Investigation of possibility to use industrial high pressure fan as steam compressor for distillation desalination plant

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Abstract. Utilization of steam compressor as a drive for distillation desalination plant requires creation either high-frequency working wheel or working wheel with high diameter. However, there may be a possibility to use an industrial high-pressure fan as a steam compressor. This article deals with this investigation of this possibility.

1. Introduction
Distillation or thermal desalination is most distributed way to obtain freshwater from seawater [1-3]. As it is known, seawater is a solution which consists of water which is volatile solvent and salts – non-volatile solid material which is solved in water. Distillation is seawater evaporation with its vapour further condensation. Typical distillation plant with mechanical vapour compression (MVC) [4] consists of stages of evaporator-condenser, heat exchangers of preliminary heating, steam compressor which drives the plant and vacuum system. In evaporator-condenser and heat exchangers of preliminary heating geometric characteristics influence heat exchange area and intensity of the heat transfer from condensate to brine. In steam compressor geometric characteristics (firstly, external diameter) influence flow velocity which in turn influence compression work and compression ratio. On practice that means that increase of the diameter allow to decrease rotation frequency at the same compression ratio and vice versa.

Due to these problems, a suggestion appears to use one of the available industrial fans which can be suited for required conditions as a drive for the plant instead of steam compressor. Considering relative ease of acquiring and low cost, such solution can be appealing. However, all available industrial fans are designed to operate in atmospheric conditions. In this case, it is necessary to check how typical characteristics of the fan will change during its operation on steam.

Radial fan BP-132-30 of the “Acvent” company was selected for investigation. External view of the fan is presented on figure 1 and its characteristics during operation on atmospheric conditions are presented on figure 2.

2. Analysis
Next analysis was applied to discover how industrial fan characteristics will change during its transition from atmospheric air to steam with the same rotor rotation frequency.

Initial data for analysis is presented in table 1.
Figure 1. Radial fan BP 132-300.

Figure 2. Characteristics of the radial fan BP 132-30 according to manufacturer.
Table 1. Initial data for analysis.

| Parameter                          | Value  |
|-----------------------------------|--------|
| Inlet pressure $p_1$, Pa          | 28000  |
| Inlet temperature, K              | 341    |
| Compression ratio                 | 1.07   |
| Steam inlet mass flow rate, kg/s  | 0.5    |

Maintaining initial dimensions and fan rotation frequency means keeping peripheral velocity and flow turning angle in blades $\Delta c_u$ constant. This according to Eulerian equation

$$L = u \cdot \Delta c_u, L = u \cdot \Delta c_u,$$

means constant specific work, applied to flow in working wheel.

From the other side, equality of volumetric flow rates with the same geometry of the flow area means equality of the flow axial velocity. Permanency of the flow exit angle (it depends on flow streamlines and presence of the guide vanes), axial and peripheral velocities causes the fact that fan velocity diagram during its operation on air and steam (as well as other working fluids) will be the same. I.e. fan operation regimes during operation on different working fluids with the same volumetric flow rates will be similar. This causes similarity of the applied work and blade flowing velocity. Thus, at the same volumetric flow rates compression ratio and loss level (COP) are kept as at operation at air. Some quantitative difference in COP value and compression ratio is possible which is caused by different viscosity of different working fluids and, consequently, change of the Reynolds number [6,7].

Transition from one working fluid on another causes change of the density which in turn causes change of the mass flow rate and power consumption by fan. Particularly, transition from atmospheric air to steam with aforementioned parameters causes decrease of the mass flow rate and consumed power in a factor of 5.

Thus, transition from the one working fluid to another does not significantly influence COP and head-capacity curve of the industrial fan (small correction is possible due to change of the COP caused by different viscosity and change of Reynolds number). Power characteristics of the fan will change corresponding to the change of the working fluid density.

Comparison of the power characteristics of radial fan BP 132-30 during its operation on atmospheric air and steam with aforementioned parameters is presented on figure 3.

![Figure 3. Power characteristics of the BP 132-30 fan during its operation in standard atmosphere and inside the distillation plant](image-url)
3. Conclusions
Performed analysis showed that it is possible to utilize industrial fans as a drive of the distillation plant instead of steam compressor. During its operation together with distillation plant with its typical pressures below atmospheric one it will be necessary to use blade ring (of both rotor and stator) of industrial fan and reproduce other elements of the flow area to keep level of hydraulic losses.

Acknowledgments
This work was carried out by lead performer of research and development effort with financial support of Russian Federation Ministry of Science and Education with the realization of Government decree №218 according to contract about providing and using subsidy № 02.G25.31.0150 from 01.12.2015.

References
[1] Maghsoudi K, Aliasghari M and Mehrpanahi A 2016 Desalination and Water Treatment 57(38), 17707–21
[2] Alasfour F N, Darwish M A and Bin Amer A O 2005 Desalination 174(1) 39–61
[3] Zimerman Z 1994 Desalination 96 51–8
[4] Darwish M A, Jawad M A and Aly G S 1990 Desalination 78(3) 313–26
[5] http://akvent.ru/catalog/ventilyatoryi-i-otoplenie/ventilyatoryi-radialnyie/vr-132-30.html
[6] Marchukov E, Egorov I, Popov G, Baturin O, Goriachkin E, Novikova Y and Kolmakova D 2017 IOP Conference Series: Materials Science and Engineering 232(1)
[7] Popov G M, Baturin O V, Goriachkin E S, Novikova Y D and Kolmakova D A 2017 Journal of Physics: Conference Series 803(1)