Enhancement of the Operation Efficiency of the Transport Air Conditioning System

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Abstract. On analyzing the operation of air coolers of railway air conditioning (AC) systems, characterized by considerable variations in current heat loads according to actual climatic conditions on the route lines, the reserves to increase its efficiency by the intensification of refrigerant evaporation in air coils and to enlarge the range of deviation of refrigerant flows from their optimum values without noticeable decreasing heat flux were revealed. It has been proved that overfilling the air cooler coils by liquid refrigerant injector recirculation enables excluding the final dry-out stage of refrigerant evaporation with extremely low intensity of heat transfer and as result provides increasing the heat efficiency of air coolers (overall heat flux) by 20–30% compared with conventional air coolers with complete refrigerant evaporation and superheated vapor at the exit. Moreover, a larger deviation of current heat load on railway route lines is permitted without considerable falling air cooler heat efficiency due to refrigerant injector recirculation at available many circulations. The method to determine the rational design heat load on air coolers of railway AC systems, providing closed to maximum refrigeration output generation over the considered period, was developed.

Keywords: Railway air conditioner · Changeable heat load · Liquid refrigerant recirculation

1 Introduction

The performance of railway AC systems is characterized by considerable variations in current heat loads on their air coolers according to actual climatic conditions on the route line. So, the problem is to determine the rational design heat load on air coolers of railway conditioners, providing closed to maximum refrigeration output generation over the considered period, and develop the system of refrigerant circulation in air coolers enabling a large deviation of current heat loads from their rational design value without considerable falling air cooler heat efficiency.

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The system of refrigerant circulation in air coolers by an injector that enables excluding the final dry-out stage of refrigerant evaporation with extremely low intensity of heat transfer and as result provides increasing the heat efficiency of air coolers (overall heat flux) by 20–30% compared with conventional air coolers with complete refrigerant evaporation and superheated vapor at the exit was proposed. The injector uses the potential energy of high-pressure liquid refrigerant, leaving a condenser, which is conventionally lost while it throttling to evaporation pressure in an expansion valve.

2 Literature Review

Many researches deal with improving the performance of AC systems by the intensification of heat transfer processes in evaporators [1, 2] and condensers [3], application of various refrigerant circulation contours: refrigerant flow variation [4] within part load [5] and intermittent [6] runnings, traditional [7, 8] and advanced [9] vapour ejector circulation and their two-stage combination with absorption chiller [10, 11], waste heat recovery absorption [12, 13] and thermopressor with liquid injection [14, 15] technics.

As the modern trend in AC systems, the application of Variable Refrigerant Flow (VRF) system is considered to modulate heat load by varying refrigerant feed to air coolers [16, 17]. The VRF system maintains the zone comfort by supplying an adequate amount of refrigerant to air coils to meet cooling duties. The performance evaluations showed that the VRF system reduced energy consumption by 40% to 60% compared to that of central AC systems [18]. In majority VRF investigation, the accent is made on ambient air processing in air coolers [19, 20] greatly influenced by current changeable loading. The problem of inefficient operation of air coolers caused by dry-out of inner walls at the final stage of inside tube refrigerant evaporation followed by dropping the intensity of heat transfer remains unsolved.

As the alternative approach of the heat load modulation in AC systems, the concept of incomplete refrigerant evaporation [21, 22] with overfilling air coils leads to excluding a dry-out of the inner surface of air coils is developed through liquid refrigerant recirculation by the injector (jet pump).

Considerable changes in the current heat loads q_0 on the air cooler need choosing its rational design value, providing maximum annual effect due to engine inlet air cooling [23] or maximum refrigeration output generation AC systems [24, 25].

The study is aimed at the development of the method to determine the rational design of heat load on the air coolers of railway AC systems, providing closed to maximum refrigeration capacity generation, and the system of refrigerant circulation in air coolers, that allows a considerable deviation of refrigerant flow from the optimum value, corresponding the maximum heat flux, without considerable reduction of heat flux, under changeable actual heat loads during railway routs.

3 Research Methodology

The operation of railway AC systems is characterized by considerable changes in the current heat loads Q_0 on the route lines and in corresponding specific heat loads i.e. specific cooling capacity related to the unit of air mass flow:

$$q_0 = Q_0/G_a, \tag{1}$$

where G_a is – ambient air mass flow in an air cooler, kg/s.

The specific cooling capacity is calculated as

$$q_0 = \xi \cdot c_a \cdot (t_{amb} - t_{a2}), \text{ kJ/kg}, \tag{2}$$

where ξ is a coefficient of water vapor condensation heat, determined as a ratio of the overall heat, removed from the air being cooled, including the latent heat of water vapor condensed from the wet ambient air to the removed sensible heat; t_{amb} is an ambient air temperature; t_{a2} is a target air temperature at the air cooler outlet; c_a is the specific heat of ambient air.

The current heat loads q_0 are calculated according to varying actual ambient air parameters (temperature t_{amb} and relative humidity φ_{amb}) on the route lines with using the Meteomanz program [26] or others.

So as the efficiency of AC systems and their refrigeration machine performance depends on their cooling loading (current cooling capacities) q_0 and a duration τ of their operation, the summarised refrigeration capacity $\sum(q_0 \cdot \tau)$ generated during railway routes over the hottest month, might be considered as a primary criterion for the choice of a rational design cooling load of AC system.

For this, the current refrigeration capacities $q_0 \cdot \tau$, generated by the refrigeration machine in response to the cooling duties for cooling ambient air to the target air temperature t_{a2}, taking into account the corresponding duration τ of each current values of refrigeration capacities q_0, have been summarized during railway routes over the summer month to determine the monthly refrigeration output generation $\sum(q_0 \cdot \tau)$.

The monthly refrigeration output generation $\sum(q_0 \cdot \tau)$ in the dependence of design refrigeration capacity q_0 for actual climatic conditions on the route line was used to determine the rational value of design refrigeration capacity $q_{0.rat}$, providing closed to maximum monthly refrigeration output generation.

4 Results

4.1 Heat Loads on Railway Air Conditioning System on Route Line

The current values of temperature t_{amb} and relative humidity φ_{amb} of ambient air with using the Meteomanz program [26] and temperature decrease Δt_a within cooling ambient air from current ambient temperatures t_{amb} to the temperature t_{a2} = 15 °C and corresponding current specific refrigeration capacity (specific heat load on the air cooler) q_0, kW/(kg/s), or kJ/kg (at air mass flow G_a = 1 kg/s), during direct route Kyiv–Kherson (K-Kh) and return route Kherson–Kyiv (Kh-K) per day for 1.08-3.08.2017 are presented in Fig. 1 and 2.

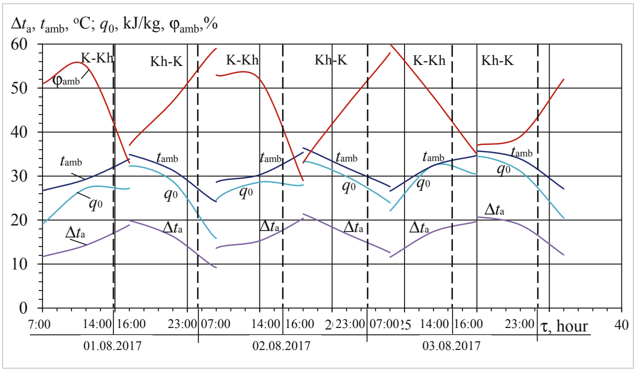

Fig. 1. Current values of temperature t_{amb} and relative humidity φ_{amb} of ambient air, temperature decrease Δt_a due to cooling ambient air to t_{a2} = 15 °C and corresponding current specific refrigeration capacity q_0 during direct routes Kyiv–Kherson (K-Kh) and return routes Kherson–Kyiv (Kh-K) for 1.08-3.08.2017.

As Fig. 1 shows the behavior of the curves corresponding to current values of specific refrigeration capacity q_0 and temperature decrease Δt_a within cooling ambient air to the temperature t_{a2} = 15 °C does not coincide because of variation in relative humidity φ_{amb} of ambient air and corresponding latent heat.

The results of summarizing the specific refrigeration capacity values $\sum(q_0 \cdot \tau)_{r1}$ (at air mass flow G_a = 1 kg/s) for cooling ambient air to the temperature t_{a2} = 15 °C during direct Kyiv–Kherson (K-Kh) and return Kherson–Kyiv (Kh-K) routes and their summarized value $\sum(q_0 \cdot \tau)$ for 1.08-3.08.2017 through summarizing their values $\sum(q_0 \cdot \tau)_{r1}$ for each route are presented in Fig. 2.

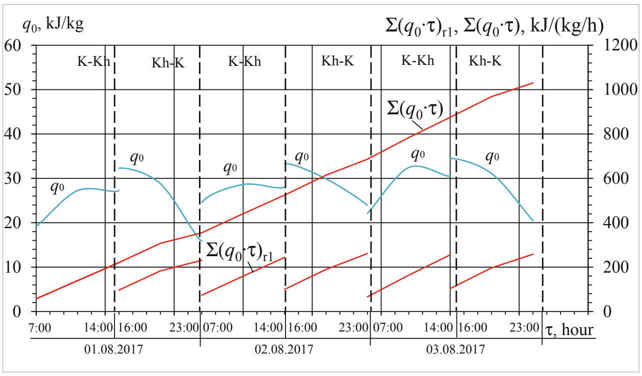

Fig. 2. Current values of specific refrigeration capacity q_0 and summarized values of specific refrigeration capacity $\sum(q_0 \cdot \tau)_{r1}$ for cooling ambient air to the temperature t_{a2} = 15 °C within each route (direct Kyiv–Kherson (K-Kh) and return Kherson–Kyiv (Kh-K) routes) and their summarized value $\sum(q_0 \cdot \tau)$ for 1.08-3.08.2017.

As Fig. 2 shows, the summarized values of specific refrigeration capacity $\sum(q_0 \cdot \tau)_{r1}$ for air conditioning in the direct (K-Kh) and return (Kh-K) routes are nearly the same that is confirmed by the monotonous rate of their increments $\sum(q_0 \cdot \tau)$ for 1.08-3.08.2017.

Considerable changes in the current heat loads q_0 on the air cooler need choosing its rational design value, providing maximum refrigeration capacity generation over the considered period. The monthly refrigeration output in relative values $\sum(q_0 \cdot \tau)$ (at air mass flow G_a = 1 kg/s) against the design of specific refrigeration capacity $q_0 = Q_0 / G_a$ of refrigeration machine for cooling ambient air to the temperature t_{a2} = 15 °C and climatic conditions on the route lines Cherson–Kyiv, and Kyiv–Cherson for July 2017 year, are presented in Fig. 3.

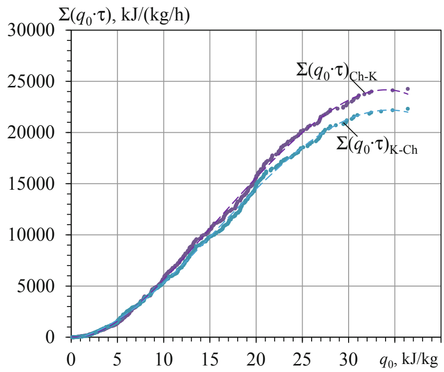

Fig. 3. The monthly refrigeration output in relative values $\sum(q_0 \cdot \tau)$ for ambient air cooling to the temperature t_{a2} = 15 °C against designed specific refrigeration capacity $q_0 = Q_0 / G_a$: $\sum(q_0 \cdot \tau)_{K\text{-}Kh}$ – summarized for all direct railway routes Kyiv-Kherson; $\sum(q_0 \cdot \tau)_{Kh\text{-}K}$ – summarized for all return railway routes Kherson–Kyiv, July 2017.

As Fig. 3 shows, the monthly (July) specific refrigeration output $\sum(q_0 \cdot \tau)$ for cooling ambient air to the temperature t_{a2} = 15 °C at specific refrigeration capacity q_0 = 32 kJ/kg, or kW/(kg/s), is evaluated as $\sum(q_0 \cdot \tau) \approx$ 22 MJ/(kg/h) for all direct railway routes Kyiv–Kherson as well as $\sum(q_0 \cdot \tau) \approx$ 24 MJ/(kg/h) for all return railway routes Kherson–Kyiv in July and achieved with the monotonous rate of their monthly increments $\sum(q_0 \cdot \tau)$ with increasing the specific refrigeration capacity q_0 up to 32 kJ/kg.

Because of the negligible rate of the monthly increments $\sum(q_0 \cdot \tau)$ the further increase in specific refrigeration capacity q_0 from 32 to 37 kJ/kg does not result in an appreciable increment in the monthly refrigeration output $\sum(q_0 \cdot \tau)$ for July but causes oversizing refrigeration machine, that leads to increasing its cost. Thus, the specific refrigeration capacity q_0 = 32 kJ/kg, or kW/(kg/s), is accepted as rational one to calculate a total designed refrigeration capacity Q_0 of refrigeration machine according to the total air mass flow G_a, kg/s:

$$Q_0 = G_a \cdot q_0, \text{ kW.} \tag{3}$$

4.2 A Fundamental Approach in Enhancing Heat Efficiency of Air Coolers

Convective evaporation of a refrigerant inside tubes (channels) is characterized by a sharp drop in intensity of heat transfer at the final stage of evaporation when so-called burnout takes place (Fig. 4). This occurs due to tube inner wall surface drying out with transition of annular flow to disperse (mist) flow.

In compact air coolers with finned tubes the coefficient of heat transfer to refrigerant α_a at the final stage of its evaporation is much lower than to air α_{air}. This results in a sharp decrease in overall heat transfer coefficient k and the heat flux q at burnout vapor fraction about $x_{cr} \approx 0, 9$ corresponding to drying the tube inner wall surface with the transition from annular to disperse flow (Fig. 4).

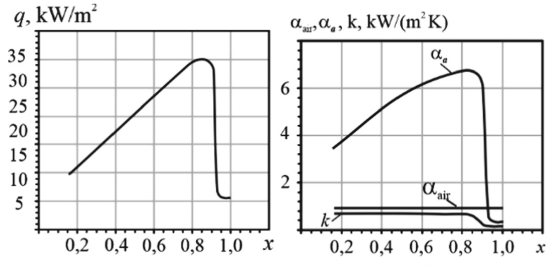

Fig. 4. Variation of heat transfer coefficients to boiling refrigerant α_a, air α_{air} and overall heat transfer coefficient k (**a**) and heat flux q with vapor mass fraction x (**b**).

Calculations were conducted for plate finned tubes of 10 and 12 mm inside and outside diameters, air temperature at the inlet t_{air1} = 25 °C and outlet t_{air2} = 15 °C, refrigerant boiling temperature at the exit t_{02} = 0 °C, refrigerant R142b.

Taking into account that a refrigerant vapor at the exit of conventional air cooler with the thermo-expansion valve is to be superheated by 5–10 °C, a share of the surface, corresponding to the final stage of refrigerant boiling and vapor superheating with extremely low intensity of heat transfer, is about 20–30%.

A sharp decrease in the heat transfer coefficient to refrigerant α_a with the transition from annular to disperse flow takes place for most of the refrigerants.

4.3 Enhancing Heat Efficiency of Air Coolers of Railway Conditioners in Varying Climatic Conditions

The performance of railway conditioners is characterized by considerable changes in heat loads according to current climatic conditions on the routes.

To provide intensive heat transfer on all the length of air cooler coils it is necessary to exclude their ending post dry out sections, i.e. make the air coolers operate with incomplete boiling. The unevaporated liquid should be separated from the vapor in the liquid separator and directed again by a jet pump (injector) to the air cooler for evaporation.

An injector recirculation of liquid refrigerant in air cooler can be successfully implemented in refrigeration machines of railway conditioners (Fig. 5).

The injector uses the potential energy of refrigerant pressure drop from condensing to evaporation pressure, which is conventionally lost while throttling high-pressure liquid refrigerant in the thermo-expansion valve.

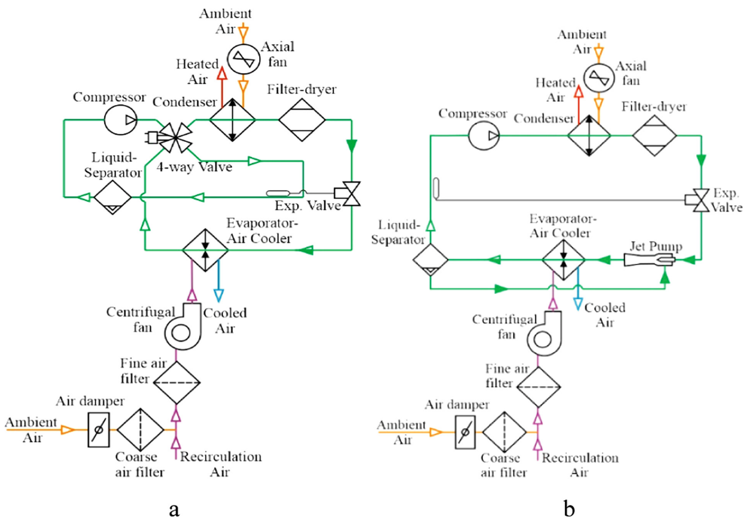

Fig. 5. The schemes of conventional (**a**) and developed railway conditioners with recirculation of liquid refrigerant in the evaporator-air cooler by the jet pump (**b**).

The highest thermal efficiency of the air cooler corresponds to the maximum value of heat flux

$$q_{\max} = k\theta, \tag{4}$$

where θ is a logarithmic temperature difference; k is an overall heat transfer coefficient. The existence of maximum heat flux $q_{\max}$ is caused by the following. With an increase in the mass velocity of refrigerant ρw the heat transfer coefficient to refrigerant α_a and overall heat transfer coefficient k increases. The refrigerant pressure drop ΔP and corresponding refrigerant boiling temperature drop Δt_0 increase also. Such opposite influence of the refrigerant mass velocity ρw upon k and θ causes the existence of maximum of function $q = k\theta$ at a quite definite value of ρw. This value is considered as the optimum mass velocity of refrigerant $(\rho w)_{\text{opt}}$.

The results of thermal efficiency comparison of conventional air cooler with complete evaporation and superheated vapor at the exit and of advanced air cooler with incomplete evaporation due to liquid refrigerant recirculation by injector are shown in Fig. 6. The conditions at the air cooler outlet are the following: refrigerant boiling temperature at the evaporator exit $t_{02} = 0$ °C, there is a dry inner tube wall with a vapor superheated in 10 °C for the conventional throttle circuit and wetted wall with $x_2 < x_{cr}$ for the injector recirculation circuit; in disperse mixture the vapor is superheated in 5 °C as compared to the boiling temperature t_{02}; refrigerant R142b; incoming air velocity w = 6 m/s.

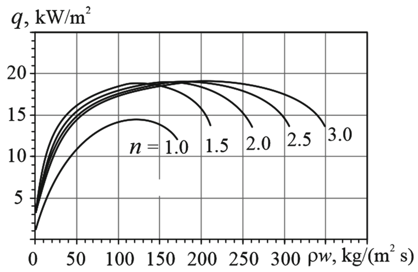

Fig. 6. Mean values of heat fluxes q against refrigerant mass velocities ρw: R142b, t_{02} = 0 °C; the number of circulation n = 1.0 – for conventional complete evaporation; n > 1.0 – for incomplete evaporation with liquid refrigerant recirculation by the injector.

Complete evaporation of refrigerant in the conventional air cooler is characterized by a number of its circulation $n = 1/x_2 = 1.0$, where x_2 – refrigerant mass vapor fraction at the outlet.

Figure 6 shows, that recirculation of liquid refrigerant in the air cooler by injector provides an increase in heat flux q by 20…30% compared with conventional air coolers with complete refrigerant evaporation and superheated vapor at the exit and enables a larger deviation of refrigerant mass velocities ρw from their optimum values (more than twice) without noticeable decreasing the heat flux q. This means that larger cooling load fluctuations are permitted without falling air cooler heat efficiency.

On analyzing the changes of current heat loads on air cooler of railway conditioner on route line Kyiv–Kherson–Kyiv within the range of q_0 = 18–34 kJ/kg (Fig. 2) taking into account of rational specific refrigeration capacity q_{0rat} = 32 kJ/kg (Fig. 4), their deviation is within the range q_{0rat}/q_0 = 0.94–1.8, whereas the available permissible deviation of refrigerant mass velocities ρw from their optimum values due to injector liquid refrigerant circulation (Fig. 6) is $\rho w/\rho w_{opt}$ = 0.5–2.0, i.e. larger.

5 Conclusions

The method to determine the rational design heat load on air coolers of railway AC systems, matching current changeable climatic conditions and providing closed to maximum refrigeration output generation over any considered period of performance, was developed. The system of refrigerant circulation in air coolers by an injector that enables excluding the final dry-out stage of refrigerant evaporation with extremely low intensity of heat transfer and as result provides increasing the heat efficiency of air coolers (overall heat flux) by about 20% compared with conventional air coolers with complete refrigerant evaporation and superheated vapor at the exit was proposed. The injector uses the potential energy of high-pressure liquid refrigerant, leaving a condenser, which is conventionally lost while it throttling to evaporation pressure in the expansion valve. Recirculation of liquid refrigerant in air coolers by injector enables a large deviation of refrigerant mass velocities from their optimum values (more than twice) without noticeable decreasing the heat flux, which means that larger current cooling load fluctuations on railway route lines are permitted without considerable falling air cooler heat efficiency.

So as any railway AC system includes liquid separator to collect excessive refrigerant during changeable current heat loads and to provide a safe performance of compressor (Fig. 5a), the proposed innovative refrigerant injector recirculation system does not need any considerable changes in conditioner design and addition refrigerant volume due to decreased air cooler dimensions by about 20% (Fig. 6).

References

1. Khovalyg, D.M., Baranenko, A.V.: Dynamics of two-phase flow with boiling refrigerant R134a in minichannels. J. Techn. Phys. **85**(3), 34–41 (2015). [in Russian]
2. Liu, H., Dong, H.: Refrigerant guiding pipe and heat exchanger having refrigerant guiding pipe. Patent US, 20130199764 (2013)
3. Bohdal, T., Sikora, M., Widomska, K., Radchenko, A.M.: Investigation of flow structures during HFE-7100 refrigerant condensation. Archives Thermodyn. Polish Acad. Sci. **36**(4), 25–34 (2015)
4. Goetzler, W.: Variable refrigerant flow systems. ASHRAE J. **49**(4), 24–31 (2007)
5. Im, P., Malhotra, M., Munk, J.D., Lee, J.: Cooling season full and part load performance evaluation of variable refrigerant flow (VRF) system using an occupancy simulated research building. In: Proceedings of the 16th International Refrigeration and Air Conditioning Conference at Purdue, West Lafayette, USA, 11–14 July (2016)
6. Zhang, L., Wang, Y., Meng, X.: Qualitative analysis of the cooling load in the typical room under continuous and intermittent runnings of air-conditioning. Procedia Eng. **205**, 405–409 (2017)
7. Butrymowicz, D., Gagan, J., Śmierciew, K., Łukaszuk, M., Dudar, A., Pawluczuk, A., Łapiński, A., Kuryłowicz, A. Investigations of prototype ejection refrigeration system driven by low grade heat. In: HTRSE-2018, E3S Web of Conferences, vol. 70, p. 03002, HTRSE-2018 (2018)
8. Smierciew, K., Gagan, J., Butrymowicz, D., Karwacki, J.: Experimental investigations of solar driven ejector air-conditioning system. Energy Build. **80**, 260–267 (2014)
9. Elbel, S., Lawrence, N.: Review of recent developments in advanced ejector technology. Int. J. Refrig **62**(February), 1–18 (2016)
10. Radchenko, R., Radchenko, A., Serbin, S., Kantor, S., Portnoi, B.: Gas turbine unite inlet air cooling by using an excessive refrigeration capacity of absorption-ejector chiller in booster air cooler. In: HTRSE-2018, E3S Web of Conferences, vol. 70, p. 03012 (2018)
11. Radchenko, M., Radchenko, R., Ostapenko, O., Zubarev, A., Hrych, A.: Enhancing the utilization of gas engine module exhaust heat by two-stage chillers for combined electricity, heat and refrigeration. In: 5th International Conference on Systems and Informatics, ICSAI 2018, pp. 240–244. Jiangsu (2019)

12. Radchenko, A., Radchenko, M., Konovalov, A., Zubarev, A.: Increasing electrical power output and fuel efficiency of gas engines in integrated energy system by absorption chiller scavenge air cooling on the base of monitoring data treatment. HTRSE-2018, 6 p. E3S Web of Conferences, vol. 70, p. 03011 (2018). HTRSE-2018 (2018)
13. Forduy, S., Radchenko, A., Kuczynski, W., Zubarev, A., Konovalov, D.: Enhancing the fuel efficiency of gas engines in integrated energy system by chilling cyclic air. In: Tonkonogyi, V. et al. (eds.) Grabchenko's International Conference on Advanced Manufacturing Processes. InterPartner-2019. Lecture Notes in Mechanical Engineering, pp. 500–509. Springer, Cham (2020), 10 p.
14. Konovalov, D., Kobalava, H.: Efficiency analysis of gas turbine plant cycles with water injection by the aerothermopressor. In: Ivanov, V. et al. (eds.) Advances in Design, Simulation and Manufacturing II. DSMIE 2019. Lecture Notes in Mechanical Engineering, pp. 581–591. Springer, Cham (2020)
15. Konovalov, D., Trushliakov, E., Radchenko, M., Kobalava, G., Maksymov, V.: Research of the aerothermopresor cooling system of charge air of a marine internal combustion engine under variable climatic conditions of operation. In: Tonkonogyi, V. et al. (eds.) Grabchenko's International Conference on Advanced Manufacturing Processes. InterPartner-2019. Lecture Notes in Mechanical Engineering, pp. 520–529. Springer, Cham (2020)
16. Khatri, R., Joshi, A.: Energy performance comparison of inverter based variable refrigerant flow unitary AC with constant volume unitary AC. Energy Procedia **109**, 18–26 (2017)
17. Lee, J.H., Yoon, H.J., Im, P., Song, Y.-H.: Verification of energy reduction effect through control optimization of supply air temperature in VRF-OAP system. Energies **11**(1), 1 (2018)
18. Liu, C., Zhao, T., Zhang, J.: Operational electricity consumption analyze of VRF air conditioning system and centralized air conditioning system based on building energy monitoring and management system. Procedia Engineering **121**, 1856–1863 (2015)
19. Park, D.Y., Yun, G., Kim, K.S.: Experimental evaluation and simulation of a variable refrigerant-flow (VRF) air-conditioning system with outdoor air processing unit. Energy Build. **146**, 122–140 (2017)
20. Zhu, Y., Jin, X., Du, Z., Fang, X., Fan, B.: Control and energy simulation of variable refrigerant flow air conditioning system combined with outdoor air processing unit. Appl. Therm. Eng. **64**, 385–395 (2014)
21. Radchenko, N.: A concept of the design and operation of heat exchangers with change of phase. Archives Thermodyn. Polish Acad. Sci. **25**(4), 3–19 (2004)
22. Trushliakov, E., Radchenko, M., Bohdal, T., Radchenko, R., Kantor, S.: An innovative air conditioning system for changeable heat loads. In: Tonkonogyi, V., et al. (eds.) Grabchenko's International Conference on Advanced Manufacturing Processes. InterPartner-2019. Lecture Notes in Mechanical Engineering, pp. 616–625. Springer, Cham (2020)
23. Radchenko, A., Bohdal, L., Zongming, Y., Portnoi, B., Tkachenko, V.: Rational designing of gas turbine inlet air cooling system. In: Tonkonogyi, V., et al. (eds.) Grabchenko's International Conference on Advanced Manufacturing Processes. InterPartner-2019. Lecture Notes in Mechanical Engineering, pp. 591–599. Springer, Cham (2020)
24. Radchenko, A., Radchenko, M., Trushliakov, E., Kantor, S., Tkachenko, V.: Statistical method to define rational heat loads on railway air conditioning system for changeable climatic conditions. In: 5th International Conference on Systems and Informatics: ICSAI 2018, pp. 1308–1312. Jiangsu (2018)

25. Trushliakov, E., Radchenko, M., Radchenko, A., Kantor, S., Zongming, Y.: Statistical approach to improve the efficiency of air conditioning system performance in changeable climatic conditions. In: 5th International Conference on Systems and Informatics: ICSAI 2018, pp. 1303–1307. Jiangsu, Nanjing, China (2018)
26. Meteomanz Homepage. http://www.meteomanz.com/. Accessed 21 May 2019