VENTILATION SYSTEMS WITH LONGITUDINAL COUNTERFLOW SPIRAL RECUPERATORS

M. Adamski

Department of Heat Engineering, Technical University
15-351 Białystok, Poland

ABSTRACT

This paper presents ventilation systems with longitudinal counterflow spiral recuperators. Heat transfer losses in ventilation system can be reduced by increasing the length of the recuperator, but in this case pressure drops increase. These two losses determine exploitation costs.
Taking into consideration the results of measurements and calculations the costs for capital expenditure and exploitation of ventilation systems are minimized.

KEYWORDS

ventilation system, counterflow spiral recuperator

LONGITUDINAL COUNTERFLOW SPIRAL RECUPERATORS

Counterflow ventilation heat exchangers are the most important parts of energy recovery systems, see Figure 1. The ventilating central stations with heat recovery consist of:

- diaphragmatic heat exchanger,
- two ventilators,
- two filters,
- electric switching-board and controller.

Apart from the standard equipment the central station can include:

- air heater
- by-pass (one or two, open in summer)
- sprinkling chambers and humidifiers,
- noise silencers,
- cooling.

The special plate design makes the spiral recuperators a preferable choice for many applications. The plates are usually made of raw or epoxy coated aluminium. The fact that the exchangers are fully produced of aluminium makes them withstand winter conditions, which ensures a longer life time.
Spiral-tube heat exchanger is made of metal sheets which are wound with constant distance between subsequent windings, see Figures 2 and 3. Owing to their advantages, spiral recuperators with the longitudinal countercurrent flow should be widely utilized for ventilation heat recuperation. In comparison with cross-flow heat exchangers, they obtain greater efficiency ε for the same value of the parameter Ntu. Furthermore, spiral recuperators have also more uniform thermal field in each transverse sections of the air stream. As a result, they are more resistant to outdropping of moisture from the air-cooled stream and the effect of

frosting practically does not occur. In order to drain condensed water vapour effectively it is beneficial that they should be installed almost horizontally or vertically so that the condensate flows to the waste pipe. The recovery of ventilation heat in highly efficient recuperator is always accompanied by outdropping of water vapour, which must be drained in the most reliable way to the sewage system.

Use:
- industrial institutions and halls,
- buildings of public utilities (banks, offices, show rooms, cinemas, etc.),
- single-family and multi-family buildings,
- halls and sports buildings: swimming-pools, water parks,
- schools, universities, laboratories, hospitals and clinics,
- shops, market-halls, supermarkets, restaurants, hotels, banqueting halls, discos.

Free choice of installation place: cellar, attic, boiler room, outside building, etc.

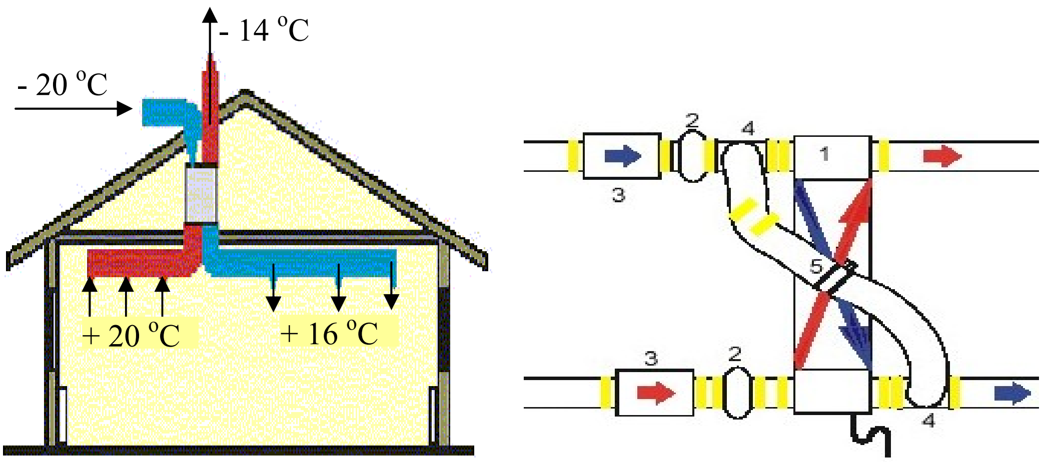

Figure 1: Examples of a heat recovery system, 1 - longitudinal spiral recuperator, 2 – ventilator, 3 – air filter, 4-5-4 – by-pass (open in summer), 5 - valve

Figure 2: Inlet and outlet side of the longitudinal counterflow spiral type recuperator

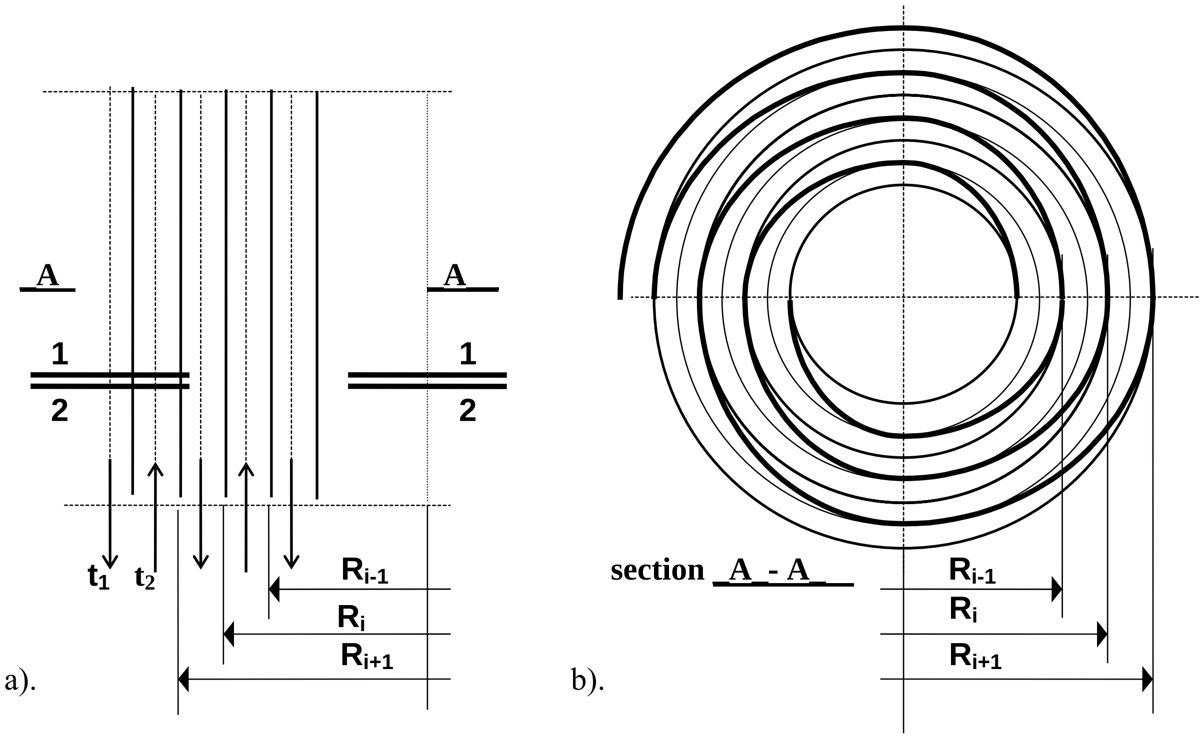

Figure 3: Longitudinal counterflow spiral type recuperator
a) longitudinal section, b) cross- section

FORMULATION OF THE OPTIMIZATION PROBLEM

The optimum length L_{opt} of the spiral recuperator could be determined using two opposite criteria [1, 2]:

- minimum heat transfer losses:

$$\dot{Q}_{outflow}(L) = \dot{Q}_{\max} - \dot{Q} = (1 - \varepsilon(L))\dot{Q}_{\max}$$

- minimum pressure drops in the channels $\Delta H_{1,2} = a_{1,2} v^n$, which induced energy losses:

$$\dot{E}_{1,2}(L) = A_C v \Delta H_{1,2} = a_{1,2} A_C v^{1+n} L \, .$$

Let's define general function as

$$N(L) = \frac{\dot{Q}_{outflow}(L) + \varphi\left(\dot{E}_1(L) + \dot{E}_2(L)\right)}{\dot{Q}_{\max}},$$

where

$$\varphi = \frac{K_R + K_{W1} + K_{W2} + 24 N_D \dfrac{c_e}{\eta}\left(\dot{E}_1 + \dot{E}_2\right)}{24 N_D c_c \left(\dot{E}_1 + \dot{E}_2\right)}$$

for minimum of the construction and exploitation costs of the recuperator.

Taking into consideration the heat exchanger effectiveness:

$$\varepsilon(L)=\frac{NTU(L)}{NTU(L)+1}, \text{ where } NTU(L)=\frac{UA(L)}{C}=\frac{4U}{D_H v\rho c}L,$$

we obtain the general function:

$$N(L)=\frac{1}{\frac{4U}{D_H v\rho c}L+1}+\varphi\frac{(a_1+a_2)A_C v^{1+n}L}{c\rho(T_{1,i}-T_{2,i})}=N_{\Delta T}(L)+\varphi N_{\Delta p}(L)$$

where a_1, a_2, n, U – are determined experimentally [3].

SOLUTION OF THE OPTIMIZATION PROBLEM

The general function $N(L)$ reaches its extreme value, if an equation $\frac{\partial N(l)}{\partial l}=0$ is satisfied, hence the optimum length of recuperator is

$$L_{opt}=\left(\sqrt{\frac{D_H(T_{1i}-T_{2i})}{4A_C U\varphi(a_1+a_2)v^n}}-\frac{D_H v}{4U}\right)\rho c$$

and:

$$N_{\min}=N(L_{opt})=1-\left(\left(\frac{A_C D_H\varphi(a_1+a_2)v^{2+n}}{4U(T_{1i}-T_{2i})}\right)^{0,5}-1\right)^2$$

Model exchangers are calculated, see Figure 4.

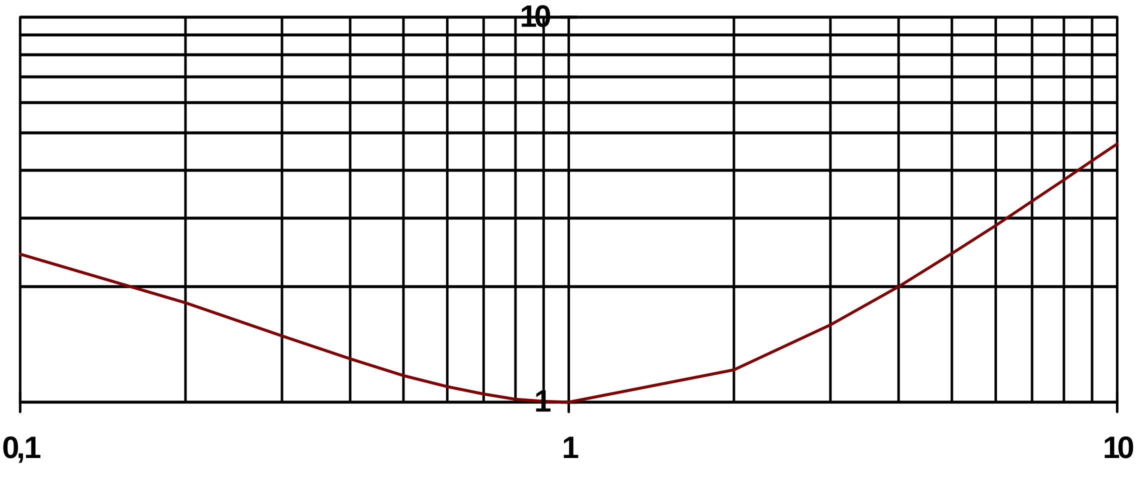

Fig. 4. Relative variation of the investment and exploitation costs N(L)/N(L_{opt}) as the function of dimensionless length of the recuperator L/L_{opt}.

The produced exchangers have the constant length, optimum flow velocities are used which the optimum diameter of recuperator D corresponds to for defined volumetric flow rate, see Figure 5.

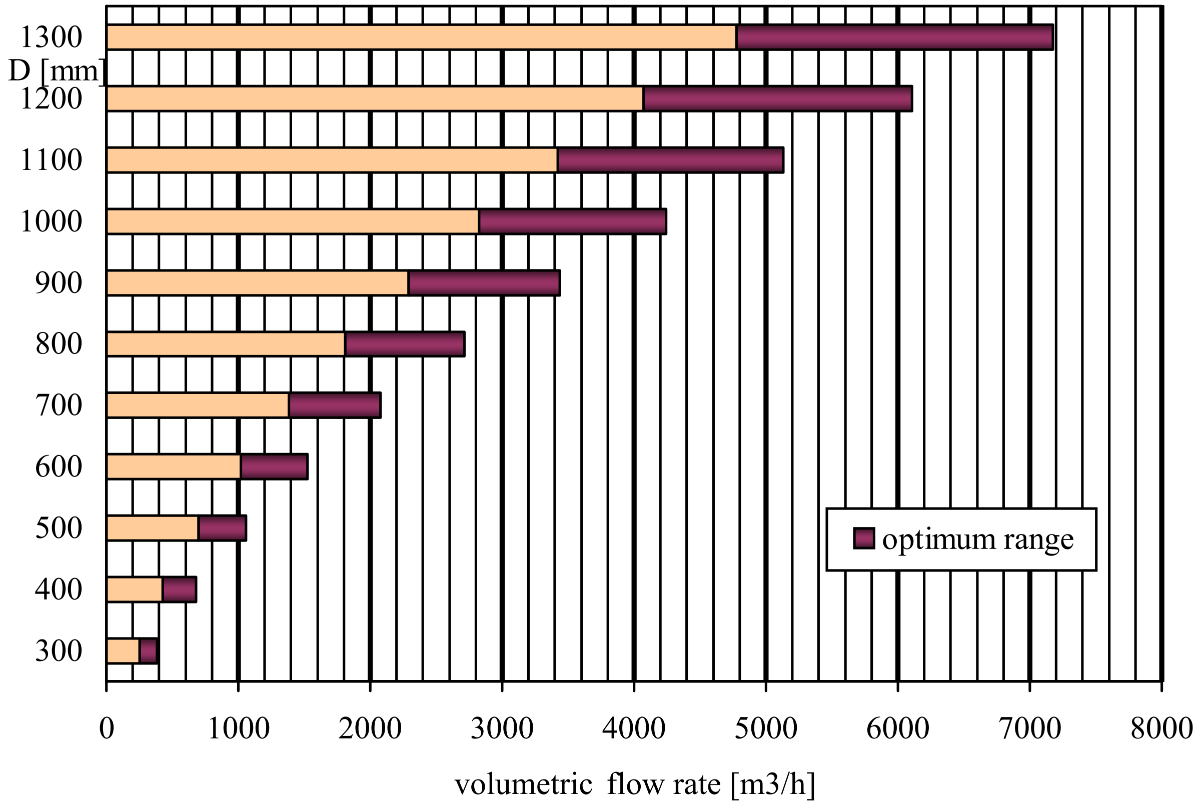

Figure 5: The optimum outside diameter of the spiral recuperator in relation to volumetric air flow rate

CONCLUSIONS

The aim of the heat recovery ventilation is to provide fresh air in the way in which the thermal comfort as well as energy saving are maintained, using a recuperator with the heat recovery from the removed air. In particular, heat recovery should be used in offices, gastronomic institutions, industrial institutions.

Taking into consideration the results of measurements and calculations the costs for capital expenditure and exploitation of ventilation systems with longitudinal counterflow spiral recuperators are minimized.

Ventilation system with spiral recuperators refunds the capital expenditure within one or two years' time.

NOMENCLATURE

A – heat transfer area, m^2,

A_C – area of duct cross – sectional, m^2,

c – specific heat at constant pressure, J/(kg K),

$C = mc = \rho A_C v c$ - capacity flow rate, W/K,

c_c, c_e – unit cost of heat energy, of electrical energy, respectively, zł/Wh,
D, L – diameter, length of exchanger, respectively, m,
D_H – hydraulic diameter of channel, m,
K – cost, zł,
N_D – number of exploitation days
T – temperature, °C,
U – overall heat transfer coefficient, W/(m^2 K),
$V = A_C v$ -volumetric flow rate, m^3/s,

Greek symbols

ρ – mean density of fluid in duct, kg/m^3,
v – velocity, m/s,
ΔH – pressure drop, Pa,

Subscripts

min, opt - minimum, optimum,
R, W– exchanger, ventilator,
1, 2 – cooled, heated air,
i, o – inlet, outlet,

REFERENCES

[1] Adamski M. (2002). Optimization of counterflow plate type ventilation heat exchangers, *IX Międzynarodowe Sympozjum: „Wymiana Ciepła i Odnawialne Źródła Energii”*,
[2] Adamski M. (2002). Obliczenia oraz optymalizacja spiralnych rekuperatorów o wzdłużnym przepływie przeciwprądowym, *X International Conference: Air Conditioning, Protection & District Heating,* pp. 17–22.
[3] Bujwicki, Sobiech, Cybulko (2001). Ekologiczne systemy wetylacji i klimatyzacji z odzyskiem ciepla, Firma Bartosz, Białystok.
[4] www.bartosz.com.pl