Analysis on heat pipes used to recover secondary resources

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Abstract. The present paper is a study on the opportunities given by the use of heat pipes in recovery processes of secondary energetic resources. There were defined the technical elements that characterize a heat pipe, the experimental stand were the experiments were conducted was presented. At the end of the paper it was presented a process within which such residual heat recovery systems can be implemented.
Key Words: heat pipe, heat recovery, waste water, energy.

Introduction. Reduction of energetic consume became a priority for all countries worldwide. This not only due to the limitation of Earth's natural resources or global warming, but also due to increase of costs of energy consumption. Most often, these energies are wasted due to defects in building construction or due to industrial equipment (installations) (Mladin et al 2004).

The current trend in the following years is moving towards a rethinking of energy policies in terms of how is energy produces and also in terms of consumer behavior. Production and efficient energy consumption is essential, use of renewable and secondary energy resources, and not least environmental protection, thus ensuring a sustainable development.

Spread on a larger and larger scale of technological processes based on the heat transfer phenomena between two fluids has given birth to a large number of heat exchangers. Thus, in complex heating processes – cooling, evaporation – condensation, boiling, sublimation etc., these heat exchange apparatus can operate either as main bodies, when representing key parts in technological processes, or only components of thermal processes, either as secondary bodies, placed in facilities for consumption reduction of energy from conventional sources.

Areas of use of heat exchangers are various, these being used in many industrial branches: metallurgic, energetic, chemical, petroleum, food, machinery, light industry, refrigeration and air conditioning etc. (Bai et al 2008).

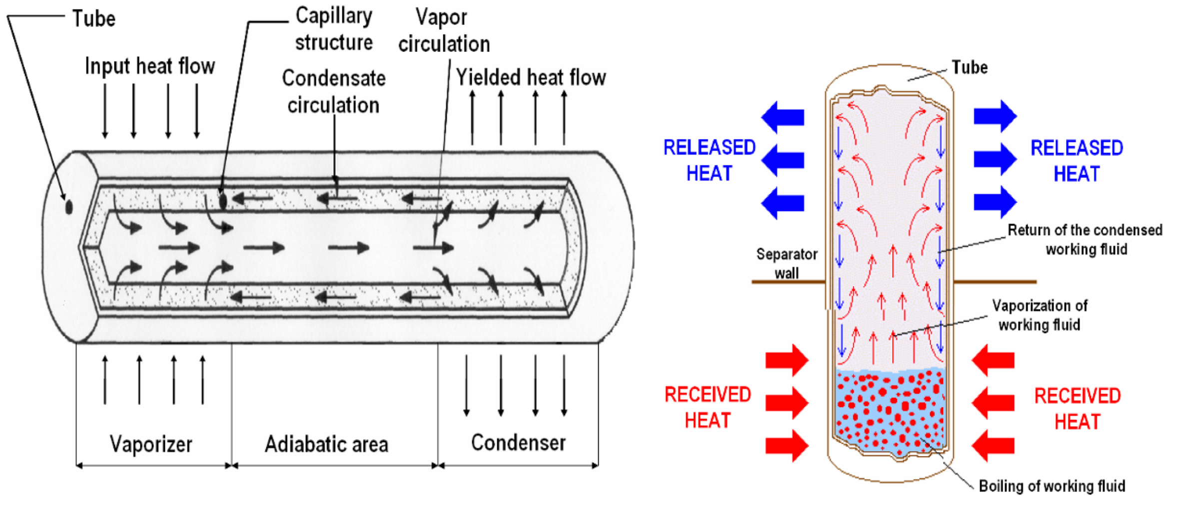
One of the main uses of heat exchangers is the complex processes of recovering the heat with low thermal potential. For this process, heat exchangers with heat pipes can be used (Chiriac et al 1992).

Heat pipes are innovative technical solutions, practical applications – prototype and industrial, with high efficiency in many technological applications (Eastman et al 1997; Ghiauş 2004; Nagi et al 2007)

An important such application is recovery of heat from thermal power plants chimneys or furnaces of various industrial producers. Research is being conducted to implement new ideas on the use of these heat pipes. This represents a reason to propose the use of heat pipes in experimental research on heat recovery from wastewater.

Material and Method. Heat pipes are metal tubes with the purpose of transferring heat from one place to another. They work by using a small quantity of working fluid contained in the sealed tube, creating vacuum. Vacuum has the purpose of decreasing the working fluid's boiling point. This working fluid, under certain conditions of pressure, boils at a low temperature passing from liquid phase into gaseous phase. In order to pass into gaseous phase, the fluid absorbs a certain amount of heat called *latent heat of vaporization.* This amount of heat will be transferred at the reverse passage from gaseous to liquid phase. At the heat pipe, the reverse phase change occurs at one of its ends, called *condenser* where the thermal agent is condensed and releases heat absorbed during evaporation. This cycle occurs continuously, heat being transferred from the warm point to the cold point (Ahmet et al 2009; Kempers et al 2008; Mostafa et al 2007; Neaga & Mărunţelu 2005; Te-En et al 2010; Yodrak et al 2010).

After the way of returning of the condensate in the evaporator area, heat pipes are divided in two categories: heat pipes with capillary filling (Figure 1a) and gravitational heat pipes (Figure 1b).



a) b)

Figure 1. Mode of operation of the heat pipe
a) capillary filling; b) gravitational (Kenter 2007).

The main issues to be considered in construction of a heat pipe are the choice of working fluid, pipe material and type of filling.

Experimental stand. Within experimental research there was used a heat exchanger with heat pipes. The goal of research was to determine their efficiency using wastewater as a heat source.

The Q – Pipe heat exchanger with heat pipes is produced by SC EnergiQ Company and its main characteristics are listed in Table 1.

The heat exchanger is composed of two compartments: the lower compartment with a volume of 0.164 m^3 and the upper compartment with a volume of 0.017 m^3.

Working fluid for the Q – Pipe heat pipes is recirculated continuously through the action of its own surface tension forces. Thermal energy is transported from the evaporator to the condenser in a continuous cycle of mass transfer and phase change of the working fluid. The phase change mechanism, with its absorption and heat release accompanying phenomena, is known as a very efficient thermal transfer process.

In the experimental stand was used a number of 40 heat pipes (Gabor 2011).

The heat recovery system had the following main components: residual heat source (wastewater), recovery installation and recovered thermal energy consumer, having mounted process measurement and control systems (heat meter, pressure gauge, flow meter, and thermometer).

In Figure 2 is represented the heat exchanger with heat pipes that was used for the experimental research. It is composed of two parts, namely:

- *The lower compartment*, where is the vaporization part of the heat pipe, in which the warm thermal agent (wastewater) circulates and gradually gives up its heat;
- *The upper compartment,* where is the condensation part of the heat pipe, in which the cold thermal agent (cold water from the network) circulates and is preheated.

Table 1

Characteristics of heat exchanger with heat pipes

Characteristics		*M.U.*	*Value*
Exterior length		m	1.433
Exterior width		m	0.086
Exterior height		m	0.760
Wall thickness		m	0.003
Separator wall thickness		m	0.010
Height of the lower compartment		m	1.108
Height of the upper compartment		m	0.305
Exterior height of tubes		m	1.390
Exterior radius of tubes		m	0.008
Interior radius of tubes		m	0.007
Distance between tubes and the lower wall		m	0.018
Distance between tubes and the upper wall		m	0.025
Material of which it is made of	wall	–	OL 37.2
	Separator wall		OL 37.2
	tubes		Cu 99.9

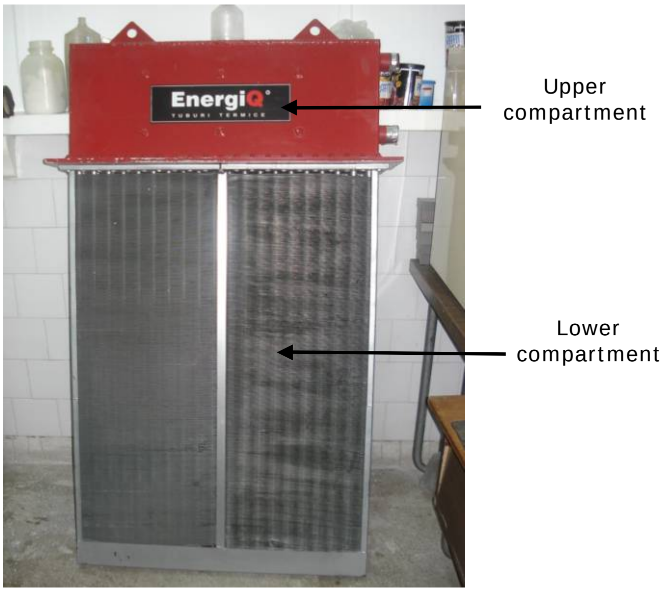


Figure 2. The Q – Pipe heat exchanger with heat pipes.

Results and Discussion. Experimental research has targeted thermal processes taking place in the heat exchanger with heat pipes and determination of its efficiency.

In Figure 3 is represented the variation of temperature recovered by heat pipes in the upper compartment, at a wastewater temperature of 50°C. The graph shows that heat pipes worked quite efficiently.

Experimental measurements were conducted at a wastewater temperature of 50ºC with a flow variation of 0.5 m^3/h (F1), 0.4 m^3/h (F2) and 0.3 m^3/h (F3). The heat exchanger with heat pipes operated for 30 minutes. The graph shows that after 25 minutes of operation, the heat exchanger began to enter in a stationary state.

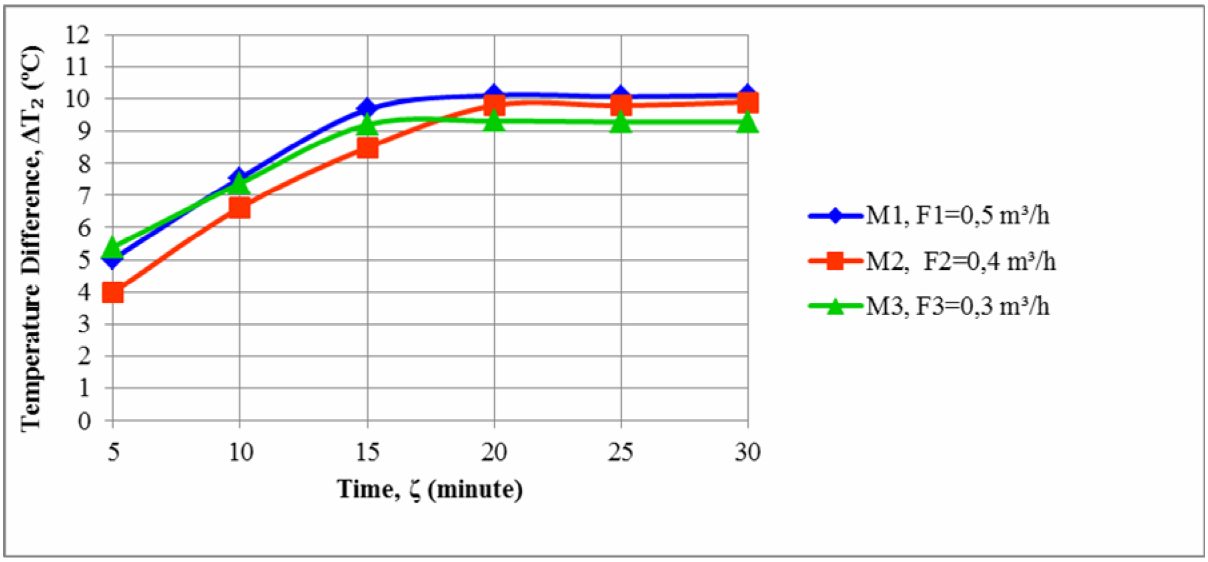


Figure 3. Variation of the temperature difference of cold agent versus time, the input wastewater temperature of 50°C.

To determine the efficiency of the heat exchanger with heat pipes, it was calculated the efficiency compared to wastewater (ε_1) and the efficiency compared to cold water (ε_2), with the following equations (Table 2; equations 1, 2).

$$\varepsilon_1 = \frac{t_1' - t_1''}{t_1' - t_2'} \cdot 100 \quad [\%] \tag{1}$$

$$\varepsilon_2 = \frac{t_2'' - t_2'}{t_1' - t_2'} \cdot 100 \quad [\%] \tag{2}$$

The average value of thermal efficiency in equation 3.

$$\varepsilon_{med} = \frac{\varepsilon_1 + \varepsilon_2}{2} \quad [\%] \tag{3}$$

where:
t'_1 – warm agent input temperature (wastewater) [°C];
t''_1 – warm agent output temperature (wastewater) [°C];
t'_2 – cold agent input temperature (cold water from the network) [°C];
t''_2 – cold agent output temperature (preheated water) [°C].

Table 2

Efficiency of the recovery process

Experimental measurements	ε_1 [%]	ε_2 [%]	ε_m [%]
M 1	32.9	32.53	32.71
M 2	33.68	29.98	31.83
M 3	32.4	30.64	31.52

Conclusions. Following experimental research we can conclude that using wastewater as heat source is a way of contributing to sustainable development. Wastewater flow is growing continuously and in most industrial or household processes it results with a heat content that is lost in the sewers.

Following measurements, the higher efficiency was obtained for measurement M1, this highlighting the fact that recovered temperature depends mostly on wastewater and cold water flows.

Energy security and climate change control must be the object of an integrated approach. It is important to elaborate strategies regarding top technologies that are efficient and use secondary energy sources, in order to ensure security of supply, controllable consumption, low price and environmental protection. It should be pointed out that many poor people spend a large proportion of income mostly on heating and hot consumption water, and by using renewable or secondary energy sources, production costs are much lower.

As technologies evolve and the cost level evolves in convenient directions, a number of secondary energy resources whose use is not justified nowadays, might be used in the future.

Acknowledgements. The experimental heat exchanger with heat pipes used in the research was supported by S.C. EnergiQ Ind. C.O. S.R.L Cluj-Napoca.

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Received: 06 November 2014. Accepted: 28 November 2014. Published online: 30 December 2014.
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How to cite this article:
Gabor T., Dan V., Tiuc A. E., Bădilă I. N., 2014 Analysis on heat pipes used to recover secondary resources. Ecoterra 11(4):17-22.