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ENERGY SAVING WORT BOILING SISTEM IN BREWING FACTORY

Mariana Geta TOMESCU (cas. Cismarescu)*, Carol CSATLOS**

*Faculty of Food and Tourism, "Transilvania" University of Braşov, Braşov, Romania
** Faculty of Food and Tourism, "Transilvania" University of Braşov, Braşov, Romania

Abstract: *Steam is produced on boiling. This steam is referred to as (water) vapour. If the vapour is allowed to escape unhindered from the chimney, people in the neighbourhood can smell that the brewery has cast out wort again. This can be considered to be odour pollution. Moreover the evaporated water mass contains a great deal of energy which in the casa escapes through the chimney. To convert 1 kg of water at 100^{0}C into 1kg of stream at 100^{0}C, about 2260 kJ = 90 psi, are required. If the stream condenses again in the surroundings, this heat energy is released again and completely lost to the brewery.*

Keywords: *steam, energy, vapour compression, boiling,, energy saver, hot water, thermocompression.*

1. INTRODUCTION

Energy usage during wort boiling - the wort kettle is the greatest energy user in the entire wort production process.
Very careful consideration must therefore be given to how to keep the energy usage as low as possible since energy is very expensive.
Energy usage is quoted in kWh or BTU or kj. Common fuels have the following thermal values (natural gas 11,20 kWh/m3, fuel oil 10,14 kWh/l, heavy oil ll,l6 kWh/kg, hard coal 8,95kWh/kg).
In the brewhouse an 80% efficiency can be expected, i.e about 80 % of the energy is utilized in the brewhouse.
The starting point of our considerations is the energy usage obtained with a conventional copper. Energy used in conventional boiling - if the wort is boiled for 90 min at 100^{0}C leading to a percentage evaporation of about 12 % in the copper, theny, in conventional boiling for each 1 hl of cast wort about 14 kWh = 56,00 BTU/bbl are required. (1 kWh = 3,6MJ = 0,948 BTU)

2. VAPOUR CONDESATION

It is therefore useful to recover at least part of the heat of evaporation.
This is done by building in a kettle vapour condenser in the kettle chimney.
If the steam is condensed here the heat of evaporation is recovered. In the kettle vapour condenser (Fig.1) the steam is passed against pipes of pockets, through which water is pumped, and the water is thereby warmed whilst the steam gives up its heat of evaporation and condenses.

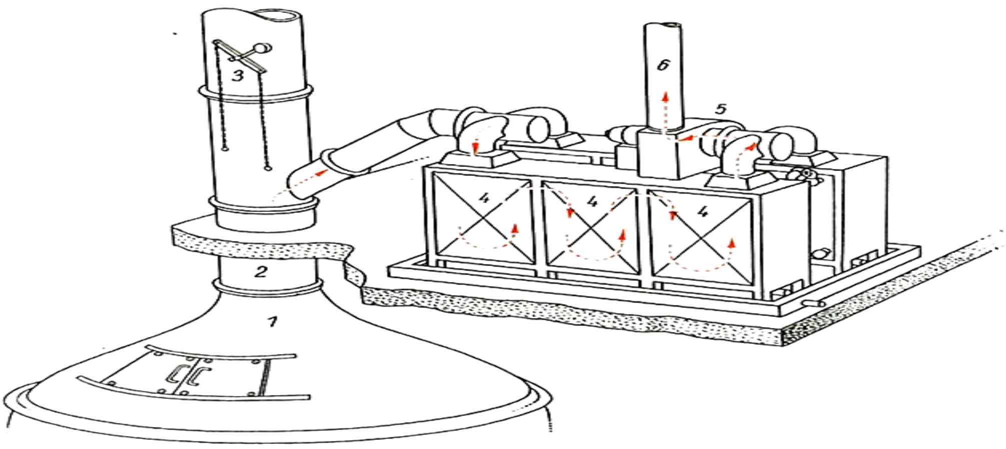


Fig.1.Kettle vapour condenser (Pfaduko)
1-wort kettle; 2-vapour chimney; 3- adjustable valve; 4-heat exchange chamber; 5-extractor; 6-blow-off pipe.

Depending on the subsequent purposes for which the heat is used,the steam is cooled in one or two stages and hot and/or warm water thereby produced. Nowadays most kettle vapour condensers are built with one stage cooling (Fig. 2.). Each hl of evaporated wort produces 0.8 hl of hot water at 80^0C.

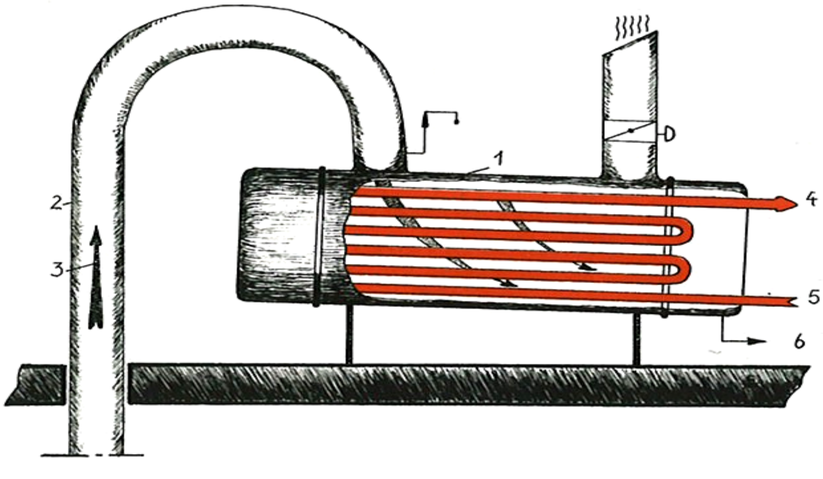


Fig. 2.Kettle vapour condenser (Pfaduko)
1-heat exchange vessel; 2-vapour chimney; 3- water vapour; 4-hot water outlet; 5-warm water inlet; 6-condensate drain.

The volume of steam is decreased considerably on condensing to form water and the water can easily be removed. Nowadays the kettle vapour condenser is often built in the form of a single-layer plate heat exchanger. The vapour flows in at the top of every second plate, and the condensed water runs out at the bottom, whilst the cooling water flows in a counterflow from below upwards in the plates between them and is thereby heated (Fig.2.a).

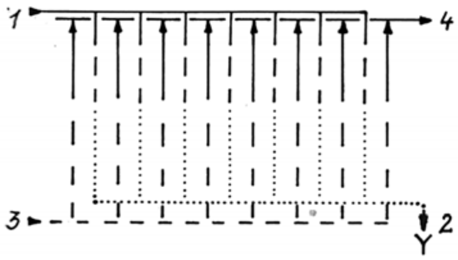


Fig.2.a.Plate heat exchanger as kettle vapour condenser
1-vapour; 2-condensate; 3-cold water; 4-hot water

On heat utilisation grounds the cooling water used is as hot as possible so that it is brought as close as possible to boiling point through the condensation of the vapour.

3. VAPOUR COMPRESSION

The vapour produced on boiling is at about 100^{0}C and thus can not be used any further to heat the wort. If, however, the vapour is compressed to a few tenths of a bar overpressure, the temperature of the vapour is raised to 102-108^{0}C and it can be used again for heating. In this way the heat consumed for evaporation in the wort boiling process can be directly recovered again.
Vapour compression is achieved either:
- by means of a mechanical compressor, in which case one speaks of mechanical vapour compression, or
- by means of a steam jet compressor which requires steam from a boiler to drive it, in this case one speaks of thermocompression.

Mechanical vapour compression is regarded as the state of the art and thermocompression is much less frequently found in breweries.

3.1 Mechanical vapour compression

The vapour produced is mechanically compressed to an overpressure of 0.2-0.5 bar (3-7psi) by a turbo, screw or rotating piston (Roots) compressor. As a result of this compression the temperature of the steam is increased and it can be used again directly for heating purposes. However a condensate is sprayed in previously to reduce the superheating. With vapour com pression steam and energy can therefore be spared since only the energy necessary to drive the compressor is needed (about 5 % of the primary energy requirement, i.e. 95 % of the primary energy requirement is spared). Heating up of the wort necessarily begins with the supply of fresh steam (Fig. 3.) from a boiler into the wort copper. The wort is forced by the circulating pump (4) through the external heater (3), heated up, and returned to the wort copper (1).When the desired boiling temperature of 102 to 106^{0}C is reached at the heater outlet, the compressor (2) is started and the vapour produced (9) is compressed to an overpressure of 0,09-0,25 bar 102 to 106^{0}C . The boiling process is thereby maintained in operation.

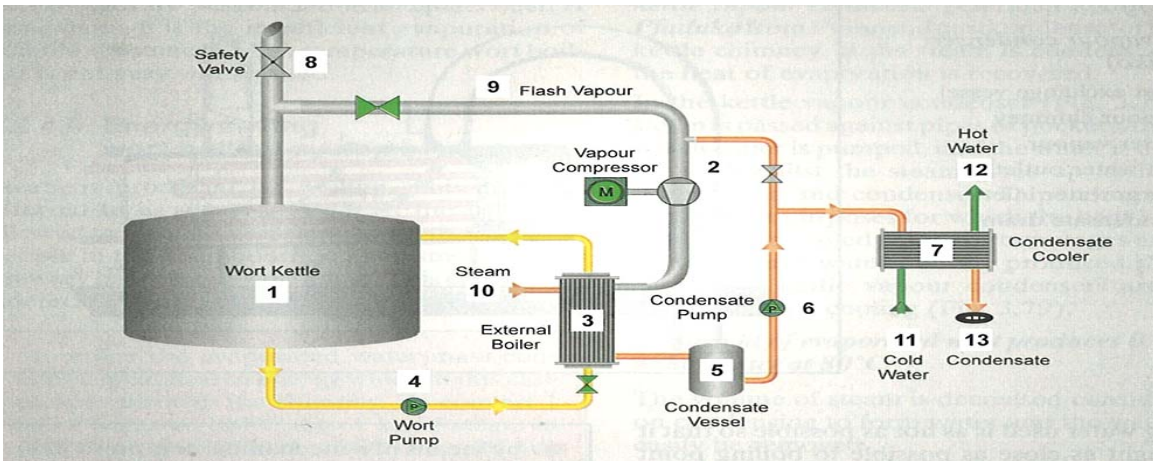


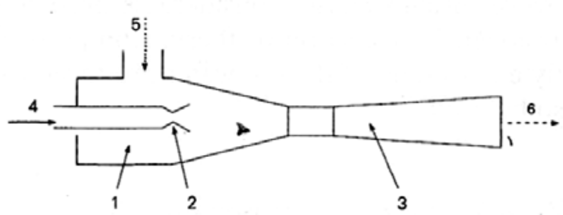
Fig.3. Mechanical vapour compression plant
1- wort kettle; 2-compressor; 3-external boiler; 4-wort circulation pump; 5- condensate vessel; 6-condensate pump; 7-kettle vapour condenser; 8-safety valve; 9- vapour; 10-live steam; 11-cold water; 12-hot water; 13-condensate

In principle the compressor only balances out the loss arising. Vapour compression can also be installed in existing plants and is also of interest to breweries which do not want to use low pressure boiling for quality reasons. There is an increased pressure in the external heater but not in the copper. However the system only operates when absolutely free of air. Consequently fully automatic air removal valves are always installed at the lowest point of the system because the heavier air sinks to the bottom. The saving of fresh steam is substantial with vapour compression. Because the heat of evaporation is used again to heat up the wort there is almost no excess hot water. A vacuum prevention system is needed for the copper to prevent air being drawn in . There are however disadvantages to set against the advantages:

- the plant engineering is complicated;
- maintenance work is necessary;
- peak electricity demands may occur as a result of the power used by the compressor.

3.2. Thermocompression

In the thermocompression process the vapour is sucked in by a steam jet pump (Fig.4) and compressed. This pump consists of a head (1) with a jet (2) through which live steam from a boiler with an overpressure of at least 8 and up to 18 bar is passed. Because of the high velocity of the live steam the vapour is entrained and in the following mixing section (3) the kinetic energy produced as a result of the increased velocity is transformed into a pressure energy of 0,1 to 0,4 bar overpressure.



Advantages with thermocompression are:

- trouble free operation with little maintenance required;
- no peaks in the electricity consumption.

Disadvantages are:

- increased production of hot water, and,
- the high steam pressure required (possibly 18 bar; new pipework needed).

Nevertheless thermocompression represents a less expensive alternative to mechanical vapour compression not only for small breweries but also for large breweries with an additional requirement for hot water. Comparisons of energy cost savings per brew (100 hl and 10% evaporation) using vapour compression instead of conventional boiling show substantial differences.

The space required for the necessary heat exchange surfaces of the internal boiler however usually causes considerable problems. Moreover, introduction of thermocompression only makes sense if the hot water produced can also be used.

Fig.4 Steam jet injector
1-head; 2-jet; 3-mixing stretch; 4-driving steam;
5-vapour; 6-mixing.

4. LOW PRESSURE BOILING WITH AN ENERGY SAVER

The heat exchange occurring at various places in general produces warm, rather than hot, water and most of this can not be used. However, very hot water is required which, if made a little hotter, can be used for heating purposes.

For this purpose it is necessary to make use of small temperature differences and to store the hot water without cooling until needed. This can be achieved with heat insulated energy storage systems (Fig. 5.).

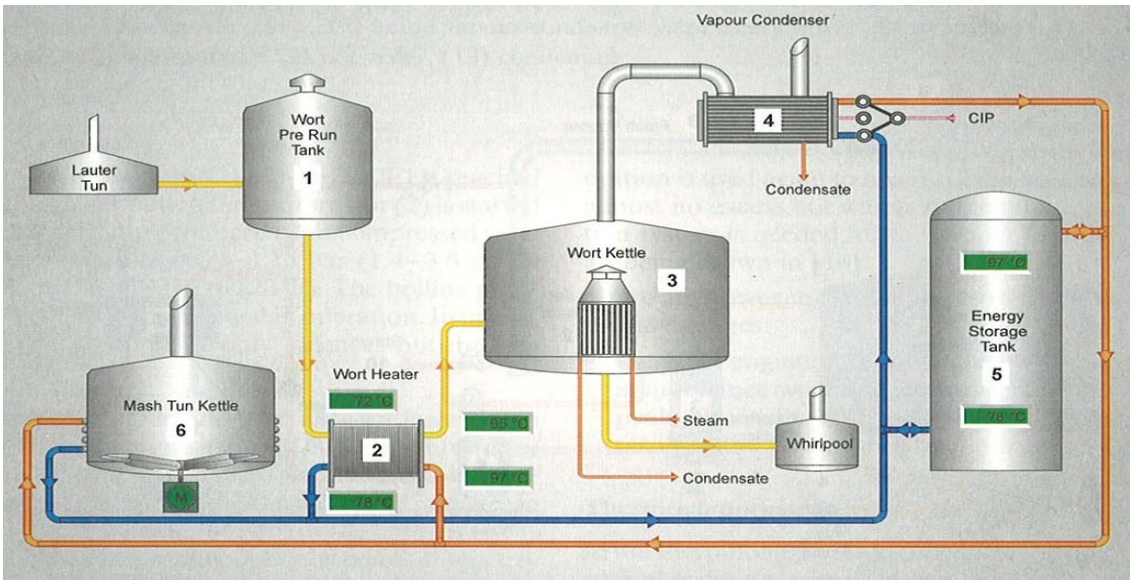


Fig.5.Energy storage system
1- wort collection tank; 2 - wort heater; 3 - wort kettle; 4 - kettle vapour condenser;
5 - energy storage vessel ; 6-mash tun kettle.

The water evaporated in the wort kettle (3) is, as vapour, condensed in the kettle vapour condenser (4) whilst the counterflow of cooling water is heated to 97^{0}C. The water heated to 97^{0}C is fed back into the upper part of the energy storage vessel (5). The wort from the wort collection underback (1) or the mash in the mash kettle (6) can be heated up by this hot water from the upper part of the energy storage reservoir. Other hot water energy sources can also be stored - care must be taken, however, that the temperature of the stored hot water is not greatly reduced thereby. The hot water is stored in a well insulated energy storage vessel. In it the boundary between very hot water and hot water is displaced depending on requirements. The mixing zone depends on the design of the storage vessel and is only 10-20 cm in the case of narrow reservoirs. With such a storage system waste heat can be stored for long times and can be called upon at any time. It is important that by intelligent use of very small temperature differences the temperature in the reservoir is not lowered.

The saving of primary energy relative to conventional boiling without heat recovery is:

- in the case of low pressure boiling about 40-50%;
- in the case of low pressure boiling with an energy saver about 60-70 %.

CONCLUSIONS

Energy saving as a result of conversion to low pressure boiling. With low pressure boiling the total boiling time is reduced considerably because of the higher temperature and the consequently accelerated dissolving and conversion processes. If, instead of the previous 12 % (10 to 15 %) only 5 to 7 % is now evaporated, 6 kWh/hl cast wort is spared in comparison with conventional boiling so that in low pressure boiling/or each 1 hl of cast wort about 9 kWh = 36,000 BTU/bbI are required. That is a large saving which arises simply from the reduction of the boiling time.

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