Műszaki Tudományos Közlemények vol. 17. (2022) 55–59.
DOI: Hungarian: https://doi.org/10.33895/mtk-2022.17.12
English: https://doi.org/10.33894/mtk-2022.17.12

STUDY OF A COMPRESSOR REFRIGERATION CIRCUIT

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Abstract

An important part of technical education is the presentation of processes through experiments and demonstration tools. This direct sensual experience is one of the sources of knowledge acquisition. The illustration provides a deeper understanding of the curriculum, making the cognitive process more intense. In this study we present a refrigerator model we have designed and implemented. Measurements are then performed on a real refrigerator to study the compressor refrigeration process. The locations where data were acquired are shown on the model.

Keywords*: compression refrigeration system, model, refrigeration cycle, temperature measurement.*

1. Presentation of a compressor refrigerator

The presentation equipment is a teaching tool suitable for illustrating the structural relationships, parts, and operating principles of objects. The didactic requirement of the presentation equipment is to be suitable for purposeful and versatile observation, and to be able to present the processes both as a whole and in detail.

The equipment showing the compressor refrigerator visually helps those participating in technical education to understand and record the structure and operation of the machines.

A compressor is a machine capable of increasing the pressure of gases. It is driven by a power machine, often an electric motor. It can be found in almost every household: it is present in refrigerators, air conditioners, cars, and most air-powered tools **[1]**.

With the refrigerator, a lower temperature than the environment can be artificially produced and permanently maintained **[2]**.

1.1. Principle construction and operation of a compressor refrigerator

The principle structure of the compressor refrigerator is shown in **Figure 1.** The main parts of the refrigerator are the compressor, the condenser, the expansion valve and the evaporator, which form a closed system. Refrigerant circulates in the closed system **[2]**.

The refrigerant can be gas or vapour. The most common refrigerant is vapour **[3–4]**. We will only discuss this hereinafter. The refrigerant is present in different states during the cooling process.

The compressor increases the pressure and temperature of the wet vapour refrigerant, so the high-pressure and high-temperature vapour continues to flow toward the condenser. The condenser is a large surface area heat exchanger. The superheated high-pressure vapour arriving here gives off its heat to the environment, and then cools and condenses. The liquid refrigerant passes through a throttle valve, which maintains the pressure difference, and where the medium expands, causes its pressure to drop and thus its temperature. It begins to boil at a lower temperature due to the lower pressure. It takes heat from its surroundings for evaporation. The heat is absorbed in the evaporator. The refrigerant arriving here is in the form of wet vapour which evaporates here completely while absorbing heat from the medium to be cooled. It leaves the evaporator as cold vapour. The compressor usually includes a recuperator, in which the incoming cold vapour is preheated by the outgoing hot vapour, so that a higher temperature refrigerant arrives at the compressor. As long as the compressor ensures the circulation of the refrigerant, these processes take place, thus the environment of the evaporator cools down, while that of the condenser heats up.

1.2. Compressor presentation

We used the compressor of a refrigerator to create the demonstration equipment. We opened the compressor and took it out of the housing, so the piston, cylinder head, valves, in this case the flow passages of the coolant, spray oiling, and the drive motor are visible, **Figure 2.**

In order to properly illustrate the cylinder head, valves and suction side muffler, we replaced the original mounting bolts and created the correct distance for visual inspection.

1.3. Presentation equipment of a refrigerator

We also used parts of an old refrigerator to create the refrigerator demonstration equipment. The presentation equipment contains the basic parts of the refrigeration circuit: the compressor, the condenser, the evaporator, the throttle valve formed as a common body with the evaporator. The equipment is completed with the dryer and the pipelines, **Figures 3** and **4**).

The condenser is usually large, so we only used a part of it.

The dryer filters the refrigerant passing through it and extracts any moisture from it **[2]**. To demonstrate its construction, the cover was cut lengthwise, the filters were cleaned, and then the silica gel balls were fixed with instant glue.

The evaporator is a 120×400×300 mm aluminium box with a tube system in its wall, where the refrigerant circulates. The throttle valve can be observed on its surface, which is trained on the entry side.

The pipes were attached to each other with a transparent flexible PVC hose for easy installation.

2. Examination of the refrigeration cycle

In order to study the refrigeration cycle, we examined the elements of a real refrigerator together. The refrigerator is a closed system, so it is only possible to measure the temperature. We have developed a measurement system for this.

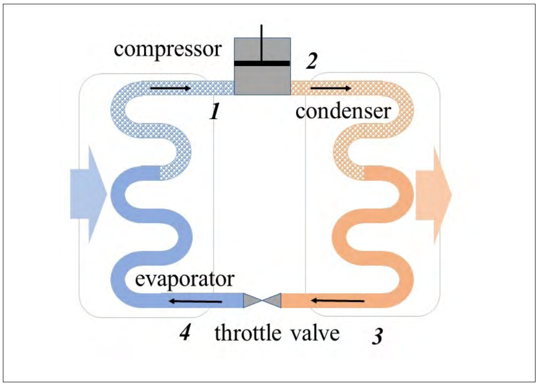

Figure 1. *The principle construction and operation of a refrigerator.*

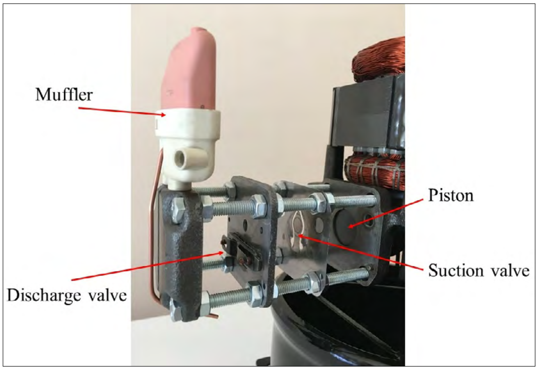

Figure 2. *Implemented compressor presentation equipment.*

Figure 3. *Presentation of dryer.*

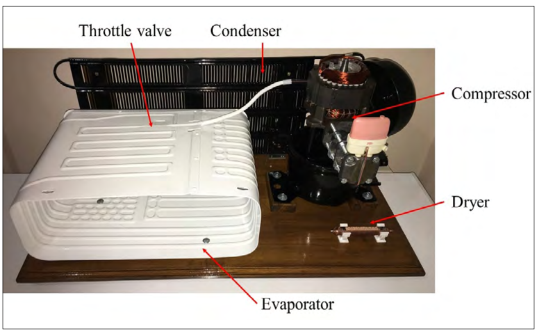

Figure 4. *Implemented refrigerator demonstration equipment.*

2.1. Measurement system

The test was carried out on an LDK refrigerator with a volume of 43 L, **Figure 5.** The condenser of the tested refrigerator is built into the side walls, the evaporator-freezer part is small. Refrigerant is isobutane, designation: R600a. Isobutane boils at −11.7 °C at normal, atmospheric pressure and can be liquefied at 25°C with a pressure of 3.5 bar **[5]**.

The main components of the measuring unit: Arduino Mega2560, 7 DS18B20 temperature sensors, 3.2" diameter touchscreen colour TFT LCD display.

The purpose of the measuring program is to create an easy-to-understand interface that shows the user the temperature values measured by all sensors at the same time **[6]**. The temperature changes are also illustrated by a graphic interface. For easier tracking, each sensor has its own color code. Navigation is possible between 4 pages on the user interface, which is made possible by the touch-sensitive display.

The flowchart of the program is shown in **Figure 6.**

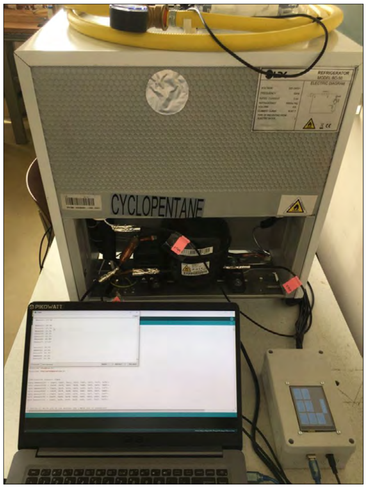

Figure 5. *The tested refrigeration machine and data collection.*

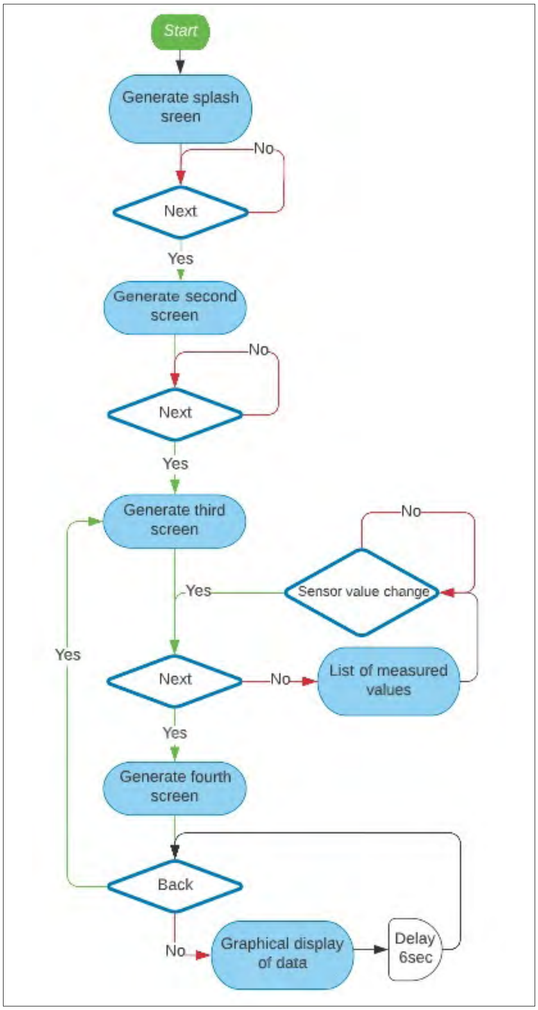

Figure 6. *Flowchart of the program.*

2.2. Measurement

In order to test the refrigerator, the seven sensors were fixed in important places in terms of operation: before the compressor and after the compressor, on the condenser, in front of the dryer, after the dryer, in front of the throttle and after the throttle. The temperature sensors were fixed with aluminum adhesive tape and heat-conducting paste.

After starting the refrigerator, the sensor data is saved in a *.txt file; these can be followed on the fourth page of the screen, **Figure 7.**

The temperature change of the refrigerant during the operation of the refrigerator at the measurement locations can be followed in **Figure 8.**

Figure 8. shows the measurement locations and identifies the elementary processes of the cooling cycle:

- S4-S1: Temperature increase by compressor;
- S1-S5-S2-S3-S6: Temperature drop by condenser;
- S6-S7: Temperature drop by throttle;
- S7-S4: Temperature increase by evaporator.

2.3. Refrigerant cycle test

Knowing the pressure and enthalpy of the refrigerant is of practical importance for the illustration and investigation of the change in the state of the refrigerant along the refrigeration cycle [4, 7, 8, 9]. Enthalpy, whose symbol is H, is a caloric state indicator with energy dimension, and its unit is [*J*].

Based on the temperature, the saturated vapor pressure of the refrigerant can be determined, this was based on the characteristic of the saturated vapor pressure of isobutane. The saturated vapor pressure values for the R600a, isobutane refrigerant at a given temperature can be found in the literature [5]. Using these values, we formed an approximate polynomial, Figure 9.

The relation of the approximate polynomial:

$$p = 4\cdot10^{-6}\, t^3 + 8\cdot10^{-4}\, t^2 + 0.562\, t + 1.5624 \text{ [bar]} \qquad (1)$$

The saturated vapor pressure values for the temperature values after the compressor and after the throttle were determined with the relation (1). The data are given in Table 1. The expected data of R600a refrigerant, which can be found in the literature, have also been indicated there.

The refrigeration circuit processes can be clearly illustrated on the p-h diagram, Figure 10, where *h* is the specific enthalpy, [J/kg].

The pressure-increasing effect of the compressor and the enthalpy increase can be followed in section S4-S1 of the diagram. The refrigerant turns into superheated vapor. The calculated pressure of 5.6 bar is acceptable based on literature data.

In section S1-S5-S6, the temperature on the condenser decreases (Figure 8). The refrigerant changes from a vapor state to a liquid state (Figure 9). Isobaric heat release, enthalpy reduction occurs.

On the S6-S7 section can be seen the pressure drop across the throttle. The temperature value measured after the choke matches the literature data (Table 1, Figure 8). If we start from the assumption that the refrigerant after the throttle is in a vapor state, it can be seen that the determined pressure of 0.6 bar can be realistic (Table 1, Figure 10).

In section S7-S4, the refrigerant evaporates, isobaric heat absorption takes place and the enthalpy increases.

Table 1. *Determined saturated vapour pressure values*

Sensor number	Sensor place	Temperature (°C)	Calculated pressure (bar)	Literature data
1	After compressor	41.75	5.60	40 ÷ 60 °C max. 8 bar
7	After throttle	−23.66	0.61	−25 ÷ −20 °C 0.5 ÷ 1 bar

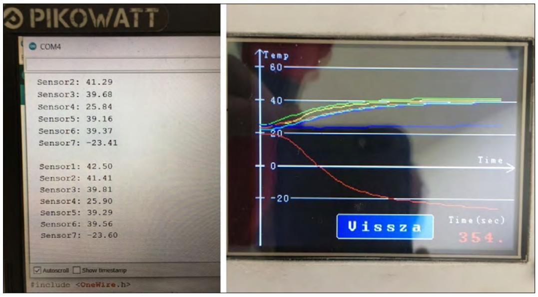

Figure 7. *Displayed data.*

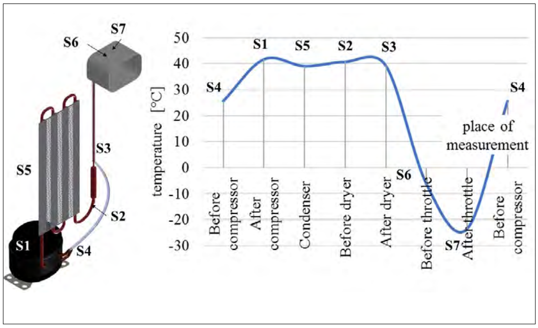

Figure 8. *Refrigerant temperature change at the measurement locations along the circuit.*

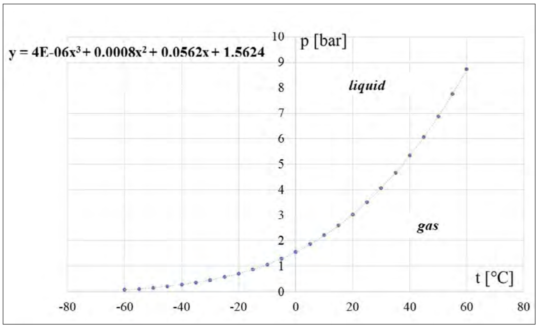

Figure 9. *R600a, isobutane saturated vapor pressure diagram.*

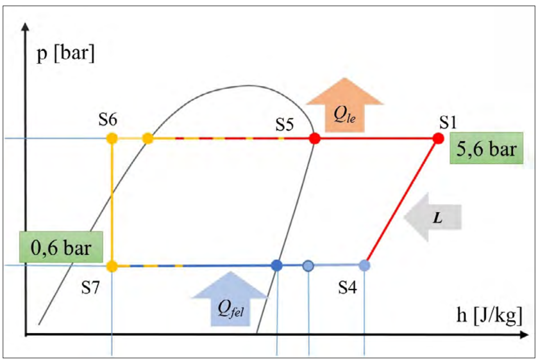

Figure 10. *Illustration of the refrigeration cycle on a p-h diagram.*

3. Conclusions

The demonstration device requires little space, is easy to use, and is safe. It presents the important parts of the refrigerator and gives an opportunity to follow the elementary processes.

With the help of the measuring unit, the temperature changes can be followed in real time. The measurement locations can be presented on the demonstration equipment.

In the refrigeration circuit, the temperature, pressure, and state of the refrigerant change. This is explained by the demonstration equipment and verified and illustrated by the measurements.

The implemented demonstration equipment connects theoretical and practical concepts.

References

[1] Kakucs A.: *Áramlástan*. Scientia Kiadó, Kolozsvár, 2006.

[2] Juhász L., Maiyaleh T., Vadász J., Vasáros Z.: *Gyakorlati hűtéstechnikai ismeretek.* Nemzeti Klímavédelmi Hatóság, Budapest, 2020.

[3] Santa R.: *Investigation of the Thermodynamic Characteristics of the Ester Oil and R152a, R125, R134a and R123 Refrigerant Mixtures.* Acta Universitatis Sapientiae Electrical and Mechanical Engineering, 13 (2021) 14–24. https://doi.org/10.2478/auseme-2021-0002

[4] Sánta R.: P*ressure Drop during Condensation of Refrigerant R134a inside Horizontal Tubes.* IEEE 3rd International Symposium on Exploitation of Renewable Energy Sources (EXPRES), (2011) 117–122. https://doi.org/10.1109/EXPRES.2011.5741804

[5] *A kompresszoros hűtőgép kivitelezése*. https://www.netfizika.hu/a-kompresszoros-hutogep-kivitelezese. (letöltve: 2021. május 11.).

[6] Harsányi R., Juhász M. A.: *Fizikai számítástechnika: elektronikai alapok és Ardunio programozás.* Typotex Kiadó, 2014. (letöltve: 2021 május 15.)

[7] Santa R.: *Comparative Analysis of Heat Pump System with IHX Using R1234yf and R134a.* Periodica Polytechnica, Mechanical Engineering, 65/4. (2021) 1–11. https://doi.org/10.3311/PPme.18390

[8] Sánta R.: *Investigations of the Performance of a Heat Pump with Internal Heat Exchanger*. Journal of Thermal Analysis and Calorimetry, 146. (2021) 11130. https://doi.org/10.1007/s10973-021-11130-5

[9] Sánta R., Garbai L.: *Measurement Testing of Heat Transfer Coefficients in the Evaporator and Condenser of Heat Pumps*. Journal of Thermal Analysis and Calorimetry, 119/3. (2015) 2099–2106. https://doi.org/10.1007/s10973-014-4303-4