The design of the small-sized apparatus of cooling circulating water

K E Bondar, D F Suleymanov and S V Laponov
Ufa State Petroleum Technological University, Branch in the Sterlitamak, Sterlitamak, 2, Oktyabrya Avenue, 453118, Republic of Bashkortostan, Russia

E-mail: kristina88_08@mail.ru

Abstract. The article reviews the information on cooling the circulating water in tower coolers. It is shown that the use of local re-cooling systems is the most relevant (small-sized devices) as they do not demand any expensive operation of extended pipeline networks, minimize emissions in the atmosphere. The designs of small-sized coolers and contact devices are also presented in this article. Currently, the used counterflow coolers have some drawbacks. The article proposes a cooling tower with a mixed current. A part of the air goes along the screw, and a part goes up helping to increase heat and mass transfer. Experiments were conducted and a comparative graph of the ratio of relative change in temperature of return water of the air flow rate was made to design the minicooler with a screw air flow in comparison with counterflow coolers. For the studied small-sized coolers in the range of ascending air flow rates up to 0.7 m/s, the relative temperature drop of the water is kept approximately in the same ratio. In the range of air flow velocities from 0.8 to 2.4 m/s, the increase in the value of the relative temperature drop of the water is more intense in the minicooler with a screw air flow in comparison with counterflow coolers. For example, at an air velocity of 1.4 m/s, the temperature difference for a minicooler with a screw air flow is 0.27. At the same time, in the specified value of the air flow velocity, the relative temperature of the water in the countercurrent minicooler is 0.24.

1. Introduction
In application of the reverse water supply in production, the quality of products depends on the quality and temperature of cooling water. At real plants, the water supply preparation of reverse waters is carried out on separate constructions of water treatment [1].

Water reverse cycles consist of a complex of the connected constructions – pumps, capacities, installations for improvement and water purification, coolers and network of pipelines. Coolers are used for cooling the cooling water moving in the closed cooling system contour. In a big variety of designs, the fan cooling tower is considered one of more effective and economic for cooling of water in the water reverse systems of the chemical companies.

But these coolers are subject to strict requirements, characterized by the specificity of their use. First of all, they must be highly reliable in order to ensure the continuous operation of the entire system. In turn, it is important that the sprinklers are characterized by high performance. In addition, it is necessary that the coolers should be the most durable - their replacement in some cases may be associated with some difficulties.
2. Materials and methods
The small-sized device with screw airflow is more effective due to increase in time of contact of the interacting phases by lengthening of a way of a part of the cooling air flow moving on the screw line. Increase in phase contact time allows for increasing the water cooling depth. During the air flow, a part of air follows the line of least resistance, i.e. the screw line, and another stream – a countercurrent to water [2-5].

Development of new designs of the coolers allowing one to transfer the enterprises to local cooling systems of water (minicooler) which are more mobile is relevant for concrete process units or devices, less power-intensive, effective, ecologically safe. Transition to local cooling systems excludes need for expensive operation of extended networks of pipelines, minimizes emissions in the atmosphere [6].

3. The study
The screw minicooler (Figure 1) works as follows: in water distribution system 7 the water heated in technological process of the closed system contour is brought. It evenly passes on the sprinkler (Figure 2) on which square heat and mass transfer exchange of a water and air screw flow which is created by fan 2 proceeds. Water flows down on the sprinkler laid on a partition 4 on which it is cooled in by drop infusion – the film mode. Then it comes to water-collecting tank 5. Water is caught on water catchers 8.

![Figure 1](image-url)  
**Figure 1.** The small-sized cooler with a screw air flow: 1 – case, 2 – fan, 3 – tangential branch pipe, 4 – partition, 5 – water-collecting tank, 6 – output branch pipe for water, 7 – water distribution system, 8 – water catchers, 9 – output branch pipes for air.
Experiments were conducted and we built a comparative graph of the ratio of relative change in temperature of return water of the air flow rate to design minicooler with a screw air flow in comparison with counter flow coolers.

The relative temperature difference of the circulating water was determined by the formula:

$$\eta = \frac{t_{\text{in}} - t_{\text{out}}}{t_{\text{in}}}.$$  \hspace{1cm} (1)

The analysis of the obtained dependences as a result of the research allows us to draw the following conclusions:

- for the studied small-sized coolers in the range of ascending air flow rates up to 0.7 m/s, the relative temperature drop of the water is kept approximately in the same ratio;
- in the range of air flow velocities from 0.8 to 2.4 m/s, the increase in the value of the relative temperature drop of the water occurs more intensively in the mini-tower with a screw flow than in the

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**Figure 2.** Screw sprinkler.

**Figure 3.** Dependence of the relative temperature difference of the circulating water on the air flow rate: ▲ – counterflow minicooler; ○ – minicooler with a screw air flow.
counterflow one. For example, at an air velocity of 1.4 m/s, the temperature difference for a small cooler with a screw flow is 0.27. At the same time, in the specified value of the air flow velocity, the relative temperature of the water in the countercurrent mini-tower is 0.24;

- with the further increase in the air flow rate, the efficiency of the screw mini cooler becomes even more noticeable.

The main advantage of the tubular minicooler (Figure 4) is universality (block execution of basic elements) and the small occupied space.

![Figure 4. Tubular small-sized device: 1 – pump for water supply, 2 – water distribution section, 3 – sprinklers, 4 – water catchers, 5 – water catcher section, 6 – fan, 7 – air delivery section, 8 – pump for water pumping, 9 – water taking away section.](image)

This device works as follows: heated water in the technological process, by means of the pump 1 of a water reverse system, comes to water distribution section 2 in which it is evenly distributed on sprinkler 3 (Figure 5). On the surface of the sprinkler, heatmass exchange of the water and air flow forced by fan 6 is carried out [7, 8]. Water, passing through the sprinkler, is cooled by drop infusion – the film mode – and it flows down in water-collecting section 9. In the top part there is water catch section 5 in which there is a catching of drops of liquid on water catchers 4.
The sprinkler and water catcher of the cooler: 1 – pipes with cellular walls, 2 – the radius of the bend, 3 – welded face ends of pipes.

The most widespread type of the sprinkler installed in coolers of chemical industry is drop and film [3]. The sprinkler of the cooler works as follows. During the operation of the cooler, the cooled cooling water is pumped on the sprinkler. The sprinkler, being the contact device, promotes a uniform drop and film current on a surface of mesh cellular pipes of 1 cooling water. At the same time there is an interaction of the cooling ascending air flow with cooling water accompanied by a decrease in temperature of the latter.

The efficiency of this sprinkler is caused by the fact that polymeric mesh cellular pipes are made bent and welded in places of contact of the face ends because the probability of a free skip of a drop stream of liquid in space without contact with the surface of the sprinkler is excluded and design durability increases.

4. Conclusion
The advantages of the screw minicooler are the increase in the contact time of the interacting phases due to the lengthening a way of a part of the cooling air flow moving on the screw line.

The advantages of the tubular cooler are small overall dimensions, a possibility to increase the number of blocks. A block design makes it possible to adapt to any loading and air temperature.

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