

Ice rink – design of size of water storage tanks with small heat source for ice resurfacing machine

M Kovac, K Kovacova

Technical University of Kosice, Faculty of Civil Engineering, Vysokoskolska 4, 040 01 Kosice, Slovakia

E-mail: martin.kovac@tuke.sk

Abstract. The paper describes a method of design of storage tanks volume for an ice resurfacing machine in ice rink by using heat source with small thermal power (idea of downsizing). The main aim is to minimize investment costs for boiler room (the heat pump water-water). The achieved results show saving of investment costs about 35%. The request is the minimum water temperature at the value of 45°C before each filling process of resurfacing machine. Therefore it is very important to design the storage tanks volume where the water temperature will not be below the 45°C before the each filling an ice resurfacing machine during the hockey match or training. The required volume of storage tanks was calculated at the value of about 2000 litres if there is used the heat source with thermal power 45 kW. The number of storage tanks is given by boiler room dimensions too. In this case 3 storage tanks were designed.

1. Introduction

Most rinks use heated water to resurface the ice. Hot water flows more evenly onto the ice and bonds more strongly to the old ice than does cold water. The reason for this is that hot water melts some of the old ice, smoothing out small cracks and flaws in the ice [1]. From the surveys mapping the energy consumption of ice rink we can see that the energy for ice resurfacing is about 6 % - 10 % of total energy use in modern ice arenas [2, 3, 4].

The paper describes the technical design of storage tanks volume with small heat source for ice resurfacing machine in the ice rink. The design of heat source is based on the idea of „downsizing“, where the heat source with low thermal power is used. This heat source is combined with so volume of water in storage tanks in which the temperature does not drop below 45°C before each filling process of resurfacing machine.

The consumption of water for resurfacing machine is from 400 to 700 litres per one operation [5]. In this case it is needed the storage tank with minimum volume 700 liters. So the heat source with small thermal power (e.g. 45 kW) will have a problem with warming of water in storage tank (700 liters) to the required value of temperature during the short time interval (length of one hockey period is 20 minutes + (plus) resurfacing of ice is during the break – (minus) time for filling a resurfacing machine). By using of heat source with higher thermal power (e.g. 90 kW) we will achieve the required temperature of water in storage tanks in short time but the investments cost of that heat source will be higher. Using a heat source with small thermal power in combination with adequate volume of storage tanks could be a good way (idea of downsizing). The maximum attention is needed



in the process of calculation of required volume of storage tanks in the combination with heat source with small thermal power.

2. General requirements for resurfacing of ice

Resurfacing of ice surface is made by using of resurfacing machine. A blade shaves a thin layer from the surface of the ice. After a horizontal screw (auger) gathers the shavings, a vertical screw propels them into the snow tank. Water is fed from a wash-water tank to the „conditioner“, which rinses the ice. Dirty water collected in front of a squeegee is vacuumed, filtered, and returned to the tank. Clean water from the ice making tank is delivered to the ice through a pipe and spread evenly by a towel pulled across the ice behind the „conditioner“ [6].



Legend:

- 1 - blade
- 2 - horizontal screw
- 3 - vertical screw
- 4 - snow tank
- 5 - wash-water tank
- 6 – „conditioner“
- 7 – ice making tank

Figure 1. Typical resurfacing machine [6].

The consumption of water for resurfacing machine is from 400 to 700 litres per one operation. The used water has to meet the required chemical properties, with neutral pH value and free from mechanical particles. The temperature of water is from 30 to 50 °C. The average water temperature for resurfacing machine is 45°C. The filling time of resurfacing machine is from 3 to 11 minutes. The ice is usually resurfaced 5 – 10 times per day [7].

3. Design of storage tanks volume

In this case will be the gas boiler used as a heat source. But the owner of ice rink wants to use the electric heat pump (water to water) instead of gas boiler in near future. Logically, the request is to minimize the investment costs for heat pump. The energy source for heat pump will be waste heat from ice cooling technology. In analyze is considered with thermal power of heat source (gas boiler, electrical heat pump) at the value of 45 kW. The request is the minimum water temperature at the value of 45°C before each filling process of resurfacing machine. During a hockey game we have three period with standard length of 20 minutes and two brakes with 15 minutes. In real the each period is longer than 20 minutes. The resurfacing of ice surface is made before the start of game and then after first and second period of a game. When the resurfacing machine is filled by the water from the storage tanks the water temperature drops in storage tanks (filling with cold water from a water supply). The used heat source (gas boiler or heat pump) heats the water in storage tanks continuously.

If we know the thermal power of heat source, operation time of heat source, the amount of cold water and its temperature we can calculate the water temperature after heating by using the following equation (1). This equation describes the thermal energy in water. For our case we have modified the equation (1) into the equation (2).

$$Q = mc\Delta T \quad (1)$$

where Q is thermal energy in liquid; m is mass of liquid; c is specific heat capacity of liquid and ΔT is temperature difference of liquid.

$$\begin{aligned} P_{\text{gen}} \eta_{\text{gen}} t_{\text{gen}} &= m_w c_w \Delta T_w \\ P_{\text{gen}} \eta_{\text{gen}} t_{\text{gen}} &= \frac{V_w \rho_w}{3600} c_w (\theta_{w,\text{warm}} - \theta_{w,\text{cold}}) \end{aligned} \quad (2)$$

where P_{gen} is thermal power of heat source; η_{gen} is efficiency of heat source; t_{gen} is operating time of heat source; m_w is mass of water; V_w is volume of water; c_w is specific heat capacity of water; ρ_w is density of water; ΔT_w is temperature difference of water; $\theta_{w,\text{warm}}$ is temperature of hot water and $\theta_{w,\text{cold}}$ is temperature of cold water.

By using equation (2) we can calculate the temperature of water which was supplemented into the storage tanks after filling of resurfacing machine. This volume of supplemented warm water with calculated water temperature is mixed with water in storage tanks. So we need to calculate the final water temperature in storage tanks by using the following equation (3).

$$V_1 \theta_1 + V_2 \theta_2 = V_3 \theta_3 \quad (3)$$

where V_1 is volume of water remaining in storage tanks after filling a resurfacing machine; θ_1 is temperature of water remaining in storage tanks after filling a resurfacing machine; V_2 is volume of water added from a water supply into the storage tanks after filling a resurfacing machine; θ_2 is temperature of cold water added into the storage tanks from a water supply after filling a resurfacing machine; V_3 is volume of water in all storage tanks and θ_3 is temperature of water in all storage tanks after warming by using of heat source.

The next figure (Figure 2) shows the water temperature in storage tanks during a hockey game. The temperature of water was calculated by using equation (2) and (3). The initial conditions which were used in calculation of water temperature in storage tanks are shown in the following table (Table 1).

Table 1. Initial conditions.

Parameters	Values
Thermal power of heat source	45 [kW]
Number of heat sources	1 [-]
Thermal power of all heat sources	45 [kW]
Time for filling a resurfacing machine	6 [minutes]
Temperature of cold water added into the storage tanks	7 [°C]
Temperature of hot water in storage tanks before a hockey game	60 [°C]
Heat capacity of water	4.186 [kJ/(kgK)]
Density of water	999.7 [kg/m ³]
Real volume of storage tanks	2289 [l]
Maximum consumption of water for resurfacing machine	700 [l]

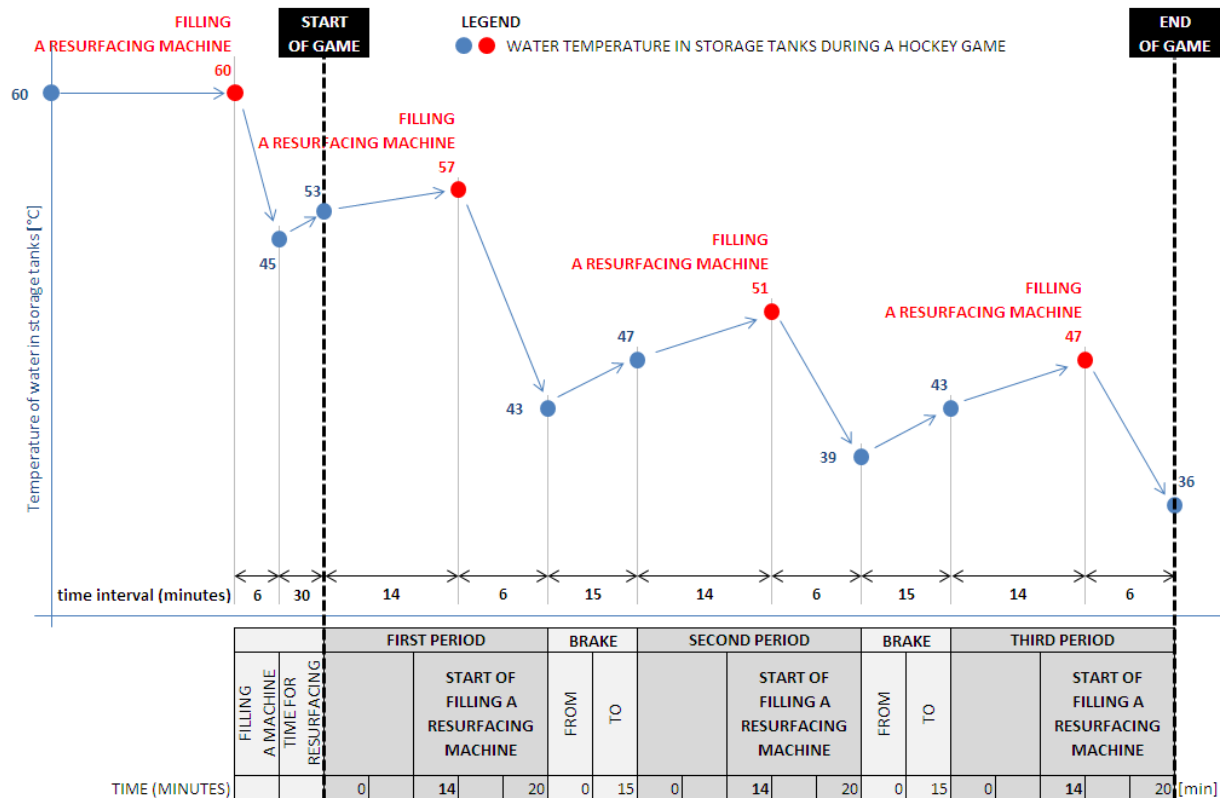


Figure 2. Water temperature in storage tanks during a hockey game by using a heat source with small thermal power (45 kW).

4. Functional scheme of boiler room

The next figure (Figure 3) shows the functional scheme of suggested heat source with small thermal power (gas boiler or planned installation of heat pump in near future) and with water storage tanks. In order to achieve the maximum heat transfer from the heat source (gas boiler or planned installation of heat pump in near future) into the storage tanks we use the tanks without twisted heat exchangers. The maximum effective heat transfer from the heat source (gas boiler or planned installation of heat pump in near future) into the water in storage tanks is designed through the flat plate heat exchanger. The storage tanks are connected with pipes (cold water into the tanks, warm water from tanks for resurfacing machine, heating pipes) through the Tichelmann solution.

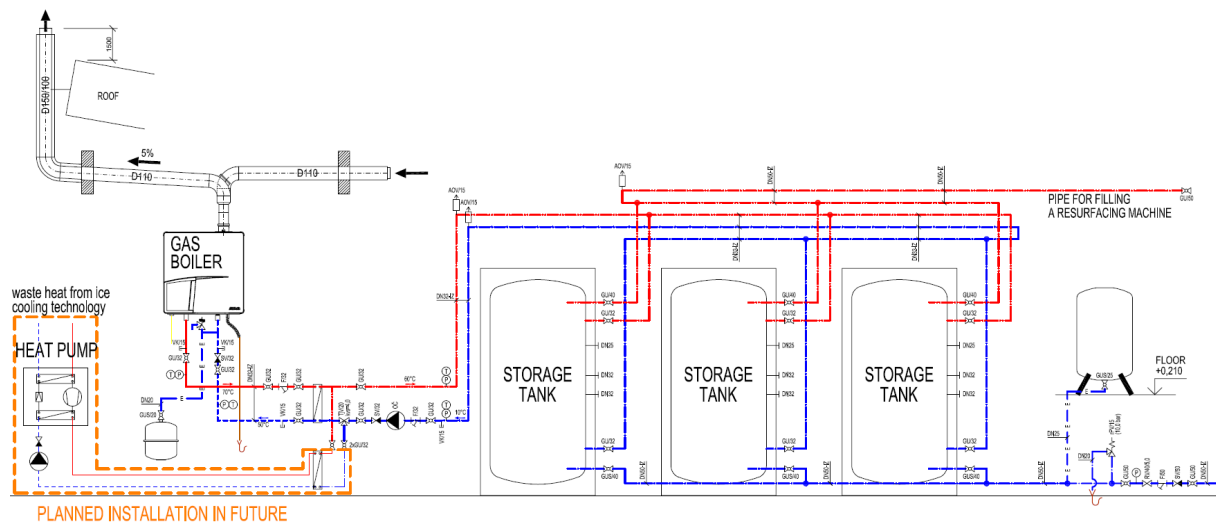


Figure 3. Functional scheme of gas boiler installation with storage tanks of water.

5. Conclusion

This paper describes a design of storage tanks volume for resurfacing machine by using heat source with small thermal power (idea of downsizing). The aim of paper was to show the possibility of using the heat source with small thermal power in order to supply hot water for ice resurfacing machine. In this case it is need to pay high attention to design of required volume of storage tanks where the water temperature will not be below the value 45°C before the filling a resurfacing machine. There was done the financial analyze of investment costs for electric heat pump because the owner of ice rink wants to buy them in near future. There were compared two variants. In first variant there is used the heat pump with small thermal power (45 kW) in combination with 3 storage tanks. Their water volume is about 2000 liters. In second variant there is used the heat pump with higher thermal power (90 kW) in combination only with 1 storage tank. The water volume of storage tank is about 700 liters in this case. The investment costs of first variant were calculated at the value of about 21 000 Euro. For the second variant the investment costs are about 33 000 Euro. If we compare these two variants we can say that using the idea of “downsizing” will bring savings in investment costs about 35%. If we compared gas boilers as heat source, the difference in investments cost would be minimal.

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