Turboexpander-refrigerant to reproduce arctic weather

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Abstract. This paper describes a schematic diagram of an air cooler created on the basis of a turboexpander, presents its functioning principle and scopes of application in research and industry. The developed model of an air chiller allows cooling the air in the temperature range of minus 40÷140 °C. The air chiller has software control over time. The developed apparatus is proposed to use as a cooler to simulate the atmosphere of the Arctic in a research laboratory.

1. Introduction
Under the approved state program the planned amount of money allocated for the development of the Arctic until 2025 is more than 190 billion rubles. The second stage of the program (2018-2020) provides for the development and installation of a significant amount of equipment, mainly Russian-made in the Arctic zones. The third stage of the state program is aimed to create a leading scientific and technical reserve and technologies, including for the development of the shelf of the Arctic seas.

The conditions of the Arctic, where the temperature can reach minus 70 °C, require a specific infrastructure. Materials, products, mechanisms created for the Arctic zone require special manufacturing. The design of the equipment demands a prerequisite engineering test in the chambers with temperatures up to minus 70 °C. Test methods should provide the ability to quickly change the temperature of the cooled samples according to a given law.

To provide the temperature tests the special climate chambers are used, which adapt multistage vapor compression machines as cooling devices. Steam compression machines have a high cost and low reliability. The steam compressors has the limit of the working temperature of minus 75 °C. The machines have a complex control system, require highly qualified after-sales service, whilst requirements for test climate chambers are reliability, economical operation and simplicity of operation.

2. Results
This paper describes a successful actual experience with a unique new solution for “heat-cold” climate chambers. The cooling unit was created to automatically perform a thermostat control of several volumes at a temperature of minus 80°C. The unit equipped with the thermal regulator can vary the temperature according to a given law. It is possible to create temperature conditions in the range of cryogenic temperatures (up to minus 180°C).

The schematic diagram of the installation is shown in Fig. 1. The principle of adiabatic expansion of the air in a turboexpander device with the removal of the external work to an oil heat exchanger is used to generate cold in the chamber. Compressed air serves as the drive unit and the working medium of the refrigeration cycle.
Figure 1. Schematic diagram of the air cooling device

Firstly the compressed air at the temperature of 20°C and dried to the dew point of minus 70°C enters a recuperative heat exchanger $I$, where it is cooled to the temperature of minus 40°C by the exhaust air from the consumer. Then the air comes into the turboexpander $2$ and expands to the temperature of minus 100°C. Finally the air cools consumers and then the direct flow to heat exchanger $1$. The expansion work is removed by the oil brake $3$, where the oil is heated. The heated oil is cooled in the heat exchanger $4$ and returns to the oil system $5$.

The cooling device can either be placed in a climate chamber or located at a distance from it. The cooling device is designed to transfer chilled air at a slight overpressure. This eliminates the use of heat exchangers and ventilation inside the chamber. The drive of the installation and the working medium is compressed air at a pressure of 0.6 MPa. It is possible to additionally use the exhaust air for conditioning and drying the room. The module is completely autonomous and equipped with a control system.

Six air refrigerating machines (BXM) were manufactured for the company of the Tomsk region JSC Siberian Chemical Combine. They have been in operation since 2014 and have shown high reliability and simplicity of operation.

The copyright of the BXM and the technologies used in the machine are protected by several Russian patents. The patent holder is Tomsk State University (TSU), LLC “APA-KANDT SIBERIA”. LLC “APA-KANDT SIBERIA” and TSU concluded a partnership agreement on the use of intellectual property to manufacture the industrial designs.

Information on the BXM and its using is published in the papers [1-3]. We have registered the patents on the industrial design [4, 5]. During the introduction of the BXM, the related tasks have been solved. We have developed an air purifier for the turboexpander refrigeration machine and registered the patent [6]. Copyright certificates have been received for the turboexpander cooler control system and the calculation program of the cooling facility [7, 8]. We have also registered the patent on the cooling method using the BXM [9].

Information confirming the technical capabilities of the turboexpander cooler has been published in the scientific journal [3]. In addition to experiments with the target substance, the data on the cooling unit itself were processed. Five years of operating experience in a wide range of temperatures and loads showed additional advantages of the turbo-expander cooling method. We have also collected and
analyzed data from 12 objects have being cooled by the BXM working on various “heating-cooling” algorithms.

It should be noted the flexibility of the BXM. The unique capabilities of the machine have been used to conduct a number of scientific researches. The studies have been carried out at cryogenic temperatures (up to minus 180 °C). Experimental data have been obtained on the saturated anhydrous HF pressure dependence on temperature in the range from 77 K to 213 K. Based on the data we have formulated the equation of the pressure-temperature dependence for the saturated vapor HF, which is valid in the range from 140 K to 190 K [3]. We have also investigated the conditions of an effective removal process of HF from a gas medium in a dynamic mode in the presence of non-condensable gases.

Investigations on the gas-dynamic processes of the chilled air flow in the pipeline system and heat exchange with the walls of the tank make it possible to calculate the cooling characteristics of the given objects with high accuracy. Successful actual experience of the cooling project at cryogenic temperatures, as well as positive operating experience have shown the high advantages of the new cooling unit. In spite of the low refrigeration coefficient of the BXM at the temperature of minus 70°C (about 0.9) in comparison to the vapor compression units with a refrigeration coefficient of 1.5—2, the first one has advantages. The maintenance costs are minimal, the unit provides savings in electrical energy due to the appropriate adjustment of the cold air temperature, the periodic maintenance of the BXM consists in heating the regenerative heat exchanger once a year during the routine maintenance equal to 4 hours.

3. Conclusions
Experience in solving various technical problems using the BXM-0.5/6 has shown the prospect of applying the unit as a cooler to simulate the atmosphere of the Arctic in a research laboratory or quality testing laboratory, and enterprise.

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