# A BALANCING ACT ON THE TEMPERATURE SCALE

## The pros and cons of different bottling temperatures for carbonated beverages

*The determination of the correct filling temperature for carbonated beverages is usually made an the basis of improved economic efficiencies as well as the need for a consistent CO2 content within and across bottling runs. But there is one other factor that ought to be considered as well when selecting a filling temperature: the entire process.*

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Everybody knows the story of the Optimist who jumps from the window of the twentieth floor of a high-rise. By the time he reaches the second floor he notices that neither the jump nor the fall have done him any harm ... so far.

About twenty years ago, a newly formed company brought a volumetric filling valve for cans onto the market. It allowed for much faster filling times than any other then known valve. Unfortunately, the new valve also required a longer pressure-release phase, which completely swallowed up the time gained during the faster filling phase.

The lesson: When evaluating new technologies, one should always consider the entire process, not just a part of it. This applies also to decisions about correct filling temperatures for carbonated drinks.

Photo: Krones

## Bottling near the freezing point

The concept of bottling liquids near the freezing point may strike some people as absurd, because it is likely to result in product temperatures below the dew point, which would cause condensation. Depending on the packaging material in use, therefore, such low temperatures could require the installation of devices to raise the temperature of the finished product to prevent condensation.

Cardboard trays laminated with plastic foil are one way to solve the condensation problem. However, but they are now being phased out, especially in Germany. Instead, multi-unit packs are generally made from materials that would be greatly affected by condensation, and they are commonly used just about everywhere, mostly for non-returnable bottles.

Yet nobody would think of installing a tunnel heater for finished products sent to market in such packages, unless for compelling reasons. A decrease in filling temperature to achieve greater bottling line performance could be one of those reasons, except in Germany, perhaps, where condensation tends to be much less of a problem because of the ubiquitous use of reusable plastic cases there.

In North America and East Asia, on the other hand, non-plastic packaging materials as well as filling temperatures near the freezing point are common, and condensation can be a serious issue. There, products are usually chilled in a pre-mixer. This guarantees a constant and evenly distributed temperature, which is desirable, especially when the product has high concentrations of 002. Many bottlers, however, would prefer to package their products at higher temperatures, mostly for economic reasons.

## Consistency of CO2 content

Considering that many drinks manufacturers who fill their products cold are currently looking for ways to raising their filling temperatures, why should manufacturers who currently **fill their products warm, look into switching to filling them cold? The driving force behind such considerations is usually economic efficiency, that is, a** reduction in operating cost, as long as the change does not affect product quality.

During the start-up phase of a new filling run - at the beginning of a shift, after a line interruption, a cleaning cycle, or a product change, for instance - it is usually unavoidable that a few bottles or cans have CO2 levels that fall outside the tolerance range. This is because the required CO2 saturation pressure is tem**perature-dependent,** and as the product temperature increases during machine down-times, the required CO2 saturation pressure increases, too.

The three main phases of the filling process for carbonated drinks are: pressurization before filling, filling, and pressure release after filling. The filling pressure must be set to ensure that as little dissolved CO2 as possible can escape from the container during its passage through the line.

That is why the filling pressure tends to be set higher than the CO2 saturation pressure, whereby the difference between the CO2 saturation pressure and the filling pressure should be as small as possible. Pressure differences that are too high increase the time it takes to reach the filling pressure. They also waste gas (usually 002) and extend the pressure release time.

## Uneconomical filling pressure settings

Fixed, pre-selected, recipe-dependent filling pressure settings are what everybody uses nowadays. They obviously work. However, they also shift the cost burden of adjustments from the set-up phase to the operational phase of the machine. For instance, if the fixed filling pressure is set about 300 hPa too high, the result may be a waste of as much as 20 MT of CO2 per year in a normal mid-size Operation.

Reducing the filling pressure, however, does not always result in an overall improvement of filling line performance, because, with **fixed-input settings, the times for filling and pressure release are built into the processes and do not change. The fixed positions of mechanical guides, too,** may prevent any gains in efficiency.

Theoretically, a filling pressure can be set to any value above the CO2 saturation pressure. In practice, however, it is common to set the filling pressure to at least 300 hPa above the CO2 saturation pressure. In some filling lines, though, filling pressures may be set higher to ensure that the bottle or can does not lose too much CO2 on its way through the line. Here are the most common causes for excessive filling pressures:

- The product valve (faulty construction, faulty installation, faulty parameter inputs, lack of feed-back from other portions of the process, etc.),
- The construction of the filier head (issues pertaining to diameters, diameter changes, flow impediments, assembly, etc.),
- The installation of the filier (lax production methods, poor flow control, impeded product flow because of rough surfaces **left behind by circular drills, faulty** assembly, etc.),
- Foreign gases (such as air) in the drink (because of insufficient degassing in the mixer, or as a result of air uptake from leaky pump gaskets or during the filling process, etc.).

If problems occur, the above items are the first trouble spots that ought to be inspected and corrected, if necessary, before any other measure, such as lowering the filling temperature, is contemplated. For instance, if one filier head performs better than all the others, this is a sure sign that the filier valves do not work properly and ought to be adjusted.

## Everything is relative

**In** practice, it is possible to work with just about any filling temperature from high to low. A company in South Africa, for instance, packages a highly carbonated drink at 27°C (81 °F), using a rather large-size mechanical filling line. The machine performs at a lower level than its through-put capability, but the company deliberately chose a larger filling line deliberately, so that it could allow for longer pressure release phases.

However, apart from the higher price of a larger-than-necessary machine, operating and energy costs are higher, too. Then there is the greater amount of product waste at start-up and shut-down to consider, as well as the larger number of filier heads, which results in increased maintenance costs. Finally, the higher filling pressure shortens the life span of returnable bottles.

An opposite example is a Japanese company that bottles its products at 2°C (36°F). It is currently considering raising its filling temperature. For this company, any effect it can expect from operating above 2°C (36°F), however, is relative. Though the company would prefer to fill at an ambient temperature of 15°C (59°F), this is not possible, given the current state of the machine. The company would have to improve the valve surfaces that are in contact with the liquid by polishing them electrolytically. A simple adjustment of the pressure release phase, however, might achieve the same result.

In Germany, summer temperatures and thus product temperatures seldom exceed 20°C (68°F). On most production days, drink temperatures there are kept at around 16°C (61 °F) during filling. Systems that are preset to run at that temperature obviously become less efficient if they were made to run at a higher temperature.

If the ambient temperature changes, therefore, a simple adjustment is often sufficient to increase the machine's performance. In real life, however, it appears that neither human fine-tuning nor any control system built into the machine by the manufacturer can achieve optimum performance levels under all temperatures conditions encountered by a filling line.

In practice, therefore, most operators encountering higher filling temperatures than desired tend to keep all parameter settings unchanged, except for the filling pressure. They then decrease the filling speed to lengthen the pressure release phase, and simply accept the fact that this procedure also lengthens the duration of both the filling pressure and the filling phase.

## The effects of a four-degree (°C) drop

What would be the effect of a decrease in the filling temperature of a carbonated lemon soft drink, for instance, by 4°C (7.2°F)? For this calculation, we can assume that it would take about 180 kWh of thermal energy to reduce the temperature of some 40,000 liters of the liquid by 4°C. Considering the performance differences of different chillers, this drop would require about 1.5 to 2 kWh per 1,000 liters.

Such a reduction in temperature would also allow for a reduction of the filling pressure, which, in turn, would yield a savings of at least 50 g of $CO_2$ per cubic meter of liquid. The amount of electrical energy needed to run the machine, however would not change, because the filling line's overall performance would not be adversely affected by the reduction in temperature. Increases in the amount of product waste could also be kept in check if the systems were set up to chill the water before it is mixed to make the drink (perhaps after the water has been vacuum-degassed, so as not to influence overall degassing).

Strictly from an energy perspective, it would also make sense to install in the water flow an $NH_3$ chiller as well as a cooler that is operated by an $NH_3$-evaporator; and the water flow should be fed by a constant cold water source. This would be the most economical solution.

## Summary

Any reduction in the filling temperature should be considered only after a thorough analysis of the potential for optimisation of the entire filling line, and after a critical evaluation of the economic impact of any improvements. In certain configurations, however, a small reduction in the filling temperature can be a cost-effective way of increasing overall filling efficiencies.