Wort cooling

12.1 Single-stage wort cooling

After hot trub separation in the whirlpool, the wort is preferably cooled to a temperature of 5 to 15 °C for bottom-fermented beers and to 15 to 18 °C for top-fermented beers (pitching temperature). Apart from few exceptions, closed wort cooling systems are used today for cooling. Single-stage plate heat exchangers (PHE) are mainly used as wort coolers, but multi-stage (two/three-stage) versions of PHEs are also in operation. Treated fresh water (= brewing water) is used for single-stage plate heat exchangers for bottom-fermented beer wort cooling; this fresh water is cooled in a cooling plant from the respective fresh water temperature to 2 to 5 °C (pre-cooled brewing water) and stored in an insulated brewing water tank. Cooling of the brewing water and filling of the brewing water tank can be implemented during low tariff periods with cheaper electrical energy.

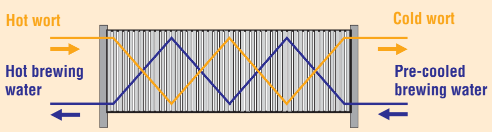

Fig. 12.1: Structure of single-stage wort cooler

Wort cooling must be completed for a brew within a maximum of 60 minutes to avoid increased thermal stressing of the wort. Single-stage plate heat exchangers must be designed in such a way that hot brewing water of at least 80 °C is generated. Single-stage plate heat exchangers are also used for wort cooling of top-fermented beer.

12.2 Two-stage wort cooling

In two-stage wort cooling, the wort is cooled during the first stage of the PHE (pre-cooling section) using non-cooled brewing water. The second stage of the PHE (post-cooling section) is either fed with ice water or another refrigerant (e.g. alcohol-water mixture), which is supplied from a heat-insulated refrigerant tank.

Two important criteria for the design of the 1st stage of a plate heat exchanger are the so-called "liquid ratio" calculated from the quotient "heat intake of the brewing water per litre" by "heat delivery of wort per litre" and the temperature difference between inlet temperature of the brewing water and transfer temperature of the wort from the 1st stage of the PHE to the 2nd stage.

The following conditions apply:

- Liquid ratio of brewing water to wort: 1.1 to 1.0
- Maximum temperature difference: 4 K

Improperly designed pre-cooling sections lead to increased cooling requirements in the post-cooling section and therefore to higher costs for electrical energy. The same conditions apply to the cooling time for a brew and the temperature of the outlet hot brewing water as for the single-stage version.

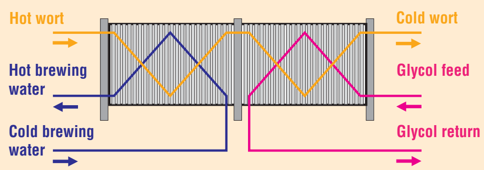

Fig. 12.2 – left: Two-stage wort cooler with glycol postcooling

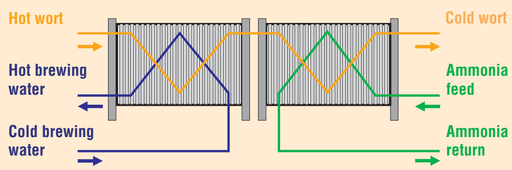

Fig. 12.3 – right: Two-stage wort cooling with direct ammonia cooling in the post-cooling stage

12.3 Ice water storage system

Dimensioning of an ice water storage tank is based on the ice storage capacity and the thawing performance. Sufficient storage capacity of the ice water storage tank must be provided according to the daily number of brews. The thawing performance has to be high enough to ensure that the technologically determined cooling time of the wort is 60 minutes at the maximum.

The maximum ice thickness of the pipes or plates in the ice water tank for refrigerant or secondary refrigerant should not exceed 35 mm. The limiting factor when using an ice water storage tank is the daily number of brews.

Energy consumption during wort cooling/ heat recovery

To minimise electrical energy consumption for the proportional provision of cooling using a compression cooling system for wort cooling, the following criteria must be observed, depending on the design of the plate heat exchanger.

The following applies to two-stage PHE:

- Lowest possible wort transfer temperature from pre-cooling to post-cooling section
- Feed temperatures of secondary refrigerant (ice water) as high as possible in the PHE
- Use of ice water storage systems to balance out peak electric power consumption during high tariff times and fill up the ice water storage tank using low cost electrical energy during low tariff times (only suitable for systems with long brew rhythms)

The following applies to single-stage PHE:

- High brewing water outlet temperature from the PHE
- High pitching temperatures for the wort
- Use of storage tanks with pre-cooled brewing water to minimise costs for electrical energy
- Use of absorption refrigeration system with H_2O/LiBr material combination, which is driven by waste heat from an e.g. energy storage system

Table 12.1 shows a comparison of different single and two-stage wort cooling processes. These examples assume a cast wort volume (hot) of 1,000 hl to be cooled from 96 to 8 °C. Treated, uncooled brewing water with a temperature of 13 °C is available for cooling. The operating refrigerant system uses screw compressors, ammonia as the refrigerant and evaporative condensers with an average condensing temperature of 28 °C. In a two-stage wort cooling setup using a refrigerant (e.g. glycol-water mixture) under the specified boundary conditions, a proportional electrical energy consumption can be calculated for the refrigerating compressors of 203 kWh per brew and 184 kWh per brew for direct evaporation of ammonia in a separate plate unit.

The basic rule is that an increase in evaporating temperature of 1 Kelvin and constant condensing temperature reduces electrical energy consumption for the refrigerant compressor by approx. 3 %. Table 12.1 shows that the proportionate electrical energy consumption for a refrigerant compressor in a single-stage wort cooling process, where the evaporating temperature is -7 °C, is 238 $kWh_{(el)}$ per brew. In refrigeration systems which can be operated with two different evaporating temperatures, electrical energy of 192 kWh per brew is used at an evaporating temperature of -1 °C.

Table 12.1: Comparison of single and two-stage wort cooling processes

Process refrigerant temp. [t_0/t, °C]	Cooling medium / refrigerant	Cooling med. inlet temp. [°C]	Volume BW (82 °C) [hl/brew]	Cooling demand [MJ/brew]	Electrical energy [$kWh_{(el)}$/brew]
Single-stage (-7/28)	Brewing water	5	1,167	4,107	238
Single-stage (-5/28)	Brewing water	5	1,167	4,107	219
Single-stage (-1/28)	Brewing water	5	1,167	4,107	192
Two-stage (-7/28)	Glycol/H_2O	-4	1,184	3,513	203
Two-stage (-5/28)	Ammonia	-5	1,184	3,446	184

BW: brewing water
t_0: evaporating temperature of the refrigerant
t: condensing temperature of the refrigerant
Wort transfer temperature: 16°C
Wort cooling from 96 °C to 8 °C, reference capacity: 1,000 hl hot cast wort