klimatyzacyjnych z użyciem elektronicznego mikromanometru MRK z sondą Prandtla, (Test procedure for ventilation and air conditioning systems using the MRK electronic micromanometer with Prandtel pipe), *Ciepłownictwo, ogrzewnictwo, wentylacja*, 9.

[23] Król M., Blaszczok M. (2013). Problemy wyznaczania chwilowej mocy nagrzewnicy powietrza w układach wentylacji mechanicznej (Problems of determining air heater power in mechanical ventilation systems), *Rynek Energii*, 4.