

# OPTIMISE YOUR CAPACITY

Brewery capacity is a surprisingly elastic and elusive number, what with variations in brewing methods – think high gravity brewing – brew lengths, packaging formats, manning requirements, and preferred fermentation and stabilisation techniques employed. Thankfully help is at hand: *Ian Smith* and *David Quain* provide here a detailed checklist for making the most of your plant

**W**ith margins continuing to be squeezed, increasing brewery process capacity is an important strategy to reduce costs. Additionally, with industry consolidation there may be opportunities to capture extra production volume and increase productivity by spreading fixed costs over a larger volume. Site costs can also be lowered by making better use of plant and reducing the number of shifts in an area. Optimising and enhancing capacity can also delay or avoid capital expenditure on new vessels and equipment.

Conversely, plant can be mothballed, reducing costs of maintenance and manpower. This can be a tricky route as ‘mothballing’ requires regular inspection and basic maintenance. If the plant is definitely surplus to requirements, it may be better to remove it completely.

It is important that existing plant is working to full capacity (measured as hectolitre degrees per hour) prior to committing to capex. Further, when making investment decisions there must be a clear understanding of brewery capacity. By definition there is only one bottleneck, but it can move around as the plant is optimised.

## First steps

It is important to understand the capacity of a brewery in terms of both plant and the end-to-end process. Further, it is necessary to factor in an appreciation of how the ‘mix’ of products/packages impacts on capacity. For each piece of plant there should be a stated capacity (specified by the supplier) validated through commissioning and plant handover. Tanks will have a working capacity and may also have a specified cooling load capacity.

The first step is to model the plant using the defined capacities and identify the pinch points and the process bottleneck. For example, for a packaging line, the equipment should conform to a ‘V curve’, where the key item of plant, normally the filling machine, defines the line capacity. Plant – upstream and downstream – is rated at an increasingly larger capacity the further the equipment is away from the filling machine. This ensures that the filler is never starved or subject to delays from downstream equipment.

This principle can also be applied to processing plant where a key item (e.g., the filter) defines the plant capacity. The ancillary plant has a larger capacity to ensure that the filter operates at maximum capacity. As such items are normally the most expensive these need to run at the stated capacity.

Having established the nominal capacity of the plant, the actual performance should then be assessed. This will quickly identify any plant or process that is not performing correctly, which can be addressed by an action plan that can be prioritised and tackled in manageable parts. The use of Pareto analysis – a statistical technique in decision making – can add value as can a system such as ‘top loss’. This is where only the top few items are tackled initially, and any other items wait until these have been solved.

In prioritising work, it is important to understand the effect the underperforming plant has on the overall capacity. Conversely, it is pointless optimising plant with a large overcapacity which is achieving what is required even though it is performing badly. There may be other reasons



for optimising such plant, but increasing the plant capacity is not one of them.

## Capacity modelling

A capacity model is required to understand how individual items of plant affect the overall capacity. There are many models available, some of which are complex, but they all use the same principle of modelling the throughput of each area.

The key is to measure the volume that can be processed through the area, taking into account the batch sizes, manned capacity, product abv, residence times, downtime (cleaning, maintenance and breakdowns) and the product mix.

An underlying weakness is how to allow for seasonality, unmanned shifts and capacity lost due to complexity. For one product produced in a single package format, capacity is relatively simple to determine. If several products are produced in many package formats, then time and capacity are lost due to changeovers and the part utilisation of the plant. This is very difficult to model, with most models simply building in a factor to account for this and reducing capacity accordingly.



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Similarly, seasonality is modelled with a factor to give the ‘peak’ capacity to achieve the desired annual volume. Likewise a factor is built in to allow for downtime due to shifts not being manned, e.g., at the weekend when tanks need to be empty to allow a timely start to the new week.

More sophisticated tools allow the process to be simulated using a computer model which can then be ‘run’ to simulate different scenarios and obtain a virtual ‘what if?’ analysis. These models enable the effect of complexity and downtime to be modelled.

A real world ‘what if?’ analysis using the plant can be used to test constraints and operating protocols. This provides real insight into pinch points, plant bottlenecks and can be a useful improvement tool. Such optimisation exercises

can result in the bottleneck moving. If the dynamics of the plant are understood, such changes can be predicted and allowed for.

#### **Efficiency measurement & planning**

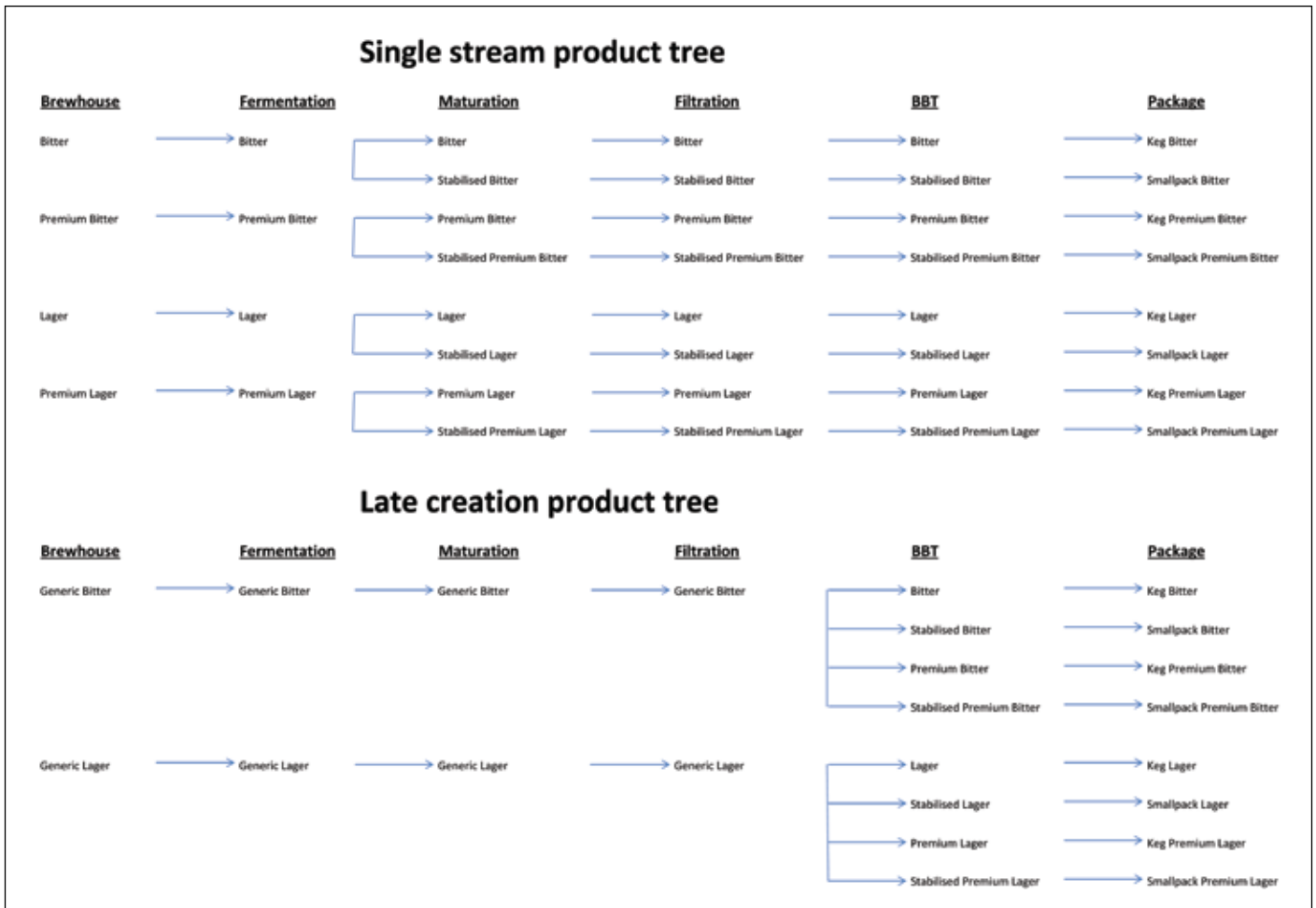
The efficiency of all process areas should be routinely measured against the nominal capacity. There are different ways of doing this, with comparisons being made against installed capacity, be it ‘installed’, ‘manned’ or ‘productive’. There are also different approaches to account ancillary and external downtime. Well-known systems are defined in the DIN (Deutsches Institut für Normung or the German Institute for Standardization) standards, and also as MEU (Machine Effective Utilisation). These methods all have slightly dif-

ferent purposes, but in all cases they should be timely so that they can be acted upon. It is also important to benchmark against the industry best practice, and not just use historical performance.

Production planning is a key part of maximising plant utilisation. Although outside the scope of this article, the approaches fall into two types of operating ‘push’ or ‘pull’. With ‘push’, the beer is brewed and then moved through the process against an order, but with ‘pull’, the demand is from the end of the process, which pulls the beer forwards as the demand is levied. In practice, customer driven ‘pull’ is now more common.

#### **Simplification**

Complexity has a major impact on brewery capacity and simplifying the plant, process and products can result in large gains in capacity. That said some types of complexity have a greater impact than others. For example, every product change leads to downtime together with ‘tops and tails’ that need to be processed separately. A large range of products also ties



**Downtime reduction: Late creation versus single stream**

up many tanks with part volumes.

One way to reduce complexity is 'late creation' where products are diversified at the end of the process. This is achieved by brewing, fermenting and maturing a single source 'mother' beer produced to the lowest common specification, which is then modified at filtration to produce a range of products by dilution and/or adding colour, bitterness and malt extracts. The utilisation of maturation tanks is then increased by reducing the number of part tanks, which also provides flexibility through a short lead time to packaging. Such an approach simplifies quality assurance/control and reduces product changeover at filtration with an ensuing capacity benefit.

The stabilisation of the beer is also best done at as late a stage as possible using silica gel and/or PVPP at the filter, rather than in the maturation tank. This maintains flexibility without the expense of having to stabilise a full tank of beer when only part requires stabilisation.

Although sales and marketing functions are unlikely to be supportive, packaging operations can be much simplified by reducing packaging material choice. Good examples include using a standard bottle and crown, fixed can size and a single colour can end.

**Shift patterns**

There is a trade-off between manning the maximum number of shifts (so that the plant can be run around the clock), against the unnecessary extra cost this will incur for much of the year. In an ideal world, the plant would be manned to meet the level of activity. Whilst this may be achieved by employing seasonal staff, there can be training, retention and possible issues with industrial relations.

The traditional peaks and troughs of trading have become 'spikier' through promotions linked to sporting events or holiday campaigns. Demand can be unpredictable when sport related or as a consequence of competitor activity. Although it is possible to build up stock in 'commodity' packs, promotional packs often have to be produced at short notice. Flexibility and sprint capacity are essential to meet such demand, and can often only be met by increasing the number of manned shifts.

**High gravity brewing**

High gravity brewing (or increasing the extent of 'high gravity'), is a very easy way to boost the capacity of the brewery, particularly where fermentation and/or maturation capacity is limit-

ing. Broadly, high gravity brewing is about 20 to 50 percent above the sales gravity, with the beer being processed at 12 to 15°P (1048 – 1060 Sacch). Above this wort production can become less efficient, with potentially higher losses. Pushing the envelope with atypical amounts of sugar syrups can overcome this but can result in issues over flavour matching.

Problems with disproportionate concentrations of esters and higher alcohols are typically managed by close attention to wort oxygen levels. Whilst the occasional brewery may routinely operate at very high gravity (≥18°P), the toxic effects of ethanol on yeast physiology and viability have tended to limit this approach to 15°P or so.

As high gravity brewing impacts across the process it is important to check the capability of not only the brewhouse but all of the plant. For example, the filtration and dilution equipment can be a limiting factor in the exploitation of high gravity brewing. Similarly, the longer fermentation times of higher gravity worts should not outweigh the gains from processing beer at a higher abv.

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**Brewhouse**

If the brewery bottleneck is the brewhouse, then it is critical to understand what the rate-limiting step is. The capacity of each item of plant needs to be checked, as well as the interaction with the other vessels. It is also necessary to consider the size of the fermentation vessels, so that the batch size produced from the brewhouse is compatible. The wort separation stage is often the rate-limiting step, and this can be increased by maximising the dry goods loading and/or by reducing the cycle time. If the wort separation stage is not the rate-limiting step, the bottleneck item should be up-rated if the brewhouse is to run at the maximum capacity. Where dry goods loading is limiting, the brewhouse capacity can be extended by using liquid adjuncts added to the wort copper/kettle.

The downtime of the plant (such as cleaning and maintenance) also needs to be reviewed, as carefully reducing this can give extra production time. The CIP (cleaning in place) of the external calandria is often an area of delay which can be reduced by the installation of a modern heat exchanger (which requires less frequent cleaning), or by the installation of a second heat exchanger, so that production can continue while one unit is being cleaned.

Where feasible, a good opportunity to increase the capacity of the brewhouse is to replace the lauter tun with a mash filter. These have a very rapid cycle time, produce high gravity worts efficiently and have excellent extract recovery. Batch sizes can be inflexible but this should not be a problem if the brewery has been simplified with large common production batches.

**SWEATING YOUR ASSETS – 10 TOP TIPS**

- Mothball/remove redundant plant – oversize processing plant to give ‘sprint’ capacity
- Know your bottleneck
- Understand the impact of SKU mix
- Determine *nominal* and *actual* capacity
- Simplify product streams
- Simplify/unify packaging materials
- Consider (more) high gravity brewing
- Tighten fermentation cycle time – consider acceleration
- Consider reducing maturation time
- Upgrade capability (cooling, centrifugation or filtration)

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**Fermentation**

Fermenters are expensive and fermentation cycle time provides a hefty chunk of the brewing process, so creating new capacity without capex has long been a keen focus. Whilst high gravity brewing (see above) has achieved a step change in fermenter productivity, more recent work has focussed on accelerating fermentation and, in doing so, reducing vessel cycle time.

Top of the pile is ‘temperature’, raising it or simplifying the (stepped) profile with – less easily addressed – renewed interest in the benefits that applied stirring can bring to speeding up fermentations. Less sexy but arguably more doable is to tighten fermentation consistency by attending to the details of wort oxygenation and pitching yeast control and quality.

Fermenter cycle time can be further trimmed by moving beer out ‘warm’ through an appropriately sized in-line cooler rather than cooling *in situ*. Similarly, the rate limiting diacetyl reduction is accelerated by warmer temperatures and – where permissible – the addition of  $\alpha$ -acetolactate decarboxylase.

A big opportunity in increasing fermenter capacity is to decrease the freeboard/headspace which can represent 20% or so of the nominal volume. Whilst the addition of silicon anti-foam at collection or in response to overfoaming has long been popular, other approaches include spraying microbiologically sound water or use of hop products antifoams. Whatever approach is used it cannot have any deleterious effect on final beer quality.

A word of caution: whilst highly attractive from a capacity perspective, approaches to improving fermenter efficiency also require the protracted validation of product matching together with robust testing of consumer acceptability.

**Maturation**

Although maturation times, in particular for German or Czech breweries, are still two to four weeks (or longer), maturation elsewhere is defined in days and hours. With diacetyl removal occurring during primary fermentation, such accelerated maturation is more about solids removal and chill stabilisation.

The use of dual purpose cylindroconical vessels for fermentation and maturation leads to compromises both in terms of different cooling demands and a loss of maturation capacity from the need for freeboard during the fermentation.

The part emptying of maturation vessels – due to brand complexity - also compromises plant capacity. Planning to fully empty maturation vessels requires amenable packaging plans and the availability of bright beer tanks.



### Processing Plant

The processing plant – chilling, centrifugation and filtration – is an area where it is important to have overcapacity. The marginal cost of installing larger capacity is relatively small compared to the cost of fermentation, storage tanks and packaging plant. Fermentations do not always run to schedule and it is wasteful of capacity if vessels queue up to transfer. Similarly, packaging plans change and products can be out of specification. In both cases the 'sprint capacity' of oversized processing equipment enables the situation to be recovered.

### Filtration

Investment of technical effort will typically benefit filtration capacity. With powder filtration, time is lost between filter runs, such that utilisation is typically 75% or so. Ensuring both the maximum allowed pressure differential and powder space are utilised will extend filter runs. This requires adjusting the rate of bodyfeed addition to suit the quality of the beer being filtered by monitoring the change in differential pressure and then adjusting the powder dosing.

Installing an additional filter has a dramatic impact on capacity. For example, three powder filters can service two filtration lines. With staggered turnarounds the efficiency of both lines can be increased from about 75% to near 100%.

Crossflow filtration has received favourable press coverage in recent years, especially as beer supply can be turned on virtually instantaneously as required. However, there have been reported problems with the filterability of certain beers, and energy consumption is high.

### Bright beer tank capacity

The number and size of bright beer tanks (BBT) is always a source of debate as their primary roles are to allow a batch to be analysed and released for packaging, and to act as a capacity buffer between the processing and packaging areas. It is a difficult area to model, and often rules of thumb are applied to determine the required capacity. Complexity will destroy BBT capacity but if only a few products are packaged, then a small number of relatively large tanks will be suitable. If the product range is large, many more tanks will be required; if some of the packaging runs are short, small tanks are needed.

If the processing capacity is oversized, then the number of tanks can be reduced as there is sprint capacity to maximise the utilisation of the tanks. A high-speed small pack line will often consume beer at a faster rate than can be filtered by a single filter, and this can be accommodated by stockpiling bright beer by running the processing plant for additional shifts.

It can be argued that any use of BBTs is

planning for failure! With today's technology, why is it not possible for the beer to be filtered, diluted, carbonated and adjusted for colour and bitterness in-line, with just a small buffer tank between the processing plant and the packaging plant? Although a brave step the rewards would be enormous.

### Packaging operations

Although outside the scope of this article, improvements in packaging capacity can be achieved through Lean, six sigma and other improvement techniques. ■

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