HEAT PUMPS UTILIZATION IN THE PASTEURIZATION INSTALLATION

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Abstract: The article shows a comparative analysis of two schemes of heat and cold supply of the pasteurization installation: the traditional scheme of heat delivery from the Power Plant and cold delivery from the refrigerator, and the supply scheme of both types from the double use heat pump. It is proved that in the supply scheme from the Heat Pump the total consumption of primary energy form external sources is over 1.5 times less than in the traditional scheme.
Key words: pasteurization, heat pump, energy consumption.

Traditional pasteurization installation

Pasteurization is a method of fermentable food preserving by the destruction of pathogenic bacteria present in the product as a result of the thermal treatment. Thermal treatment consists of food heating at temperature below 100 °C followed by sudden cooling up to 4–6 °C.

Pasteurization installations have a various construction, most being in the class of heat exchangers [1]. In the Figure 1 is showed the traditional scheme of pasteurization that includes the company heating system. Initially the product is preheated with the heat of

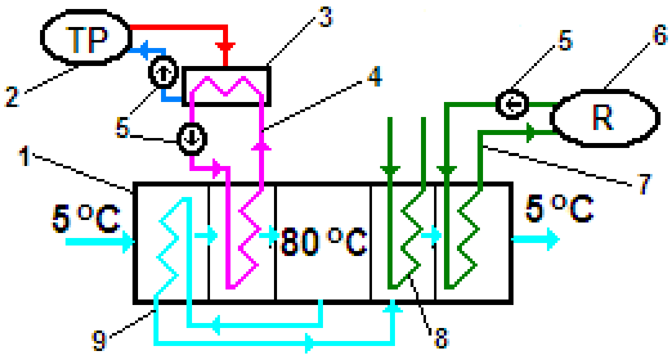

Fig. 1. The thermal schema of the traditional pasteurization installation:

1 – Pasteurizer, 2 – Thermal Plant, 3 – water preheater, 4 – heating contour, 5 – pumps, 6 – Refrigerator, 7 – final cooling contour, 8 – preliminary cooling contour, 9 – heat recovery contour

the pasteurized product, and then it is heated up to temperature of pasteurization, as is shown in Figures 1 – 80 °C, prepared with hot water from Thermal Plant. The product was cooled in the recovery and the pre–cooler with water that has a temperature of about 20 °C and is cooled up to storage temperature with cooling agent from Refrigerator.

The Figure 2 shows the energy flow diagram (Sankey diagram) for the mentioned scheme. To simplify the diagram, recovery flow was not indicated. The heat added to the unit with water heater – Q_{inc} as the base value of about 100%, was considered. The Thermal Plant efficiency of about 90% was admitted, the efficiency of the obtaining electricity for refrigeration, with consideration of losses in transmission and distribution electric networks – 33%. Compared with heating heat, as is showed in the diagram the fuel

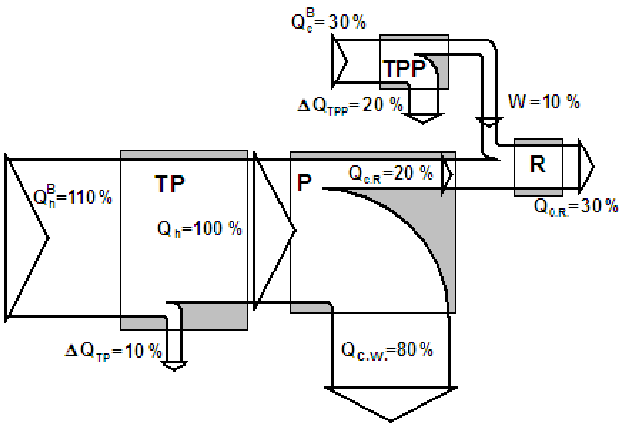

Fig. 2. The Sankey diagram for the traditional scheme of pasteurizing plant energy supply:
TP – Thermal Plant, P – pasteurizer, TPP – Thermal Power Plant, R – Refrigerator;
Q_h^B – fuel energy consumed in TP (for heating), Q_c^B – fuel energy consumed for produce electrical energy for driving the R compressor (for cooling), Q_h. – inserted heat for heating the product, ΔQ_{PP} – heat losses in PP, ΔQ_{TPP} – TPP losses, $Q_{c.w.}$ – the eliminated heat from the preliminary cooling water system, $Q_{c.R}$ - evacuated heat from P to R, W_R – compressor´s driving energy, $Q_{0.R}$ – the removed out heat through the R condenser.

energy consumed totally for pasteurization process is of about 140%. A huge amount of energy – 110% is eliminated as heat into the environment.

Heat pumps energy efficiency

The utilization of the heat removed as a source of heat with a low potential (l.p.h.) in the heat pump (HP), would allow significant reduction of energy consumption in the process.

To be energy efficient the HP should have the fuel consumption – B_{HP} at the production of the one quantity of heat – Qt less than the same amount of heat generated by a Thermal Plant (TP) – B_{TP}:

$$B_{HP} < B_{TP} \tag{1}$$

At the usage of HP in the thermo technological installation, along with heat and cold product is used – Q_c, form the B_{TP} will be reduced the amount of respective fuel – B_R:

$$B_{HP} < B_{TP} - B_R \tag{2}$$

For those consumptions are the following expressions:

$$B_{HP} = \frac{Q_t}{Q_i^r \cdot COP \cdot \eta_e}; \tag{3}$$

$$B_{TP} = \frac{Q_t}{Q_i^r \cdot \eta_{TP}}; \tag{4}$$

$$B_R = \frac{Q_c}{Q_i^r \cdot \varepsilon_R \cdot \eta_e}. \tag{5}$$

In the formulas above Q_i^r is the inferior heat of fuel burning, COP – the HP performance coefficient, η_e – The efficiency of electricity production and transportation, η_{TP} – TP thermal energy production efficiency, ε_R – the refrigerator cooling efficiency.

Introducing the expressions (2) and (3) in (1), for the Heat Pumps efficiency for which is used only heat we will have the expression

$$COP_{ef.t} > \frac{\eta_{TP}}{\eta_e} \tag{6}$$

Applying the existing average values $\eta_{TP} = 0{,}90$ and $\eta_e = 0{,}35$, we got $COP_{ef.t} > 2{,}57$.
Taking in consideration that:

$$Q_c = Q_t \cdot (1 - \frac{1}{COP}) \tag{7}$$

and

$$\varepsilon_R = COP - 1 \tag{8}$$

From the expression (2–5) we will have:

$$COP_{ef.(t.+c.)} > \frac{\eta_{TP}}{2 \cdot \eta_e} \tag{9}$$

The indicated above values of the η_{PP} and η_e $COP_{ef.\,(t\,+\,f)} = 1{,}29$, it is 2 times smaller than the pump with simple destination.

The pasteurization installation with a heat pump

Since the investment in heat pumps is essentially higher than in Thermal Plant the limit of HP energy efficiency is considerably higher: for a simple installations – with approx. 3,0, for the double purpose – 1,5.

In the figure 3 is presented a schematic diagram of energy supply of pasteurization installation with heat pump, where for heat production is used as a source of l p.h. from the cooling product process.

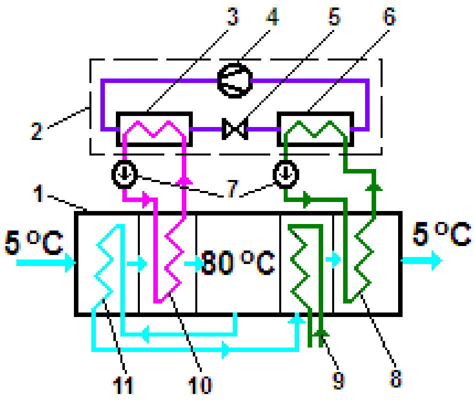

Fig. 3. The thermal power scheme of the pasteurization plant with heat pump:

1 – Pasteurizer, 2 – heat pump, 3 – HP condenser 4 – compressors, 5 – throttle valve, 6 – evaporator HP, 7 – pumps, 8 – final cooling contour 9 – outline precooling, 10 – heating contour, 11 – contour of the heat recovery.

In the figure 4 is presented the Sankey diagram for this scheme, which shows that total expenditure on external energy source is only 90% of the heat introduced into the process, which is over 1.5 times less than in the traditional scheme.

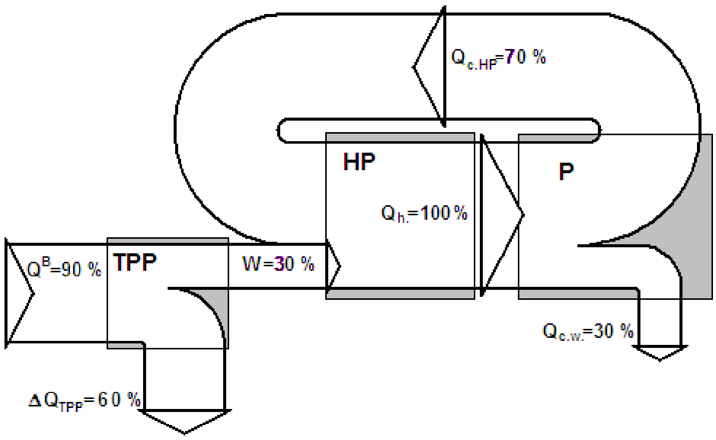

Fig. 4. The Sankey diagram for the traditional scheme of pasteurizing plant energy supply: HP – heat pump, P – pasteurizer, TP - Thermal Plant; Q_B – fuel energy consumed in TPP for electricity compressor drive HP, W- compressor´s driving energy, $Q_{h.}$ – heat input for product worming, ΔQ_{TP} – heat loss in TP, $Q_{r.e.}$ – evacuated heat from of preliminary water cooling installation, $Q_{r.PC}$ – the low potential heat used in HP.

For the process with temperature limits showed in figure 4: vaporization – 5 °C and condensation – 80 °C, using software package Cool Pack has been studied the heat pump cycle in two stages for the refrigerant R600a – isobutane. The decreased temperature in the contours of the evaporator and condenser were allowed by about 15 K, the efficiency of the compressor – 0,8. The obtained COP value is 2,6 that are considerably higher than the minimum efficient value.

Conclusions:

1. The traditional pasteurization installation has a complicated scheme of energy supply, which includes Thermal Plant and Refrigerator.
2. The two stage heat pump minimum efficient value of COP: simultaneous heat and cold supply, is reduced twice and is – 1,5.
3. At the energy supply of pasteurization installation with heat pump the total primary energy outside expenditure are over 1,5 times lower than in the traditional scheme.

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