Modern filling systems for carbonated soft drinks

6.1 Introduction

Modern filling systems for carbonated beverages are based on simple yet well proven principles, although these can be applied in many different ways depending on the filling system. Optimum performance during filling, high filling accuracy and the preservation of maximum product quality are simple enough requirements for the complexities of a filling process. Different factors, which in their turn will vary depending on product type, have a direct influence on the quality of the product to be filled. The essential factors to be considered are:

1. the gas constituents present in the beverage and the influence those gases exert during the filling process – for example, carbon dioxide and oxygen
2. pressure and pressure characteristics during filling
3. temperature
4. viscosity.

By examining these variables and changing them whenever necessary, filling conditions can be optimised, filling speed can be maximised and product quality can be preserved.

The most important considerations for effective filling of carbonated beverages are maintaining the content, controlling beverage temperature during filling and preventing oxygen pick-up. As a result of carbonation, CO_2 is present in the beverage in a dissolved state. In an enclosed system, such as a pressurised beverage buffer tank, equilibrium will exist after a certain time between the pressure of the gases in the liquid and the corresponding pressure in the tank. CO_2 must be prevented from coming out of solution during filling by setting the filling pressure in the filler bowl approximately 1 bar higher than the saturation pressure for the required beverage CO_2 content. Even if saturation pressure is maintained, extreme care must also be taken to ensure that the beverage has been allowed sufficient time to settle prior to filling and that it is filled gently into the container. The profile of the container can also be a critical factor in the gentle filling of the beverage. In most filling systems, the beverage is transferred to the inside surface of the container at the highest possible level and then flows to the bottom of the container. Smooth container contours will allow the gentlest flow of the beverage.

Following this procedure ensures that:

1. CO_2 loss in the beverage, with the resultant reduction in quality, is avoided.
2. CO_2 consumption during carbonation can be more accurately adjusted, and therefore reduced.
3. The filling, settling and snifting times are optimised.
4. Product losses as a result of fobbing during snifting are prevented.

Although the CO_2 content of the beverage has the primary effect on the performance and cost efficiency of the filling process, CO_2 consumption, settling and snifting times and the oxygen content in the beverage all have a major influence in the preservation of beverage quality. Oxygen is present in the beverage in dissolved form and also as a constituent of the air in the container prior to filling. For soft drinks, the consequences of excessive oxygen pick-up during filling are well known.

Oxidation of beverage ingredients may cause adverse changes in colour and taste.

Oxygen pick-up by the beverage can be controlled at three stages:

1. oxygen load at the filler inlet (initial load)
2. oxygen pick-up during filling
3. oxygen contained in the residual air in the container headspace after filling.

Oxygen pick-up upstream of the filler inlet can be caused by several factors:

1. air inclusion in pipes
2. insufficient syrup storage time
3. over agitation during the mixing process of the beverage
4. inadequate de-aeration at the carbonation stage.

Oxygen pick-up during filling is directly correlated to the purity of the CO_2 as pressurisation gas in the filler ring bowl and air in the container prior to filling. In order to reduce the content of air in the container, flushing with CO_2 can be performed immediately before filling. For flexible containers, such as PET bottles and aluminium cans, this takes place as the container is presented to the filling valve, before sealing, when CO_2 from the filler ring bowl is flushed into the container to replace as much of the air as possible. This process can be substantially improved when using rigid glass containers, after sealing to the filling valve, by evacuating gas from the container using a vacuum prior to pressurising with CO_2. This process can be repeated when filling particularly oxygen-sensitive beverages and an almost pure CO_2 environment can be produced in the container.

The filling pressure depends on the required CO_2 content of the beverage. Setting the correct filling pressure in the filler bowl will prevent CO_2 coming out of solution in the beverage during the filling process. If the temperature of the beverage is lower, CO_2 solubility will be better. Good solubility of the gas at low temperatures requires a lower saturation pressure and hence a lower pressure in the filler bowl. The consequence of this is that shorter times are required for pressurisation and snifting and the occurrence of fobbing will be reduced. Gas consumption will also be reduced.

The fourth factor to be considered is beverage viscosity. Higher-viscosity products require a different approach to the filling process. However, carbonated soft drinks usually have a low viscosity and are free flowing, so this is not a consideration here.

The container and beverage characteristics form the basis of the appropriate design for a filling system, and the filling process must not alter or impair the beverage characteristics. It is important when planning the filling system that the appropriate filling steps are matched to the beverage characteristics and container. The filling process can be split into several phases:

1. evacuation
2. flushing with gas
3. pressurising with gas
4. filling at one speed or two speeds
5. fill level correction
6. settling and snifting.

Evacuation is used only on rigid containers, where the container is subjected to a vacuum to remove 90% of the air content before pressurising with gas. This is a significant process when filling particularly oxygen-sensitive beverages as the step can be repeated after pressurising with gas, thus removing 90% of the mixed gas, leaving a highly concentrated gas atmosphere in the container.

Flushing with gas is used primarily for flexible containers such as PET bottles and aluminium cans, which cannot be subjected to vacuum. This step is carried out as the container is presented to the filling valve, using either gas from the filler ring bowl or pure gas.

Pressurising with gas is carried out after the container is sealed to the filling valve. Gas from the filler ring bowl flows into the container until both pressures are the same.

Filling takes place in a tubeless filling system when the filling valve opens and beverage flows over a vent tube into the container. A liquid spreader, or deflector, causes the beverage to flow on to the inside wall of the container. Gas in the container is displaced by the beverage and flows through the vent tube into the filler ring bowl. In the now less common tube filling system, suitable for tall containers, beverage flows into the container through a tube located close to the bottom of the container. A two-speed fill can be used here, with slow fill until the beverage reaches the tube, then fast filling to the top. When the fill quantity is reached, either the beverage reaches the gas return point of the vent tube, stopping the filling step, or the vent tube can contain an electronic probe to stop the filling step. Other filling systems using the volumetric principle pre-measure the quantity of beverage into the container.

Fill level correction is used when product cost is high, the container is very narrow at the fill point and fill level accuracy is particularly important. There are various methods used to perform this step, but most commonly the container is first overfilled then product is extracted via the vent tube, using vacuum.

Settling and snifting serve to gently lower the pressure in the container and allow the beverage to settle to prevent fobbing of the beverage as it is lowered from the filling valve.

6.4 Glass bottle filling

6.4.1 Operation

Having examined in detail the filling phases available from the modern-day counter-pressure filler, especially the electro-pneumatically operated type, we will now consider the particular requirements for the filling of glass bottles:

1. Bottle handling to the filler infeed
2. bottle handling around the filler
3. lifting the bottle to the filling valve
4. air removal from the bottle prior to filling.

Bottle handling to the filler infeed must be carefully controlled to minimize noise yet still avoid bottle-to-bottle contact as bottles enter the infeed scroll. Intelligent conveyor systems which follow the speed of the filler with line sensors and variable-speed drives go a long way towards gently controlling bottles into the filler. Filling speeds for glass bottles of 800–1200 bottles/min are now commonplace, so even greater care is necessary to positively control the infeed to the filler. One example of this, in the form of a decelerating bottle stop, is shown in Figure 6.8.

This device is used on a filler which operates at a constant filling speed and uses a pneumatic cylinder for bottle control. Bottles are allowed to enter the filler from rest by releasing the bottle stop starwheel and accelerating both filler and infeed conveyor to operating speed when the first bottle reaches the filling valve. The piston holding the bottle stop starwheel then retracts against the flow of bottles to its park position upstream of the infeed scroll. When the filler is required to carry out a controlled stop at speed, the now freely rotating bottle stop starwheel is locked and the force of conveyed bottles causes the cylinder to extend. Cylinder movement is dampened and slows the moving bottles until they come to rest in front of the infeed scroll.

Bottle handling around the filler must be under complete control to ensure stability, accurate positioning to the filling valve and gentle transfer to the discharge bottle conveyor, as per Figure 6.9. Bottles from the infeed conveyor enter the infeed scroll and are pitched to match the filler pitch and then transferred to the infeed starwheel. This transfers the bottles to the filler carousel, where the centring bell is lowered on to the bottle neck before it leaves the starwheel. Bottles are discharged from the filler carousel in the opposite way, by lifting the centring bell from the bottle as it enters the discharge starwheel before transferring to the discharge conveyor. As the bottles enter the filler carousel they are raised to seal against the filling valve by a lifting cylinder, as seen in Figure 6.10. The cylinders are precisely controlled to gently but quickly raise and lower the bottles.

As described earlier, one important factor when filling oxygen-sensitive beverages is the removal of air from the bottle prior to filling. This step can be performed by flushing the container with CO_2. However, for a more efficient removal of the air, an advantage of filling a rigid container is that a vacuum step can be introduced before flushing, as illustrated in Figure 6.11.

6.4.2 Bottle burst protection

When carbonated beverages are filled into glass bottles, there is a risk of bottles bursting in the filling machine under pressure. This usually occurs if a bottle has a weak point or has been damaged in some way. It is necessary to protect other bottles from ingress of glass fragments when a burst occurs on the filling machine, so that the risk of a consumer finding a sliver of glass in the product is minimal.

Filling machines for carbonated beverages in glass bottles are fitted with stainless steel protective divider plates between the filling valves. These are matched to the optimum bottle height and protect neighbouring bottles in the event of a bottle bursting.

The most likely place for a bottle burst to occur is at the point of pressuri sation. Protective stainless steel guards are fitted around the filler carousel at the pressurization area. These guards are commonly lined with rubber for shock and noise absorption and fit closely to the protective divider plates. This minimises the risk of glass fragments reaching neighbouring bottles, and the majority will fall to the floor.

It is essential that any remaining glass in the filling valve area is removed to prevent ingress into bottles. This can be done by manually flushing the area with water, but it is more commonly an automatic process. A filling machine equipped with a burst bottle protection system will incorporate a high-volume water shower on the carousel and programmable bottle rejection at the filler discharge. A typical bottle burst protection system is shown as Figure 6.12. On a bottle bursting, the water shower will be automatically triggered and the whole of the filling valve area will be flushed for several turns of the carousel. At the same time, a number of bottles from either side of the filling valve where the burst occurred are rejected from the discharge conveyor. Subsequent bottles from the filling valve where the burst occurred are also rejected for several rounds of the carousel. Typically, three or four bottles on either side of the particular filling valve will be rejected for two rounds and bottles from the filling valve will be rejected for five rounds.

During the filling process, bottles are pressed against a rubber seal in the centring bell. This seal is of special food-quality rubber which is flexible enough to form a seal with the bottle yet hard enough (typically 75 shore hardness) to resist penetration of glass. However, it is an important part of maintenance to have a routine program of regular seal replacement.