Consequences of water hammer in closed systems in the brewing sector

AVOIDING PRESSURE SURGES | Water hammer in pipelines or in other systems in breweries can oftentimes be acoustically noticeable. Dust particles on the floor under pipeline racks, originating from wall bracket drillings, attest to the force of such phenomena. This mechanical stressing of plant components gives rise not only to premature wear but also, in certain instances, can endanger the finished beer product, either microbiologically or through unintentional contamination with cleaning or disinfectant agents.

VDI Gesellschaft Entwicklung Konstruktion Vertrieb (Association of German Engineers – Development, Design and Marketing (VDI-EKV)) published a new guideline in June 2004. This guideline VDI 3842 "Oscillations in pipeline systems" covers practice-related descriptions of oscillation phenomena in pipeline systems in plants. It deals with methods of calculation for determination and verification of stresses in pipeline systems and with measuring procedures for analysing pipeline oscillations, as well as with methods of evaluating oscillations and oscillation-induced loadings. Furthermore, it covers measures to be taken in order get better control of oscillation problems (1).

All water hammer phenomena in pipeline systems are pressure oscillations whereby the value of the amplitude and the duration of oscillations are dependent largely on the following criteria:

- velocity of medium;
- internal and external pipe diameter;
- length of pipeline;
- closing time of shut-off device;
- density of medium;
- modular elasticity of medium;
- modular elasticity of pipeline material;
- sonic velocity.

Definition of water hammer in enclosed systems

A pressure surge arises when the time of a change in flow velocity or the mass flow goes below a limit value tlimit (also referred to as reflection time t_R). Should at a particular location in the pipeline (point of disturbance) a change (dw) in flow velocity (w) with $t \leq t_{limit}$ occur, a change (dp) of static pressure (p) takes place as a result of conversion of kinetic energy into other energy forms.

Measuring and recording water hammer

Pressure peaks arise in fractions of a second. In order to measure these exactly, measuring amplifiers are used for recording, whereby conventional sampling rates are increased from 100 to 2000 samples/s in order to measure the actual pressure peaks more accurately.

Origin of water hammer in closed systems

Possible origins for water hammer are numerous, e.g.

- abrupt stoppage of fluids in motion;
- switchover operations – changing of pressure level;
- switching pumps on and off;
- switchover processes with control valves and valve combinations;
- dosing pumps;
- power failure and emergency shutdown.

Measurements in commercial operations have shown that e.g. a switchover process in the CIP plant during pipeline cleaning can give rise to considerable pressure surges (Fig. 1).

Consequences of water hammer

The consequences of water hammer in pipelines and other systems can be multifaceted. Some consequences of pressure surges are relatively easy to recognise, such as deformed butterfly valves as a result of the fact that it is no longer possible to open or close these. Most effects are oftentimes difficult to identify and sometimes have serious consequences in terms of product quality, such as hairline cracks in heat exchanger plates of flash evaporators or wort coolers.

Water hammer reduces the functionality or lifetime of:

- pipelines: material fatigue, hairline cracks on weld seams;
- plate heat exchangers: hairline cracks on plates;

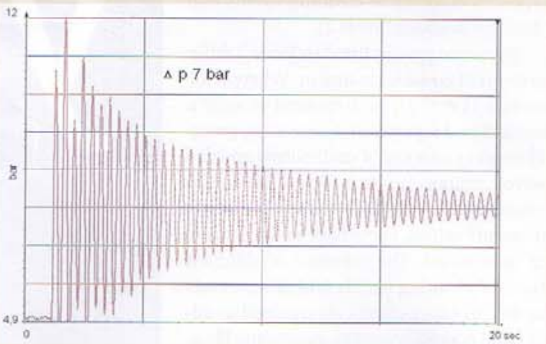

Fig. 1 Pressure oscillations on switchover during pipeline cleaning

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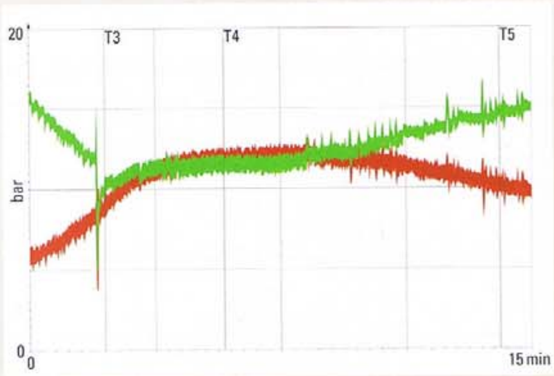


Fig. 2
Pressure readings (inlet unpasteurised/discharge pasteurised) on a flash pasteurisation unit on changing flow velocity

PASTEURISATION UNITS (BEER) AT VARIOUS TEMPERATURES AND HOT HOLDING TIMES

Beer temperature °C	Hot holding time 1 min	Hot holding time 30 sec
70	28	14
71	38	19
72	53	27
73	74	37
74	104	52
75	144	72
76	201	101
77	280	140
78	390	195
79	543	272

Table 1

- membranes: membrane ruptures;
- separators: increased mechanical wear and tear/service intervals;
- measurement devices: material strain/destruction;
- valves and butterflies: deformation of components, pressuring and overloading leakage chamber;

etc.

Some of the less obvious effects of water hammer in systems are covered below using selective examples. In a commercial operation, pressure measurements were carried out using a measurement amplifier capable of 2000 readings per second, in contrast to the usual measurement amplifiers with maximum 100 readings per second. Thus it became possible to measure even transient pressure surges accurately and realistically. With pressure recorders usually installed in plants (flash pasteurisers, CIP, etc.), it is impossible to measure the real value of water hammer. This can have safety and cost-related consequences.

Cross contamination in flash pasteurisation units

All flash pasteurisation units are fitted with a heat exchange zone so that energy in the beer to be cooled can be recovered. From a safety standpoint, the pressure of beer in the hot side should be a number of bars higher than that of the cold side. This makes sense because, if a hairline crack develops in the heat exchanger plate, the sterile beer, after the hot holding zone, is pressured over into the beer which may still be contaminated on the side being heated up and not the reverse. The design of flash pasteurisers with such a "positive pressure gradient" has been state-of-the-art for many years. Nevertheless, it may happen that, even in relatively new plants, a reversal of pressure levels can arise briefly in certain circumstances, as shown in measurements in commercial plants (Fig. 2).

It is obvious from readings taken that, during a change in flow velocity, beer pressure on the unpasteurised side was higher than on the pasteurised discharge side for some three to four minutes. Should beer-spoilage bacteria or yeasts be present in the inlet side, a brief but more or less severe contamination of pasteurised beer may be expected, depending on contamination levels. For contamination to take place in the flash pasteurised beer, a hairline crack would have to be present in at least one of the heat exchange plates in this section.

It is oftentimes very difficult to find the root cause of such problems because, on the one hand, checks of the heat exchange plates for cracks involves considerable expenditure and, on the other hand, parameter settings for the flash pasteurisation unit, such as temperature of beer, flow rate etc., do not show up anything obvious.

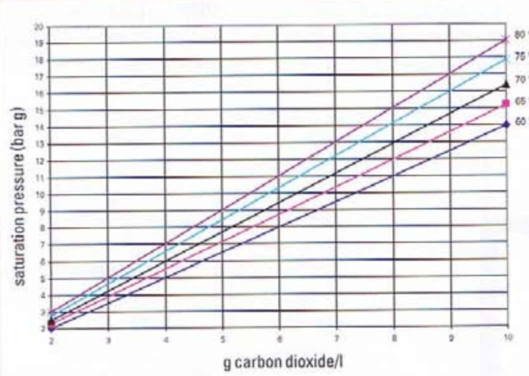


Fig. 3 Carbon dioxide saturation pressure in beer at higher temperatures (1)

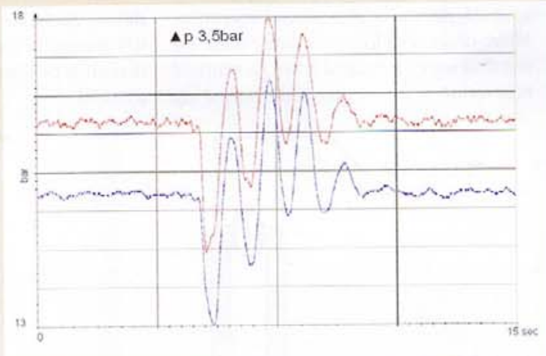


Fig. 4 Pressure readings on flash pasteuriser during bright beer tank switchover – red trace, pressure at discharge side/blue trace, pressure at inlet side

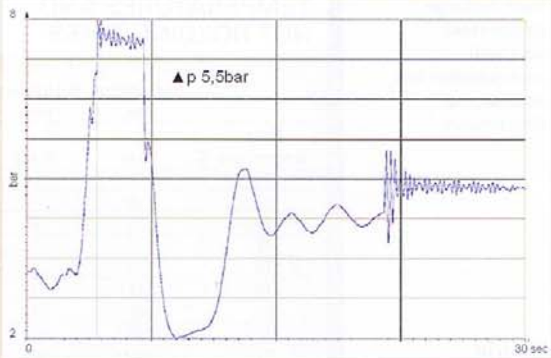


Fig. 5 Pressure readings on membrane filter when filler stops

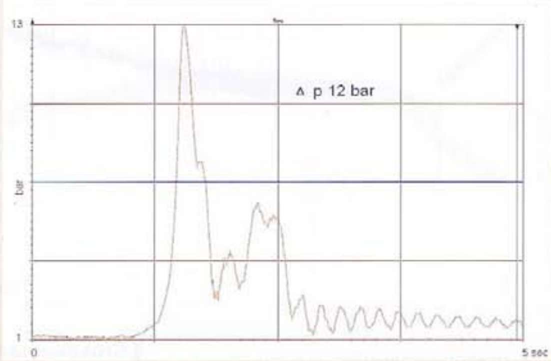


Fig. 6 Pressure readings during CIP cleaning of a cylindroconical tank on switchover, measured at cleaner supply line at valve junction

Getting below carbon dioxide saturation pressure in the flash pasteurisation unit

Should carbon dioxide saturation pressure at the particular temperature in beer in the hot holding zone not be reached, even for a short time, foam develops. If this happens, the desired microbiological effect (killing off of all micro-organisms in beer) is no longer assured. With the protection of the "insulating" gas bubbles, micro-organisms can pass through the flash pasteurisation unit unharmed because the presumed pasteurisation units are not assuredly achieved any more. Even when the vitality of micro-organisms is somewhat diminished as a result of being subjected to a certain amount of heat, they are still in a position to reproduce in filled beer containers, though frequently somewhat slower.

A sample of stock turned up positive after 26 days in a commercial operation. Micro-organisms from the same shelf life test that were inoculated into a pasteurised beer (vital micro-organisms) showed up positive in the stock sample already after 10 days. This demonstrated that, in the case of inadequate flash pasteurisation (foam in beer), the vitality of micro-organisms was reduced but they remained capable of reproducing, if the time frame allowed was long enough.

This is of considerable importance for laboratory work in breweries. In contrast to vital micro-organisms, in samples with weakly vital micro-organisms, it is indeed possible that the incubation time is not sufficient in order to be able to show up micro-organisms present under in-house incubation conditions selected for the enrichment samples. In particular in flash pasteurisation of hazy Hefeweizen beers produced by tank fermentation (high CO_2 levels), there is an increased risk.

Hefeweizen beers are frequently treated unfiltered/centrifuged using flash pasteurisation. As larger particles are sometimes still present in the beer, higher pasteurisation units between 100 and 200 PU are often used.

Table 1 shows that temperatures of about 74–76 °C are required for 100 to 200 pasteurisation units, with a hot hold of 60 seconds, or 76–78 °C for hot hold times of 30 seconds.

Should Hefeweizen beer be produced using tank fermentation, it contains carbon dioxide levels of about 6 to 8 g/l, frequently more than bottom-fermented beers. These two variables, higher temperatures in the flash pasteuriser and higher CO_2 levels, cause carbon dioxide saturation pressure in the beer to go up accordingly (Fig. 3).

Table 1 shows that e.g. somewhat more than 77 °C is required in a flash pasteuriser with a hot holding time of 30 seconds and a set 150 PU. If Hefeweizen beer contains e.g. about 7 g/l of carbon dioxide, this results in a carbon dioxide saturation pressure of somewhat more than 12.5 bar g under these conditions (Fig. 3). If this beer pressure is not maintained in the flash pasteuriser, even for a short time, beer foam develops in the plant, with the negative consequences referred to above.

Many flash pasteurisation units originally bought for bottom-fermented beer are designed for a pressure of maximum 13 to 15 bar g and thus operate in the region of the carbon dioxide saturation pressure referred to in the example above. Should pressure fluctuations arise in the system, it may be expected that the carbon dioxide saturation pressure will not be reached.

Particular risk periods when pressure fluctuations may be expected are:

- in the start-up phase;
- when flow rates change;
- during switchovers;
- when displacing with water.

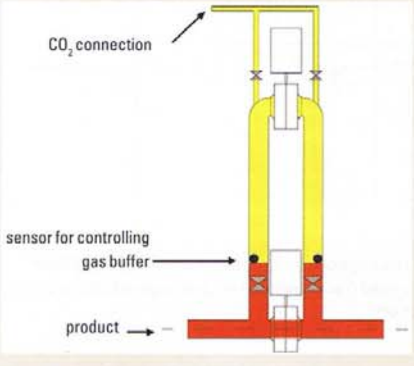


Fig. 7 Pulsation damper

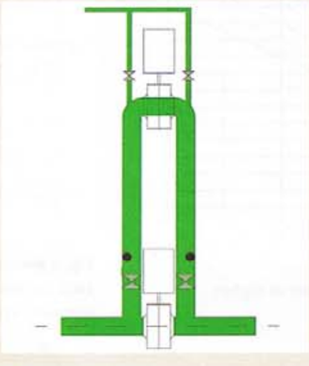


Fig. 8 Cleaning

In the following example, pressure conditions in a flash pasteurisation unit are shown during a bright beer tank switchover (Fig. 4).

In this case, pressure settings are already relatively high at about 15 or 17 bar. It can be seen that, after a pressure drop of about 2 bar and about 5 seconds, pressure oscillations arise before settling down at original values again. When pressures are lower to start with, the carbon dioxide saturation pressure may not be reached when hot holding temperatures are high, with corresponding carbon dioxide levels in beer.

Pressure surges in membrane filter plants

Membrane filters are preferred at the filler entry of the particular filling unit for cold sterile beer filling. Specific filtration costs are very much dependent on the length of time a filter insert will run for, i.e. what beer volume can be filtered, before it plugs up and has to be replaced. Pressure surges such as they sometimes arise upon closing the beer line (filler stop) can reduce the running time of the filter membrane, depending on frequency and vehemence of water hammer (Fig. 5).

Pressure surges during cleaning operations

Fig. 6 shows that considerable water hammer can arise in the system also during cleaning and disinfection operations on tanks or pipelines when conditions are unfavourable. The extent to which cleaning or disinfecting agents can pass into pipelines filled with product that may be tied in as part of the pipework depends on the particular shut-off device and its proper functioning.

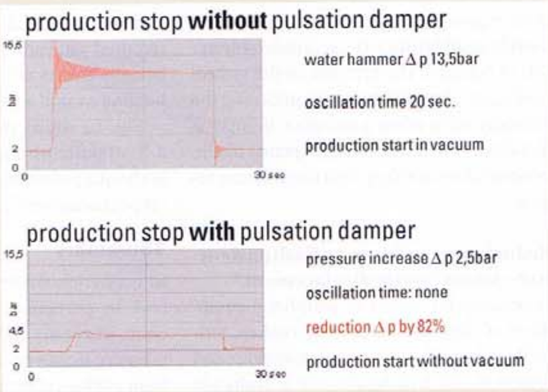
Avoiding pressure surges in pipeline systems

There are various alternatives in order to avoid water hammer in systems:

- coordination of controller and valve stroke times;
- throttling air on pneumatic cylinders,
- gentle start-up of pumps.

A relatively simple method involves installing a so-called pulsation damper that uses a gas buffer to absorb water hammer.

Fig. 9 Effect of pulsation damper when production stops



Basic arrangement of a pulsation damper (2)

The required gas buffer is built up in a U-shaped pipe installed as a bypass on the main line. The required amount of gas is added through a gas connection. Sensors control the unit (Fig. 7). By having sensor control maintain a defined gas buffer, it is possible to achieve reliable suppression of water hammer in the product.

Due to the simple design of the pulsation damper, cleaning and disinfection is uncomplicated. Sterilisation temperatures common in breweries are also no problem (Fig. 8).

Effect of a pulsation damper

The effect of a pulsation damper is described below using selected examples.

Reducing resonance at filler entry when stopping production

If butterfly valves are used to stop beer inflow when necessary, e.g. at a production stoppage at the filler entry, considerable water hammer arises during closure under unfavourable conditions. Pressure readings in a filler inlet pipe are shown in Fig. 9 when beer flow is abruptly stopped using a butterfly valve. The initial pressure is increased about 13.5 bar. After opening the valve, the pressure drops into the vac-

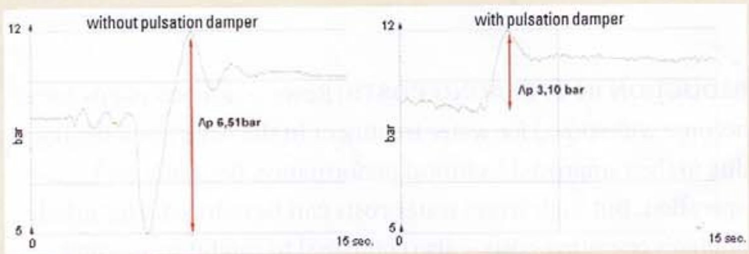


Fig. 10 Pressure readings on flash pasteuriser in status mode "water displacement" with and without pulsation damper

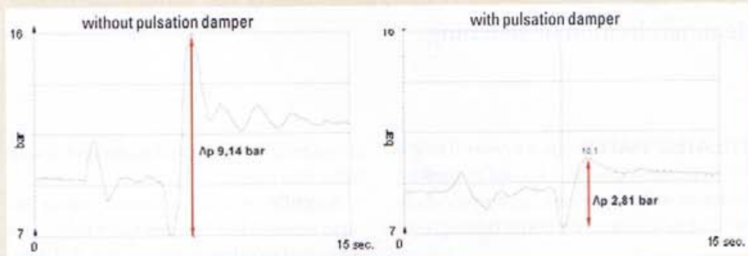


Fig. 11 Pressure readings on flash pasteuriser in status mode "type changeover" with and without pulsation damper

uum region for a short time. The carbon dioxide equilibrium is thus considerably upset. In contrast, the pressure in the system goes up by about 2.5 bar only on closing the butterfly valve when a pulsation damper is installed. When the valve is opened again, pressure does not drop into the vacuum region.

Reducing resonance on a flash pasteuriser – status "water displacement"
Depending on design of peripheral equipment of the flash pasteuriser (valves, butterfly valves etc.), pressure oscillations can arise in the flash pasteurisation unit already in status mode "water displacement" (Fig. 10). The functional capability of the plant can be jeopardised in particular when the required saturation pressure of carbon dioxide in beer is not reached within the hot holding zone of a flash pasteuriser.

Fig. 11 shows the pressure readings on a flash pasteurisation unit, both with and without a pulsation damper, in status mode "type changeover".

Summary

In breweries, water hammer is a frequent and, in particular, an acoustic phenomenon. There are quite numerous effects of pressure surges on the filled product. Apart from obvious effects of water hammer (e.g. deformation and breakage of plant components), effects which can endanger product safety are sometimes hard to identify. Some of these effects and their consequences are described. There are some alternatives for avoiding water hammer in pipeline systems or in other equipment. A relatively simple possibility of avoiding water hammer is described using a patented pulsation damper (3).

References

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3. Patentnummer AT 411386B.

Reducing waste water in water treatment by means of reverse osmosis

REDUCTION IN OPERATING COSTS | Reverse osmosis plants have become widespread for water treatment in the beverage industry, due to their improved technical performance, flexibility and operation. But high waste water costs can be reduced. This article analyses operating costs – also compared to capital costs – and describes a process that has been implemented and is suitable for operating reverse osmosis with approximately the same yield as full demineralisation or softening.

TREATED WATER plays a central role in the beverage industry. It is used as brewing liquor, as water for producing non-alcoholic beverages, as water for bottle rinsing, even as water for various redilutions and also as boiler feed water.

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Recently, water treatment using reverse osmosis has become more important compared to other processes (e.g. full demineralisation, softening) because reverse osmosis requires hardly any chemicals, does not lead to salinisation, also eliminates possible contaminations such as nitrate or insecticides, can be operated much easier in hygiene terms, requires little space and largely "takes care of itself" without problems.

Operators generally classify costs for electrical power, chemicals, new membranes and labour as operating costs. However, costs for water running to waste account for most of the operating costs.

Operating costs of a reverse osmosis plant

Factors contributing to operating costs of reverse osmosis are shown in Table 1 by way of example. A plant was selected that produces about 10 m³ of permeate/h from a typical municipal water in two stages. The operating costs for a single-stage plant would not be much different in this respect.