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# Development Of A Device For Softening The Circulating Water Of The Cooling System Of Stationary Mine Compressor Units

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## ABSTRACT

The operation of mine compressors in the mining industry is one of the energy-consuming processes that require resource saving. In the balance of mining enterprises, the specific weight of compressor equipment that produces compressed air as pneumatic energy is 20-35% and its further improvement affects the indicators of subsequent technological processes. The widespread use of compressed air requires the need to reduce operating costs by developing effective technical solutions in the process of producing compressed air at industrial enterprises and increasing the energy efficiency of operating compressor units.

To date, a number of significant shortcomings of the cooling system caused by the peculiarities of the principle of their operation have been identified throughout the world during the operation of mine compressor units. Thus, the undercooling of air in reciprocating compressors for every 5-6°C increases the energy consumption for air compression by 1%, and the productivity decreases by 8-10%, which leads to significant economic losses in the production of compressed air.

In this regard, there is a need to study the influence of the quality of compressed air cooling on the efficiency of the compressor unit, to develop scientific foundations for improving the efficiency of mine compressor units by improving their cooling system, to develop a device for softening make-up water.

## KEYWORDS

Compressor, cooling system, temperature, compressed air, heat transfer, cooling tower, intercooler, power consumption, air heating, supply coefficient, air cooler, scale in coolers, water softening, coal sorbent.

## INTRODUCTION

As the performed analytical studies of the operational efficiency of reciprocating mine compressor units show, most of the compressor units operated at mining enterprises operate with low productivity compared to the one stated in the technical passport and high specific electricity consumption. A decrease in the productivity of mine compressor units and leaks in the network lead to a decrease in the pressure of compressed air, as a result of which the actual power of pneumatic energy consumers is reduced by 25-45% compared to the nominal one.

The performance of the compressor cooling system is most affected by the performance of the compressor cooling system to reduce productivity and increase the specific energy costs of mine compressor units.

Significant disadvantages of cooling systems of mine compressor units are due to the peculiarities of their operation, in particular, increased dustiness of atmospheric air entering the compressor, increased water hardness, the length of main pipeline networks, as a result, special requirements are imposed on the operation of the cooling system of mine compressor units. In addition, due to the lack of clean fresh water, the cooling system uses water with a high content of salts and various impurities, which worsens the operation of intermediate and end refrigerators.

Improving the efficiency of the cooling system of mine compressor units is possible due to the development of effective methods for preventing the formation of deposits on the heat exchange surfaces of intermediate and end refrigerators.

In cooling towers, part of the cooling water is lost due to drip entrainment and evaporation, in some cases, water losses, compensated by make-up (additional) water, amount to 20-30% during one day.

As a result of the operation of the recycling system, the evaporation of part of the water, as well as the constant addition of make-up water, a gradual increase in the concentration of salts dissolved in water occurs. One of the optimal solutions to prevent the formation of scale on the surfaces of the heat exchangers of compressor units is the initial use of filtered water as circulating water, but at the same time there is a need for constant filtration of the added make-up water.

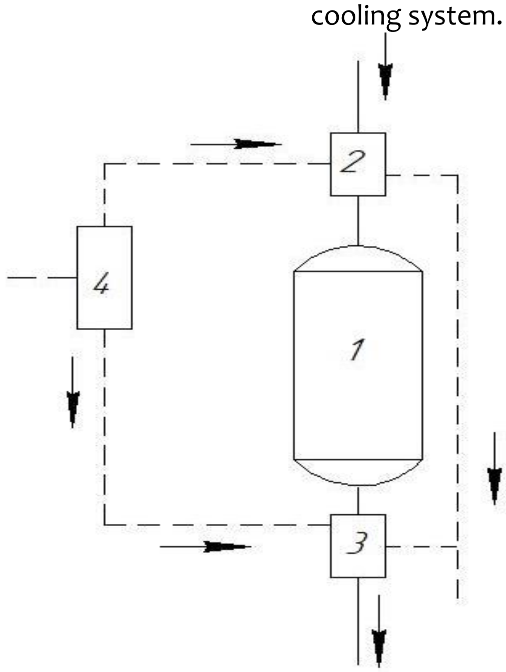
## MATERIALS AND METHODS

In order to effectively filter the added make-up water into the cooling system, a device for softening the make-up water of the cooling system of compressor units has been developed. The basis of this device is a filter containing the filter material shown in Fig.1. It is recommended to use bentonite-carbon sorbent as a filter material, which can be regenerated repeatedly (up to 7-8 times). After regeneration, the carbon sorbent does not lose its original properties.

**Fig. 1. Granulated bentonite-coal sorbent**

During the experimental testing of the developed filter, it was revealed that the efficiency of water purification is higher at high temperatures of the filtered water. Therefore, at the inlet to the filter, the water is heated in the water heater and at the outlet of the filter, the water is cooled back, in this regard, a heat exchanger is used as a heater and cooler.

Figure 2 shows a general view of the make-up water softening device of the compressor unit cooling system.




1 – a filter containing a carbon sorbent; 2 – water heater;
3 – water cooler; 4 – vortex tube

**Fig. 2. Make-up water softening device**

Heating and cooling of make-up water requires significant energy costs, therefore, to reduce energy losses, heating and cooling of water is carried out by a vortex pipe, the principle of operation of which is based on the effect of vortex temperature separation of air.

The principle of operation of the vortex tube is based on the Wound effect. The compressed air passing through the vortex tube is divided into streams of hot and cold air. The hot air flow from the hot end of the vortex pipe is fed to the water heater, and the cold air flow from

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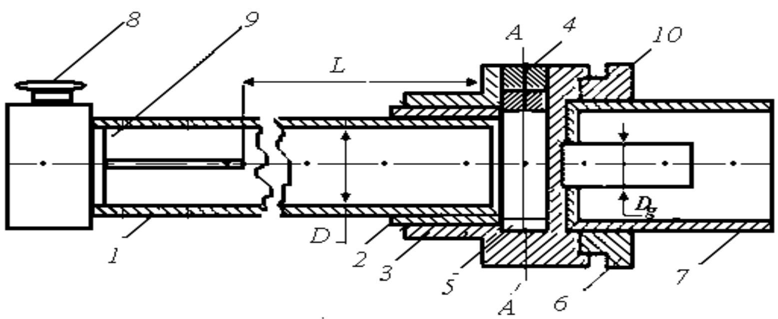
the cold end of the vortex pipe is fed to the water cooler. The compressed air coming out of the cooler and the water heater is mixed and fed into the pipeline through which the compressed air is supplied to consumers.

The distinctive features of the vortex tube are the absence of moving parts and small dimensions. Figure 3 shows a general view of the vortex tube.

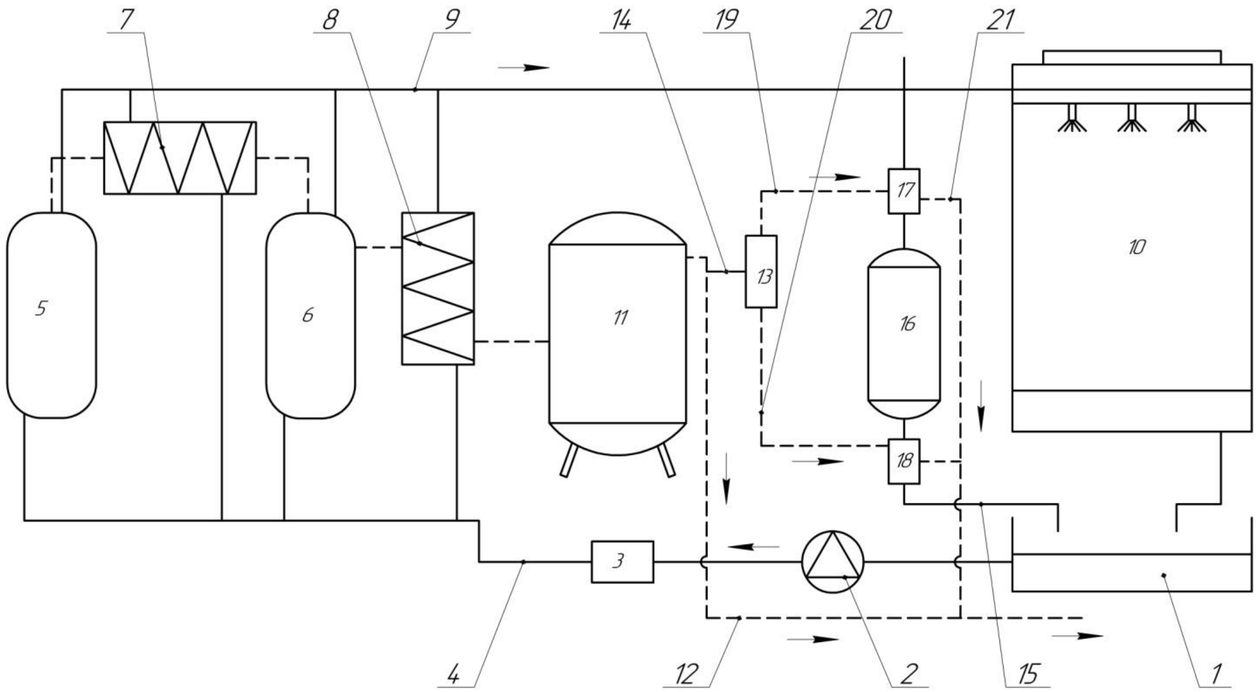
In the annular cavity of the body 3 of the vortex tube, a tangential rectangular channel with a height h and a width b is propylene. The flanged tube 1 with a diameter D is installed in the annular cavity of the housing. The snail 4 forms a nozzle inlet, a generator with a hole Dg of the cold fraction 5 and a sealing gasket 10, pressed with a nut 6, are installed in the same cavity of the housing, at a distance L from the snail, a four-bladed crosspiece 9 and a throttle 8 are tightly installed at the opposite end of the tube 1.




1 – flanged tube, 2 – nut, 3 – housing, 4 – snail, 5 – cold fraction generator at the cold outlet, 6 – nut, 7 – tube, 8 – throttle, 9 – crosspiece, 10 – gasket

**Fig. 3. The design of the vortex tube**

Figure 4 shows a general view of the cooling system of compressor units when a make-up water softening device is installed in it. The cooling system of mine compressors after the installation of the make-up water softening device will work as follows (Fig. 4). When the cooling system is operating, the circulating cooling water from the sump 1 is fed by a pump 2 through the pipeline 4 to the intermediate heat exchanger 7, the end heat exchanger 8, also to the first stage of the compressor 5 and the second stage of the compressor 6, before the water is fed through the electromagnetic treatment device. The water, cooling the compressor stages and heat exchangers, is heated and fed through the pipeline 9 to the cooling tower 10 for its subsequent cooling. In the cooling tower 10, the heated water is cooled and discharged to the sump 1 and then the whole process is repeated. Some of the water in the cooling process in the cooling tower 10 evaporates and is lost in volume. To compensate for the lost volume of cooling water, the sump is fed.




1-sump; 2-pump; 3-electromagnetic water treatment device; 4 – cooling water pipeline; 5 – the first stage of the compressor; 6 – the second stage of the compressor; 7-an intermediate refrigerator; 8-end refrigerator; 9-heated water pipeline; 10-cooling tower; 11-compressor receiver; 12-pipeline for supplying compressed air to the consumer; 13-vortex pipe; 14-pipeline; 15-make-up water pipeline; 16-filter; 17-water heater; 18-water cooler, 19-hot air flow pipeline; 20-cold air flow pipeline; 21-pipeline

**Fig. 4. General schematic view of the cooling system of compressor units after installing a make-up water softening device in it**

In order to purify the make-up water from various impurities and hardness salts, a filter 16 containing a carbon sorbent is installed on the make-up water pipeline 15. The make-up water, before being fed to the sump, is heated in the heater 17, then softened in the filter 16, at the exit from the filter it is cooled in the cooler 18.

Heating and cooling of the make-up water at the inlet and outlet of the filter is carried out due to the hot and cold air flow received from the vortex pipe. Compressed air from the receiver 11 is fed to the pipeline 12 to supply compressed air to the consumer, one part of the compressed air from the pipeline 12 is fed through the pipeline 14 to the vortex pipe 13. The compressed air, after passing through the vortex tube 13, is divided into a hot stream traveling through the pipe 19 to the heater 17, and a cold stream traveling through the pipe 20 to the cooler 18. The streams of hot and cold air, leaving the heater 17 and the cooler 18, mixing through the pipeline 21, are fed into the pipeline 12 and then sent to the consumer.

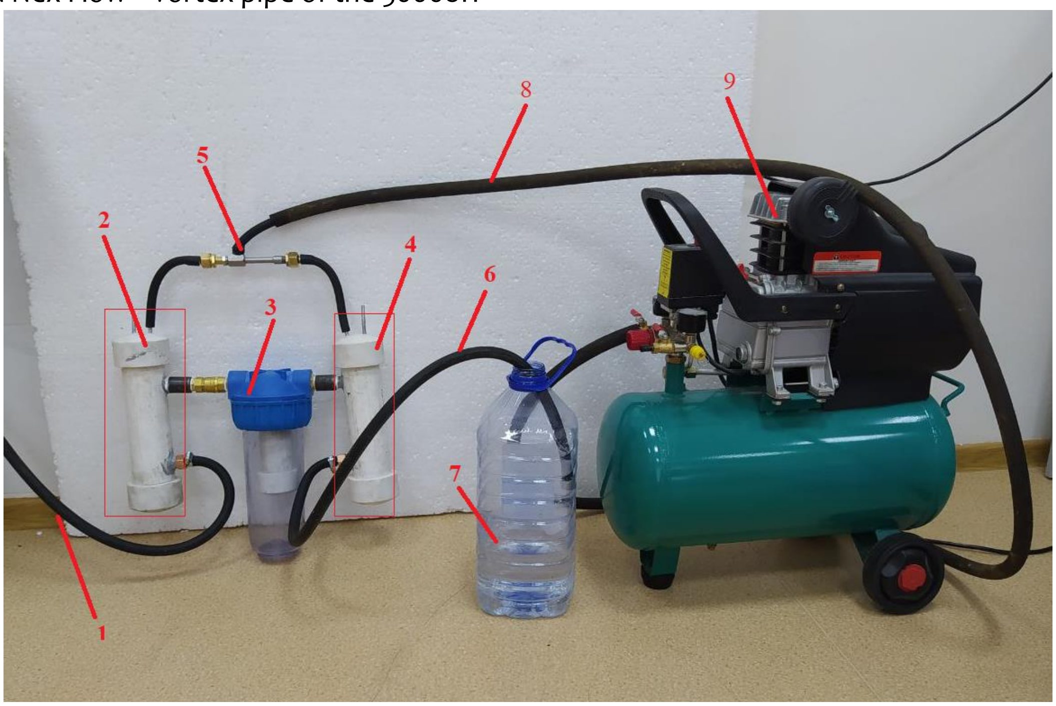
The proposed device for softening the make-up water of the cooling system of compressor units makes it possible to purify the water cooling the compressor from salts and various impurities, thereby preventing the formation of scale on the heat exchange surfaces, which increases the efficiency of operation of compressor units.

## THE MAIN PART

In order to determine the effectiveness of the developed device for softening the make-up water of the cooling systems of compressor units, experimental tests were conducted.

The following devices and aggregates were used to conduct the experimental study: a compressor, a developed device for softening water, a Nex Flow™ vortex pipe of the 50008H brand, connecting hoses, a sampling container, an IRT – 4 thermometer and a water hardness meter Colorimeter DR 900.

A photo of the experimental setup is shown in Fig. 5.




1 – water supply hose; 2-water heater; 3-filter containing bentonite-carbon sorbent; 4-water cooler; 5-vortex pipe; 6-purified water supply hose; 7-sample container; 8 – compressed air supply hose; 9-compressor

**Fig. 5. Photo of the experimental setup**

A heater 2 is connected to the water softening device 3 on one side, and on the other side a water cooler connected by a hose 6 to a water sampling tank. The heater 2 and the cooler 4 are made in the form of a heat exchanger, the hot end of the vortex pipe 5 is connected to the heater 2 from above, the cold end of the vortex pipe is connected to the cooler from above, the vortex pipe is connected to the compressor 9 by means of a hose 8.

The experimental work was carried out as follows: the softened water was fed through the hose 1 to the heater 2, acquiring a certain temperature in the heater, it entered the filter 3, leaving the filter, the water passes the cooler 4, where its temperature decreases and is diverted to the tank 7 by means of the hose 6. The temperature conditions of the vortex tube were regulated by changing the pressure of compressed air coming from the compressor.

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The experimental work was carried out several times with different water temperatures(28, 30, 35, 40, 45, 50, 55 and 60 °C).

The results of the experimental studies of softened water samples are shown in Table 1.

**Table 1.**
**Results of experimental tests**

| Test № | t, °C | Overall stiffness, mg/l | Ca, mg/l | Mg, mg/l |
|---|---|---|---|---|
| №1 (the original) | 28 | 0,21 | 0,07 | 0,14 |
| №2 | 30 | 0,1 | 0,03 | 0,07 |
| №3 | 35 | 0,09 | 0,027 | 0,063 |
| №4 | 40 | 0,05 | 0,015 | 0,035 |
| №5 | 45 | 0,04 | 0,012 | 0,028 |
| №6 | 50 | 0,02 | 0,006 | 0,014 |
| №7 | 55 | 0,019 | 0,005 | 0,014 |
| №8 | 60 | 0,018 | 0,005 | 0,013 |

Based on the results of experimental studies of the developed make-up water softening device, the dependence of the decrease in the total hardness of the softened water on its temperature is established.

Figure 7 shows the dependence of the decrease in the total hardness of the softened water on its temperature.

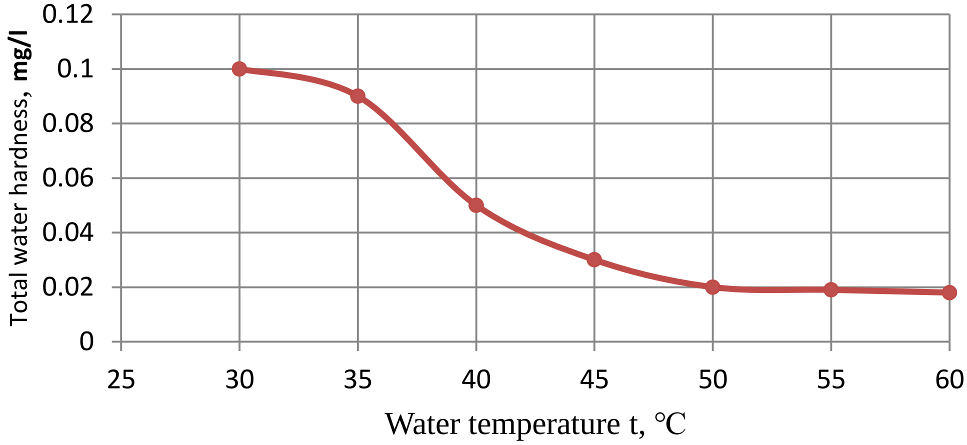


**Fig. 7. The dependence of the change in t he total hardness of the softened water on its temperature**

The results of experimental studies shown graphically in fig. 7 show that the greatest efficiency of water softening is achieved at water temperatures of 50-60°C.

When softening water with a total hardness of 0.21 mg / l, and a temperature of 30°C, at the outlet of the filter, the total hardness of the softened water was 0.1 mg/l. With an increase in the water temperature, a decrease in hardness was observed and with an increase in the water temperature to 50°C, the total water hardness at the outlet of the make-up water softening device decreased to 0.02 mg/l.

## CONCLUSION

Effective filtration of the added make-up water into the cooling system is possible in the developed device for softening the make-up water of the cooling system of compressor units. The basis of the make-up water softening device is a filter containing a bentonite-carbon sorbent made from inexpensive local raw materials, which can be regenerated several times. After regeneration, the carbon sorbent does not lose its original properties.

Based on the performed studies, the dependence of the change in the total hardness of water on its temperature in the developed device for softening the recycled water of the cooling system of compressor units is established, the efficiency of water purification in the developed device is achieved at water temperatures above 50°C, while the total hardness is reduced by 93%.

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