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The Recuperation of Waste Heat in the Air Conditioning Systems

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Abstract: Proper climatic conditions are important for comfort and well-being of people in any room. These conditions can be assured only through the intensive exchange of stale room air with properly treated fresh air. We try to evaluate and represent systems of ventilation, air conditioning and recuperation. In conclusion, there is an evaluation of investment and operating costs. The evaluation is the foundation for evaluating the suitability of investment and proper use of energy.

Key Words: Energetics, air conditioning, recuperation of heat, estimation of costs

1 Introduction

Most of the countries which due to their climatic conditions use an essential share of energy for heating of buildings [1-3], depend heavily on imported fossil fuels, but have a good potential to exploit the waste heat or use the renewable energies.

The comfort and well-being of people in a certain environment depends on the temperature, dampness and cleanness of air and air circulation. In respect to this, satisfactory microclimatic conditions have to be provided. At the same time, effective use of energy has to be taken into account.

Providing fresh air, which we must heat and dump in the winter and cool and dry in the summer, is connected with high operating costs. We try to reduce this costs with the minimum of energy used, which is possible by using recuperators, regenerators and heat pumps in order to exploit the waste heat of the air conditioning systems.

1.1 Air Conditioning and Air Conditioners

Air conditioning means maintaining constant climatic conditions in a room – constant temperature, dampness and the quality of air. All these Conditions can be achieved by using air conditioners [4-7].

To save energy, air conditioners are mostly constructed with extensive borders of assurance of temperature and dump. They are equipped with mixed chambers and apparatus for recycling heat energy of waste air. This is valid for apparatus, which works with a bigger part of fresh air and a smaller part of recycled air.

We differentiate many methods of recycling waste heat energy:

- recuperation, the procedure of recycling heat energy with heat transferees, that transfer heat only,
- regeneration, the procedure of recycling heat energy with heat transferees, that transfer heat and dump,
- recycling heat energy over indirect medium,
- mixing fresh air with waste air,
- variable systems of air flow, which constantly regulate the quantity of air in the air conditioners in order to adjust to the variable number of people.

1.2 Recuperation (Heat Recovery)

Recuperators transfer heat are combined with two systems – in one system there is liquid with a higher temperature and in the other there is liquid with a lower temperature [4], [7]. On the basis of heat transfer, the liquid with higher temperature is being cooled down because of the heating of cooler liquid. The advantage that this system has (in comparison to regeneration) is in division of fresh and waste air, which means there are no odors, poisonous and noxious gases mixed with the fresh air.

1.3 Regeneration

It is a process of regenerative heat transfer of first warm and then cool air over heat accumulator.

2 Experimental Part

The effective use of energy of two separated air - conditioning systems was analysed. The first analysis was done in the kitchen, coffeehouse and guest room (ZONE I) and the second one in the buffet (ZONE II) [7].

3 Cooling Load and the Amount of Air

3.1 Cooling Load

Cooling load is a caloric power, which has to be diverted from the space in a certain time period in order to assure the desired condition of air in the space [4-7].

The largest source of dry and dump cooling load in the kitchen derives from the load, brought about by the use of kitchen device. This amount represents 70% of the total cooling load produced in the kitchen.

3.2 The Amount of Input Air

The decision which air conditioning system to use depends on the amount of input air. If we supply air to, for example, cool down the space in the case of cooling load or heat the space in the case of heating load and we supply the demanded amount of fresh air at the same time, then the maximum input air is crucial for further calculations.

To determine the amount of input air and the amount of fresh air, we use more criteria:

- cooling load,
- the number of exchanges in one hour,
- maximal amount of fresh air per person,
- the pollution of air.

The amounts of input air and exhausted air are presented in Table 2 and the amounts of input of fresh air are presented in Table 3.

3.3 Cooling and Heating of Fresh Air

In the summer time, when the outside temperatures are higher than the inside temperatures, it is necessary to cool down the fresh air coming from the outside, which presents an additional cooling load.

In opposite, we have to warm the fresh outside air in the winter which is connected with heating load. The capacity of heater is determined according to the amount of fresh air that has to be heated, and its

Table 1: Values of dry and dump cooling load in rooms equipped with air conditioners

Room	Dry cooling load of rooms (W)	Dump cooling load of rooms (W)	The sum of dry and dump cooling load of rooms (W)
Kitchen	4030	4799	8829
Guest room	3909	900	4809
Coffeehouse	10017	2017	12034
Together ZONE I	17955	7716	25672
Buffet ZONE II	6583	1784	8367

Table 2: Amounts of input air and exhausted air

Amount of air: / Room	Input air according to the number of exchanges (m^3/h)	Input air according to the number of people (m^3/h)	Input air according to the cooling load (m^3/h)	Exhausted air according to the number and electric power of devices (m^3/h)	Exhausted air according to the size of the kitchen nap (m^3/h)	Selected air supply (m^3/h)	Selected air exhaust (m^3/h)	Number of air exchanges in the room
Kitchen	1374	120	469	2150	2218	2000	2200	36.8
Gast room	1226	800	1463	-	-	1500	1500	14.9
Coffeeshop	3510	1200	3750	-	-	3800	3800	13.5
Together ZONE I						7300	7500	
Buffet ZONE II	2603	1360	2625	-		2700	2700	12.9

Table 3: Amounts of input fresh air:

Amount of air / Room	Supply of air to the room (m^3/h)	Exhaust of air from the room (m^3/h)	Supply of air over the air conditioner (m^3/h)	Exhaust of air over the air conditioner (m^3/h)	Supply of fresh air (m^3/h)	Air Circulation (m^3/h)
Kitchen	2000	2200	600	-	390	210
Gast room	1500	1500	1500	1500	1050	450
Coffeeshop	3800	3800	3800	3800	2660	1140
Together ZONE I	7300	7500	5900	5300	4100	1800
Buffet ZONE II	2700	2700	2700	2700	2700	-

current temperature. In the winter time, the temperature of air we want to reach is 22 degrees. The results of power needed to cool down and heat air are presented in Table 4.

The results in Table 4 show that for cooling and heating of fresh air apparatus with bigger powers are necessary. The reason for that is in the feasibility of effective use of energy.

4 Air Conditioning Systems

On the basis of our calculations of cooling load in the rooms we chose an air conditioning system, which enabled us to effectively use the heat of waste air [4-7]. Consequently, we save a lot of energy. The supply and exhaust of air in rooms is done over the canal wire. The distribution of air is possible because of blow diffusers and suck riddle.

We chose zone combining one canal air conditioner GEA type AT Plus. Primarily, the task of the air conditioner is to assure suitable room temperature and air quality. We analysed three variants with different effective uses of energy:

- Variant I: apparatus, including plate recuperator, working with 100% fresh air, is presented in picture 1,
- Variant II: apparatus, including plate recuperator and a mixed chamber, working with 70% fresh air and 30% recirculated air, is presented in picture 2,
- Variant III: apparatus, including regenerator and mixed chamber, working with 70% fresh air and 30% recirculated air, is presented in picture 3.

In table 5 the cooling powers of recuperators in summer and winter time are analysed.

Table 4: Results of calculation of necessary power needed to cool and heat the fresh air

Description	Input (m^3/h)	Power needed for cooling (kW)	Power needed for warming (kW)
ZONE I: - Ventilation air conditioning: 100 % fresh air 70 % fresh air	 5900 4100	 19.3 13.4	 78.7 54.7
- Input to the kitchen nap	1400	-	150.2
ZONE II: - Ventilation air conditioning:	 2700	 8.8	 36.0

Table 5: Cooling powers of recuperators in summer and winter time:

Variant	Season	The efficiency of the recuperator (%)	Cooling power of recuperator kW Warming power of recuperator kW	Necessary power of refrigerator kW Necessary power of heater kW
I	summer	52	6.3	27.7
I	winter	64	47.9	31.0
II	summer	54	4.4	23.9
II	winter	65	34.0	21.7
III	summer	75	49.6	19.3
III	winter	75	55.6	16.1

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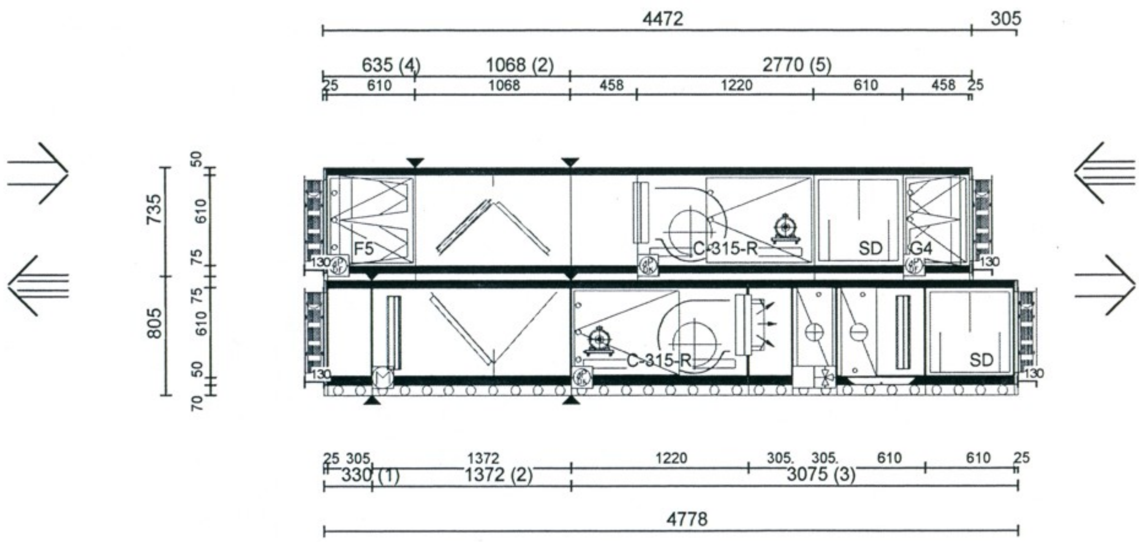

Fig. 1: Air conditioner with plate recuperator – variant I.

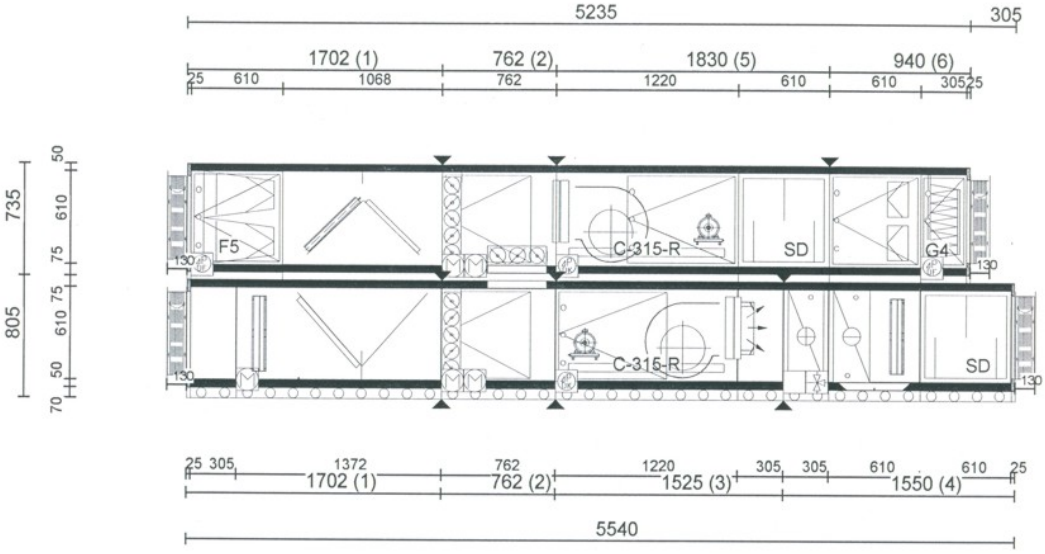

Fig 2: Air conditioner with plate recuperator and mixed chamber – variant II.

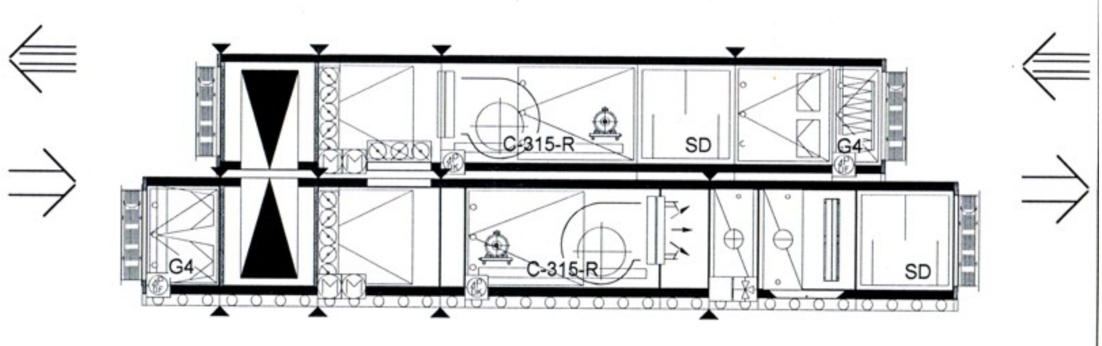

Fig. 3: Air conditioner with regenerator and mixed chamber – variant III.

5 Costs and Economic Justification of Investment

The task of planning and designing air conditioning systems is not only providing satisfactory climatic conditions, but also on the basis of analyses and calculations offer such solutions to meet basic economic requirements.

Every project of air conditioning systems has to include:

- the cost of investment,
- the estimation of operating costs; the estimation is made on the basis of comparisons of operating costs of different variants.

5.1 Investment Costs

For estimation of investment it is very important that we define the demand for an air conditioner. We also have to do inventory of materials and works. Analaysed variants include air conditioners with regulation and electrocomodic case, complete canal wire, water cooler with armatures, pipes, pumps, valves and isolation.

Investment estimation based on the demand for an air conditioner is presented in table 6.

5.2 Operating Costs

An exact estimation of operating costs of air conditioning system is a very extensive procedure, because we must have a lot of data at our disposal: the type of the climatic system, outside climatic parameters, operation (work) time, the sources of heat and cold.

In table 7 operating costs of analysed variants are presented, savings per year and time of repayment of investment - the comparison between an air conditioner with and without recuperator.

Table 6: Investment estimation on based demand:

ZONE I					
Variant	Air conditioner with regulation and electrocomodic case (EUR)	Complete canal wire (EUR)	Water cooler with armatures (EUR)	Pipes, pumps, isolation, valves (EUR)	Total (EUR)
I	25528,00	18336,00	12344,00	7258,00	63467,00
II	29176,00	18336,00	12344,00	7258,00	67106,00
III	31883,00	18336,00	12344,00	7258,00	70009,00
ZONE II					
I	15307,00	6320,00	6320,00	3555,00	32095,00

Table 7: Operating costs variants I, II, III in (EUR):

Costs	Air conditioner without recuperator	Variant I	variant II	Variant III
The price of apparatus Water heater Water cooler Recuperator Mixed chamber and equipment Regenerator	 46473,00 13236,00	 369,00 12676,00 1871,00	 369,00 12676,00 1871,00 2780,00	 369,00 12676,00 2780,00 3742,00
Total Additional investment	13701,00	14916,00 1215,00	17697,00 3995,00	19568,00 5867,00
The costs of capital invested per year 10 % EUR	1370,00	1491,00	1769,00	1956,00
Year costs of heating Additional costs for maintenance, energy and repairment	1933,00	704,00 145,00	704,00 145,00	317,00 145,00
All year cooling costs Additional costs for maintenance, energy and repairment	489,000	234,00 145,00	189,00 145,00	102,00 145,00
Total of costs per year	3792,00	2713,00	1693,00	2667,00
Saving on operating costs per year		1201,00	1489,00	1712,00
The time needed for repayment of investment (years)		1.01	2.67	3.43

Operating costs include:

- costs of use; costs of electric energy, warming, cooling and water,
- working costs; sustenance and service,
- costs of remount; a bigger repair and reserve part,
- costs of capital; amortisation costs and interest.

6 Conclusion

With the calculation of the cooling load we determined that a large heating load in the summer is due to the large glass surfaces. The dry cooling load has a decisive effect on the amounts of input air. The amount of input air is also affected by the room and its use itself, which is sometimes connected with a great intensity of ventilation. We analysed three types of air conditioners with different degrees of efficient use of energy and recycling of waste heat.

Additionally, we made an estimation of investment, the evaluation of operating costs, comparative analysis of investments into the recuperation of heat and a calculation of predicted repayment of additionally invested capital. The comparisons show a favorable additional investment in all three cases because of the short time of repayment of invested capital and, consequently, the recuperation of heat in ventilation and air conditioning is justifiable.

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