Improving the Efficiency and Reliability of the Internal Heating System on the Example of a Shopping Center

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Abstract. Shopping centers belong to the type of buildings in which all internal engineering systems are present. Therefore, the study of the shopping center, as an example of carrying out work on the application of various proposals for the use of secondary energy in the complex and, consequently, for energy saving and improving reliability and efficiency, is relevant. In addition, the use of various heat carriers allows us to consider the issue of energy saving more widely. The article compares the traditional heat supply system and the combined system, as well as the development of optimal energy-ecological solutions for the design of the heat supply system of a shopping center using the heat of condensation of refrigeration equipment used to comply with the technological process of cooking and storing food. The peculiarity of the proposed solution is that CO₂ is used as a refrigerant in the refrigeration system, which is proposed to be used as a heat carrier for heating water in the hot water supply system.

1. Introduction

The purpose of the work is to perform a comparative analysis of traditional heat supply systems and a combined system, as well as to develop optimal energy-ecological solutions for designing an internal heat supply system for public buildings on the example of a shopping center using the heat of condensation of refrigeration equipment. [1, 2, 3, 4, 5]

The object of the study is an operating shopping complex located in the city of St. Petersburg.

The initial data for the study were the architectural plans of the complex, the working draft of the cooling system and the working draft of the ITP. All the features of technological processes provided by internal heat supply systems were investigated. [6, 7]

2. Research of internal heat supply systems

During the study, engineering calculations of the parameters of the operation of the hot water supply system, including the supply T₃ and circulation T₄ pipelines, were performed (Figure 1) [8]. The use of a hot water circulation system was justified.

A scheme of a two-pipe DHW system was developed, and a graph of the distribution of hot water temperatures from the most remote water collecting device to the connection point of the DHW system...
to the heat network in the ITP was drawn up, taking into account the presence or absence of thermal insulation of pipelines in the sections according to the approved methodology [8]. The system equipment was also selected, including booster and circulation pumps, water flow meters, a storage tank, a balancing valve for linking the system.

3. Study of the features of the applied cooling system of the shopping center

The refrigerant in the cooling system is CO$_2$, which is undoubtedly a feature of such a system and makes some adjustments to the layout of the chiller.

The object under study uses a transcritical refrigeration system, in which the condenser is replaced by a gas cooler, since CO$_2$ cannot condense at a temperature above 31°C (critical temperature).

The pressure-enthalpy diagram and the cycle for CO$_2$ are shown in Figures 2 and 3.

![Axonometric scheme of the DHW system](image1)

**Figure 1.** Axonometric scheme of the DHW system.

![Pressure-enthalpy diagram for CO$_2$](image2)

**Figure 2.** Pressure-enthalpy diagram for CO$_2$. 
4. The results of the study on improving the efficiency and reliability of the heating system of the shopping center

The proposed heat recovery scheme is shown in Figure 4. The main element of this system is a coaxial heat exchanger, which is the main feature of the proposed system, installed parallel to the air condenser. It performs the function of a water condenser, in which water is heated.

With the help of electromagnetic valves, the built-in controller redistributes the refrigerant flows between the air and water condensers. During the absence of water sampling and its small size, all the refrigerant passes through an air condenser, after which all the heat is disposed of into the atmosphere. When a signal is received from the hot water temperature sensors, the chiller controller blocks the access of the refrigerant to the air condenser and all the refrigerant is redirected to the water, and the water circulating in the heat exchanger begins to heat up.

To increase the reliability of the internal heat supply system, namely the hot water supply system, it includes a combined water heater, which is also connected to the heating network and has the function of an electric water heater. Its operation is provided for preheating water if the temperature of hot water is below 65 °C when heated from the recovery system. And also in case of an accident in the recovery
system, the combined water heater will provide an uninterrupted supply of hot water to the needs of the shopping complex. [9–22]

To heat water for the needs of hot water supply by cooling CO$_2$ in the gas cooler, a spiral (coaxial) heat exchanger was designed for the following conditions:
- the initial water temperature $t_c = 5$ °C;
- the final water temperature $t_h = 65$ °C;
- the initial temperature of CO$_2$ to the gas cooler $t_{CO_2}^h = 105$ °C;
- the final temperature of CO$_2$ after the gas cooler $t_{CO_2}^k = 40$ °C.

The temperatures are taken from the «pressure-enthalpy» diagram. In the SolidWorks software package, a 3D model of the object under consideration – a spiral heat exchanger – is built.

![Diagram of heat exchanger](image)

1) Distribution of temperatures in the heat exchanger;
2) Velocity distribution in the section of the heat exchanger spirals;
3) The flow lines of the heating coolant – carbon dioxide;
4) Streamlines of the heated coolant – water.

**Figure 5.** Simulation results of a coaxial heat exchanger.

The calculation grid is constructed using a generator of polyhedral cells, as well as a generator for thin volumes. The basic mesh size for the housing, water and plates is 10 mm, the number of thin layers is 3. Prismatic layers are assigned to the walls on the side of the housing and the heating or heated medium for a more accurate calculation of heat transfer temperatures.

For the water inlet boundary, the mass flow rate is set according to the calculation $W_w = 1.01$ kg/s, as well as the initial temperature of the heated water $t_c = 5$ °C.
For the water outlet boundary, the mass flow rate \( W_w = -1.01 \text{ kg/s} \) is set, where the minus sign indicates the direction of fluid movement, and the final required water temperature for the hot water supply system \( t_w = 65^\circ \text{C} \) is also set.

For the carbon dioxide inlet boundary, the mass flow rate is set according to the calculation \( W_{\text{CO}_2} = 0.89 \text{ kg/s} \), as well as the initial temperature of the heating carbon dioxide \( t_{\text{CO}_2}^i = 105^\circ \text{C} \).

For the carbon dioxide outlet boundary, the mass flow rate \( W_{\text{CO}_2} = -0.89 \text{ kg/s} \) is set, where the «minus» sign indicates the direction of fluid movement, and the final required temperature of carbon dioxide \( t_{\text{CO}_2}^k = 40^\circ \text{C} \) is also set.

5. Conclusion

As a result of the conducted research, the use of heat from refrigeration equipment in a shopping center was evaluated in order to increase the efficiency and reliability of the heat supply system, where, along with a large number of consumers of the cooling system, there is a need for hot water. The proposed heat recovery system provides an annual savings of 3.4 million rubles based on the results of the economic calculation performed using the specifications of the equipment used. The payback period of the system is 3 months, which is negligible in modern conditions.

6. References

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