University of Belgrade
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PERFORMANCE INVESTIGATION OF FINNED TUBE AIR COOLER

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Beograd, 01.12.2016.

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1. Introduction

HE (fin-and-tube configuration) are commonly used in HVAC&R, petrochemical, food industries, and other industrial fields.

In technical practice, some cases of humid gas cooling: air cooling in refrigeration plants, cooling of the products of combustion in thermal-power plants, cooling of various gases in the process industries.

- The aim of the research was to make the software solutions, that would in practice be able to provide fast and reliable determination of the parameters of such heat exchanger.

2. Air cooling-coils with plate fins

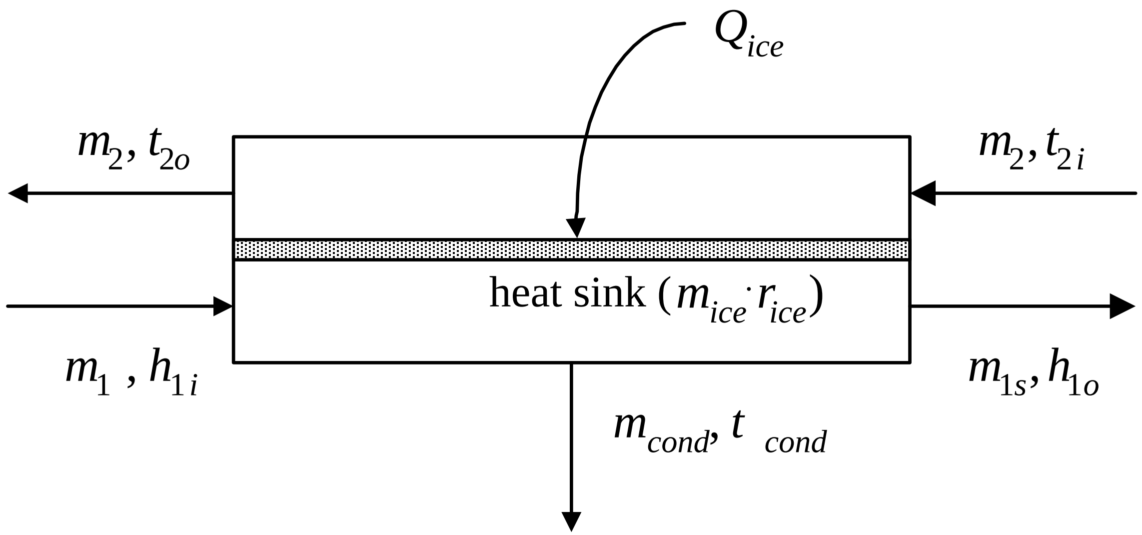
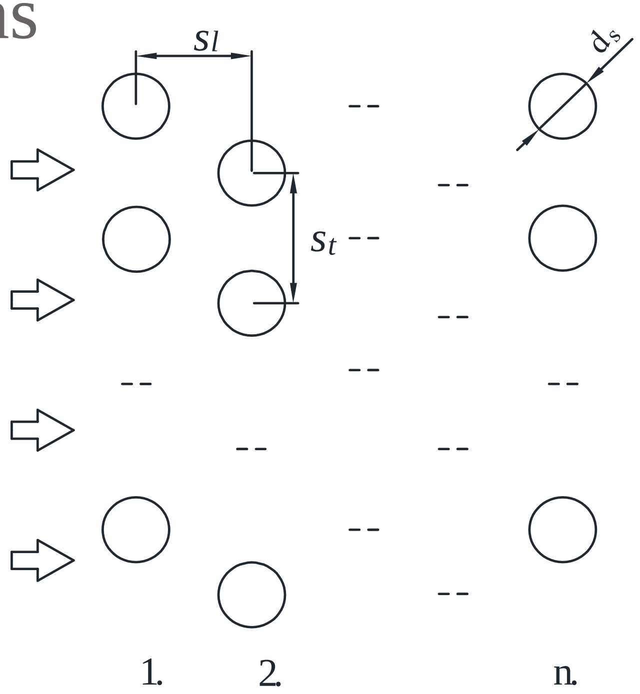


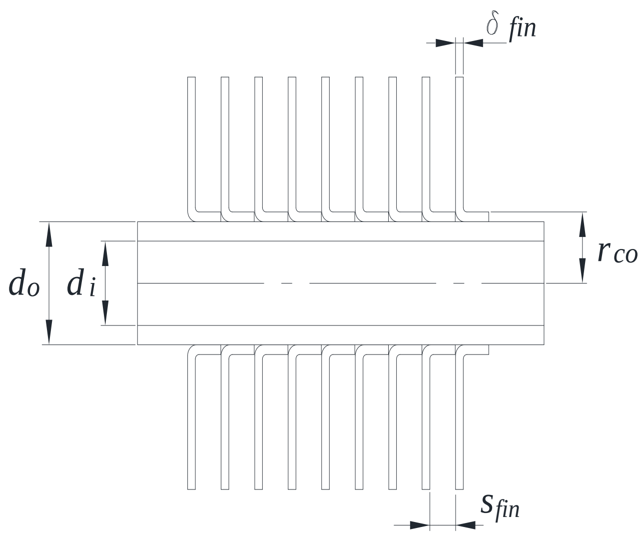
Fig.1 Schematic view - cooling and dehumidifying of air stream

$$\dot{m}_2 \cdot c_{p2} \cdot t_{2,i} + \dot{m}_1 \cdot h_{1,i} + \dot{Q}_{ice} = \dot{m}_2 \cdot c_{p2} \cdot t_{2,o} + \dot{m}_1 \cdot h_{1,o} + \dot{Q}_{cond}$$

2. Air cooling-coils with plate fins

Heat Exchanger	1	2
B, H, mm	360	360
L, mm	120	240
d_i, mm	11,9	11,9
d_o, mm	12,6	12,6
d_{co}, mm	12,9	12,9
n_H, -	12	12
n_L, -	4	8
n_{TO}, -	48	96
n_{Fin}, -	63	63
δ_{Fin}, mm	0,3	0,3
s_{Fin}, mm	5,71	5,71
S_s, m^2	5,19	10,5





3. Experimental setup and measurements

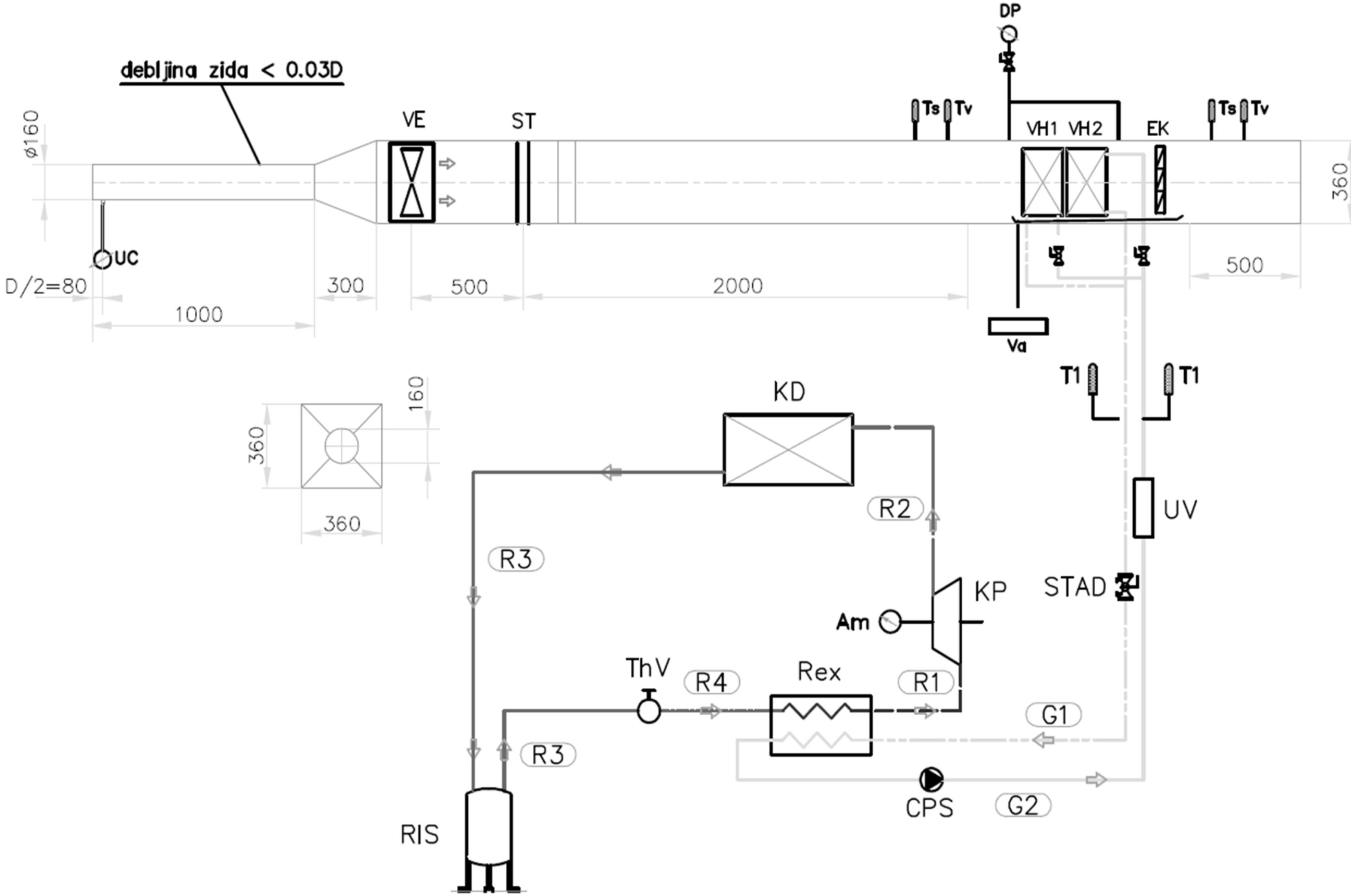
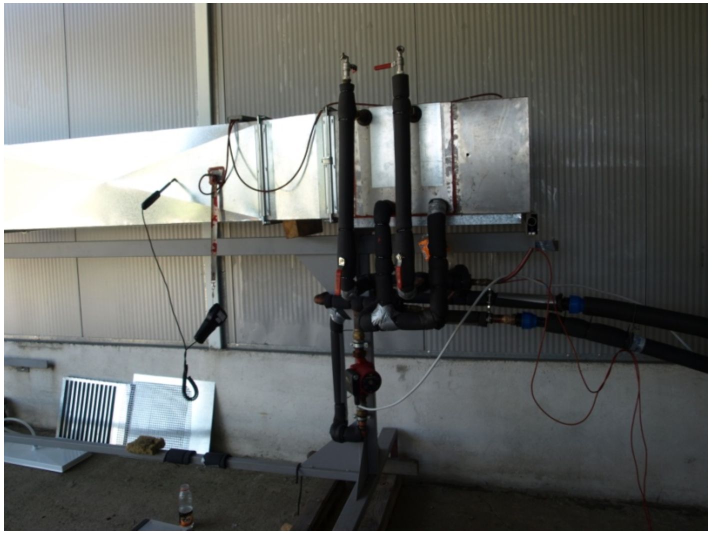


Fig.2 P&I diagram

3. Experimental setup and measurements



3. Experimental setup and measurements

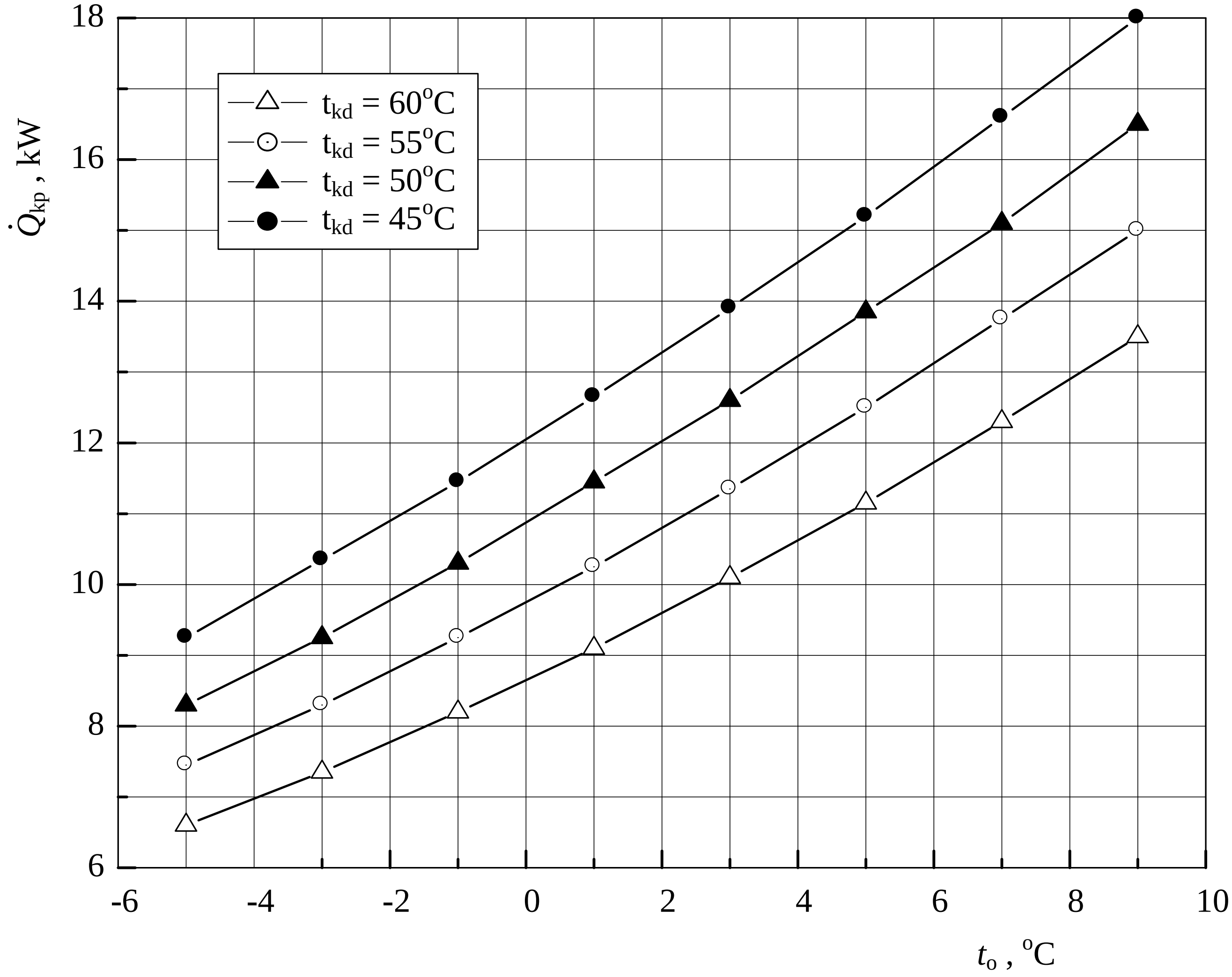


Fig.3 Operating characteristics of used compressor

3. Experimental setup and measurements

Heat exchanger duty calculated for the air side

$$\dot{Q}_1 = \dot{m}_1 \cdot \left(h_{1i} - h_{1o}\right)$$

Air enthalpy is

$$h_1 = c_{pa1} \cdot t_1 + Y_1 \cdot \left(r + c_{pw1} t_1\right)$$

where humidity air ratio is

$$Y_1 = 0{,}622 \cdot \frac{\varphi_1 \cdot p_{sat}(t_1)}{p_{tot} - \varphi_1 \cdot p_{sat}(t_1)}$$

3. Experimental setup and measurements

Heat exchanger duty calculated for the water side

$$\dot{Q}_2 = \dot{m}_2 \cdot c_{p2} \cdot \left(t_{2o} - t_{2i}\right)$$

c_{p2}, [Jkg^{-1}K^{-1}], specific heat capacities of cold fluid.

Mean value of heat duty (i.e. measured heat duty) is determined as

$$Q_m = \frac{Q_1 + Q_2}{2}$$

For each working regime, unsteadiness is estimated using

$$\Delta_{St} = \frac{s_Q}{Q_m} = \frac{\sqrt{\left(Q_1 - Q_m\right)^2 + \left(Q_2 - Q_m\right)^2}}{Q_m}$$

Common engineering practice is that the acceptable level of heat balance dispersion (unsteadiness) is in the range of 3-7% (even 10%). Δ_{St}<10% adopted as a criteria for further analysis.

3. Experimental setup and measurements

According to this heat duty is expressed as

$$Q_m \pm s_Q$$

Since heat exchanger operated with counter–current flow, mean logarithmic temperature difference is

$$\Delta t_{av} = \varepsilon_t \cdot \frac{(t_{1i} - t_{2o}) - (t_{1o} - t_{2i})}{\ln \dfrac{t_{1i} - t_{2o}}{t_{1o} - t_{2i}}}$$

and the measured overall heat transfer coefficient is

$$k = \frac{Q_m}{S_{HE} \cdot \Delta t_{av}}$$

3. Experimental setup and measurements

The overall heat transfer coefficient for air side

$$\frac{1}{k_s} = \left(\frac{1}{\alpha_1} + R_1\right) \cdot \frac{1}{\eta_1} + \left[\frac{d_i}{2 \cdot \lambda_w} \cdot \ln\frac{d_o}{d_i} + \frac{d_o}{2 \cdot \lambda_f} \cdot \ln\frac{d_{co}}{d_o} + \left(\frac{1}{\alpha_2} + R_2\right)\right] \cdot \frac{S_s}{S_i}$$

α_1 and α_2, [$\mathrm{Wm^{-2}K^{-1}}$], are the heat transfer coefficients for hot and cold fluids respectively,

R_1 and R_2, [$\mathrm{m^2KW^{-1}}$], are the fouling resistances for hot and cold fluids,

λ_w, λ_f, [$\mathrm{Wm^{-1}K^{-1}}$], is thermal conductivity of the pipe and fins.

Heat transfer coefficient for cold fluid is calculated using

$$\alpha_2 = \mathrm{Nu}_2 \cdot \frac{\lambda_2}{d_\mathrm{u}}$$

3. Experimental setup and measurements

Nusselt number for laminar flow in circular tube Re < 2000 is

$$\mathrm{Nu}_2 = \left(4{,}364^{3{,}39} + 0{,}553 \cdot \left(\mathrm{Re}_2 \cdot \mathrm{Pr}_2\right)^{1{,}445}\right)^{0{,}295} \cdot \left(\frac{d_i}{d_{i\,\mathrm{min}}}\right)^{0{,}04} \cdot \left(\frac{\mu_2}{\mu_{2w}}\right)^{0{,}14}$$

For turbulent flow (Re > 2000) Nusselt is

$$\mathrm{Nu}_2 = 0{,}0235 \cdot \left(\mathrm{Re}_2^{0{,}8} - 230\right) \cdot \left(1{,}8 \cdot \mathrm{Pr}_2^{0{,}3} - 0{,}8\right)$$

Re, Pr are Reynolds and Prandtl numbers respectively.

4. Conclusion

The question is whether the available literature sources are related only to the specific product and construction of a HE or there is some analysis with the generally applicable conclusions that may apply at the same time a number of other structures.

The following results were achieved:

- It was made (designed) an experimental installation for testing hydraulic and thermal performance of the air cooler - heat exchanger with finned tubes with moisture condensation;
- There were confirmed the correlations for calculating the pressure drop and heat transfer coefficient in “dry” regimes;
- There were determined and confirmed the correlations for calculating the pressure drop in regimes with the moisture condensation;
- It was defined the improved calculation method for determining heat duty and quantity of separated condensate per unit time (as well as other relevant parameters of this HE) in both “wet” and “dry” regimes.

[1] Khalfi, M.S., Benelmir, R. Experimental study of a cooling coil with wet surface conditions, Int. J. of Thermal Sciences, 2001.
[2] SRPS ISO 3966: 2013 BSRIA AG 3/89.3
[3] SRPS EN ISO 5167: 2007 merenje protoka fluida pomoću uređaja sa diferencijalnim pritiskom ugrađenih u cevovode kružnog poprečnog preseka
[4] EN 306: 1997 Heat exchangers – Methods of measuring the parameters for establishing performance
[5] EN 307: 1997 Heat exchangers – Guidelines for preparing installation, operating and maintenance instructions required to maintain the performance of each type of heat exchanger
[6] EN 1148: 1997 Heat exchangers – Water to water heat exchangers for district heating – Test procedure for establishing the performance data
[7] EN 305: 1997 Heat exchangers – Definitions of performance of heat exchangers and the general test procedure for establishing performance of all heat exchangers
[8] https://opi.emersonclimate.com/was.extension.opi.web/OPIServlet?action=compsearch Emerson, Copeland

THANK YOU!