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TEST STAND INTENDED FOR THE STUDY ON THE LEAK TIGHTNESS OF AIR-HANDLING UNITS WITH BUILT-IN HEAT RECUPERATORS

Key words

Ventilation, tightness, heat recuperators, outside air leakage, inside air leakage.

Abstract

The article presents a prototype device and methods for the testing of the tightness of air handling units with built-in heat recuperators. The tightness test is a preliminary test that helps to verify whether the device can in fact be used in a mechanical ventilation installation. The external and internal air leakage was tested with the use of a standard gas meter equipped with an electronic impulse transmitter. The test stand cooperates with a built-in control system developed by the authors to determine thermal efficiency and humidity recovery in recuperators constituting elements of the developed air-handling unit.

Introduction

An air-handling unit with built-in heat recuperators is intended for the removal of air from the building and the supply of fresh air from the outside, which is filtered and properly conditioned (heated or cooled). The proper operation of the unit, the effective heat recuperation, and the safety of the ventilation system are highly dependent on the tightness of this device, both internal and external [1, 2].

The external tightness of an air-handling unit concerns the tightness of its casing. It needs to be noted that there are no 100% tight air-handling units on the market. The external tightness is measured with the amount of air that either escapes or penetrates through the unit's casing. The tightness of the casing is particularly important for the quality of air supplied into the building, and it is a basic requirement for the application of the unit in ventilation systems with increased hygienic demands. Particularly unfavourable is the situation when the unfiltered outside air enters the vacuum chamber of the air-handling unit.

The internal tightness, defined mainly by the tightness of the heat exchanger, prevents the mixing of clean and used air, e.g. from "clean" rooms (like the living room) and "dirty rooms" (like the bedroom, toilet, kitchen, etc.) A tight heat exchanger enables the extraction of "dirty" air polluted, for instance, with gasses, and after the recuperation of heat, it transports outside the building, without letting it to blend with the clean air inside.

The measure of tightness is the value of air leakage between the casing and the surroundings or the casing and the chambers inside the air-handling unit. The tightness is expressed as leakage mass flux in units such as kg/s, which enables a comparison with the nominal air mass flow in test equipment declared by the manufacturer. The ratio of these values, after comparison with the standard requirements, forms the basis for the approval of the device for use in a ventilation system, and it helps to determine the class of tightness, which is extremely essential from the point of its qualification for special applications, e.g. the pharmaceutical industry.

The tightness of air-handling units should be conducted prior to tests on their thermal and humidity efficiency. Test on leaky units are purposeless, because their results will certainly be compromised, and the actual thermodynamic processes inside the recuperator cannot be identified. The methodology of tightness tests and the general draft of the measurement system are specified in PN-EN 308:2001P [3].

1. Method of measuring internal and external leakage

External leakage tests are performed in the system outlined in Figure 1. On one side of the intake air, a pressure gauge is attached, whereas on the other, a fan creating pressure differences in the air inside and outside the casing. Between the fan and the unit, a meter for the measurement of leakage is located. In the diagram (Fig. 1) an additional security by-pass securing the meter from damage during the initial adjustment of test parameters is included.

The external leakage is measured at pressure differences of 400 Pa, separately for positive and negative pressure. In the case of devices intended for installation with the static pressure of 250 Pa or smaller, the measurements are conducted for the pressure value of 250 Pa. The measured leakage mass fluxes are calculated as a percentage of the nominal airflow in the unit. During the tests, the density of air should be between 1.16 to 1.24 kg/m^3.

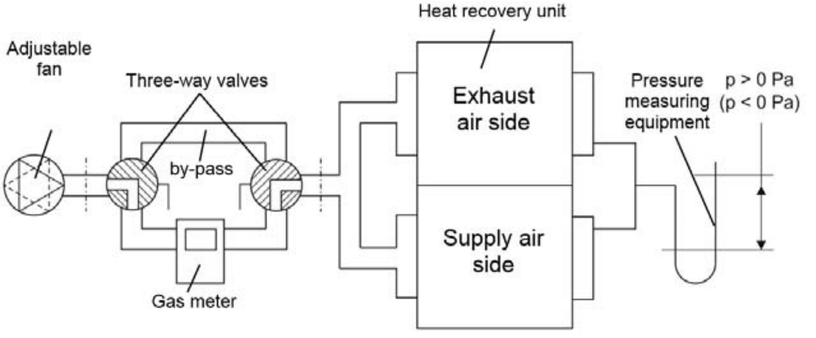

Fig. 1. Diagram of the system for testing external leak tightness of air-handling units with built-in heat recuperators

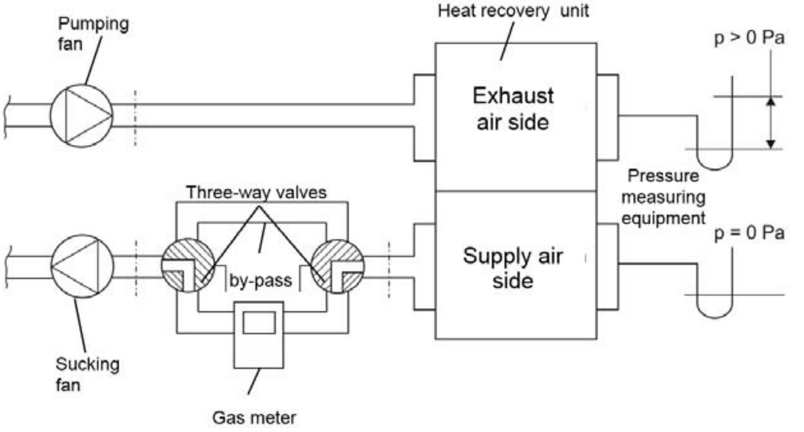

Fig. 2. Diagram of the system for testing internal leak tightness of air-handling units with built-in heat recuperators

The internal leakage of the exhaust air is measured in a system presented in Figure 2. The positive pressure of the air pressed is maintained at the level of 250 Pa or 100 Pa for devices intended for installation with a static pressure of 250 Pa. In the case of the air sucked into the system, the fan maintains the pressure of 0 Pa. The air flow meter placed between the sucked in air and the fan enables the determination of the leakage value. The results of the tests are presented in form of a percentage value of the nominal flux of the air-handling unit.

The method is used for units with built-in heat recuperators or units in which an intermediate agent in form of, e.g., a liquid is used. The method is not applied for the measurement of the internal tightness in recuperators with moveable energy bunkers, which are never 100% tight due to their structure and principles of operation.

2. Design and development of the stand

The stand was designed as a separate, mobile system module intended for heat and humidity recovery efficiency tests in air-handling units [4, 5, 6, 7]. Such a solution was dictated by the possibility to integrate tests in one laboratory by means of the following elements of the infrastructure of the existing system:

- The structure for unit positioning and power supply at the time of tests,
- The pressure measuring circuits with a suitable measurement range,
- The systems for automatic control of the performance of the fans, and
- The electronic systems controlling the compatibility of system operation with the software used.

The image of the virtual spherical model of the stand configured for external tightness tests is presented in Figure 3. The plugged terminals of Unit 1 are on one side connected via pneumatic wires (9) to pressure transducer (8). On the other side, the terminals are connected via flexible wires with collector (6), and the pressure inside, which is regulated by one of fans (2), is connected to the collector via gas meter (3) or by-pass (5) (depending on the position of three-way valve (4)). The by-pass protects the gas meter against uncontrolled pressure changes or flux differences that can occur at the time of the unit being prepared for the tests to be carried out, or during the stabilization of the pressure, etc. On the outlet of the fan, a ball valve was placed, which facilitates the adjustment of pressure and the cooling of the engine.

The gas meter in a test system plays the role of an accurate flow meter. The authors used the industrial G25 bellows gas meter with the efficiency class 1.5 and the measurement range between 0.25 and 40 m^3/h. The first roll of the mechanical counter of the meter has a built-in impulse magnet cooperating with a reed relay with impulse transmission of 0.1 m^3/imp. The impulses are counted by the MacR2 recorder that is typically used for the measurement of the volume of the flowing agent. Apart from the reading the counter and its value changes, the recorder is also used for the current measurement of the volume of gas fluxes, which are calculated based on the measurement of time intervals between individual impulses from the gas meter. The results of flux measurements are displayed on the screen of the recorder and transmitted to the measurement system via the serial transmission channel.

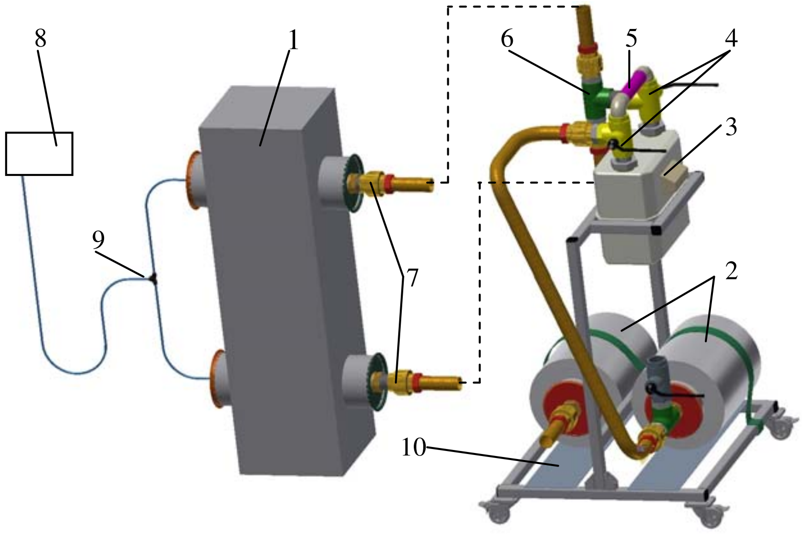

Fig. 3. Virtual model of the test stand intended for the study on the leak tightness of air-handling units with built-in heat recuperators: 1 – tested unit, 2 – fans, 3 – gas meter, 4 – three-way valves, 5 – by-pass, 6 – collector, 7 – connection pipe, 8 – pressure transducer, 9 – pneumatic wire, 10 – supporting frame

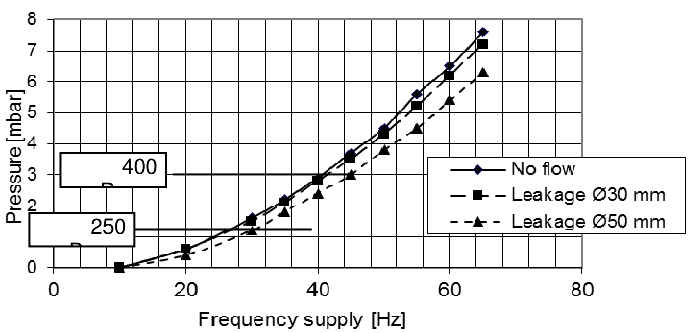

Fig. 4. Graph of the correspondence between the pressure induced by the fan and the frequency of the supply pressure

Fans (2) (Fig. 3) are intended for the initiation of changes in pressure between the inside of the unit casing and the surroundings. The first of them generates positive pressure inside the casing during external tightness tests or on the side of the air pumped during the internal tightness test. The other fan generates negative pressure in both types of tests according to the diagrams presented in Figures 1 and 2. A diagonal channel fan by Harmann Jettec driven by asynchronous three-phase engines was used. Figure 4 presents the graph of the correspondence between the pressure induced by the fan and the frequency of the supply pressure.

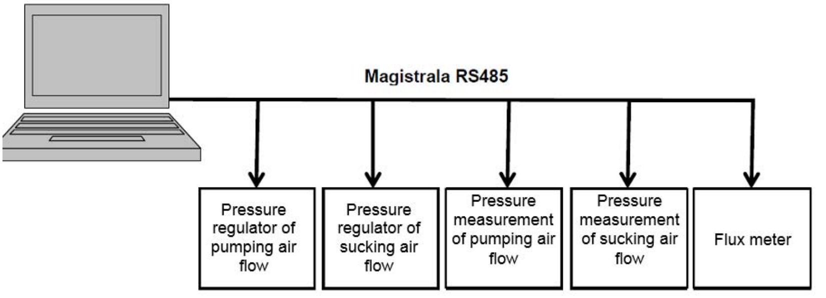

Fig. 5. Diagram of the control system of the test stand

The system uses pressure sensors and fan controllers permanently built in the installation for heat recuperation tests. The draft of the control system is presented in Figure 5. The control computer, by means of dedicated software, sets the value of the air pressure achieved via the proper control over the rotational speed of the fan. The flux meter transmits the results of calculations of the current flow value that are the result of the test conducted.

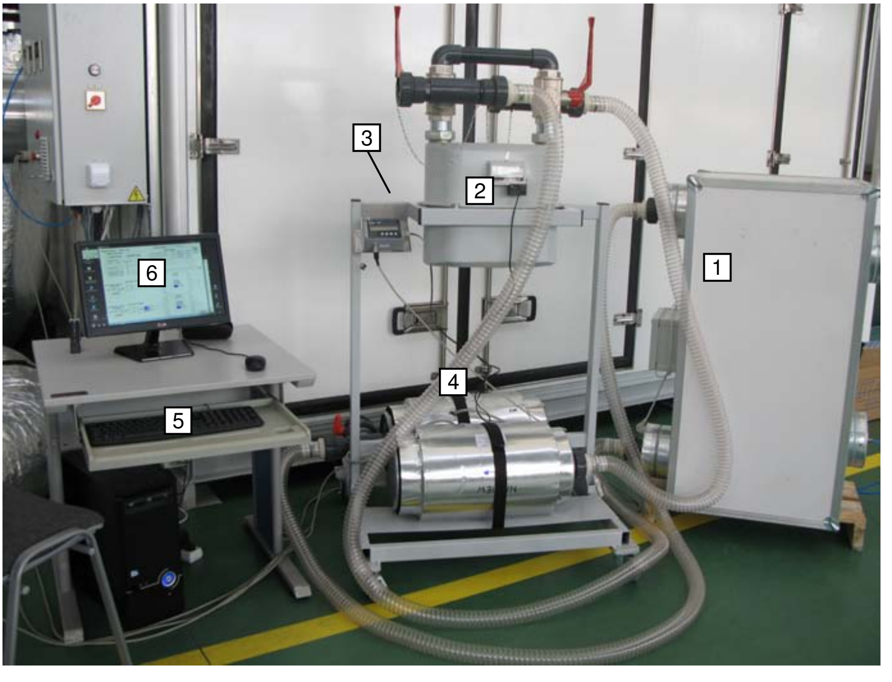

Fig. 6. Test stand for the study on the leak tightness of air-handling units with built-in heat recuperators: 1 – tested unit, 2 – gas meter, 3 – pulse recorder, 4 – fans, 5 – control computer, 6 – monitor, in the background – the installation for heat recuperation efficiency tests

Figure 6 depicts the prototype of the stand – a mobile module that can be freely attached to a detached test object or a test object mounted in the installation for heat recuperation efficiency tests. A tight connection between the stand and the tested air-handling unit can be achieved due to tight connectors (standard connectors used in ventilation systems sealed with silicone).

The joints between fans, the gas meter, the air handling unit, and air pressure sensors are made from flexible pneumatic wires joined with tight connectors, which enables quick exchange of a test unit according to the drafts presented in Diagrams 1 and 2.

3. Tightness tests for air-handling units

Verification tests were performed using an air-handling unit with a spiral heat exchanger with the nominal flow of 450 m3/h. The test started with a proper, tight connection of unit wires with unit terminals. The value of nominal pressure was entered into the control system and the test type is selected. Next, the fan was switched on and its rotational value set. The value of pressure was displayed on the screen (Figure 7). Once the pressure was stabilized, the recording of the leakage value began (presented in form of the diagram). The limit value should be lower than the value calculated by the programme, which is equal to 3% of the nominal flow. After the completion of the test, the programme saved the results of the leakage measurement in m^3/h, kg/s or as a percentage of the nominal flow.

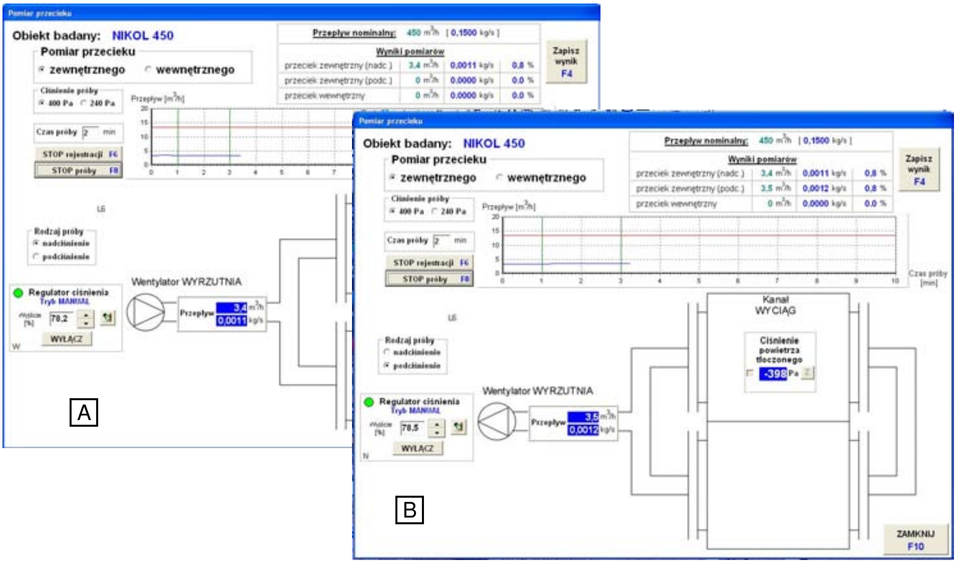

Fig. 7. Screens of the control programme: A – the measurement result of external leakage at positive pressure, B – the measurement result of external leakage at negative pressure

The internal leakage test requires stable values of both positive and negative pressure caused by two separate fans, as presented in Figure 8A. The end of the internal leakage measurement test adds another result to the procedure of tightness tests. The compound results of the leakage measurement are presented in Table 1.

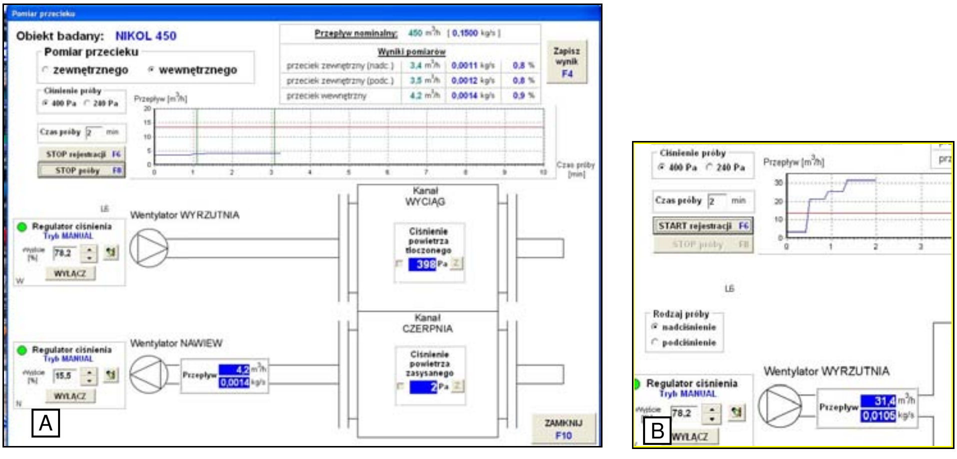

Fig. 8. Screens of the control programme: A – the measurement result of internal leakage, B – the result of the registration of the change in the value of the external leakage

Table 1. The results of measurements of the leak tightness of the air-handling unit with built-in heat recuperators with the nominal air flow q_{mn}= 450 m^3/h (0.15 kg/s)*

	Test pressure [Pa]	Leakage value [m^3/h]	Leakage value* [kg/s]	Leakage [% q_{mn}]
External tightness	400	3.4	$1.13 \cdot 10^{-3}$	0.75
External tightness	-400	3.5	$1.17 \cdot 10^{-3}$	0.78
Internal tightness	250	4.2	$1.40 \cdot 10^{-3}$	0.93

* the assumed density of air amounted to 1.2 kg/m^3

Figure 8B depicts the graph of the intentionally evoked change in the value of the external leakage. The graph clearly indicates that the measurement system using both the gas meter and the impulse recorder requires a sufficiently long time to stabilize the readings, which stems from the periodic emission of impulses by the mechanical counter of the gas meter.

The stand can be used for research on the tightness of casings, heat recuperators or other modules included in air-handling units. In such tests, particular attention should be paid to the time required for the stabilization of leakage conditions and the readings of the measuring system.

Summary

The stand for tightness tests according to the PN-EN 308:2001P is a natural continuation of R&D activity conducted by the ITeE-PIB in the field of air-handling units with heat recuperation. The stand presented in the paper is intended for the measurement of internal and external leakage, whose value is decided on the possibility of the unit to be practically used in a ventilation system. The development of the stand enabled complex tests on heat recovery modules, particularly tightness tests that are their obligatory preliminary stage.

The air leakage was measured using a legalized bellows gas-meter, with the accuracy class of 1.5. The stand is a mobile actuator and a measurement module used in the following functions:

- The initiation of positive or negative air pressure inside the unit,
- The measurement and recording of external and internal leakage, and
- The calculation of the measurement in a format required for the assessment of the unit.

The device works using measurement sensors, inverters, and specialised software of a system for heat recovery efficiency tests.

The authors verified the stand during tests on an air-handling unit with spiral heat exchangers with the nominal airflow of 450 m^3/h.

The tightness tests enabled the execution of complex investigations on air-handling units with heat recovery. The original system can also be used in R&D concerning the verification of parameters of new technical devices for heat recuperation in air-handling units.

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Stanowisko do badania szczelności central wentylacyjnych z odzyskiem ciepła

Słowa kluczowe

Wentylacja, szczelność, wymienniki ciepła, przeciek zewnętrzny, przeciek wewnętrzny.

Streszczenie

W artykule przedstawiono prototypowe urządzenie i metodykę badania szczelności zewnętrznej i wewnętrznej central wentylacyjnych z odzyskiem ciepła. Badanie szczelności jest wstępnym testem sprawdzającym przydatność urządzenia do zastosowania w instalacji wentylacji mechanicznej. Do dokładnego pomiaru przecieku wewnętrznego lub zewnętrznego centrali zastosowano legalizowany gazomierz wyposażony w elektroniczny nadajnik impulsów. Stanowisko współpracuje ze zbudowanym przez autorów układem sterowania instalacji do wyznaczania sprawności temperaturowej i odzysku wilgoci w rekuperatorach wchodzących w skład centrali.