Preparation of Experimental Measurement of Heat Pump Parameters

František Vranay(✉), Ján Domanický, and Michal Gorás

Faculty of Civil Engineering, Technical University in Košice, Košice, Slovakia
{frantisek.vranay,jan.domanicky}@tuke.sk

Abstract. The main object of the paper is a description of experimental measurement of air/water heat pump parameters. The measurements should be used to determine the full efficiency of the operation in the modes that occur in practice in the supply of heat and cold during the operation of buildings. In a series of other measurements and other devices, it is also a tool for comparing them and determining their suitability for the selected application. Monitoring and evaluation is complex, with air parameters on the primary side, internal refrigerant circuit parameters and on the secondary water circuit side being recorded. The required operating conditions are ensured by an air-conditioned chamber where we are able to maintain the required air and water parameters on the secondary side for a long time and accurately. Detailed knowledge of these contexts will allow more accurate optimization of system designs and their energy balances.

Keywords: Heat pump · Renewable energy source · Heating factor · Low temperature heating · Heat recovery · Efficiency · Measurement · Operating Parameters

1 Introduction

The current situation in the energy sector forces us to change our view of the situation with fuels and energy resources for the supply of heat and cold to buildings. Conventional fossil fuels and foreign-dependent resources are being replaced by renewable energy sources. These resources come in different forms, but have in common that they are at the point of consumption and are inexhaustible. To use them (drive equipment), electrical energy is needed, but in a significantly reduced need.

Typical systems with this advantage are heat pumps. In our case, we will analyze the most available air/water heat pump system. For their design and energy balance, it is necessary to know the characteristics in different modes of operation. They are influenced by the parameters of the air on the primary side (temperature and humidity), and the water temperature on the secondary side, (output to consumption). The documents supplied by heat pump manufacturers are generally incomplete or insufficient for energy balances. Our task is to test such a device in laboratory conditions, where we are able to simulate stable real conditions in an air-conditioned chamber. The output will be the working characteristics for the entire working range in terms of temperature and humidity on the primary side, but also the influence of the secondary side.

Z. Blikharskyy (Ed.): EcoComfort 2022, LNCE 290, pp. 441–449, 2023.
https://doi.org/10.1007/978-3-031-14141-6_45

2 Measurement Description

A climatic chamber in the Civil Engineering faculty of TUKE premises in the school laboratory is used for experimental measurements. This chamber has the ability to simulate various boundary conditions - humidity and temperature. The temperature range is from −40 °C to +120 °C and the relative humidity from 10%–90%. An auxiliary structure is formed in this chamber, on which the outdoor unit of the heat pump is located. It is thus stabilized against shifts and damage. Since the chamber has two chambers with the possibility of partitioning, the unit is located in the place of the dividing wall, which was chosen in this research and therefore it is not necessary to create conditions for both parts but since both parts have their own heat pump and humidity treatment will work in this case. To create exterior conditions.

To increase the range and accuracy of measurements, a second additional grid-shaped support structure is created in the space just in front of and behind the unit, where humidity and temperature sensors are positioned according to precise dimensions to examine the exact parameters in front of and behind the heat pump fan. The location of the sensors is shown in Fig. 1. There are a total of 12 temperature sensors in front of the unit, 3 of which are also used to measure humidity. There are 11 pieces behind the unit; with 2 the humidity is measured.

Fig. 1. Location of sensors around the heat pump outdoor unit

The indoor unit is located in close proximity to the chamber approximately 1.5 m from the chamber, the length of the Cu pipe between the indoor and outdoor unit is 8.5 m. From the indoor unit is connected to a hot water tank with a volume of 300 L, which is connected from the well. We can therefore regulate and set the water temperature, so that if the water temperature is high, it is possible to start part of it and mix it with water with a lower temperature. Thus, direct discharge of the tank is possible.

The following Fig. 2 and Fig. 3 show the indoor unit and hot water tank assembly.

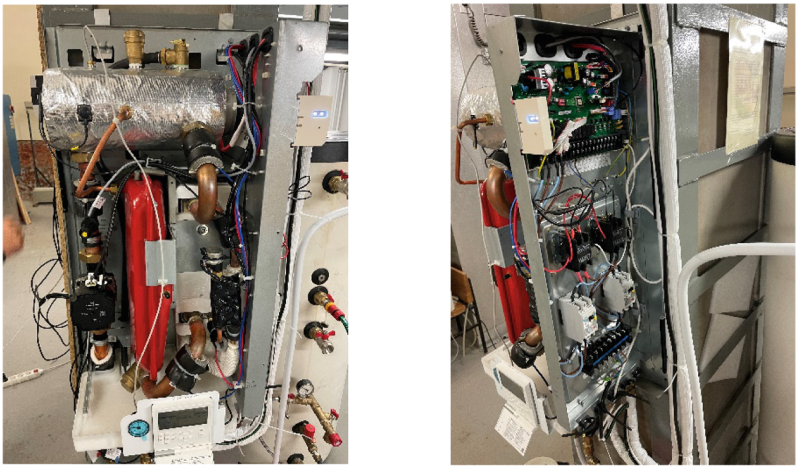

Fig. 2. An indoor unit of the heat pump

Fig. 3. Connection of DHW tank

3 Procedure Description

In this research, several measuring devices are selected. The already mentioned temperature and humidity sensors are installed in the chamber. It is also possible to monitor its own parameters in the heat pump, such as refrigerant consumption, compressor operation, and bivalent source operation.

Two calorimeters are installed on the indoor unit, its distribution system. Using them, it is possible to read various values such as power, flow, and medium temperature in the supply and return pipes, etc. The measurement is also supplemented by electricity meters in order to monitor electricity consumption.

All parameters and measured values must be monitored and saved. Therefore, MBUS and MODBUS units are used in this research. Using software that was created directly for this measurement, these values can not only be stored but also subsequently evaluated.

Using the interrelationships, it is possible to derive the behavior of the heat pump under certain external conditions.

In addition to the work of the compressor, the defrosting of the evaporator is also interesting. At negative values of the outdoor temperature and also the increased humidity, the heat pump freezes. The heat pump can defrost its evaporator, but this affects its efficiency. The subject of research is also the work of defrosting and the number of cycles per certain time unit.

The measured values will be the carrier of the efficiency of the given heat pump. For a better illustration, Fig. 4 shows a circuit diagram of the measured system.

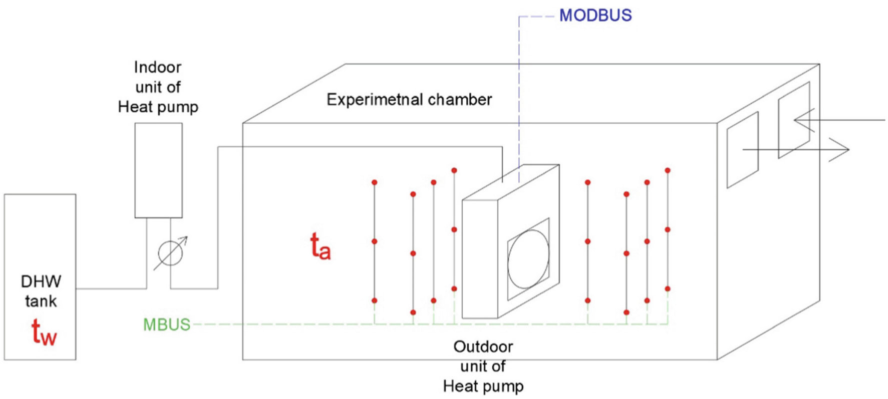

Fig. 4. Heat pump system wiring diagram

The experiment was performed in a chamber (Fig. 5a), and the determination of values was performed using a measuring station Ahlborn (Fig. 5b).

a b

Fig. 5. Experimental equipment: a – An experimental chamber, b – Measuring station Ahlborn

4 Measurement Outputs

In Fig. 6 it is possible to see directly the inside of the measuring chamber.

Fig. 6. Sensors around the heat pump

The grid is created using precision-spaced wooden prisms to record data over a wider range of heat pump surroundings. The sensors are located in front of and behind the pump. There are a total of 23 pieces of temperature sensors, of which 4 are able to measure humidity and 2 pieces measure the velocity of the air.

Measurements were performed during phase 1 at 5 h intervals to stabilize the changes. In this measurement, the temperature was set to +5 °C. The graph (Fig. 7) shows its course in red and white. Yellow shows the course of humidity. We can see how the chamber tried to create the required humidity. In the second phase, air temperatures of −15 °C, −5 °C, 0 °C, 10 °C, 25 °C (this range will be reduced) and a constant course of 24 h will be set.

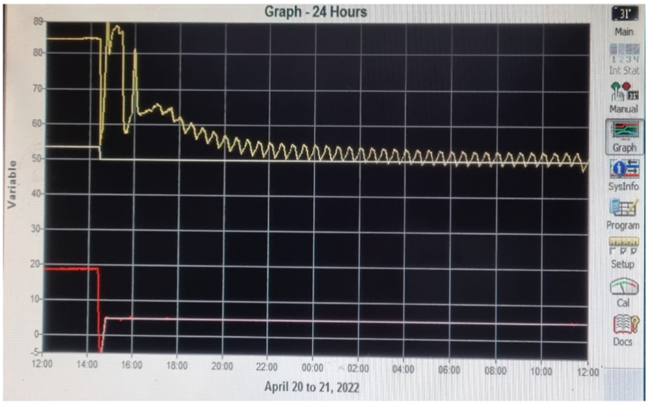

Fig. 7. Chamber setting output and its measurement

The output from the measuring center is in Fig. 8. Required temperature for the evaporator 20 °C, humidity in the same place 60%. Outputs from measuring points (from the grid) - temperature, humidity, air flow rate are also shown.

To obtain the COP value, measurements of heat produced by calorimeters (Fig. 9 C1 and C2) and electricity to drive the pump by electricity meters (Fig. 9 E1 and E2) are required. HP1 is an outdoor unit, HP2 is an indoor unit and ST is a storage tank.

Determining the COP, therefore, the coefficient of performance. The COP curve is compiled from the measurements not only at 5 °C but over the entire range of the hot pump. Thus, the temperature range −20 °C to +35 °C. Humidity range between 10% and 90%. The resulting relationship can be derived as C divided by E (Eq. 1). The heat pump performance curves, the evaporator freezing and thawing balance, the determination of the pump operating range limits and, last but not least, the measurement noise level using added meters will follow. It is for energy saving [18–20].

$$COP = C/E, \tag{1}$$

where: C - produced heat [kWh], E - energy of operation (E1 + E2) [kWh].

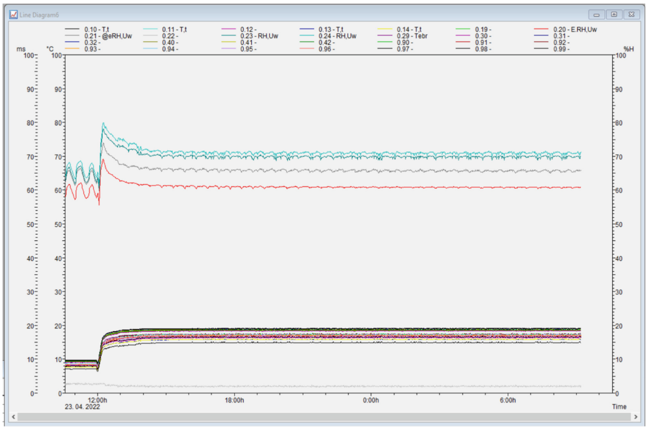

Fig. 8. Measurement output using AMR WinControl software

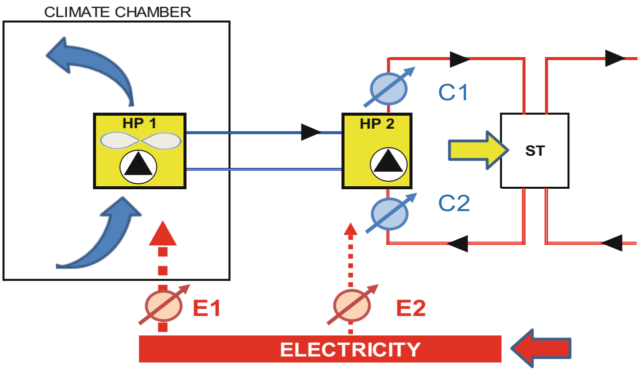

Fig. 9. Measured quantities

The results require long-term measurements and therefore we do not yet have a sufficient number of measurements to publish reliable results. The conclusion will be more types of measurements with differences in methodology. Therefore, we now present preliminary outputs for this boundary conditions:

– air temperature −15 °C, water 45 °C and air humidity 50% COP equals 1.1
– air temperature −5 °C, water 45 °C and air humidity 50% COP equal to 1.9
– air temperature +20 °C, water 52 °C and air humidity 60% COP is equal to 2.5.

5 Conclusion

Based on the measured input and output parameters, the operation and function of the heat pump will be monitored in close future. Using the measured values, a graphical representation of the parameters is created depending on the changes in the boundary conditions (COP values, humidity around the heat pump and temperature) using graphs, which will be completed by evaluating the results.

The aim of this measurement is to contribute to the topic of renewable heat sources, measuring important parameters of the heat pump, which can help producers and consumers in its selection, but last but not least, education in this area.

These data can serve as inputs to the energy balances in the design and assessment of the heat pump.

Acknowledgment. This work was supported by the Agency for the Support of Research and Development on the basis of Contract no. APVV-18-0360.

References

1. Sarbu, I., Sebarchievici, C.: Heat pumps – efficient heating and cooling solution for buildings. WSEAS Trans. Heat Mass Transfer **5**(2), 31–40 (2010)
2. Ruhnau, O., Hirth, L., Praktiknjo, A.: Time series of heat demand and heat pump efficiency for energy system modeling. Sci. Data **6**(1), 1–10 (2019)
3. Tretyakova, P.: Assessment of heat pump efficiency for microclimate formation in a greenhouse In: MATEC Web of Conferences (2018)
4. Act No. 86/2019 Coll. 555/2005 Coll. on Energy Performance of Buildings and on Amendments and Supplements
5. Deng, J., Wei, Q., Liang, M., He, S., Zhang, H.: Does heat pumps perform energy efficiently as we expected: field tests and evaluations on various kinds of heat pump systems for space heating. Energy Build. **182**, 172–186 (2019)
6. Aste, N., Adhikari, R.S., Manfren, M.: Cost optimal analysis of heat pump technology adoption in residential reference buildings. Renewable Energy **60**, 615–624 (2013)
7. European Commission: Energy performance certificates across the EU. Mapping of national approaches (2015). https://ec.europa.eu/energy/en/topics/energy-efficiency/energy-performance-of-buildings/certificates-and-inspections
8. Jouhara, H., Yang, J.: Energy efficient HVAC systems. Energy Build. **179**, 83–85 (2018)
9. Guelpa, E., Mutani, G., Todeschi, V., Verda, V.: Reduction of CO2 emissions in urban areas through optimal expansion of existing district heating networks. J. Clean. Prod. **204**, 117–129 (2018)
10. Stefanco, M., Kosicanova, D., Vranay, F., Kusnir, M., Lojkovics, J., Stone, C.: Heat pumps as a means of efficiency using renewable energy sources. In: 14th International Geo Conference on Energy and Clean Technologies, Albena, Bulgaria: SGEM (2014)
11. Kerdan, I.G., Raslan, R., Ruyssevelt, P., Gálvez, D.M.: An exergoeconomic-based parametric study to examine the effects of active and passive energy retrofit strategies for buildings. Energy Build. **133**, 155–171 (2016)
12. Thiers, S., Peuportier, B.: Energy and environmental assessment of two high energy performance residential buildings. Build. Environ. **51**, 276–284 (2012)
13. Keirstead, J., Jennings, M., Sivakumar, A.: A review of urban energy system models: approaches, challenges and opportunities. Renew. Sustain. Energy Rev. **16**, 3847–3866 (2012)
14. Di Leo, S., Salvia, M.: Local strategies and action plans towards resource efficiency in South East Europe. Renew. Sustain. Energy Rev. **68**, 286–305 (2017)
15. Del Río, P., Burguillo, M.: Assessing the impact of renewable energy deployment on local sustainability: Towards a theoretical framework. Renew. Sustain. Energy Rev. **12**, 1325–1344 (2008)

16. Directive (EU) 2009/28/EC on the Promotion of the Use of Energy from Renewable Sources. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32015L1513&from=EN. Accessed 17 Dec 2018
17. Panwar, N., Kaushik, S., Kothari, S.: Role of renewable energy sources in environmental protection: a review. Renew. Sustain. Energy Rev. **15**, 1513–1524 (2011)
18. Myroniuk, K., Voznyak, O., Yurkevych, Y., Gulay, B.: Technical and economic efficiency after the boiler room renewal. In: Blikharskyy, Z. (ed.) EcoComfort 2020. LNCE, vol. 100, pp. 311–318. Springer, Cham (2021). https://doi.org/10.1007/978-3-030-57340-9_38
19. Savchenko, O., Voznyak, O., Myroniuk, K., Dovbush, O.: Thermal renewal of industrial buildings gas supply system. In: Blikharskyy, Z. (ed.) EcoComfort 2020. LNCE, vol. 100, pp. 385–392. Springer, Cham (2021). https://doi.org/10.1007/978-3-030-57340-9_47
20. Zhelykh, V., Voznyak, O., Yurkevych, Y., Sukholova, I., Dovbush, O.: Enhancing of energetic and economic efficiency of air distribution by swirled-compact air jets. Prod. Eng. Arch. **27**(3), 171–175 (2021)