

## Field Measurements And Analysis Of Supermarket Refrigeration Low Temperature Units

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### ABSTRACT

Making refrigeration sustainable, as a result, demands a system approach that not only fast-tracks the move from HFCs to natural refrigerants, but also considers and prioritize the energy. A number of experiments are carried out over pilot units and the detected temperatures were validated. The study site is designed using specifications, guidelines, or specifications. which can be used consistently to ensure efficient equipment design. Using the field measurements, low temperature level cooling demands and COPs are calculated for peak loads, filtered and averaged to monthly values. The temperature fields are determined taking into account the features of the unit structure, revealing the disadvantages and advantages for tested pilot unit. The obtained study results make it possible to determine the thermal fields for commercial refrigeration equipment, to determine the places of excessive thermal load and the ability to collect the input data to start the creation of a single model for calculating the commercial refrigeration equipment.

**Key words:** *Low Temperature Units for Supermarkets; Heat Inflows; Peak Loads; Power.*

### 1. INTRODUCTION

The Kigali Amendment to the Montreal Protocol entered into force in January 2019 as a legally binding agreement aiming to phase down the production and use of HFC gases. With the Kigali amendment commercial refrigeration users will need to replace their cooling systems running on these gases, which opens the opportunity to replace these systems with state-of-the art systems. Commercial refrigeration equipment used for storing and displaying fresh and frozen products has a variety of designs. Recently, the refrigerant R-404A has been widely used [1]. Therefore, the choice of refrigerants with lower GWP than R-404A should be done in a comprehensive manner, taking into account all factors. HFC/HFC blends with lower HWP and non-halocarbons options such as R-717, R-744 and R-290 are increasingly being used, especially as research and development to improve system performance continues; this trend will intensify after new standards and codes come into force in the next few years. In these works, analysis and raiding of three refrigeration agents (R404a; R452a; R290) electric power supply are carried out at one parameters of refrigeration systems [2].

### 2. MAIN SECTION

#### 2.1. Conducting an experiment

For the analysis we used a freezing chestnut model M200V, a modified sample for scientific research (Figure 1). Two stationary, high and low pressure mechanical gauges and two shredder valves were added to the standard design of the chest freezer to allow connection of higher precision electronic gauges, vacuuming and refilling of the hall system. Sight glasses are also placed on the system to monitor the processes running in the refrigeration circuit. P06S-20 network analyzer is included in the electrical circuit for possibility to remove electric power consumption indicators. Thermometers TPM-10 are also placed on all the coils of sheet-tube heat exchangers and along the system contour, and FY12 thermo hygrometers are removed in the cooled chamber and in the

environment. The refrigeration circuit, despite the modifications, corresponds to the standard scheme of capillary refrigeration equipment. During the experiments, the stand was configured to control the periodic operation of the blower fan of the precapacitor and compressor (blowing was carried out during system operation), and LED lighting was turned off to reduce heat and energy consumption (LED-chop for lighting is an additional option, and according to ISO 23953-2 2005(E) energy efficiency measurements are performed without it). The study was conducted in the laboratory at the research sites in the 3rd climate class ( $T_{amb} = 25\text{ }^{\circ}\text{C} / \text{HRoc} = 60\%$ ). The equipment used for measurements and monitoring was checked in advance with certified analogues and calibrated. Each system test was performed for at least 24 hours. When conducting research in the compressor, the oil was replaced according to the needs of the refrigerant.

- 1- Glass sashes
- 2- Inner case
- 3 Outer Enclosure
- 4-Compressor bay
- 5- Grid of compressor compartment
- 6- Controller
- 7 System management
- 9- Network Electric Current Analyzer
- 10 Condenser Thermometer Panel
- 11- Evaporator Thermometer Panel
- 12- Basic parameters panel

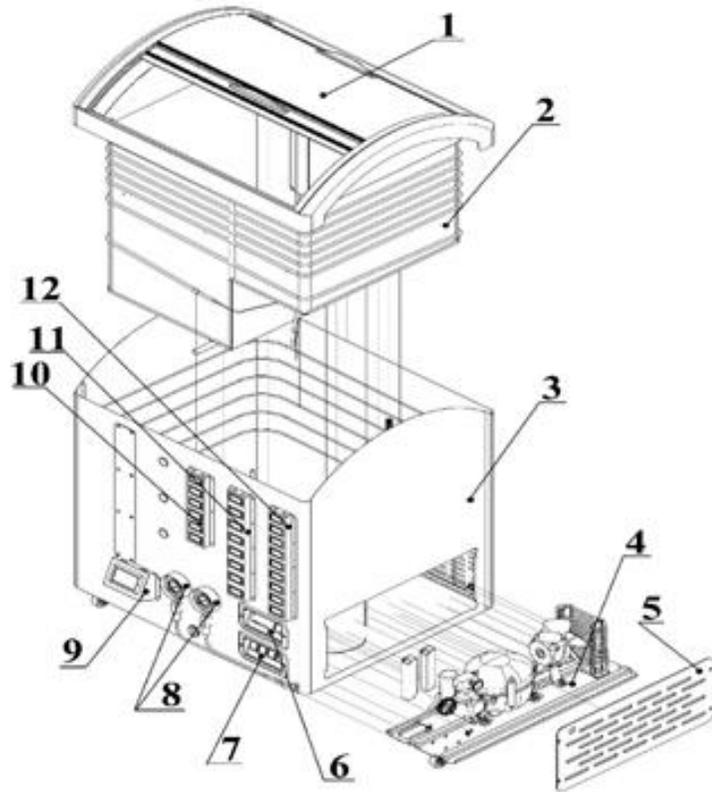
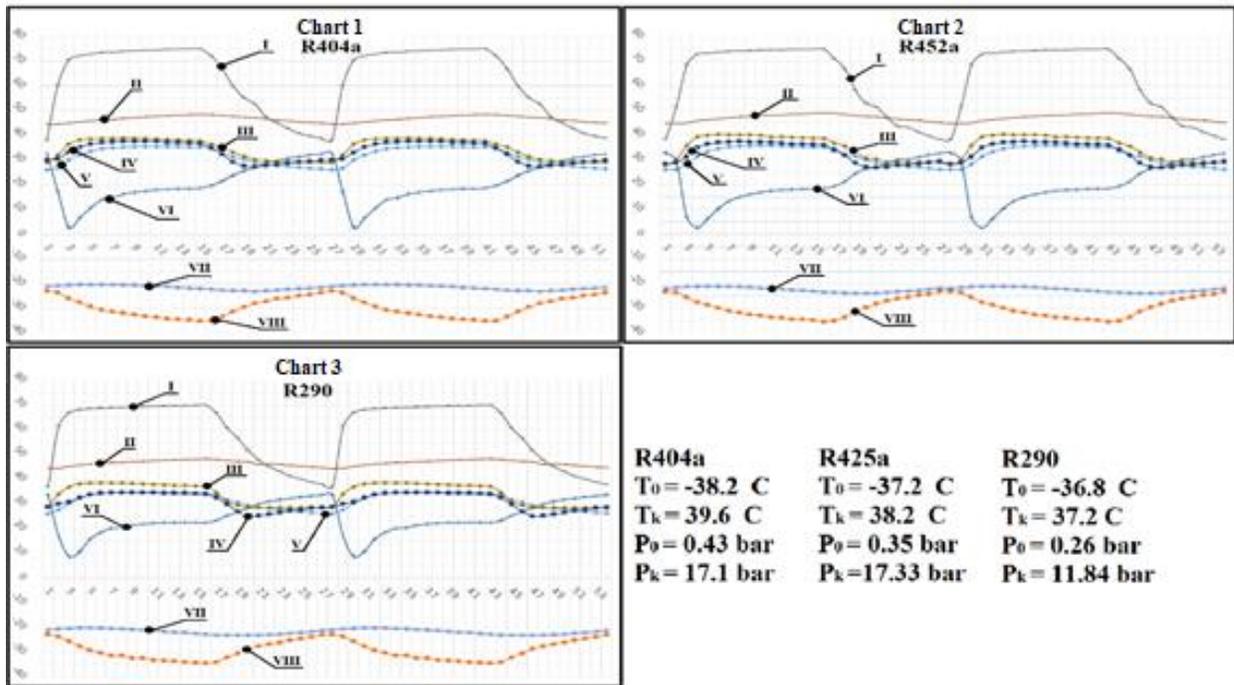


Figure. 1. Experimental stand M200V.

## 2.2. The experiment results

The following refrigerants were filled into the Refrigeration System in sequence (R404→R452a→ R290), and after setting the operating parameters, the refrigeration unit was connected to the mains. In accordance with the experiment procedure on commercial refrigeration equipment, all measurements were taken after the chest went into operation. The following results were obtained at the input of the experiment: In the course of electricity measurements, manometer readings and thermal indicators of the refrigeration system were taken, according to which the system operation schedule was built during the cycle (Figure 2).



**Figure 3. Parameters of the stand operation on the investigated refrigerants.**

I - Graph of injection temperature change ( $T_{inj}$ ); II - Graph of compressor oil temperature change ( $T_{ko}$ ); III - Graph of change of temperature of the beginning of condensation ( $T_{k1}$ ); IV - Graph of change of average value of temperature of the condenser ( $T_{k2}$ ); V - Graph of temperature change of the end of condensation ( $T_{k3}$ ); VI - Graph of the change of suction temperature in the compressor ( $T_{suc}$ ); VII - Graph of temperature change in the cooled volume ( $T_{ov}$ ); VIII - Graph of changes in the average value of evaporator temperatures ( $T_0$ );

The analysis of experimental researches of the refrigerating appliance on various working bodies shows the following:

1. The injection temperature during the active period of operation is stable and varies within: R404a – 75...72.1°C; R452a - 74.8 - 71°C; R290 - 70.1 - 66.8°C.
2. The temperature of the compressor oil does not exceed 50°C, which meets the technical requirements.
3. The obtained temperatures of the beginning of condensation, respectively refrigerants during the active period of the refrigeration machine are close to the readings of manometers. These results mean that the overheating is removed completely, and in the condensate there is only a phase transition of the refrigerant. Values of condensation start temperatures: R404a – 39 - 36.6°C; R452a - 40.4 - 36.9°C; R290 - 38.6 - 34.6°C.
4. The temperature of the condenser on the graph is the average value of the temperatures of the six turns of the condenser and corresponds to the following temperatures: R404a - 36.2 - 35.3°C; R452a - 36.9-25.3°C; R290 - 35.5-34.1°C.
5. The temperature of the end of condensation. This temperature is removed from the bottom of the dehumidifier filter, and its value is slightly higher than the value of the condenser temperature. This phenomenon is explained by the placement of the filter in the compressor compartment, where the temperature of the volume is increased due to heat dissipation from the precapacitor and the compressor. The results obtained are: R404a - 37.6-34.9°C; R452a - 37.5-33.9°C; R290 - 34.7-32.5°C.
6. The suction temperature of the pipeline during the cycle is unstable, during the inactive period of the

refrigeration system in the circuit through the capillary tube equalizes the pressure ( $P_k = P_0$ ), this leads to boiling of the refrigerant in the condenser, and its condensation in the evaporator. This phenomenon explains the drop in temperature on the high pressure circuit below the ambient temperature.

6.1. At the beginning of the active phase of the refrigeration system and the liquid evaporator filled with the evaporator, it is partially boiled in the suction line heat exchanger. This process causes a sharp drop in temperature on the suction line to the range of 10 - 0°C for 3-5 minutes of the active phase. This phenomenon promotes the return of oil to the compressor and its normal circulation in the system and confirms the compliance of the amount of refrigerant to the system.

6.2. At the end of the active phase of the refrigeration system temperature is kept stable below the ambient temperature and does not tend to decrease, this result indicates a normally filled evaporator and compliance with the regenerative heat exchanger refrigeration system.

7. The set temperature is controlled by the controller with the programmed temperature parameters equal to -23 °C and the hysteresis parameter corresponds to 0.5 at such parameters, the temperature in the cooled volume is in the range of -23°C and cooks around 3-4°.

8. The temperature of the evaporator, similar to the temperature of the condenser was taken from eight turns and plotted as an arithmetic mean. These temperatures are approximately equal to the boiling point, and their minimum values are: R404a - (-36)°C; R452a - (-37)°C; R290 - (-36)°C.

Figure 3 and Table 1 show the results of experimental-calculation studies.

**Table 1. The results of the experiment.**

Refrigerant	R404a		R452a		R290	
t, min	15 (running)	12(stop)	16(running)	12(stop)	16(running)	12(stop)
G, kg	0.095		0.105		0.075	
$t_{rr}$	0,55		0,57		0,57	
COP	3,02		3,13		3,19	
EEI, %	58		55		46	
EEC	E		E		D	
$T_o, ^\circ C$	-38,2		-37,2		-36.8	
$P_o, bar$	0,43		0,35		0.26	
$T_k, ^\circ C$	39,6		38,2		37,2	
$P_k, bar$	17,11		17,33		11,84	
U, Wolt	220-230					
F, Gertz	50					
$E_{daily}$ , kWh/24	2,20		2,42		2,01	

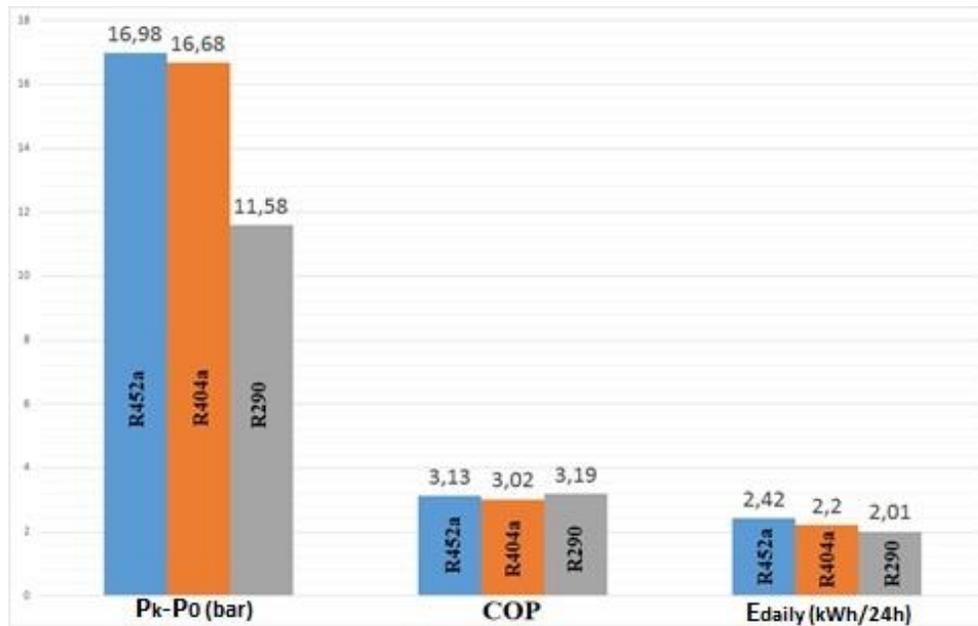


Figure 4. Comparison of considered refrigerants.

### 3. CONCLUSIONS

The conclusion of this study is to confirm the possibility of a complete transition to a natural analogue with GWP = 0. In parallel, the low energy efficiency of the analogue R404a. Although R452a is fully interchangeable with R404a without oil or compressor changes, it is not an energy efficient refrigerant. In addition, R452a has a GWP = 2141, indicating a ban on its use from 2022. Comparing the R290, its advantage in terms of energy efficiency and cost is obvious. The advantages of R290 also include its monogamy, and therefore, as the experiment shows, and its equality, the temperature in the liquid phase, in the volume of the heat exchanger. R290 remains the most promising analogue of R404a in low-temperature technology in the field of commercial refrigeration equipment. The Conclusions section should list the major conclusions of the work and summarize the significance of the paper as clearly and concisely as possible.

### NOMENCLATURE

<i>P</i>	pressure (bar)	<i>Edaily</i>	daily energy consumption' (kWh/24h)
<i>To</i>	operating temperature' (0C)	<i>COP</i>	Coefisin of perfomans
<i>HRoc</i>	relative air humidity ( % )	<i>EEl</i>	energy efficiency index (%)
<i>t rr</i>	relative of persentege running time	<i>EEC</i>	<i>Energy Efficiency Class (A....G)</i>
<i>G</i>	refrigerant charge ( kg)	<i>GWP</i>	global warming potential'( CO2 kg)

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