The concept of low-cost didactic rig in the field of heat pumps

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Abstract. The Centre of Sustainable Development and Energy Saving in Miękinia conducts broad didactic activities for various groups of students. For its own purposes, and also as a concept to use for other didactic centers, a low-cost didactic stand in the scope of heat pumps was designed and implemented. The constructed device presents the operating principles and schematically describes the basic elements of the ground source heat pump system. The device was constructed using a used piston and hermetic compressor from an old fridge. As an evaporator and condenser, a heat exchanger made from copper pipe curved meandering was used. A carefully selected capillary tube was used as an expansion element. The distribution of the components and the visualization of the didactic rig were devised. The whole concept assumed the usage of propane (R290) as an ecological refrigerant. The project also includes cost statements for creating an alternative to a commercial, low-cost stand for teaching purposes at various levels of education and suggests ways of using the set.

1 Introduction

The history of heat pumps is much older than we think. For the first time in 1852, William Thomson Kelvin proved that we can also use refrigerators for heating, thus consuming less energy because we take it from the environment. Thus were the foundations laid for heating devices which would be cheaper in terms of operation [1].

Heat pumps appeared several years ago as available solutions for heating and warming up domestic hot water. They are devices that are characterized by many years of unattended exploitation, an ecological nature and cheap operation costs. Because there is no combustion in the heat pump, they do not emit toxic substances or dust, such as PM2.5 and PM10 fractions. What's more, the use of heat pumps allows for savings at the building construction stage. There is no need for a chimney in a building, places for storing fuel and even boiler rooms. This partly compensates for the higher price of the device.

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2 Purpose of the works

Heat pumps are often seen by the average user as incomprehensible devices. Despite the fact that they are commonly used nowadays, unfortunately their operating principles are still unclear to many of us [2]. Confronted by this problem, it was decided to create a low-cost didactic rig in the heat pump arena. This didactic stand simulates a ground source heat pump with direct evaporation and condensation.

3 A heat pump as a heating device

A heat pump is a device that moves heat from one place to another. A heat pump moves heat from a low temperature source to a higher temperature sink. Common examples are fridges, freezers and air-conditioners, where heat is extracted to achieve a cooling effect, or when operating in reverse, to heat water or a space. A heat pump usually takes heat from the air or the ground, but it can also extract heat from water.

Heat pump systems are widely used in Western and Northern Europe and in the USA. In Central Europe, the heat pump market is starting to develop.

A schematic diagram of the refrigerant circuit is found in Figure 1. Heat at a low temperature level evaporates as a working fluid (a medium with low boiling point-refrigerant), the steam is compressed in a compressor and heated up. A refrigerant under high pressure and temperature transfers heat in the condenser to the water or air. After, the refrigerant is cooled and condensed. In the next step, the condensed refrigerant passes through an expansion valve. This device causes a decrease in the pressure and temperature of the liquid. In the last step, the refrigerant flows to the evaporator, where the refrigerant absorbs heat from the low temperature heat source and evaporates. Then, the refrigerant returns to the compressor and the cycle is repeated.

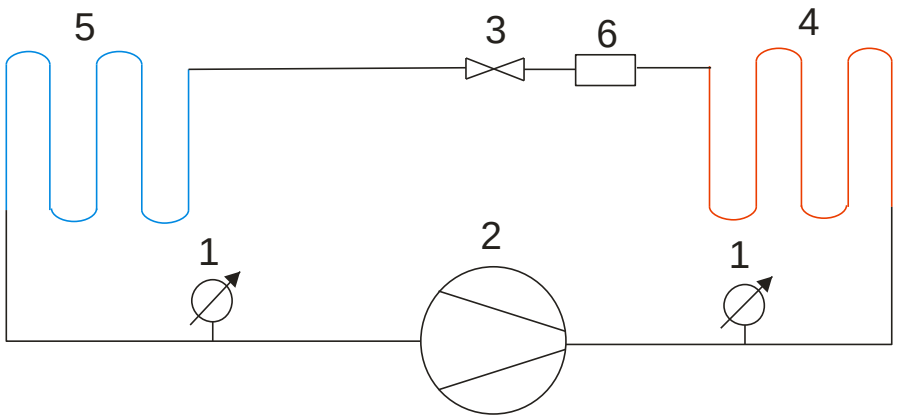

Fig. 1 Schematic diagram of the refrigerant system

4 The concept

The layout concept assumed a small size device (80x80cm), simulating a ground source of energy. For this purpose, it was decided to place the energy sink and energy source on shelves placed at different levels (Figure 2). It was assumed that the ground (the source of energy) and the floor installation (the energy sink) would be made from copper pipe. As an expansion element, a copper capillary tube was chosen for economic reasons, and whose

diameter and length needed to be selected. As additional safety element, intended to keep the whole system dry, a special filter was placed.

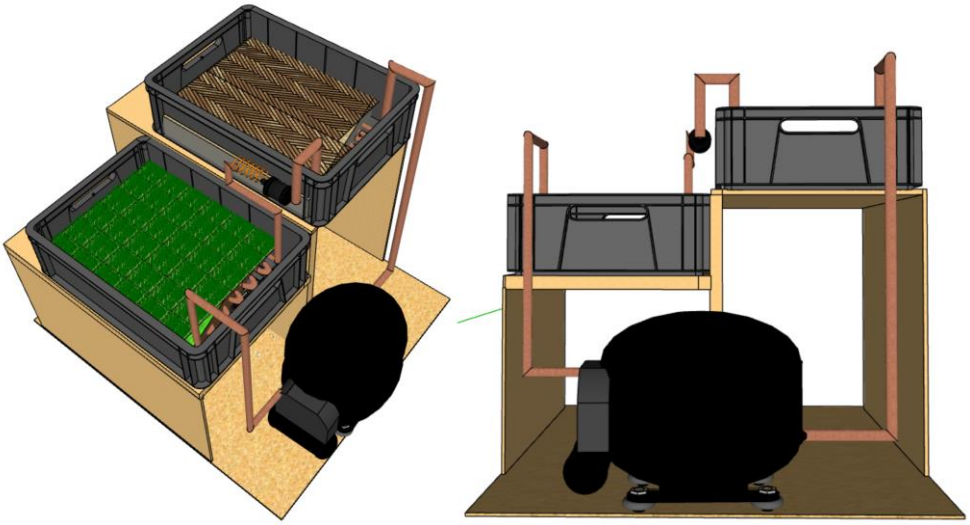

Fig. 2 The model of the didactic rig

The visualization of the didactic rig was created. Heat exchangers placed in cases will be partially visible so that the system has better educational value and shows the cross-section of the heat source and heat sink.

5 Design and selection of system components

The didactic rig consists only of the necessary elements required for the correct operation of the heat pump and elements enabling and supporting easy reception of the project. These elements are: two heat exchangers in the role as a condenser (5) and an evaporator (4), a compressor (2), capillary tube as an expansion element (3), filter (6) and manometers both high and low pressure (1) - Figure 1.

The next step was the correct selection of the elements. The compressor was obtained from an old refrigerator.

The next step was to determine the dimensions of the heat exchanger. Using the dimensions of the old equipment, a pipe thickness of 8 mm was assumed, so that there would later be no problems when using the compressor connectors. The length of each heat exchanger was estimated at 5m. Manometers of a low and high pressure were purchased as was the filter-drier. For capillary selection, the free software "Capillarus" was used [3]. It is a calculator for the selection of the length and cross-section of the capillary and models the choking of the refrigerant, depending on the type of refrigerant used.

6 Propane (R290) as a refrigerent

After soldering the elements, a pressure test was conducted as refrigerant propane (R290) was chosen. It is a natural refrigerant with zero ozone depletion potential (ODP) and a very low impact on global warming potential (GWP = 3). This refrigerant is very similar in its properties to R22. It is perfectly mixed with mineral oils as well, allowing it to obtain a lower discharge temperature than is traditional with, for example, R134a. Unfortunately, R290 is a flammable refrigerant [4].

In installations using flammable refrigerants (internal installations without additional requirements) the permissible mass of the refrigerant in the installation is 150g [5]. To make sure that the device would meet the requirements, the amount of charge was determined.

$$M = A * l * \rho \text{ (kg)} \quad (1)$$

M - mass of the refrigerant (kg)
A - internal pipe crosssection (m^2)
l - pipe length (m)
ρ- density of the refrigerant (kg/m^3)

The calculated values of the mass of the refrigerant that will be in the refrigeration system are listed in Table 1.

Table 1 Determination of the mass of the refrigerant in the unit

	Inner diameter of the pipe	**Length of the each pipe**	**Density of the refrigerant**	**Refrigerant amount in the condenser**	**Refrigerant amount in the evaporator**	**Total mass of the refrigerant**
Unit	m	m	kg/m3	kg	kg	kg
Value	0,006	5	450	0,025	0,019	0,044

Fig. 3 **Didactic rig at the end stage of construction**

7 Summary

A low-cost heat pumps didactic rig (Figure 3) provides many possibilities for educating a wide range of recipients. Thanks to its mobility, it is perfect for promoting ecological behavior during workshops with children in primary schools, as well as during educational sessions for professionals and technicians. It can be also used to cover the basics of higher education subjects such as heat pumps, refrigeration and air conditioning, thermodynamics and other related issues. Students become familiar with the concepts of the heat pump, its heat source and heat sink in a practical way. Students will learn about methods of heating other than by means of the combustion of fuels.

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