What brewers need to know about the quality characteristics of cylindroconical tanks (CCT)

And what they should consider when planning their tank cellar

1st of July 2015

Ziemann Holvrieka

Contents

Introduction

Why cylindroconical tanks?

The most important advantage of a cylindroconical tank (CCT) as compared to the traditional combination of open tun and horizontal storage tank is the closed fermentation system. It reduces the risk of microbiological contamination to almost zero. Further, important advantages for brewers are:

- Ideal tank for CO_2 recovery, which makes the brewery independent of other CO_2 sources
- Yeast can be selectively harvested, which reduces the risk of autolysis
- Highly efficient automatic CIP cleaning
- Reduced cooling energy consumption due to direct tank cooling
- Higher fermentation and storage volume per operating area
- High technological flexibility
- Simple, as it allows for modular extension
- Operation selectable from manual to fully automated

However, a tank must meet high quality requirements in order to make appropriate use of all these advantages. It must also be tailored to the specific needs of the brewery regarding size, equipment and installation. This White Paper contains the essential principles for this task and clues based on many years of experience in tank construction.

The aim was to answer the essential questions concerning the selection and use of a CCT in a comprehensive and pragmatic manner.

Figure 1: Compared to open fermentation

Figure 2: ...cylindro-conical tanks have the advantage that the contamination risk is almost zero

Quality specifications and test methods

Which laws/specifications/ standards must be adhered to?

All CCTs up to a legally defined operating pressure are containers built according to a common method and generally do not require specific certification. CCTs must be treated as pressurised tanks that need to comply with the appropriate specifications when this gas pressure is exceeded.

Pressurised containers in Europe, for example, are regulated by the PED 97/23/EC.

This directive determines that a tank with an operating pressure of more than 0.5 bar is a pressurised container and subject to inspection. Good engineering practice applies when the pressure is lower than 0.5 bar.

The design and layout of pressurised containers are also described in different sets of regulations.

Globally relevant are the AD 2000 regulations, the standard DIN EN 13445 as well as the ASME code.

Which pressure must be taken into account?

Relevant pressures in the brewing industry are the CO_2 bunging pressure ($P_{bunging}$) as well as the hydrostatic pressure of the liquid column (P_{hydro}). Both add up to the operating pressure PS (see Fig. 3):

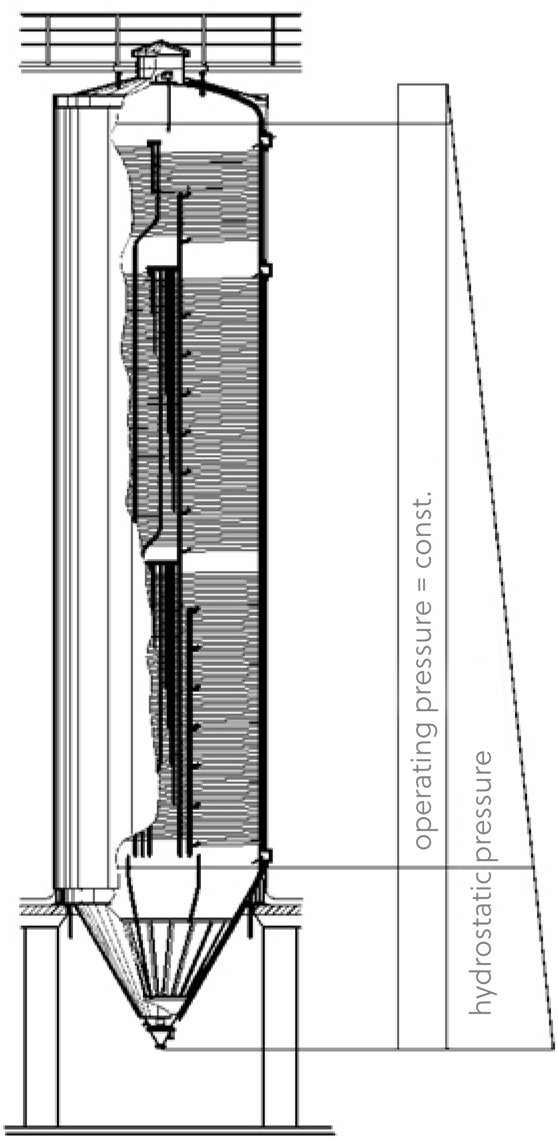

Figure 3: The operating pressure is the total of the bunging pressure and the hydrostatic pressure

$$PS = P_{bunging} + P_{hydro}$$

Ten metres of water column correspond to one bar overpressure for P_{hydro}.

Design, material and equipment

Which materials are used?

High-quality CCTs generally consist of stainless steel. Type 1.4301 is used in most applications. Higher alloyed steel types such as type 1.4404 are used in corrosive ambient conditions. This increases the material costs.

$$R_a = \frac{1}{l}\int_0^l |Z(x)|dx$$

What is cold- or hot-rolled steel?

Steel is rolled to the desired sheet thickness before it is delivered. Cold-rolled steel has a slightly higher strength than the starting material and a clearly smoother surface, which means lower grinding and refinement efforts during tank construction.

What does surface roughness mean and what is its relevance for tank construction?

The surface of rolled steel sheets is not smooth, although it gives this impression to the naked eye. However, under a microscope, the surface looks more like the profile of a mountain. The mean roughness is expressed in µm by the R_a value.

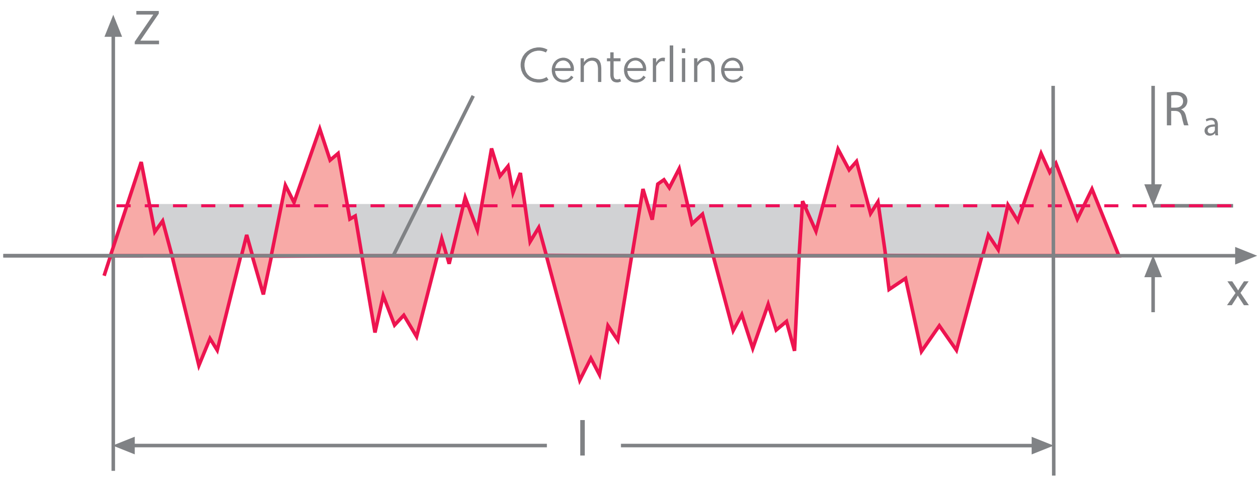

Figure 4: Explanation of the R_a value

Microorganisms may adhere to the surface, depending on the surface roughness, so that it becomes impossible or harder to remove them during cleaning. This implies a possible contamination risk for the end product or increased cleaning costs.

The common specifications regarding the hygienic design of tanks, such as the EHEDG directives, therefore specify a surface roughness **below 0.8 µm**.

The tank builder can affect the surface quality on the one hand through material selection, i.e. coldrolled steel has a smoother surface than hot-rolled steel. On the other hand, the surfaces of the tanks are polished to an appropriate value of less than 0.8 µm (see Fig. 5). Additional steps such as mechanical or electrical polishing can reduce the surface roughness to values between 0.3 µm and 0.4 µm. However, this is associated with additional work steps and therefore additional costs.

The most important tank areas with regard to surface roughness are the bottom, the welding seams and the cone. It must be considered that a flatter cone angle requires a higher surface quality to ensure that all microorganisms will reliably slide off. The included cone angle of a CCT should be between 60° and 90° and common values range between 60° to 75°.

Figure 5: Surfaces of tanks are polished to a surface roughness of less than 0.8 µm

What must be considered with regard to the tank insulation?

The thickness of the insulation foam should be at least 120 mm. This insulation layer must be reliably protected against humidity - as any form of humidity such as steam or condensate irreversibly damages the tank insulation.

The insulation is sealed towards the environment by stainless steel or aluminium sheets. In case of sea transport (from supplier to customer), aluminium has an advantage, as it is not corroded like stainless steel by the chloride of the salt water.

It must also be considered that foaming should only be performed at temperatures above 5 °C to avoid the formation of condensate.

So-called Zeppelin roofs are not suitable for reliably protecting the insulation against humidity. They build up tension between the metal layers when the temperature changes and this tension may crack the rivet connections of the roof in the long run. Then the roof starts to leak. The optimal solution in this case are stainless steel roofs with dedicated rain water drains (Fig. 7).

The walkway support in the dome area should preferably not penetrate the roof insulation of the tank. This is the only way to keep the insulation undamaged. It will therefore remain permanently tight and reliably protect the tank against the effects of the weather.

The area between the tank base and the start of the tank insulation must be considered on-site.

This area must be sealed on-site to prevent a potential opening for humidity, particularly in the case of outdoor installations.

Figure 6: A CCT is insulated

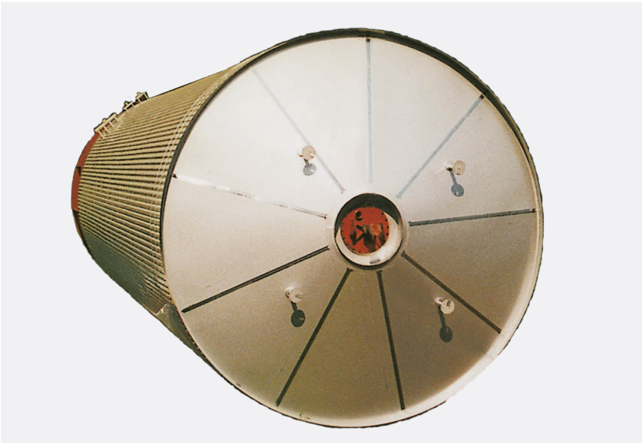

Figure 7: Dedicated rain water drainage protects the insulation against humidity

Figure 8: The area between the tank base and the start of insulation must be considered on-site

Which fittings are normally used for a CCT?

The fittings are grouped as follows:

- Fittings for filling and emptying
- Safety fittings (vacuum, overpressure)
- CIP fittings
- Gas fittings, e.g. for CO_2 or sterile air

Additional control instruments, e.g. for temperature or filling level as well as a sampling device are used

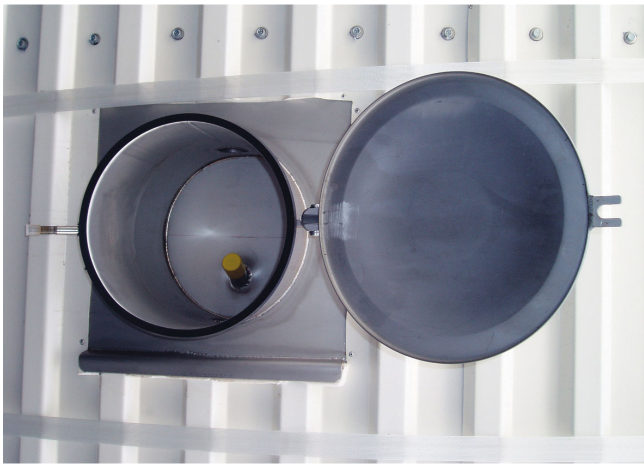

Figure 9: Temperature sensor at the CCT

What are dome fittings?

The dome fittings usually include:

- An overpressure valve
- A vacuum valve
- CIP cleaning with supply line
- A filling level sensor and
- A pressure sensor

The tank dome also has a manhole that can be used to enter the tank as required.

How is a modern dome area designed?

Modern dome covers consist of weatherproof polyurethane. They are light, due to the material used. They also do not have to be insulated, as polyurethane has much lower heat conductivity than stainless steel.

All relevant parts of the walkway such as the walking surface or the railings provide maximum safety. The adjustment of the walkway system should therefore be directly performed from the secured platform.

The design and production of the walkway should be highly standardised in order to provide a competitive price in spite of using stainless steel.

Figure 10: Modern dome covers made of polyurethane are significantly easier to handle

Design of the tank cooling

How much heat must be dissipated during the fermentation process?

The yeast produces approx. 587 kJ (= 0.16 kWh) heat energy during the fermentation of 1 kg extract.

Approx. 8.3 kg extract per hl are fermented at an original wort gravity of 12° Plato and a fermentation level of 80 %. This results in a heat production of 4,573 kJ per hl. Approx. 4,300 to 4,600 kJ heat energy per hl can be assumed as a guideline for calculations.

What influence does the fermentation state have on the design and control of the cooling zones?

Approx. ⅔ dof the cooling power is required during the main fermentation and ⅓ during the secondary fermentation. The fermentation heat during the main fermentation is discharged by the upper cooling zone, which is just large enough to cope with the fermentation heat. This reduces the switching frequency of the solenoid valves to a minimum.

All cooling zones of the CCT are switched on to cool them down to hose or storage temperature within 24 to 48 hours. This process phase requires the most cooling power. Approx. 420 kJ must be discharged per degree temperature reduction and hl of beer.

Only the lower cooling zone and cone cooling are used to maintain the storage temperature.

The actual total cooling energy requirement for this type of beer production is in the range of 8,600 to 9,000 kJ/hl.

Which systems are useful for tank cooling?

The tanks can be directly cooled using ammonia as a cooling medium. A popular alternative is the indirect tank cooling with a cooling medium such as glycol.

The energy balance shows that direct cooling of tanks with ammonia is approx. 15 to 20 percent more efficient than indirect cooling with glycol. However, ammonia is toxic and its maximum amount in a cooling system is therefore legally restricted in many countries of the world. The distribution of the ammonia quantity within a tank farm is critical, as the necessary piping must be secured. Furthermore, the ammonia in the pipes is not directly available for cooling and the cooling potential generated is difficult to store. Alternatively, the ammonia can be concentrated in a compact system up to the maximum permitted amount and the resulting cooling potential is then transported to the tanks in a cooling medium cycle.

Figure 11: Cooling can be performed with cooling coils...

Figure 12: ...or with dimple plates

Guidelines for the design of the tank geometry, the tank volume and optimal installation

What is the permitted wort height in a CCT?

The yeast cells are exposed to the CO_2 spunging pressure as well as the hydrostatic pressure resulting from the wort height. The literature strongly varies with regard to the pressure considered to affect fermentation. A wort height of 15 to 20 metres is usually provided as recommended maximum height for a CCT with jacket cooling. However, very vital yeast or yeast adapted to the pressure can also produce the desired beer quality at greater wort heights. It is therefore common to find higher CCTs in the field.

The wort height and the resulting hydrostatic pressure on the yeast are only relevant before the diacetyl degradation has been completed. The actual wort height is therefore less important for mere storage.

Is there an ideal ratio of wort height to diameter?

Ideal ratios of diameter to wort height mentioned in literature range from 1:2 to 1:4.

How is a CCT installed?

A CCT is either installed by using a short skirt on an intermediate floor, a high skirt directly on the foundation or several support bases (see Fig. 13, 14 and 15).

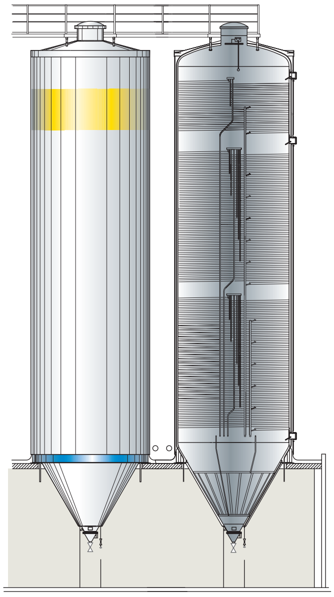

Figure 13: Installation with a short skirt on an intermediate floor

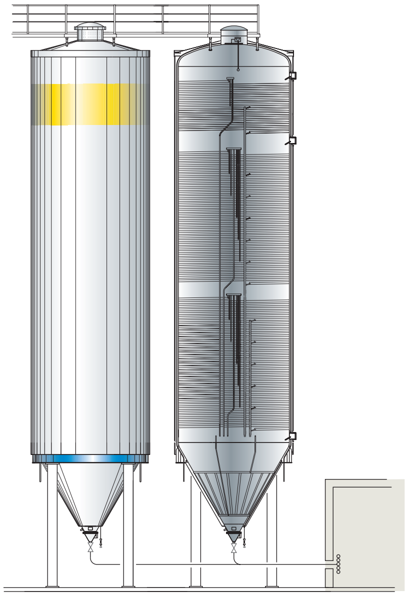

Figure 14: Installation on several support bases on a raw foundation

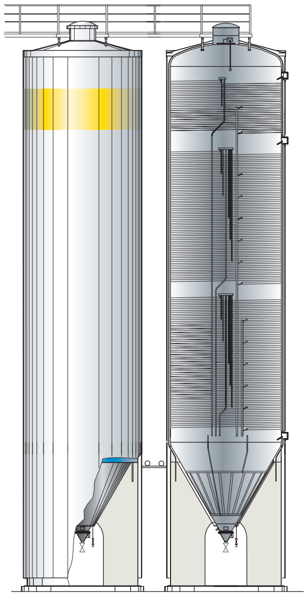

Figure 15: Installation with a high skirt

Note: The installation with a high skirt is the statically most stable version. This installation variant is therefore preferably used in regions with earthquakes or high wind forces.

Author

Hartmut Kienle

Dipl.-Ing. Hartmut Kienle

Hartmut Kienle is Diplom-Ingenieur (FH) in mechanical engineering. He studied in Kempten in the Allgäu region of Germany. His first professional experience was gained as project manager in various machine construction companies. Since 1999, Hartmut Kienle has worked at Ziemann, initially as the head of the technical office. He was appointed as technical manager of the factory Bürgstadt in 2008.

About Ziemann Holvrieka

Ziemann International GmbH in Ludwigsburg/Germany was established more than 170 years ago and is one of the globally leading manufacturers of brewery plants. The best-known beers in the world are brewed in plants from Ludwigsburg. Our customers include breweries of all sizes - from craft breweries to international corporations.

Ziemann further offers a large selection of tanks and process technology for the beverage and food industry, chemical applications and the use of Liquefied Natural Gas (LNG). Many years of experience, global references and its innovative solutions make Ziemann a reliable partner for modernizations, capacity expansions as well as for completely new turnkey brewery plants.

Ziemann provides innovative and tailor-made solutions for complete turnkey brewery plants or individual components for the entire brewing process. The product range in the area of the wort treatment extends from the malt intake, via grist mills, mash vessels, lauter tuns, mash filters, wort kettles and whirlpools up to wort cooling systems. In the area of the cold block Ziemann offers fermentation and storage tanks, bright beer tanks, yeast tanks and all required CIP tanks. Ziemann plans, engineers and automates the process and the cleaning technology in all production areas, including the installation of process pipework and the integration of all required utilities.

Thank you for your time.

For all enquiries, please contact one of our sales team at a Ziemann Holvrieka office near you.

Scan the QR code or visit www.ziemann-holvrieka.com

Ziemann Holvrieka