The project solution of the refrigeration machine scheme with the heat utilization of condensation

E N Neverov, I A Korotkiy, M Y Mokrushin, I A Prib, D I Goleshov
Kemerovo State University, 6 Krasnaya Street, Kemerovo, 650000, Russia

E-mail: neverov42@mail.ru

Abstract. Refrigeration machines are widely used in various industries to produce artificial cold. In the process of maintaining low temperatures, the refrigeration machine generates a lot of heat to compress a refrigerant, which is not used in the future, and during the condensation it is released into the environment in the form of water vapor. This negatively affects the environment because of increasing the concentration of greenhouse gases in the atmosphere. And the use of chlorine-containing refrigerants causes the destruction of the ozone layer. To reduce environmental damage, it is necessary to increase the energy efficiency of refrigeration machines and develop schemes that allow the use of low-grade heat, which is released during operation. In the work, a scheme of a refrigeration machine was developed, which allows utilizing the heat of condensation, using it for various consumers of thermal energy, therefore allowing to reduce emissions of harmful substances into the Earth’s atmosphere and increase technological capabilities of cooling.

1. Introduction
At present, refrigeration equipment is used in many industries, is an integral part of production. The world operates a large number of installations for the production of cold. The most widely used cold in industry and commerce, used for long-storage products, cooling different objects, making a comfortable life support. People used to use cold for their needs, but not everyone thinks that using artificial cold is harmful to the planet and is mainly manifested in the destruction of the ozone layer and the greenhouse effect.

To operate the refrigeration system refrigerant is used, which is compressed in the compressor, cooled in the condenser, it expands in the throttling device and evaporates in the evaporator. In order to obtain compressed gas encountered with selection of a large amount of heat. The gas temperature after compression in the compressor can be in wide limits and will reach 210 °C and above. This heat is usually transferred from the compressed refrigerant to the cooling medium, which is water or air. Due to heat exchange during condensation, water vapor is formed, which is released into the Earth’s atmosphere [1,2].

Also, compression requires a lot of energy, and as you know, the main method of its production is thermal power stations. In the process of obtaining energy, a lot of carbon dioxide is released on them, which increases the concentration in the atmosphere. The release of greenhouse gases into the environment, such as carbon dioxide, methane or water vapor, detains infrared radiation from the Earth, which can ultimately lead to climate change on Earth. [3,4,5].
Freons are used as refrigerants in refrigeration systems, which lead to destruction of ozone layer as it is composed of chlorine, which in the process of reaction, converts ozone into oxygen under atmospheric conditions [6].

Based on this, specialists working in the field of refrigeration technology ask questions related to the environmental situation and assist that it is necessary to be more careful about the environment, to create installations that will compliance with the standards, but not every invention can be called environmentally safe. Almost all refrigeration systems in the process of the work produce a significant amount of heat, which is often not used, but is released into the environment. However, the use of this heat has tremendous energy potential; therefore, the utilization of emitted thermal energy is the most important economic task, the solution of which is carried out in all developed countries of the world [7,8,9].

In recent years, more and more important is the development of techniques to decrease the environmental impact and the environment. The use of refrigerators with heat recovery is very important, because the use of heat recovery can reduce heat emissions into the atmosphere and turn this heat to use in other processes, which ultimately improves energy efficiency by reducing energy consumption for these needs. It is important to note that the heat recovery system can be installed not only on new installations, but also implemented on already deserted [10].

1.1. Objectives of the Study
This article proposes a scheme of a refrigeration system, which in the course of its work minimizes the negative impact on the environment. The creation of a system for the use of utilized heat for other needs at the facility is the basis of this development. Using the allocated heat, the efficiency of the refrigerating machine as a whole increases, and this also leads to a decrease in the load on the condenser of the machine, which helps to reduce the greenhouse effect by reducing excess emissions of thermal energy into the environment.

2. Materials and methods
At Kemerovo State University, a scheme compression refrigeration system was developed for the efficient utilization of the heat generated during its operation, with subsequent use for technological needs. The tasks laid down in the proposed scheme are to ensure that the heat of condensation is utilized, which will reduce the load on the condenser, transfer heat to the required distance for future use, and increase the efficiency of the chiller as a whole.

To solve these problems, to ensure heat recovery and reduce the load on the condenser, two or more intermediate heat exchangers are installed in the area between the compressor and the condenser in the circuit of the plant, depending on the technological solution in the installation. It is most preferable to use prepared water as the heat carrier, since it is economically more profitable than any other heat carrier. High potential heat is removed in the intermediate heat exchangers due to the thermodynamic properties of the media used. The heat removed by the heat carrier is used to heat pipeline water to consumers, as well as for further heating, for example, soil, snow melting pits, and process water. Improving the efficiency of the chiller is achieved by transferring part of the condensation heat in the heat exchanger to the coolant, as well as by the ability to control the condensation temperature using three-way valves, which allow one, two or both plate heat exchangers to be switched on or off from the refrigeration machine. Also, this feature allows you to use the refrigeration machine in climatic areas with different outdoor temperatures. And the possibility of cooling the coolant is achieved by installing a plate heat exchanger on the low pressure line between the throttling device and the compressor. Further, the cooled coolant is used to remove heat from ice fields or chambers located at a considerable distance from the refrigeration machine. Propylene glycol is recommended to be used as a coolant, since it is an environmentally friendly, fire- and explosion-proof solution. In order to save budget use a solution of propylene glycol and water in a percentage ratio of 40% to 60%. Depending, on the geographical location of the installation, on the maximum calculated winter temperature and the temperature of the coolant [11].
Figure 1 shows a diagram of a refrigeration machine with utilization of the heat of condensation. The refrigeration machine has a rotary-screw compressor (1), a high pressure switch KP (2), a shutdown valve Rotolock (3, 16, 19, 25), a relief valve SFV (4, 17), an oil separator (5), through which oil is separated from refrigerant, check valve SCA (6), condensation pressure regulator KVR (7), pressure regulator in the receiver KVD (8), pilot valve CVP (9), pilot-operated relief valve with pilot control ICS (10), ball valve GBC (11), plate heat exchangers (12, 23), three-way valve (13, 30), air-cooled condenser (14), non-return valve NVR (15), linear receiver (18), filter drier DCR (20), sight glass (21), temperature control valve TE (22), low pressure switch KR (24), oil temperature regulator ORV (26), oil cooler (27), oil filter (28), oil flow switch (29).

The refrigeration machine operates as follows. When the compressor motor (1) is turned on, the refrigerant is compressed, after which it is supplied to the oil separator (5), where the refrigerant vapor is separated from oil droplets that pass through the oil temperature regulator, and then enter the oil cooler (27), where they can be forced cooled by a fan installed on the oil cooler, and then enter the compressor crankcase. Forced cooling of the oil prevents it from boiling and reaching the flash point of the oil. Also, oil can pass through a temperature controller (26), and then immediately enter the compressor crankcase. And refrigerant vapors, passing through a three-way valve (13), enter the plate heat exchanger of the first stage (12), where high potential heat is removed to heat the water, and then to the second stage heat exchanger, where the average potential and remaining heat is removed for heating soil, floors and pits. In this case, the three-way valve (30) disconnects the condenser (14) from the system and the refrigerant enters immediately into the linear receiver (18). Also, heat exchangers (12) can be used separately for heating the ground, floors, snow melting pits, piped water or other needs of the enterprise. In this case, the three-way valve (30) includes a condenser (14) in the system, in which the process of complete condensation occurs. The number of heat exchangers included in the system from 0 to 2, depending on the selected mode of heat consumption and the position of three-way valves (13). Steam after heat exchangers, or passing them, enters the condenser (14), where it condenses and is supplied to the linear receiver (18), where it enters the thermostatic valve (22) through the filter dryer (20). Next, the refrigerant is throttled and fed into the plate heat exchanger (23), where the cooling medium is cooled, which cools the ice field or chambers remote from the refrigeration machine. After the plate heat exchanger (23), the refrigerant passes through the filter dryer (20), enters the compressor (1) and the cycle repeats.

3. Results and Discussion
Refrigerating machine consisting of shutdown and control valves connected in series a compressor, condenser, throttling device, an evaporator, a piping connecting between the compressor and the condenser, two heat exchangers removing heat of condensation in order to remove high-potential heat from the refrigerant. Removing the heat load from the condenser, the cooling capacity of the installation increases, and it also becomes possible to use the removed heat for other purposes (ground heating, snow melting pits, process water). Also, the refrigerating machine is equipped with the possibility to disconnect the condenser from the system by the three-way valve, which allows to minimize the thermal energy emissions. The refrigeration machine allows three-way valves to switch the heat exchangers to provide different condensation temperatures in the condenser, thereby allowing you to adjust the cooling capacity of the plant.

The refrigerating machine is equipped with a plate heat exchanger, which allows cooling the coolant in order to use it to remove heat from ice fields or chambers located at a considerable distance from the chiller.
Figure 1. The scheme of refrigeration machine with utilization of heat condensation

4. Results and Discussion

Refrigerating machine consisting of shutdown and control valves connected in series a compressor, condenser, throttling device, an evaporator, a piping connecting between the compressor and the condenser, two heat exchangers removing heat of condensation in order to remove high-potential heat from the refrigerant. Removing the heat load from the condenser, the cooling capacity of the installation increases, and it also becomes possible to use the removed heat for other purposes (ground heating, snow melting pits, process water). Also, the refrigerating machine is equipped with the possibility to disconnect the condenser from the system by the three-way valve, which allows to minimize the thermal energy emissions. The refrigeration machine allows three-way valves to switch the heat exchangers to provide different condensation temperatures in the condenser, thereby allowing you to adjust the cooling capacity of the plant.

The refrigerating machine is equipped with a plate heat exchanger, which allows cooling the coolant in order to use it to remove heat from ice fields or chambers located at a considerable distance from the chiller.
5. Conclusion
The proposed refrigeration machine provides utilization and transportation of heat to various consumers of thermal energy, which increases the energy efficiency of the refrigeration machine by removing heat from heat exchangers, and also reduces environmental pollution during operation. Also, the installation allows you to cool objects at a considerable distance from them, which helps to increase technical features or eliminates the possibility of harmful substances entering the product that is being cooled.

The refrigerating machine runs on ozone-safe refrigerant that do not contain chlorine atoms, which minimizes the potential of ODP and GWP. This plant is an environmentally safe, complies all modern requirements and standards, reduces the concentration of heat emissions and helps to minimize the destruction of the ozone layer and the greenhouse effect. And the use of non-toxic refrigerant and coolants allows not only to preserve nature and the environment, but also to preserve the quality of refrigerated products. The installation provides an object not only of artificial cold, but also allows the use of extracted heat for different technological needs of the enterprise, which leads to significant savings in general.

Acknowledgment
The main authors are very grateful to the student of the Kemerovo State University Radzhaboi Rustamov, for his help in translating the article into English.

References
[1] Shakirova G G 2015 Modern Innovations: Fundamental and Applied Research vol 1 no 1, ed S V Valtsev, A S Kotlova et al (Moskva: OOO «Olimp») pp 6-7
[2] Denisov-Vinsky N D 2011 MegaPascal 2 8-16
[3] Avdeenko O A and Lazareva L P 2009 Vologda Readings 75 5-8
[4] Belsky Y D 2012 Modern Society, Education and Science (Tambov: OOO "Consulting company Ucom") pp 16-7
[5] Lebedev S V and Penkov M V 2019 Structural Transformations of Territory Economics: in Search of Social and Economic Equilibrium T 3 ed A R Khalikov (Ufa: OOO “NIC Bulletin of Science ”) pp 136-45
[6] Israphilov D I and Mukhamatdinov I A 2017 Science Yesterday, Today, Tomorrow vol 8 no 42, ed M A Vasinovich, N V Dmitrieva et al (Novosibirsk: ANS «SibAk») pp 58-62
[7] Buchin S and Smagin S 2010 Climate World 62 74-7
[8] Neverov E N, Korotkiy I A, Raschepkin A N and Ibragimov M I 2020 Bulletin of the International Academy of Refrigeration 1(74) pp 22-6
[9] Neverov E N, Korotkiy I A and Korotkaya E V 2019 IOP Conf. Series: Earth and Environmental Science 395(1) 012066
[10] Neverov E N, Korotkiy I A, Korotkih P S, Lifenceva L V et al 2019 IOP Conf. Series: Earth Environ. Science 224 012039
[11] Baranenko A V, Bukharin N N, Pekarev V I, Sakun I A and Timofeevsky L S 1997 Refrigeration Machines (St. Petersburg: Polytechnic) p 499