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PRORAČUN INDIREKTNOG ADIJABATSKOG HLAĐENJA ZA UČIONICU S RAČUNALIMA
THE EVALUATION OF INDIRECT ADIABATIC COOLING FOR A COMPUTER ROOM

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Sažetak: *Članak govori o ventilaciji i klimatizaciji učionice s računalima pomoću indirektnog adijabatskog hlađenja. Stanja i promjene stanja prikazane su u Mollierovim h-x dijagramima za ljetne uvjete. Napravljen je proračun i prikazani su rezultati.*

Ključne riječi: - indirektno adijabatsko hlađenje
- klimatizacija
- ventilacija

Summary: *The paper deals with the ventilation and air-conditioning of a computer room by using indirect adiabatic cooling. The state and changes of the air states are presented in Mollier h-x diagrams for summer conditions. The calculation is performed and the results are presented.*

Key words: - indirect adiabatic cooling
- air-conditioning
- ventilation

1. UVOD

Za besprijekorni rad računala najbolji su uvjeti: temperatura od 15°C do 27°C i relativna vlaga od 30% do 80%. Pri nižoj vlazi postoji opasnost pojave statičkog elektriciteta, a pri višoj je moguća pojava kondenzacije. Za ljude koji se nalaze u sobama s računalima traži se temperatura od 22°C do 26°C, ovisno o spolu, načinu oblačenja i o brzini strujanja zraka te relativna vlaga od 40% do 60%. Za boravak ljudi bitno je osigurati da razlika u temperaturi u sobi i ulaznoj temperaturi zraka ne bude veća od 4°C. Da bi se to postiglo, potrebni su veliki protoci zraka koji se dovode do perforiranih stropova ili podova, dok se velikom površinom osigurava niska brzina strujanja zraka. Za takve velike protoke zraka potrebno je da velik dio (oko 90%) zraka recirkulira i ponovo se vraća u prostoriju kako ne bi bili preveliki gubici energije [4]. No, kada se hlađenje izvodi pomoću indirektnog adijabatskog hlađenja, ljeti se može hladiti samo vanjskim zrakom bez recirkulacije, jer se ne troši električna energija na hlađenje nego samo na ventilatore i na vodenu crpku.

1. INTRODUCTION

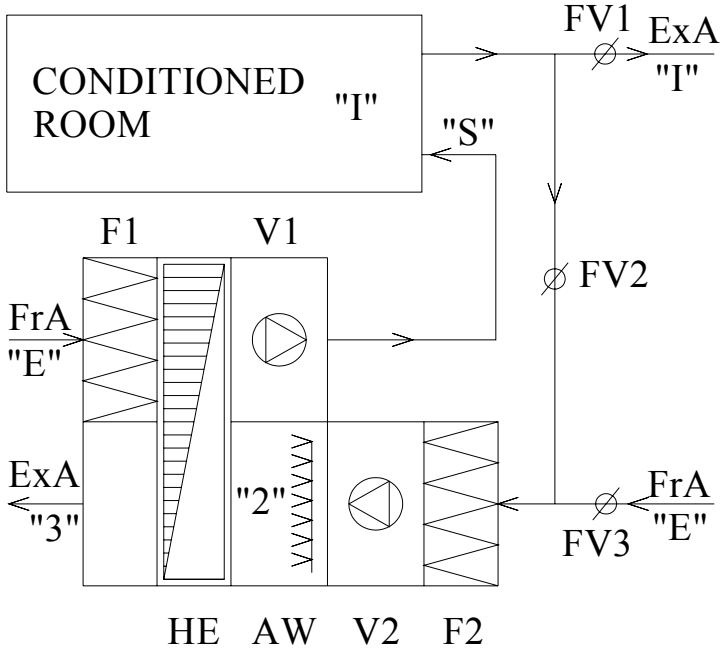
The best working conditions for computers are within the temperature range of 15°C to 27°C with a relative humidity of 30% to 80%. At lower humidity, there is the risk of static electricity formation and at higher humidity, there is the risk of condensation. The temperature between 22°C and 26°C is required for people in computer rooms, depending on gender, style of dressing and the streaming velocity of the air, and the relative humidity ranging from 40% to 60%. It is important to assure that the temperature difference between the temperature in the room and the inlet temperature stays lower than 4°C because of people. To achieve this, a high airflow rate that is supplied to perforated floor or ceiling is necessary, while large surface ensures low air velocity. For that high airflows, it is necessary to recycle the greater part (about 90%) of the air, so that there will not be too high loss of energy [4]. With the use of indirect adiabatic cooling, however, during the summer season, it is only possible to cool with outdoor fresh air without recirculation, because the electrical energy is used only for the fans and the water pump, but not for cooling.

2. INDIREKTNO ADIJABATSKO HLAĐENJE

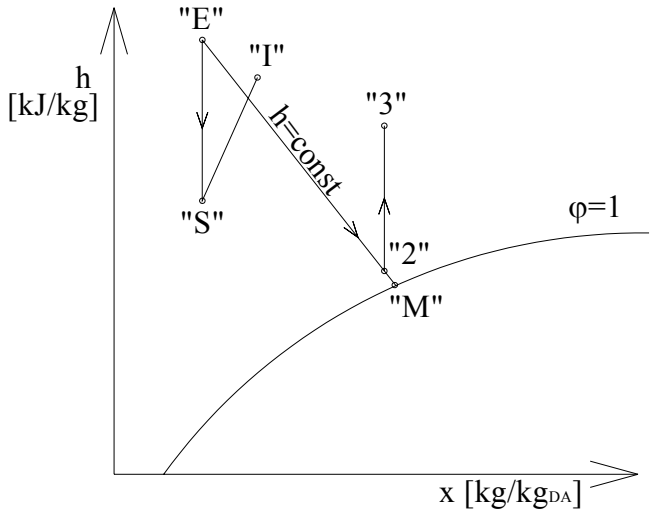
Sustav za indirektno adijabatsko hlađenje sastoji se od dvaju ventilatora, perilice zraka i izmjenjivača topline (Slika 1) [2]. Na ulazu su dva filtra za smanjenje ulaza prašine. Prašina onečišćuje vodu u perilici zraka i uzrokuje kod ljudi zarazu dišnih putova.
Voda ishlapljuje u perilici zraka, škropljeni zrak se time hladi i u izmjenjivaču topline hladnoća se prenosi na neškropljeni zrak. Treba koristiti rekuperativni izmjenjivač topline jer se mora prenositi samo toplina, a ne vlaga. Korišten je rotacijski izmjenjivač topline jer on može raditi s visokim masenim protocima zraka. Na takav način dovodni zrak ”S” ima istu apsolutnu vlažnost kao i vanjski svježi zrak jer dovodni zrak nije ovlažen u klimatizacijskom uređaju. U ljetnim su uvjetima klapne 1 i 3 otvorene, a klapna 2 je zatvorena. Na slici 2 prikazana su stanja i promjene stanja zraka u Mollierovu h-x dijagramu u ljetnim uvjetima. Takav jednostavan klimatizacijski uređaj nema mogućnost mijenjanja vlažnosti zraka i ne vraća energiju iz otpadnog zraka ljeti.

2. INDIRECT ADIABATIC COOLING

The system for indirect adiabatic cooling consists of two fans, an air washer and a heat exchanger (Fig. 1) [2]. The filters are on the inlet, in order to decrease dust. Dust contaminates the water in the air washer and induces such health problems as respiratory tract infections.
The water evaporates in the air washer, the sprayed air is then cooled down and the coldness is transferred to the unsprayed air in the heat exchanger. The recuperative heat exchanger should be used because only the heat should be transferred in the heat exchanger, but not the humidity. A rotational heat exchanger was used, because it could operate with high mass flow rates of air. In such a way, the supplied air ”S” will have the same absolute humidity as the outdoor fresh air, because the supplied air is not humidified in the air conditioner. Under summer conditions, flap valves 1 and 3 are opened and the flap valve 2 is closed. States and state changes of the air in the Mollier h-x diagram for summer conditions are shown in Figure 2. Such a simple air-conditioning device cannot change the humidity and will not recuperate the energy from the exhaust air in the summertime.



Slika 1. Shema indirektnog adijabatskog hlađenja
F – filter, V – ventilator, HE – rotacijski izmjenjivač topline, AW – perilica zraka, FV – klapna, FrA – svježi zrak, ExA – otpadni zrak, ”E” – stanje vanjskog zraka, ”I” – stanje unutrašnjeg zraka, ”S” – dovodni zrak do klimatiziranog prostora, ”2” – stanje zraka na izlazu iz perilice zraka, ”3” – stanje zraka na izlazu iz izmjenjivača topline
Figure 1. Scheme of indirect adiabatic cooling
F – filter, V – ventilator, HE – rotational heat exchanger, AW – air washer, FV – flap valve, FrA – fresh air, ExA – exhaust air, ”E” – external air state, ”I” – internal air state, ”S” – supplied air to the conditioned room, ”2” – state of the air on the outlet from air washer, ”3” – state of the air at the outlet from heat exchanger



Slika 2. Mollierov h-x dijagram za ljetne uvjete
Oznake kao na Slici 1
Figure 2. Mollier h-x diagram for summer conditions
Lettering as in Figure .

U zimskom je razdoblju klapna 2 otvorena, a klapne 1 i 3 su zatvorene (Slika 1). Zimi ne radi perilica zraka, a izmjenjivač topline koristi se za rekuperaciju topline iz otpadnog zraka. Uređaj se tada koristi samo za ventilaciju, gubici topline moraju biti pokriveni dodatnim grijanjem.

3. REZULTATI PRORAČUNA

Dimenzije učionice s računalima prikazane su na Slici 3 [3].

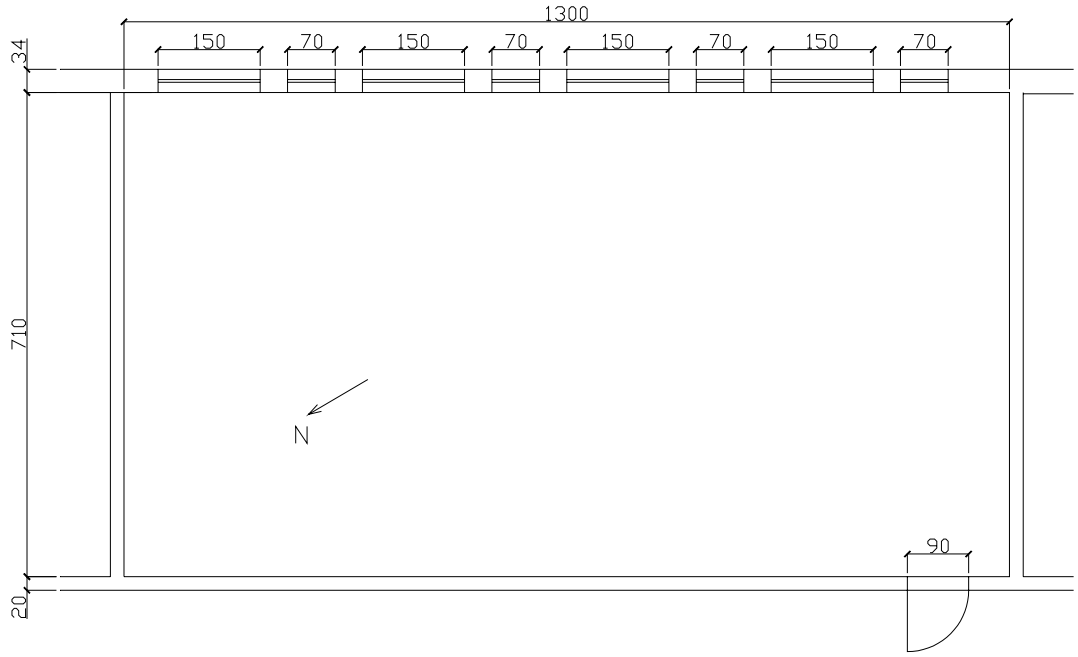
Gubici topline bili su računati [1] za najveću vanjsku temperaturu 33°C ljeti i najmanju -12°C zimi, maksimalnu unutrašnju temperaturu 26°C ljeti, temperaturu vlažnog termometra 20°C vanjskog zraka ljeti, 12 ljudi u učionici, 10 računala 350W/kom, visina prostorije 300 cm, visina prozora 220 cm, zidovi od cigle, unutrašnje osvjetljenje 5W/m^2, radno vrijeme od 8 do 18 h. Za proračun bio je korišten program Bilancia 3.03, rezultati su u Tablici 1.

During the winter conditions, the flap valve 2 is opened and flap valves 1 and 3 are closed (Fig. 1). In the wintertime the air washer does not work and the heat exchanger is used for recuperation of the heat from the extracted air. The device is then used only for ventilation and the heat losses have to be compensated by additional heating device.

3. RESULTS OF CALCULATION

The dimensions of the computer room which was calculated are shown in Figure 3 [3].

The heat losses and incoms were calculated [1] for a maximal external summer temperature of 33°C, and a minimal winter external temperature of -12°C, a maximal indoor summer temperature of 26°C, a wet bulb summertime external air temperature of 20°C, with 12 people in the room, with 10 computers 350W/pc, a ceiling height of 300 cm, a window height of 220 cm, brick walls, internal lighting of 5W/m^2, and working hours from 8 to 18. The program Bilancia 3.03 was used for calculations and the results are shown in Tab. 1.



Slika. 3. Učionica s računalima. Dimenzije su u cm
Figure 3. Computer room. Dimensions in cm

Tablica 1. Toplinski gubici i dobici u učionici. Rezultati u kW
Table 1. Heat losses and gains of the computer room. Results in kW

Month Hour	1	2	3	4	5	6	7	8	9	10	11	*12*
1	-4.83	-4.34	-3.19	-1.74	-0.34	0.7	1.1	0.72	-0.38	-1.94	-3.49	*-4.53*
2	-4.91	-4.44	-3.32	-1.88	-0.48	0.55	0.95	0.57	-0.52	-2.06	-3.59	*-4.62*
3	-4.99	-4.56	-3.45	-2.02	-0.63	0.39	0.79	0.42	-0.66	-2.19	-3.59	*-4.69*
4	-5.07	-4.66	-3.59	-2.17	-0.78	0.24	0.63	0.27	-0.81	-2.3	-3.78	*-4.76*
5	-5.13	-4.74	-3.69	-2.30	-0.83	0.21	0.58	0.12	-0.93	-2.40	-3.86	*-4.83*
6	-5.17	-4.79	-3.75	-2.09	-0.66	0.36	0.75	0.33	-0.99	-2.46	-3.91	*-4.87*
7	-5.16	-4.77	-3.18	-1.53	-0.20	0.77	1.21	0.90	-0.42	-2.43	-3.88	*-4.85*
8	-0.41	0.65	2.30	3.80	5.02	5.95	6.43	6.24	5.09	3.01	0.89	*-0.16*
9	0.44	1.59	3.16	4.54	5.65	6.54	7.08	7.00	5.97	3.99	1.78	*0.49*
10	1.19	2.30	3.78	5.08	6.14	7.02	7.57	7.55	6.61	4.74	2.58	*1.24*
11	1.58	2.62	4.02	5.29	6.35	7.23	7.79	7.78	6.89	5.09	3.01	*1.66*
12	1.64	2.61	3.96	5.24	6.35	7.29	7.80	7.74	6.84	5.11	3.11	*1.77*
13	1.49	2.42	3.77	5.16	6.41	7.38	7.86	7.67	6.67	4.93	2.98	*1.66*
14	1.30	2.23	3.65	5.12	6.44	7.43	7.89	7.64	6.55	4.76	2.81	*1.49*
15	1.16	2.08	3.51	5.03	6.45	7.48	7.91	7.56	6.42	4.61	2.67	*1.36*
16	0.97	1.87	3.31	5.00	6.45	7.50	7.93	7.55	6.22	4.40	2.47	*1.17*
17	0.76	1.58	3.21	4.89	6.35	7.41	7.84	7.47	6.14	4.09	2.25	*1.00*
18	0.58	1.49	2.98	4.66	6.13	7.20	7.63	7.25	5.93	4.02	2.05	*0.82*
19	-4.03	-3.24	-1.86	-0.28	1.22	2.30	2.72	2.31	1.09	-0.71	-2.58	*-3.83*
20	-4.11	-3.40	-2.10	-0.57	0.88	1.94	2.37	2.01	0.84	-0.89	-2.68	*-3.88*
21	-4.23	-3.59	-2.33	-0.84	0.57	1.62	2.05	1.72	0.59	-1.09	-2.81	*-3.97*
22	-4.37	-3.78	-2.57	-1.11	0.28	1.32	1.75	1.42	0.32	-1.31	-2.98	*-4.10*
23	-4.54	-3.99	-2.82	-1.38	0.01	1.04	1.45	1.11	0.03	-1.55	-3.16	*-4.26*
24	*-4.70*	*-4.19*	*-3.05*	*-1.60*	*-0.19*	*0.85*	*1.25*	*0.87*	*-0.22*	*-1.78*	*-3.34*	*-4.41*

Tablica. 2. Rezultati psihrometričkih svojstava zraka.
Table 2. Results of the psychrometric properties of the air.

specifična vlažnost zasićenog zraka "M"	x_m''	14.963	g/kg_{DA}	specific humidity of the saturated air "M"
entalpija zasićenog zraka "M"	h_m''	58.418	kJ/kg_{DA}	ethalpy of the saturated air "M"
specifična vlažnost vanjskog svježeg zraka "E"	x_e	9.518	g/kg_{DA}	specific humidity of the external fresh air "E"
entalpija vanjskog svježeg zraka "E"	h_e	57.712	kJ/kg_{DA}	ethalpy of the external fresh air "E"
relitivna vlažnost vanjskog svježeg zraka "E"	φ_e	29.833	%	relative humidity of the external fresh air "E"
temperatura rosišta vanjskog svježeg zraka "E"	t_{re}	13.025	°C	dew point temperature of the external fresh air "E"
specifična vlažnost zraka "2"	x_2	14.451	g/kg_{DA}	specific humidity of the air "2"
entalpija zraka "2"	h_2	58.125	kJ/kg_{DA}	ethalpy of the air "2"
temperatura zraka "2	t_2	21.211	°C	air temperature "2"
relativna vlažnost zraka "2	φ_2	89.708	%	relative humidity "2"
specifična vlažnost ulaznog zraka "S"	x_s	9.518	g/kg_{DA}	specific humidity of the inlet air "S"
entalpija ulaznog zraka "S	h_s	46.408	kJ/kg_{DA}	ethalpy of the inlet air "S"
temperatura ulaznog zraka "S	t_s	22.001	°C	temperature of the inlet air "S"
volumenski intenzitet protoka zraka "S"	V_s	5963.3	m^3/h	volume flow rate of the inlet air "S"
radna razlika temperatura	Δt_s	3.999	°C	working temperature difference

4. ZAKLJUČAK

Klimatizacijski uređaj s indirektnim adijabatskim hlađenjem koristi električnu energiju samo za ventilatore, za elektromotor rotacijskog izmjenjivača topline i za vodenu crpku perilice zraka. U usporedbi s kompresorskim hlađenjem ima nisku potrošnju električne energije, a time i niske radne troškove. U zimskim se uvjetima izmjenjivač topline može koristiti za rekuperaciju topline čime se povećava povrat investicije. Indirektno adijabatsko hlađemje ima višu početnu investiciju.

4. CONCLUSION

The air-conditioning device with indirect adiabatic cooling uses electrical energy exclusively for the fans, for the AC motor of the rotational heat exchanger and for the pump of the air washer. In comparison with compressor cooling devices, it has lower consumption of electrical energy and therefore it has lower operating costs. In the wintertime, the heat exchanger can be used for heat recovery, which increases the return of investment. Indirect adiabatic cooling has larger initial investment.

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Strukovni prilog

Technical note

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