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THE INFLUENCE OF HEAT SOURCE LOCATION ON SURFACE TEMPERATURE DISTRIBUTION OF THE INDOOR SIDE OF EXTERNAL WALLS IN AN UNINSULATED APARTMENT IN WARSAW DURING THE HEATING SEASON

This article presents the influence of the heat source location to surface temperature distribution of the indoor side of external walls in an uninsulated apartment in Warsaw during the heating period. The apartment is located in a multi-family residential building. This building has never been thermomodernized and therefore it is highly energy-consuming. In 2016, an air-to-air heat pump was installed in the apartment and replaced the existing heat source, a dual-function gas boiler. The device is used both for heating the apartment during the heating period and cooling it during the summer. Such system works particularly well in non-insulated objects, in which the partition's internal surface temperature changes dynamically as the outside temperature changes. This article describes the results of the thermovision test of the walls of this flat. The surface internal temperature distribution on the selected three walls was examined under different atmospheric conditions while maintaining similar internal conditions.

Keywords: air-to-air heat pump, uninsulated building, thermovision, alternative heating system, walls

1. Introduction

The Central Statistical Office in Poland (Polish name: GUS) indicated in 2014 [1], that as much as 31% of final energy was consumed by households which ranks it highest among other groups of users in Poland. It turns out that as much as 68,8% of the energy used was needed for heating. In Poland, where around 80% of buildings are at least 30 years old [2], this situation is increasingly being corrected. The main way to improve the energy efficiency of buildings is to thermomodernize them. Thermomodernization measures include first of all improvement of thermal insulation of the building's external partitions, including external walls, roof, floor (if technical conditions allow it), replacement of

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windows and doors, modernization of the heating system and system of hot water preparation.

Due to the large scale of the problem, it is not possible to thermomodernize all buildings at once. While in the case of single-family buildings the possibility of making upgrades improving their condition depends on one, sometimes several people, in the case of multi-family housing the situation is more complicated, depends on many people and the costs are much higher. In an apartment in a multi-family building, if applying additional insulation is not possible, the heating source can be replaced.

In this work, installation of an air-to-air heat pump was analyzed. This infrequently utilized solution can successfully operate as an alternative heat source in apartments. Thermal comfort is a very important factor from the point of view of the user. Buildings that are not thermally insulated are much more exposed to changes in external conditions. During winter, when the outside temperatures are low, the indoor temperature drops quickly. A similar situation occurs in the summer, high external temperature affects the increase of internal temperature. This article analyzes the influence of outside temperature in the winter on the wall's internal temperature and its distribution. In order to investigate the temperature distribution of internal walls in the analyzed apartment, measurements were carried out using infrared thermography using a thermal imaging camera.

2. Technical data of the analyzed building

This analysis examines a real flat of 100 m^2, located on the last floor of a multi-family residential building in Warsaw in III climate zone. The building is characterized by a low energy standard of the external partitions. The external walls are made of a slag hollow brick (40 cm) and the wooden roof was insulated with mineral wool (10 cm) about 20 years ago. The apartment has two alternative heating systems. The first of these is a dual-function gas boiler (used for heating and hot water preparation). The second one is a split type air conditioning system which was installed at the beginning of 2016. The intention of the apartment owner was to cool the flat in the summer. In the 2016–2017 heating season as an experiment he decided to use the air-to-air pump system as an alternative heating system. The wall unit of the heat pump is located in one of the corners of the living room and provides heat to the whole apartment.

3. Thermovision of external walls of the examined apartment

The author of this article carried out experimental studies in the heating season 2017–2018, which showed that the use of an air-to-air heat pump (Figure 1), even in a flat with a low energy standard can be economically more advantageous than central gas heating [3]. The conducted analysis indicated that

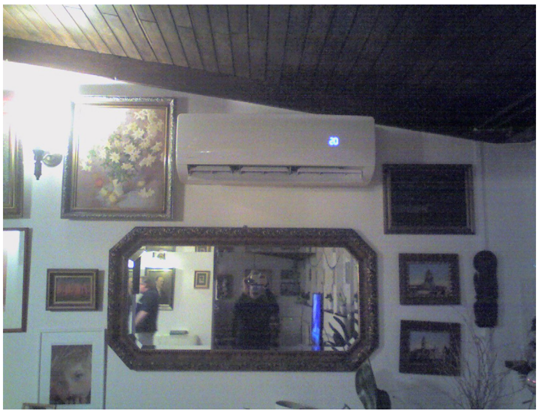

Fig. 1. Air-to-air heat pump

when the heat pump works in one room, temperature in rooms located further from the heat source can be lower. However, this phenomenon did not have a negative impact on the comfort of using the whole flat. In order to check the temperature distribution of walls from the inside infrared thermography, commonly called thermovision, was used. The tests were carried out at various outside temperatures, in several rooms of the flat. The heating device was set up in such a way as to heat the flat to 22°C.

3.1. Thermovision examination

Infrared thermography is a technique for measuring, displaying and recording the surface temperature of the tested objects, based on measurement of incoming infrared radiation [4]. The radiation that reaches the thermal imaging camera originates from the object being studied, as well as from the ground, clouds, sky and surrounding objects [5]. The result is so-called a thermogram, which is a picture illustrating the temperature distribution. This technique allows contactless measurement of the temperature distribution over a large area and from a considerable distance [6]. As a result tests can be carried out in both small and multi-story buildings [4].

According to the PN-EN 13187 standard [7], the increased heat transfer through building partitions is needed to use thermography. This means that tests can be carried out during the heating season. An additional condition that should be met is the corresponding difference in external and internal temperature of the building. The mentioned Polish norm [7] recommends the temperature difference of at least 5°C. Most auditors indicate that in Polish climate conditions, the minimum difference should be 15°C [4]. Thermovision tests are performed most often in the evening or at night, so the results are not affected by solar radiation. The smallest temperature amplitudes during the day and night during the heating season are observed between November and February, which makes them the best months to perform such tests [4]. When executing the thermovision test, it is necessary to specify and enter into the measuring device several parameters. These include: the distance of the camera from the tested object, ambient temperature, temperature of the sky, relative humidity and the emissivity coefficient of the tested surface.

3.2. Thermographic measurements

The measurements described in this article was carried out using a FLIR B400 thermal imaging camera with an infrared image resolution of 320×240 pixels. The tests were carried out on three different days, each around 6 pm. These days were characterized by good weather conditions, i.e. during the day there were no significant amplitudes in the outside temperature, nor was there any precipitation. In addition, a constant temperature in the flat was maintained throughout the day. The apartment was heated by air-to-air heat pump, both in the testing day and the day before. The measurements assumed the emissivity of the examined surfaces at the level of 0.85. The most important information on the measurement data is presented in Table 1.

Table 1. Measurement data

Measurement number	Date of measurement	External temperature °C
1	27.01.2017	-2,1
2	2.01.2018	1,1
3	8.01.2018	-5,6

During the tests, the surface temperature distribution of the indoor side on three selected walls of the flat was measured. Each wall separates the flat from the external environment and each one is facing a different cardinal direction. The first one (hereinafter referred to as wall 1, Figures 2, 3) is the wall on which the heat pump is located. The second wall (wall 2, Figures 4, 5) is also located in the living room. The heating device is located about 6 m from the measuring point. The third wall (wall 3, Figures 6, 7) is located in the room furthest from the heat pump. Examples of thermograms and corresponding photos of three walls on 8th January 2018 are shown in Figures 2–7. The red frames on Figures 2, 4 and 6 show the thermograms area (Figures 2, 4 and 6).

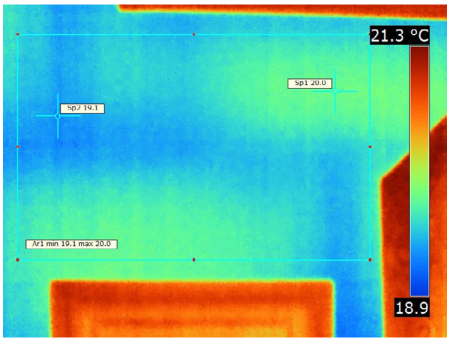

Fig. 2. Thermogram of the wall No. 1 – 8/01/2018

Fig. 3. Photo of the wall No. 1 – 8/01/2018

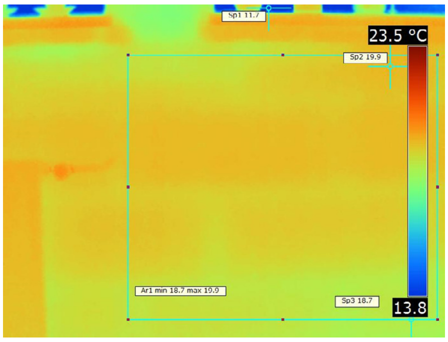

Fig. 4. Thermogram and photo of the wall No. 2 – 27/01/2017

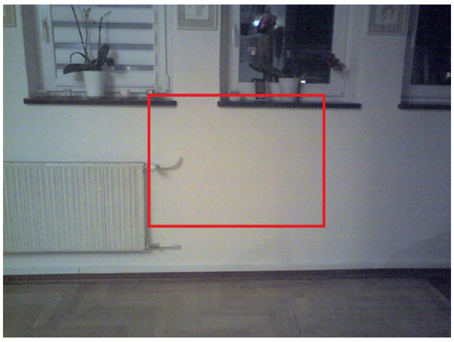

Fig. 5. Photo of the wall No. 2 – 8/01/2018

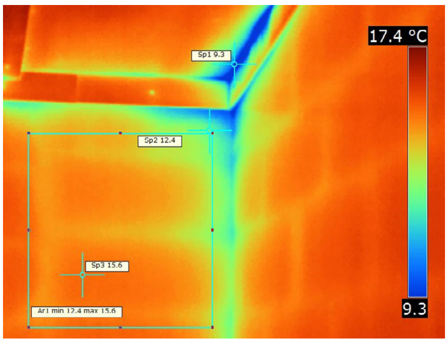

Fig. 6. Thermogram and photo of the wall No. 1 – 27/01/2017

Fig. 7. Photo of the wall No. 3 – 8/01/2018

4. Analysis of the results

In Chapter 4, Figures 8–10, the temperature distribution on the internal surface of the walls number 1–3 are shown, depending on the outside and inside temperatures of the given apartment. The temperatures were read from the thermal camera.

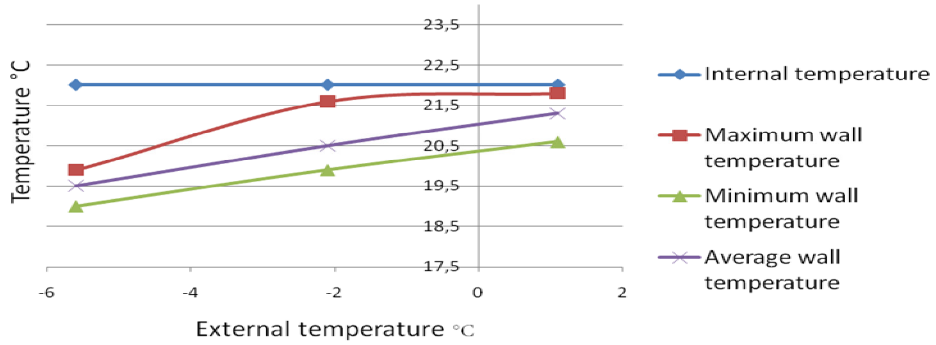

Fig. 8. Surface temperature distribution of the wall depending on the outside temperature – wall 1

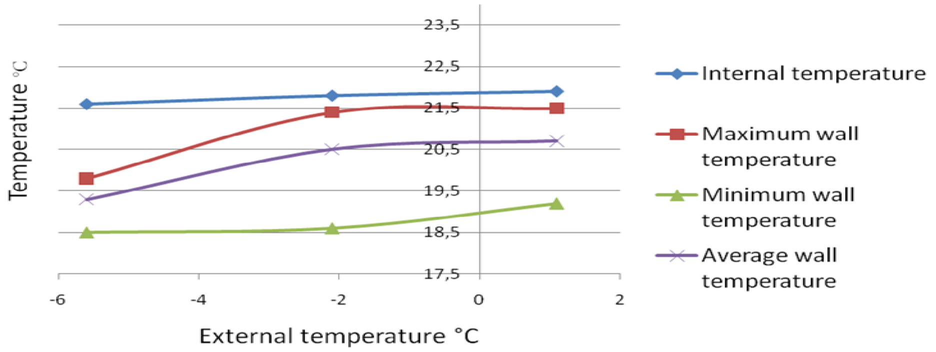

Fig. 9. Surface temperature distribution of the wall depending on the outside temperature – wall 2

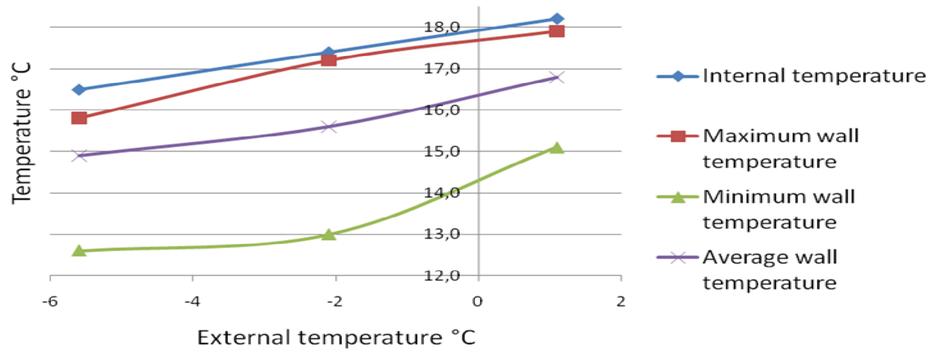

Fig. 10. Surface temperature distribution of the wall depending on the outside temperature – wall 3

Analyzing the results presented in Figures 8–10 allowed for some interesting conclusions. However, it should be noted that the analyzed surface temperature distribution of the indoor side of external walls were limited by portions of the walls and the actual surface temperature distribution over a larger area could differ from presented measurements. As previously indicated, wall 1 is the wall on which the heating device is located. Wall 2 is in the same room, however the examined part of the field is located about 6 m from the heat pump. Wall 3 is located in the room farthest away from the heat pump. The first conclusion may be drawn from the graphs on the indoor temperature prevailing in the rooms and the dynamics of its changes. The internal walls' surface temperature is lower when the outside temperature is lower and the measuring point is further away from the heating device. Surface temperature is also less stable and more distant from the assumed temperature of 22°C. However, residents of the examined apartment have a bedroom in the coldest room and are satisfied that the room has a lower temperature than the rest.

As expected, all the maximum, minimum and average temperatures of the indoor side of external partitions decrease together with the external temperature, which is caused by the increase of the heat exchange intensity with the external environment.

It is noted that the difference between the maximum and minimum temperature on the surface of wall 3, relative to walls 1 and 2 is observed. This is the result of a selected surface sample which contains a corner fragment in which a thermal bridge occurs. On the chosen wall, it was not possible to choose another representative fragment of the surface (large window area, wall covered with furniture). In another case, the difference between the indicated temperatures would be at a similar level as on walls 1 and 2.

On walls 1 and 2, the difference between the maximum surface temperature on the indoor side of wall and the internal temperature in a given apartment is much higher than on wall 3. This dependence is particularly noticeable at the lowest outdoor temperatures. This phenomenon results from the fact that in a room with wall 3 there is much lower internal temperature than in a room where there are walls 1 and 2, which causes higher intensity of heat exchange with the external environment of walls 1 and 2 and higher heat losses.

5. Conclusions

Heating an apartment with an air-to-air heat pump can be an interesting alternative to traditional heating systems, especially in non-insulated buildings that require thorough thermomodernization. Regarding people for whom the cost of modernization is too high or technical conditions do not allow for insulation of walls (a historic building or owned by a larger group of people) the use of an air-to-air heat pump can reduce bills while maintaining sufficient thermal comfort. Apart from the fact that this solution is considered to be more ecological than conventional solutions, the additional advantage is a small difference in the final thermal comfort during the heating period. This article, in which a thermovision was used, has shown that regardless of the prevailing external conditions the apartment has satisfactory thermal conditions. An additional advantage not described in this article is the possibility of cooling the apartment during the summer and in non-insulated buildings, especially in the summer, in which there is strong overheating. The use of a heating device placed in the corner of the apartment, as in the tested flat, seems not to be optimal. If the device would be placed in the central part of the apartment, it would improve the overall comfort of living. It seems that in the coming years, the air-to-air heat pump will be increasingly used as a heat source.

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