Process integration of an industrial brewing process

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1 Objective

Due to the increasing competition in beer market, GoodBrew Corporation has been thinking of optimizing the process of his beer to reduce considerably the amount of energy bill. Therefore, you have been chosen to work for the company as an engineer to come up with some new proposal of processing.

You have been asked to accomplish the following requests as soon as possible and to end up with a final report until the 4th February 2006 :

- Determine the present energy bill.
- Propose some improvements for the process, and consider the investment.
- Evaluate the opportunity to replace the boiler with a cogeneration engine.

The process is described on the following pages with some information you might find very useful. It is important to remember that all the data is presented as it could be in an industrial way, indeed it can be unstructured and even wrong at some point. Therefore, you will have to find some information on your own and to make the assumptions you think are right. In any cases, you can always ask for the technical support director, Mr. Maréchal or his assistant.

2 Description of the process

The production of beer can be subdivided in several important parts. At the beginning, the **hot part** is mixing malt and corn with a considerable amount of water. During the process, the mixture is heated to different temperatures and filtered to finally end up with the wort at a temperature of 10 °C. Then follows the **cold part** where the wort is fermented at different level of temperatures to have the desired amount of alcohol in it. It is then diluted to water and elevated to 70 °C to avoid the growing bacterium before pouring this nice yellow liquid into bottles.

The whole process is heated by steam at 6 bars that is returning to the boiler at 3 bars with a temperature of 133.5 °C. On the other hand, a distribution of cold glycol water is provided from an ammoniac cycle and distributed to some areas where the mixture has to be cooled down, especially to keep the temperature during fermentation.

The last important part of the brewery is the washing system that enables to clean the bottles, before filling up with beer, and other elements of the process.

2.1 Hot part

As mentioned before, the malt is mixed with water in a big tank (MAT) and elevated to a temperature of 48 °C with addition of hot water. The malt is especially made of sprouted barley. When it is heated, the enzymes contained in the malt, decomposes the starch in sugar. Later, this sugar will be transformed in alcohol during the fermentation. Another tank (MAK), filled with malt, corn and water, is heated to a temperature of 102 °C, before his contain is being mixed with the MAT and reheated to 75 °C. At this point, the mixture is called *Maische*.

The mixed liquid then passes through a pressing filter (filter 2001) which needs to be supplied with hot water (80 °C, mass flow of 21.3 [t/h]) that is mixed with the maische. The wastage is essentially compressed malt that can be considered as dry and called *Dreche*. After the filter, the liquid is mixed with hops and heated in the WOK to the temperature of 102 °C during one hour. It is assumed that about 10 % of the liquid mass flow is evaporated during this operation. The outgoing liquid, now called *wort*[1], is mixed with hot water coming from the *Pousse*. The liquid is one more time filtered by a centrifugal device to get rid of the cooked proteins which are called *Trub* and considered as being about 0.2 % of the mixture mass. The wort is now ready to go to the fermentation process in the cold part, but first, it is cooled in a heat exchanger with water. This water is then sent to the MAK and MAT, and also used for the filter 2001.

2.2 Cold part

In this part, the wort is first fermented at a temperature of 10 °C. The chemical reaction generates a considerable amount of energy and has to be cooled down with glycol water during the process to remain at the same temperature of 10 °C. Then follows a heat exchanger which cools the mixture at 6 °C and enables to get rid of the diacethyl that gives the beer an unwilling taste of butter. This reaction is lightly endothermic witch leads us to the good assumption that there is no use to cool the liquid with glycol water.

The *Chillage* cools down the liquid to 1 °C to precipitate the yeast and filter it. Due to the very cold temperature of the liquid, another heat exchanger with icy water is installed to remain at the same temperature.

After all, the liquid is diluted with water (15 °C) and pasteurized, to finally have the beer as a result.

[1] moût in french

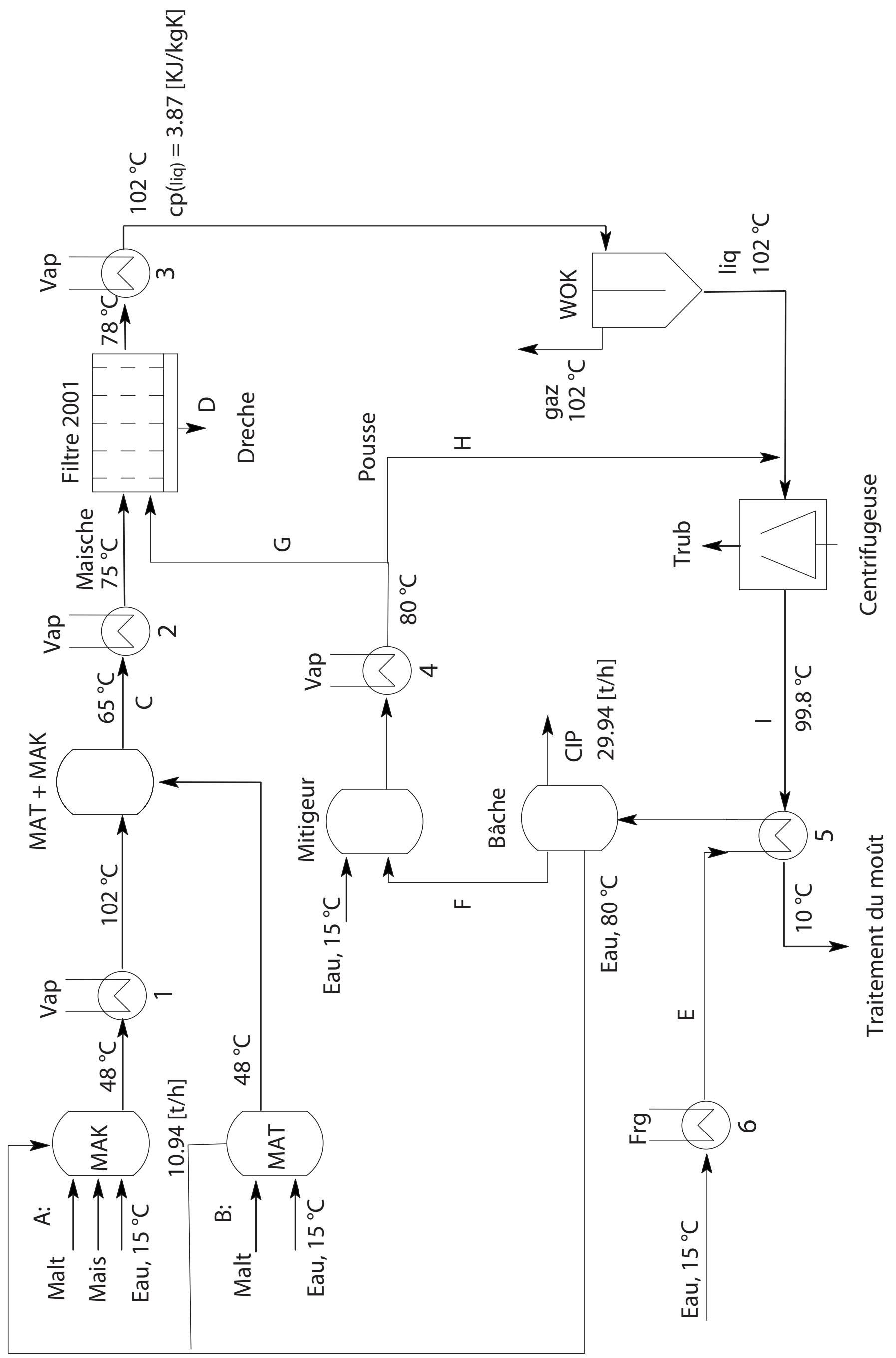

Fig. 1 – Hot part process

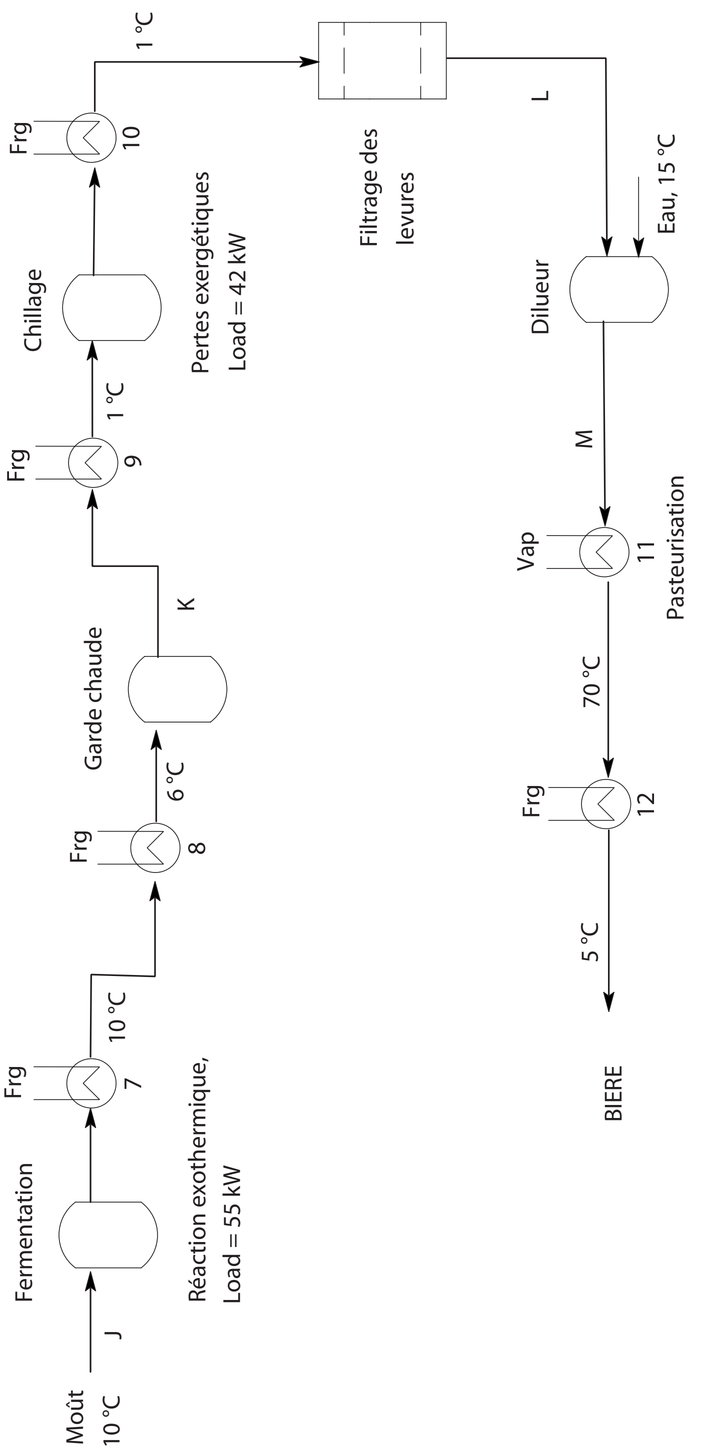

Fig. 2 – Cold part process

2.3 Steam cycle

As you can see on the process diagram, the boiler evaporates the condensed water returning and sent it back to the main process. The distribution of water vapor, which is overheated by 20 °C over the saturated state, is made at a pressure of 6 bars and returns to condensed water at 3 bars and 133.5 °C (saturated).

A pump is used before the boiler to put the liquid under pressure. Indeed, the pump modifies the pressure from 1.5 bars to 15 bars. The pressure then decrease to 8.5 bars through the boiler. Another element that changes the pressure is disposed just after the returning condensed water. It lowers the pressure to 1.5 bars what makes the liquid evaporate partially. It is also in this element, called *flash*, that additional water is added to compensate for all the lost of water vapor within the process. This additional water has to be filtered and therefore, only 75% of the water actually arrives in the flash.

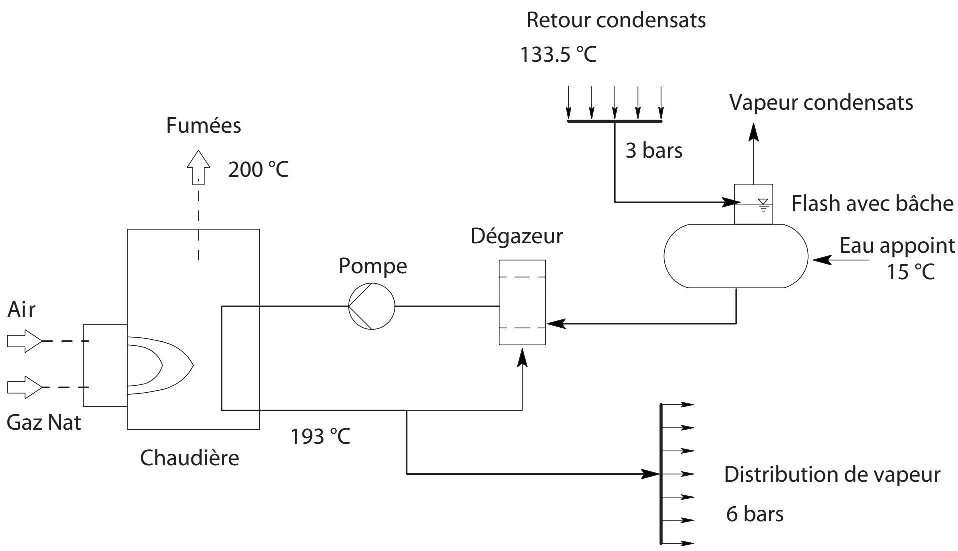

Fig. 3 – Steam cycle process

2.4 Refrigerating cycle

The cold glycol water supply is headed by a refrigerated cycle. Evaporated ammonia (NH3) is compressed to 10 bars, to enable the heat transfer with water, and then returned to 3.2 bars to be evaporated in another heat exchanger to cool down the glycol water cycle. This glycol water ($cp = 4.33$ $[kJ/kgK]$) is then distributed to the main process and return with a higher temperature. A P-h diagram of ammonium will be given or available on the net to allow you to calculate the needed states of NH3 at each position of the cycle. Because the technical service people were in a good mood, they also gave you the NH3 heat capacity which is in average : 2.1 $[kJ/kgK]$ for the gas state.

The compressor has a nominal isentropic efficiency of 86.8 % and losses of the liquid mass flow are considered as being practically non-existent. The ammonia is entering the compressor and the pressure relief valve with a saturated state. The pressure relief through the valve can be considered as isenthalpe.

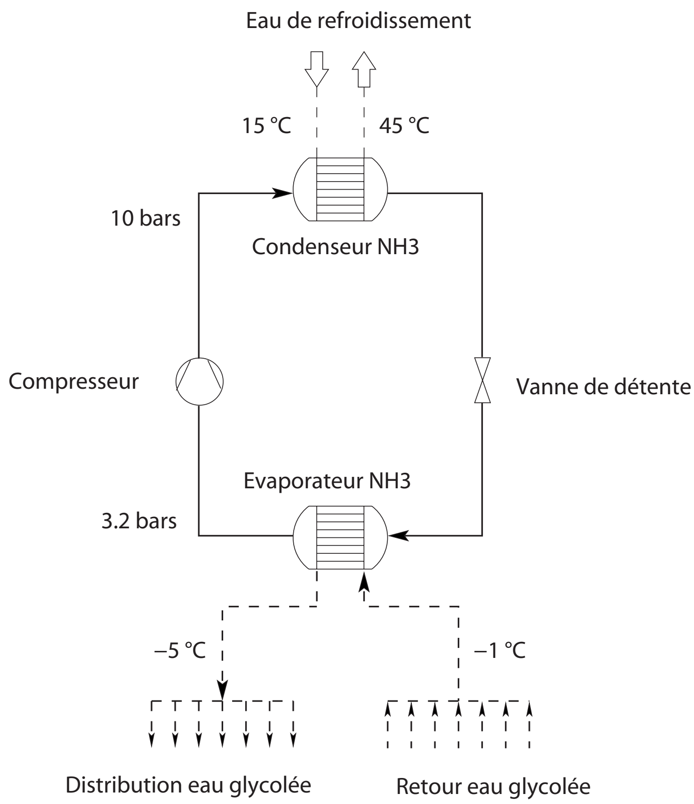

Fig. 4 – refrigeration cycle process

2.5 Washing device

Finally, the last main part of the whole process is meant to clean the bottles before filling them with the final product. To proceed, the bottles will be rinsed three time. The bath rinsing is done with hot water mixed with NaOH ($cp = 1.49$ $[kJ/kgK]$). The third rinsing is done with clear water at 15 °C. Water of the third and the bath rinsing are recuperated and sent to the first rinsing process. The liquid of the first rinsing has to be heated by water vapor meanwhile the other rinsings doesn't, because the bottles are already warmed. To resume, the bottles proceed to the first rinsing, then to the bath rinsing and finally to the third rinsing.

It is assumed that the amount of water used for the third rinsing cycle is about 1.2 times the amount of beer produced. The fraction of NaOH/water for the other supply of water is equal to 1/10. The whole cleaning system is proceeding at a pressure of 1 atm.

To avoid wasting of water, the first and third rinsings are confined into water cycle with always 10 % of liquid leaving the cycle.

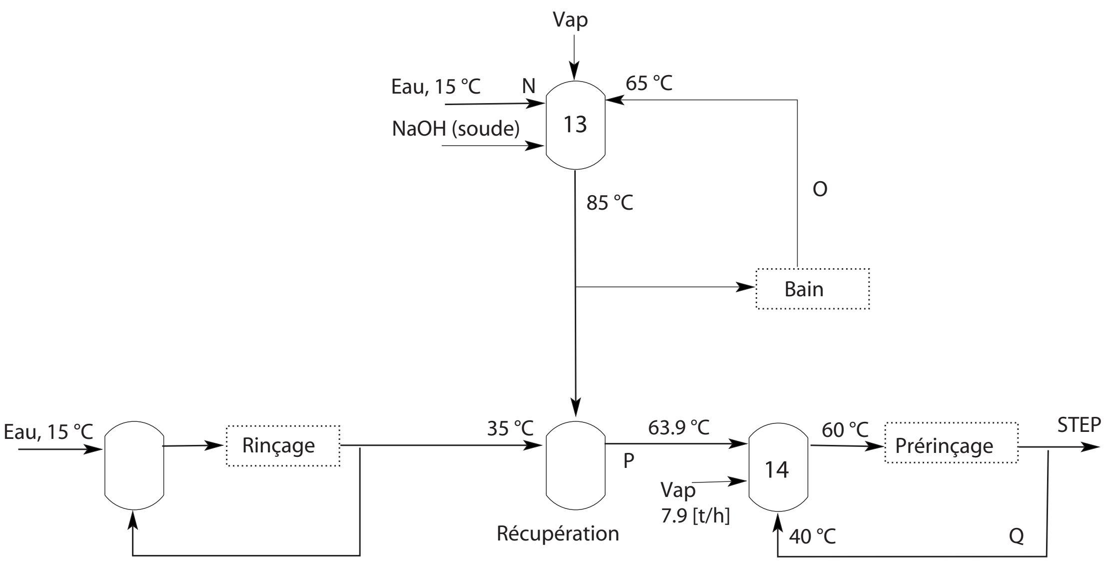

FIG. 5 – washing device process

3 Collected data

3.1 Financial service

The financial service had the kindness to give some information about different costs :

Input :	**Costs :**
Electricity	0.136 $[CHF/kWh]$
Natural Gas	0.3 $[CHF/kg]$
Water	0.07 $[CHF/m^3]$
Distilled water	1 $[CHF/m^3]$

FIG. 6 – Raw material costs

3.2 Technical service

The brewery is running 24h/24h with and stops 10 day every year for maintenance. Brakes down are assumed to occur about 4 % of the running time. The lifespan is about 9 years. The GN used enter the boiler under 5 bars of pressure and the radiation losses are about 2%. Natural Gaz has the following concentration at the atmospheric conditions.

GN composition :	
CH4	93 %
C2H6	3 %
C3H8	0.75 %
N2	2.4 %
CO2	Balance

FIG. 7 – Natural Gas description

To help you on your calculation, you will need a little program called *Thermo_base* that you will find in http ://laptop.epfl.ch (/Energétique avancée et moteurs/logiciels). This program allow you to define some fluid states, especially with water.

3.3 processing Data

Flows	**Mass flow** $[t/h]$	**P** $[bars]$	**T** $[°C]$	$\mathbf{c}_p$ $[kJ/kgK]$
A : Malt	0.950			
Corn	1.050			1.8
Water	3.87		15	
B : Malt	8.400		15	1.8
Water	6.93			
C		1.2	65	3.52
D	2.73			
E		1.2		
F	14.078			
G				4.2
H	5		80	
I		1.2	99.8	3.86
J			10	
K				3.86
L	54.94		1	3.86
M	68.68			
N	10	1.2		
O	3.08			4.16
P		1	63.9	4.16
Q			40	

FIG. 8 – Data collected through the process


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