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REVIEW

HEAT PUMP APPLICATION IN FOOD TECHNOLOGY

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ABSTRACT

The economy of food technologies is greatly influenced by their energy consumption. Almost no operation or procedure exists that could be executed without the need for electricity. At the same time, several technologies require direct or indirect input of thermal energy as well. An example to quote is the heating of the raw materials of food industry or the pasteurisation or sterilisation of finished products, but heating the production rooms or cleaning or washing the machinery also require energy. Needless to say food industry plants constantly seek ways to improve their energy efficiency such as the reintroduction of waste heat into the technology and the use of renewables. Heat recovering heat exchangers are used in the pasteurisation technology of milk. In case of lower temperatures, however, simple heat exchangers are of no use. Few practical examples of heat recovery obtained upon cooling products or raw materials exist in the food industry even though the possibility of this is available using heat pumps. Heat pumps have been successfully applied to heat apartments with thermal energy recovered from the cooling of soils, water or air or to utilise the excess heat of thermal spring waters. Our present article introduces the application possibility in a soda water plant, fundamentally determining the quality of soda water and showing an example of rational utilisation.

Keywords: food technologies, heat pump, heating, soda water

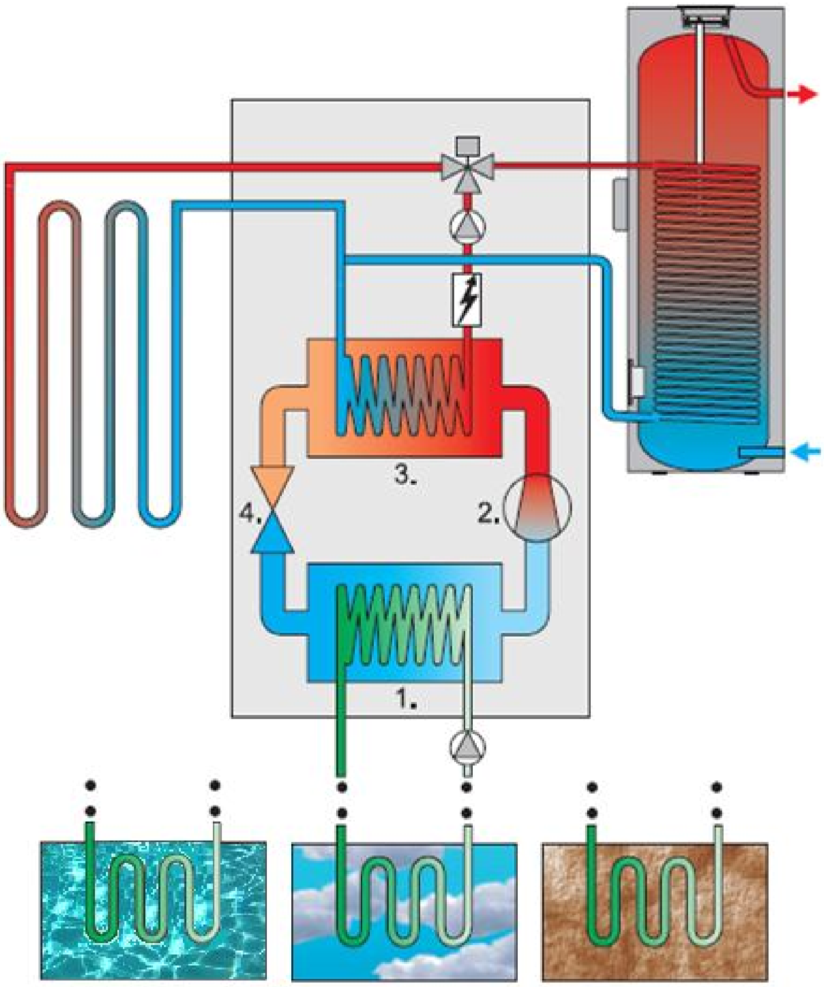
INTRODUCTION

Heat pump operation

Heat pumps are effective solutions to heating and cooling applications for all types of buildings, domestic, commercial and retail premises including food industrial applications. This well-proven technology has been in use for decades and Heat Pumps are at work all over the world providing safe, reliable heating and cooling at affordable prices. Reserves of conventional fossil fuels are finite and emissions of Carbon Dioxide and other greenhouse gases add increasingly to the effects of climate change. As a low carbon technology, heat pumps can significantly reduce the Carbon Dioxide emissions **(URL1).**

The first heat pump was built by the American inventor Robert C. Webber. It all basically happened by accident when, in the late 1940's, Webber was experimenting with deep freezing equipment and he unintentionally touched the outlet pipes of the cooling system, burning his hand. This led him to the idea behind the basic mechanics of a heat pump. He connected the outlet piping from a freezer to a hot water heater and, since the freezer was producing constant excess heat, he hooked up the heated water to a piping loop and, using a small fan, he started to force the warm air into the building. He continued to experiment by successfully harvesting heat from the ground using below-grade heat collectors. In fact, he was so satisfied with his discoveries that only a year later, he decided to sell his old coal furnace **(Komlós et al., 2009).**

At the heart of a modern heat pump is a refrigeration system. Paradoxically, the refrigeration cycle is an efficient provider of heat. There are two principle locations in the transfer of heat; the place where heat is absorbed, (the source), and where it is rejected, (the destination). The compressor in the refrigeration system also produces waste heat, and a significant proportion of this can be recovered, thereby reducing running costs and the ultimate release of CO_2 **(Reay and Mac 2008; Dexheimer, 1985; Lund, 1988)**. The easiest way in which to understand how a heat pump works is to look at the Figure 1.



a.) water b.) air c.) soil

Figure 1 Operation principle of heat pump

The first step is the evaporation (1), where the coolant circulating in the heat pump system collects heat from the air, water or the ground. This process causes the coolant to evaporate and change to a gaseous state. The second step is the compression (2).The heat pump's compressor rapidly compresses the coolant, which is now in a gaseous state and several degrees warmer. Thanks to the laws of physics behind the compression process, which cause the temperature of the compression medium with increases in pressure, the compression elevates the otherwise low potential heat of the coolant to a higher level – approximately 80°C. After that next step the condensations (3). Using a second heat exchanger, the heat from the heated coolant is transferred to the water circulating through the radiators. This causes the coolant to drop in temperature and condense back into a liquid state. The radiators distribute the heat provided into the heated areas. The chilled water in the heat loop then travels back into the second heat exchanger, where it is heated again. Finally is the expansion (4), by passing through the expansion valve, the coolant travels back to the first heat exchanger, where it is once again heated. This cycle keeps repeating itself over and over again **(Komlós and Fodor, 2011; Randy and Turner 2011)**. The resulting heat can be used for space heating or to prepare hot water. But we can obtain heat from food technology as well.

History of soda water

The definition of the notion of soda water and the corresponding quality requirements and methods of examination are contained in the standard MSZ 8808:1995 on soda water **(Codex Alimentarius Hungaricus)**.

Soda water is potable water conforming to respective health requirements and pressurised with carbon dioxide which is commercialised in pressurised glass or plastic bottles with siphon heads or 25 l metal containers fitted with special taps (soda water bottles) **(MSZ 8808, Soda water).**

The first person to compound carbon dioxide with water was Joseph Priestley in 1767. It is referenced a number of times in relevant literature that although Priestley was an enthusiastic experimenter and had a fine talent for observing things, he often derived incorrect conclusions from his tests due to his lack of scientific qualifications. In 1773, the Royal Society recognised Priestley's achievements in natural philosophy by awarding him the Copley Medal.

Jacob Schweppe of Geneva followed Priestley in the production of carbonated water, who had in 1783 invented an efficient method for large scale production of carbonated water which he kept in secret. The siphon head was developed and patented by Charles Plinth in 1813.

Ányos Jedlik came to new discoveries in 1826 when he built the “apparatus acidularis” to surprise his order compeers and could artificially produce carbonated water. Later the first soda water plant in Hungary was built according to his plans. Unfortunately this latter had rapidly gone bankrupt, leaving the great invention unutilised for the time **(URL 2)**. Therefore he was not the discoverer of the product, but made possible the cost efficient large scale production of the drink, solving all emerging technical problems, among others, the best possible absorption of the gas.

Soda production process

The most important basic material for the production of soda water is potable water suitable for human consumption. Appropriate filtration technologies are important to maintain constant high quality of the end product. Cooling the water to the desired temperature is a significantly definitive parameter of the saturation procedure beside pressure and CO_2 content. The soda water production process is described in Figure 2.

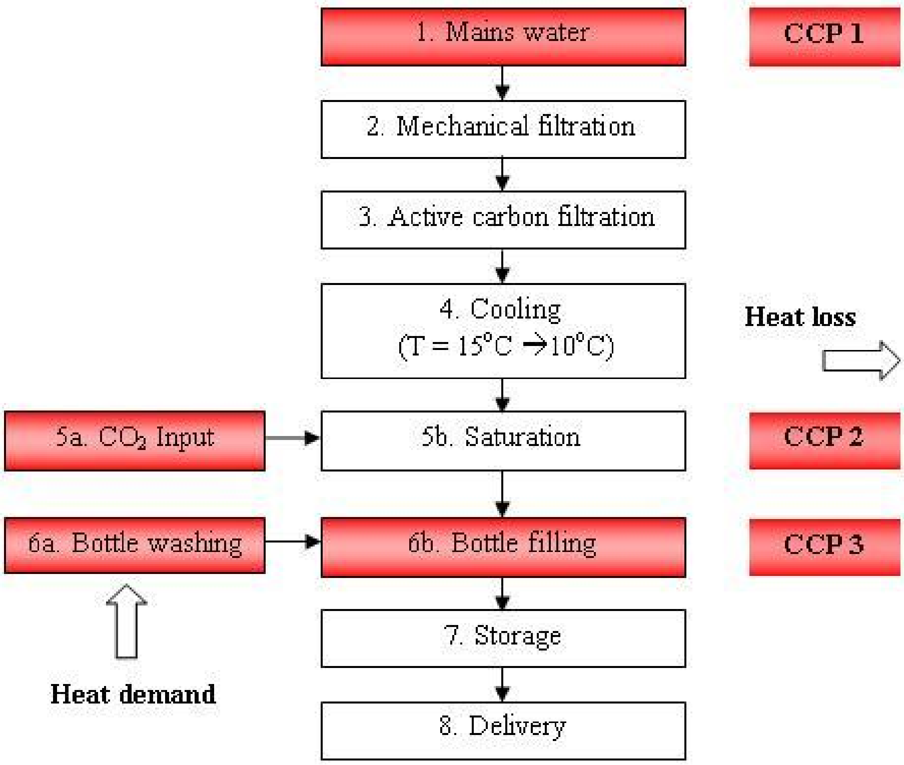


Figure 2 The soda production process

The water arriving from the water supply system flows through the optionally built in water treatment system and the cooling unit. After this, the water quantity needed for production is fed into the saturation cylinder constantly kept under operational pressure and a steady supply of CO_2. The supply of CO_2 is ensured by a special racking system. The task of the saturation machine is saturating the water with CO_2. After this has been completed the soda water is piped to the bottling equipment where it is bottled into siphon headed bottles or containers.

Recovery of waste heat in soda water manufactory

A definitive factor of how enjoyable any carbonated drink tastes is its content of carbon dioxide. This of course does not mean an unlimited content of carbon dioxide, but a quantity needed for that particular drink. In case of identical beverages a constant level of carbon dioxide content is a significant quality requirement. Saturation of the drinks with carbon dioxide, i.e. the absorption of carbon dioxide is a complex process, called saturation in industrial soda water production terminology. Carbon dioxide gas diffuses into the liquid and is absorbed therein. As temperature increases, the carbon dioxide absorption capacity of the liquid decreases and it increases with the increase of the partial pressure of the gas, as shown in Figure 3.

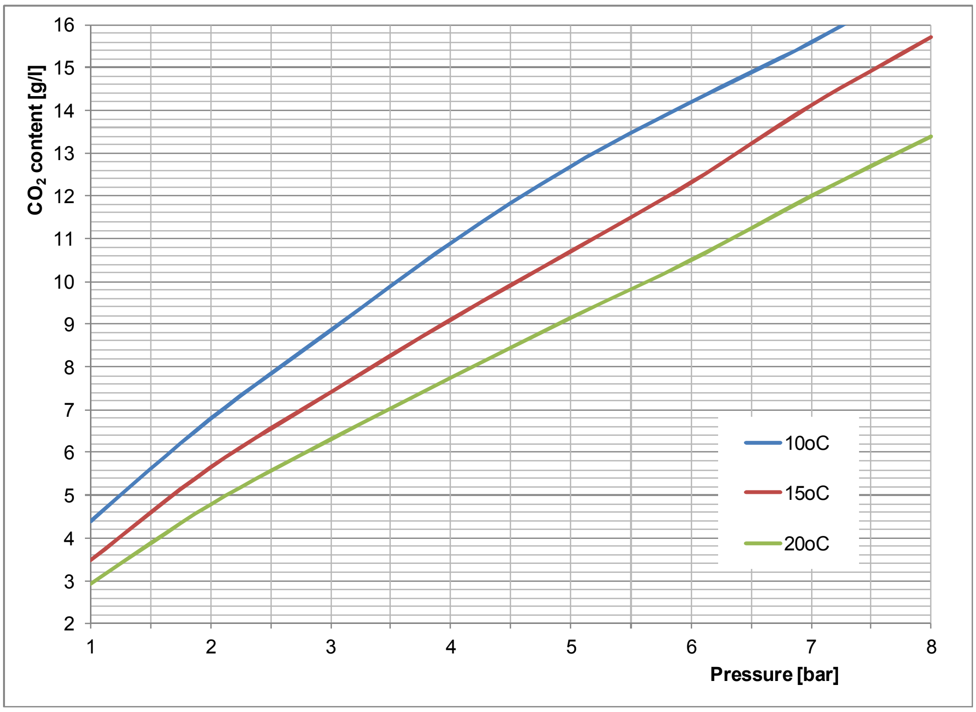


Figure 3 Absorption of CO_2 as a function of the temperature and pressure

The quantity of carbon dioxide that can be absorbed in water depends on the temperature and pressure of the water. This is why filtered water is cooled below 10°C prior to saturation. The quantity of heat resulting from this is left unutilised in most cases or unintentionally used to heat the production premises. Smaller heat pumps commercially available offer a heat output of Q_h = 7.5-10.1 kW at an electrical capacity of P_e =1.5-2.1 kW. This heat output is sufficient to heat a food industry plant or to generate 200-250 litres of water at a temperature of 50-60°C. The evaporation capacity of the mentioned heat pumps is

Q_e = 5.8-7.8 kW, which results in cooling of the mains water. According to our experience the water coming to the saturator is at 12-15°C.

$$Q_e = c \cdot \dot{m} \cdot \Delta T \quad \text{eq.1}$$

By considering the well known equation 1, with a decrease in temperature of ΔT =5 °C and a specific heat capacity of c = 4.18kJ/kgK, water with a mass flow of $\dot{m}$ = 1000-1350 kg/h is able to loss the necessary thermal energy quantity. The mass flow calculated is equivalent to that of a small soda water plant.

By considering a smaller soda water plant we have established that quality requirements necessitate the cooling of the filtered water. The heat from the cooling can be utilised with the help of a heat pump. Heat from the technological cooling is usually not utilised as periodical operation may generate problems on the heating side as well. By the tested food industry application, however heat output can be used for heating of factory or the bottles washing. The incorporation of the heat pump into the technology is shown on Figure 4.

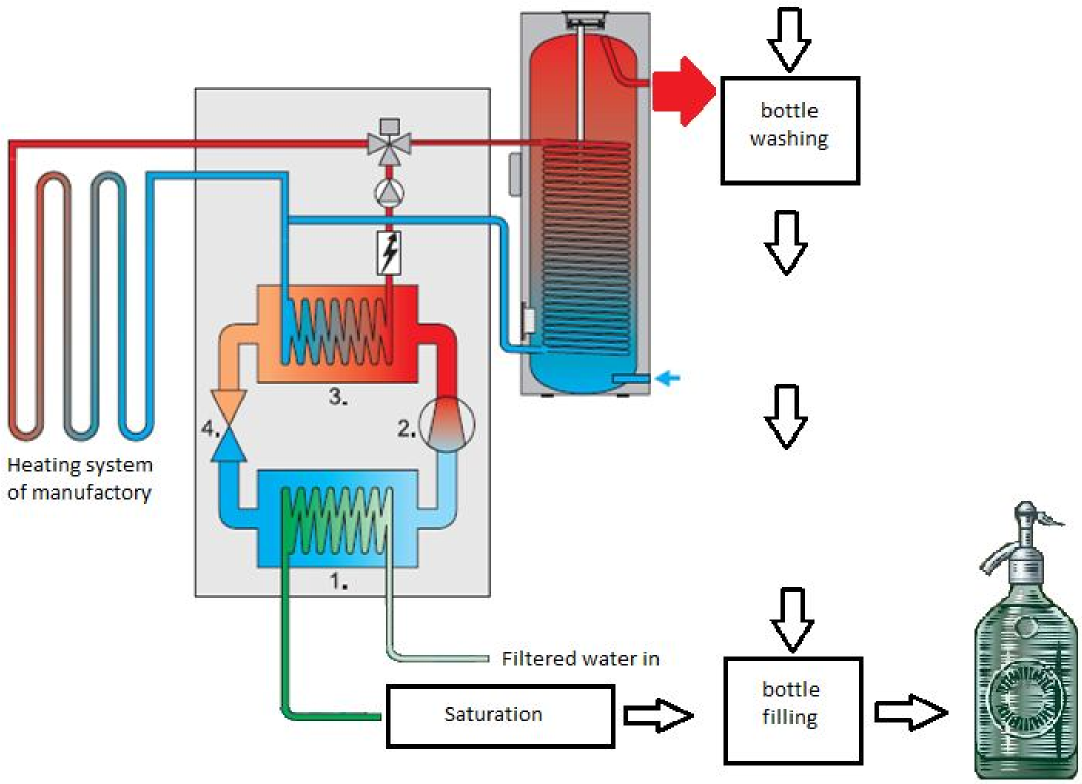


Figure 4 Heat pump in the soda process

Heat loss and heat demand therefore occur almost simultaneously and can be planned with accuracy. Considering Hungarian energy prices a return of 3-5 years can be calculated for the investment coupled with the environmental advantages detailed in this article.

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