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Systems of heat pumps in water

Artur RUSOWICZ*[1], Olaf DYBIŃSKI[1], Arkadiusz SZCZĘŚNIAK[1], Andrzej GRZEBIELEC[1], Jarosław MILEWSKI[1], Róża ROMASZKIEWICZ-KOTKOWSKA[2]

[1] Faculty of Power and Aeronautical Engineering, Warsaw University of Technology, Warsaw, Poland
[2] CRL Sp. z o.o., Radom, Poland

Abstract

The number of words in abstract should be placed in a range between 100 and 300 words. It should be justified, Times New Roman font 12 pt., spacing before 10 pt., spacing between lines 1pt. The text should be clear and complex and involve the base problems of a paper, information about methodology and results, a conclusion is crucial.

Keywords: heat pump, water loop, energy efficiency.

1 Introduction

Systems using heat pumps connected by a water loop appeared in the 1960s [1]. They were initially used in large hotels with numerous rooms, with different user preferences, some rooms heated, some cooled and a significant number of unoccupied rooms. Subsequently, the application of the water loop heat pump system was extended to facilities such as hypermarkets and shopping malls [2,3]. Facilities of this type consist of a large number of rooms, often with different purposes and different heat loads, require the use of an efficient air-conditioning system. Such a system should try to ensure that heat and cold are distributed appropriately in individual rooms depending on their current demand [4]. This situation can occur in the case of:

- transitional periods when some rooms are heated and some are cooled,
- diverse mode of use of rooms (e.g. kitchens, restaurants, stores, galleries, offices, etc.),
- rooms in the building geographically oriented differently with glazed walls and high solar transmittance,
- strongly differentiated internal heat gains from people and lighting.

The concept of the system is to connect through a water loop a series of refrigeration units that can operate in heat pump or cooling unit mode. The water flow in the water loop transfers heat to the evaporators of the units operating as heating units or through the condensers of the units operating as cooling units. In extreme cases, all devices may work in the function of heating devices and then the temperature of the water in the water loop flowing through the evaporators may drop significantly, to prevent this in the water loop system there are built-in heat sources (e.g. boilers, electric heaters, municipal district heating network), which in such a situation raise the temperature of the water in the water loop to prevent the water from freezing. The other extreme case involves the operation of all equipment in the cooling function, in which case the water in the loop flows through the condensers and its temperature rises. A cooling system is placed in the loop to lower the water temperature. In a water loop heat pump system, the most favorable loop water temperature is between 15^0C and 35^0C. Hence, the most favorable from an

* **Corresponding author:** E-mail address: (rszelag@pb.edu.pl) Romuald SZELĄG

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energy point of view is the differentiated operation of the system for the needs of the rooms among which some are heated and others are cooled.

An interesting solution is to use a system with heat recovery. The system includes heat pumps with an interchangeable role of heat exchangers. In such systems, the role of evaporators and condensers is performed by heat exchangers of indoor units, while the heat exchanger of the outdoor unit operates with a reduced load, or in the case of balancing heat loads, is not used. Such systems described in [2] are not widespread. This is related to the significant cost of such a system and the specificity of the facilities in which it can be used.

Another solution, used for air conditioning of hypermarkets and shopping centers, is a heat pump system with a ring, water loop (heat pump system in water loop). Such a system consists of three main components:

heat pumps with reversible circulation and water-cooled condensers;

the water system (the so-called water ring), which consists of circulation pumps and a water tank;

the heating and cooling system.

Heat pumps are placed in individual rooms or zones of a building. The reversible circuit allows the set temperature to be maintained regardless of whether cooling or heating is required. The individual heat pumps are connected by a 2-pipe water system, usually shaped in the form of a ring. The circulating water is maintained within a temperature range of 15^0C to 35^0C. These temperatures make it possible to eliminate thermal insulation of the pipelines. The water circulation is forced by a pumping unit capable of providing a constant or variable flow rate of water in the pipeline, depending on the momentary demand. When the temperature in the water system falls below 15^0C, a water heating system is activated. This can be gas or oil boilers, electric heaters, or heat exchangers with a district heating network. In addition, the system can use waste heat or from regeneration. The supply of heat to the water system, can be realized from: recuperators, electric generator cooling systems, etc. The cooling system, on the other hand, is activated when the water temperature rises above 35^0C in the water system. The refrigeration system can consist of compressor chillers and/or open cooling towers. The general conceptual scheme of a system with heat pumps connected by a water ring is shown in Fig.1.

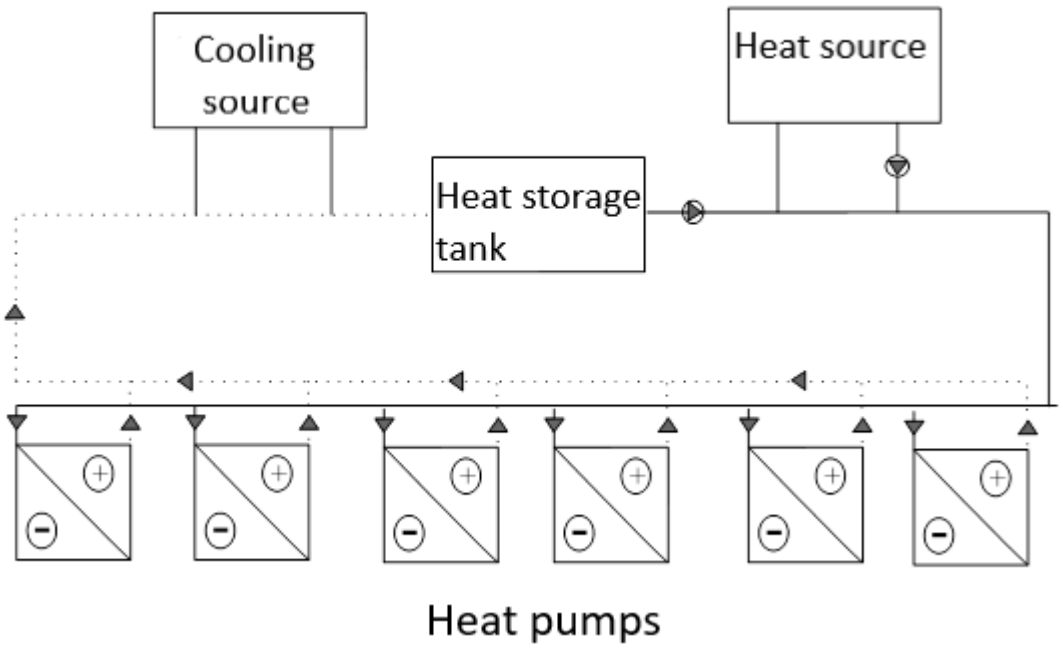

Figure 1 *Schematic diagram of the operation of an air-conditioning system with heat pumps connected by a water ring for shopping centers.*

In order to determine the feasibility of using a system with heat pumps connected by a water loop, a shopping center was analyzed, This building has a total floor area of 51500 m^2, of which 48500 m^2 is air-conditioned and 3000 sqm is only heated. The building is divided into two floors: the first floor with an area of about 28000 m^2 and the first floor with an area of about 23000 m^2 (see Table 1 for details). The roof is used as a parking lot. The two main galleries have large vertical and horizontal glass galleries. The technical rooms: boiler room, refrigeration plant and pump station occupy rooms of 50, 150 and 40 m^2 respectively. A fire tank with a volume of 600 m^3 was used as a water reservoir for the water ring. The building uses 201 water ring heat pumps, only the storage areas use conventional refrigeration units. The total cooling capacity of the heat pumps is about 6.4 MW. Two boilers with a total capacity of 800 kW were installed in the building [2].

Table 1. *Purpose and area of rooms in the shopping center*

Floor	**PRZEZNACZENIE**	**POW. [m^2]**	**WYKORZYSTANIE**	**POW. [m^2]**
I FLOOR	HIPERMARKET	10400	Sales area	8100
			Offices and services	1200
			Meat processing	1100
	Stores	3000		
			Stores	6400
			Middle zone	3450
	Shopping center	15000	Restaurant and kitchen	950
			Galleries and annexes	4100
			Offices and services	100
II FLOOR	Central zone	8100	Sales area	8100
			Stores	6400
	Shopping center	15000	Middle zone	3450
			Restaurant and kitchen	950
			Galleries and annexes	4100
			Offices and services	100

With the development of heat pump technology, water loop heat pump systems began to be modified. Heat pumps were connected to the loop using various lower heat sources, such as ground [6,7,8], air and surface and deep water [9]. Such systems allow limiting the functions to heating or cooling only, as presented in Fig.2.

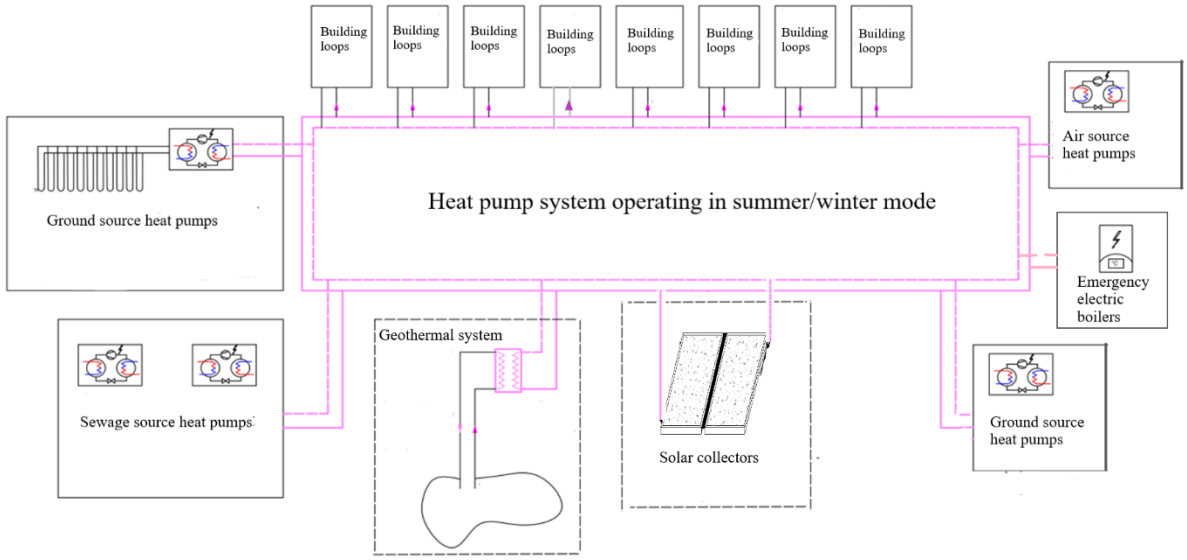

Figure 2. *The system with heat pumps connected by a water loop for facilities requiring heating or cooling*.

The next group of applications for water loop heat pump systems is becoming industrial systems [11,12]. Practically, the beginning of the use of heat pumps concerned desalination and drying plants [1]. The concept of using heat pumps to heat water in the loop for a large industrial laundry plant is presented below. Water in the water loop is heated by 3 heat pumps with bottom sources in the form of air, ground and wastewater, as presented in Fig.3. The heating of water for the washing machines is also supported by solar panels and a coal-fired boiler. In addition, the system uses heat stores. The essence of the solution is to supply water to the washing machines at such a temperature as to minimize exergy losses by mixing hot water with cold water and steam. This is a complicated task, since the washing machines carry out different washing programs, with different temperatures, process times and filling weights. Therefore, neural networks will be used to optimize the operation of the system.

Thanks to the cooperation of solar collectors with heat storage and a heat pump that allows the regulation of the temperature of the medium, it will be possible to avoid significant emissions of carbon dioxide, as well as reduce emissions of dust, sulfur oxides and nitrogen oxides generated by burning coal in the existing heat source. As a result, the enterprise will be able to boast higher energy efficiency in terms of primary energy rate per unit of product. The use of control based on self-learning algorithms on the basis of neural networks and weather forecasting will further enable the company to increase the efficiency of its operations and order execution planning in order to make the greatest possible use of heat from a renewable source such as the sun. The effect of improved energy efficiency will be determined by the avoided amount of heat produced from the coal heat source used in the technological process for heating water. It is expected to be possible to reduce the production of energy from coal by at least 50%. Thanks to the application of optimization of the enterprise's operation using neural networks and weather forecasting, it will be possible to additionally increase the efficiency of the use of heat obtained from solar collectors and stored in heat accumulators, as well as to improve the organization and execution of orders in the enterprise, thus making it possible to increase the efficiency of the enterprise.

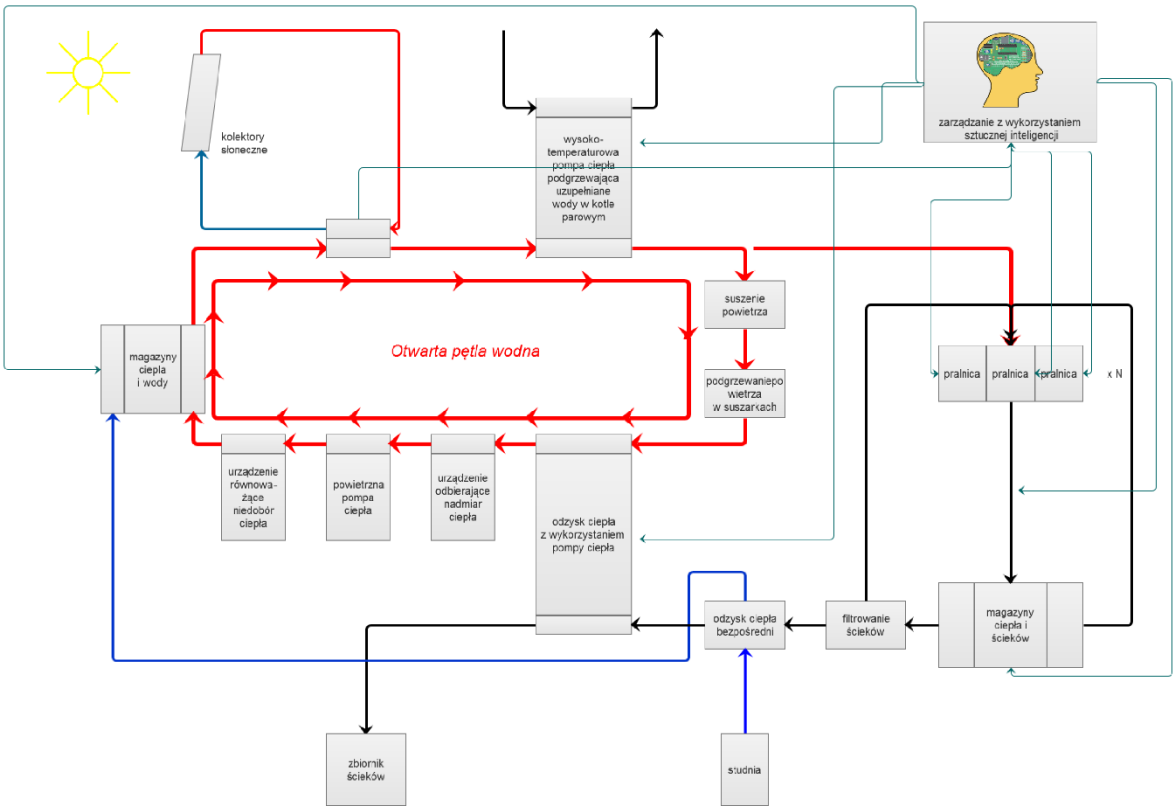

Figure 3 *The water loop heat pump system in a laundry plant.*

6 Conclusion

In summary, it can be said that systems with heat pumps connected by a water loop are an economically attractive proposition [10]. They allow significant savings to be achieved. In the winter months, they reach up to 60% of the energy saved for shopping centers [2]. On an annual basis, they reach up to 23%.

Attention should also be paid to the possibility of additionally applying cooling using "free-cooling" which allows to significantly reduce operating costs or supplementing with solar panels as an additional heat source. In industrial systems, also the potential of water loop heat pump systems allows for significant energy savings and positive environmental considerations.

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