Photo: Roger Putman.

*The Huppmann brewhouse at Oettinger Brau in Germany has been installed within a no frills industrial building. Oettinger is a leading supplier to the supermarket trade.*

# A brewer's view on a modern brewhouse project

**Mention building a new brewhouse and any brewer's eyes light up and the 'red mist' descends at the thought of gleaming shiny vessels in a marble hall set off with murals of malt and hops and modern lighting effects. The reality is often quite different and a lot of thought, analysis and soul searching have to be done before the dream is realised.**

By **Paul Buttrick**
Beer Dimensions

This article is written by a practical brewer and is not intended to be a thorough analysis of each item of equipment, but will look at the things anyone building a new brewhouse should consider. Brewhouses are expensive, basically permanent, and any fundamental mistakes very difficult and certainly costly to rectify.

From the brewer's perspective, there are five key requirements in specifying a new brewhouse – these are:

a) Brand image.
b) Capacity – how big should it be?
c) Wort and beer quality – taste, head retention, flavour and haze stability
d) Capital costs – plant choice and design.
e) Running costs – brewhouse yield, raw materials energy costs, manning and other costs.

## Brand image

It is important that a company takes into account its brand and image when developing a new brewhouse. If beer quality and tradition is core to a brand image – particularly premium brands, then positive PR can be gained from a 'showpiece' brewhouse, but if a company is more commodity based, leading with price and does not have strong individual brands, then a different approach can be made. With brand image and strength becoming more important, how many companies regret building functional brewhouses? After all, customers expect to see more than a 'chemical plant' when they visit the 'home' of their favourite beer. It does not always cost a fortune to make a brewhouse 'smart' instead of purely functional (Fig.1)

Brand image may not only influence the look of a brewery, but also dictates the raw materials and processes used. In designing a new brewhouse, there must be a serious debate on the recipe of a beer, because this will decide the plant choice and the final cost of the project.

> *"The decision by SAB-Miller to retain the triple decoction process, a copper heat exchange surface, and direct gas firing for Pilsner Urquell is no doubt the result of a debate that puts the beer and traditional process used at the heart of the image demanded by this unique beer."*

*Figure 1: A 'showpiece' Ziemann brewhouse at a Latin American brewery.*

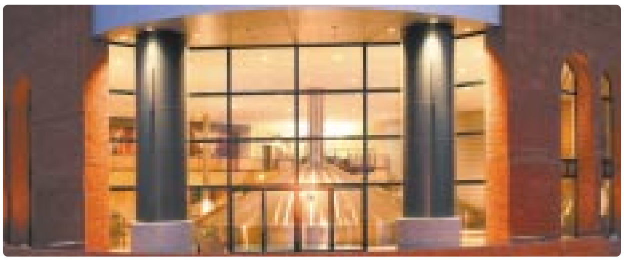

Photo: Roger Putman.

*Figure 2: Pilsner Urquell brewhouse (2004). Note the copper clad vessels with one of two 10m lauter tuns in the back ground. Over 100,000 visitors a year inspect this view from an elevated walkway.*

The decision by SAB-Miller to retain the triple decoction process, a copper heat exchange surface, and direct gas firing for Pilsner Urquell is no doubt the result of a debate that puts the beer and traditional process used at the heart of the image demanded by this unique beer. (Fig.2)

## How big should a brewhouse be?

The normal way to size a brewhouse is to take the peak weekly or monthly volume of the business and use this as the basis for the capacity calculation. It is also important to include an overall efficiency factor for the operation which would include plant cleaning, mechanical efficiency and other non-production down time. Extra capacity can then be added to take account of future volume growth. This can be done by leaving extra days or shifts available for peak working, e.g. five and seven day working, double or triple shift working or a planned option to decrease brew cycle times.

A single brewery company will take a different view to a global/national one with a number of breweries. With multi brewery operations, the capacity and capability of all the breweries must be taken into account, as is the decision about which plant is to be expanded. In these situations, an overall production and minimum cost sourcing exercise needs to be done to get the right economic answer, before taking other factors such as local marketing conditions and risks into consideration.

The planned brew length will normally be dictated by the size of other plant in the brewery – especially fermenting vessels. However – the opportunity should be taken to review both brewlength and brewing gravity, because it will affect the capacity of the whole brewery. It is important in this exercise to make sure everything ‘fits’ and not get a mismatch of vessel size and brewlength – e.g. a 500 hl brewlength with 5000hl fermentation vessels or a 1000hl brewlength with 300 hl vessels would not be ideal. It is also important to ensure that yeast pitching can be properly managed.

Brewers always like to build in flexibility, but at what level does this become uneconomic? Some breweries that are based on a two stream brewhouse, should consider whether a single stream plant is a better option. A single stream will be less complex, less costly to install, easier and more economic to run.

## Raw materials

The beer recipe can significantly influence the capital cost of a brewhouse, and its effect on ongoing brewing costs. The degree of malt modification dictates wort and beer quality as well as brewhouse processes. In traditional lager brewing, under modified malt is processed using a decoction system, with mash boiling vessels being key plant items. Many breweries are using temperature programmed mashes and some employ infusion mashing to produce lager wort. Current opinion and experience suggests that reducing the length and intensity of mash heating and copper boiling results in beers with improved flavour stability – little did ale brewers of the last century realise that they were at the forefront of 21st century brewing science!

Malt is the main raw material, but adjuncts play a big part in dictating brewhouse plant and costs. For example, the use of un-gelatinised maize grits requires the use of a cereal cooker, but using flaked maize does not. Similarly, use of liquid sugar requires storage tanks, but does not take up conversion vessel or wort separation equipment capacity. Maize grits are less expensive than maize flakes, liquid sugar is the same cost as malt. Doing an exercise weighing up the cost of extra plant and complexity against raw material and energy cost needs to be carried out.

Remember that cereal prices vary from year to year, so a spot calculation on a single year is not wise. The result of this can lead to a bit of soul searching and wise decision making on behalf of the brand owners (more often than not the Marketing function who may have to manage the PR aspects of any recipe or process changes.

Many people underestimate the part that hops play in beer flavour and quality, therefore the choice of hop products is important. Extracts produce a clean beer with little hop flavour or aroma and are easier to process due to less bulk; wort losses can be up to 1% lower than when using hop pellets. Hop pellets give more polyphenol content to wort and if added late impart aroma and hoppy flavour. Polyphenols add to the overall mouth-feel and body of the beer as well as improved flavour stability, but if in excess can detract

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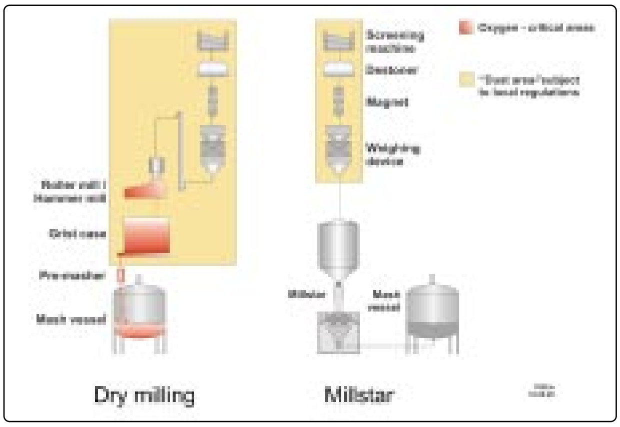
*RIGHT: Figure 3: Equipment schematic for “wet” and “dry” milling operation – diagram from Huppmann*

*FAR RIGHT: Figure 4: The “Dispax” milling system in a Dutch brewery– photo supplied by Ziemann*



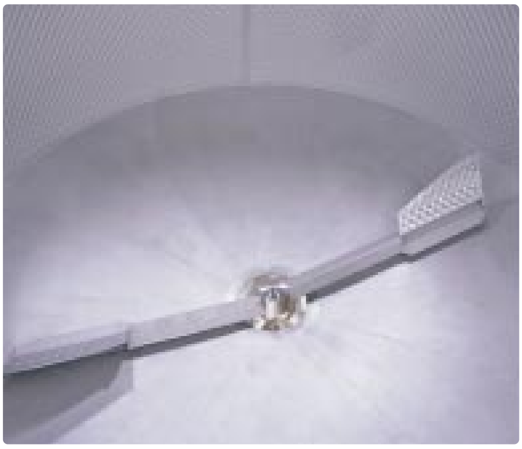


*Figure5: The dimpled surface on ShakesBeer conversion vessel – photo supplied by Steinecker*

Photo: Roger Putman.

*Figure 6: One of two centrally-fed 16 tonne Meura 2001 mash filters installed at InBev's Magor plant in South Wales.*

from haze stability. Hops whether from pellets or leaf are known to improve the quality of beer foam compared with beers brewed using extract.

The correct choice of plant will influence the overall project cost, beer quality and how much it will cost to brew for the next 20 years or more. With energy and waste costs rising, these will have an increasing influence on running costs. The latest techniques involving reduced wort oxidation and 'thermal stress' are also leading to improvements in flavour, flavour stability and head retention.

Thermal stress is brought about by any process involving excess heat at high temperatures in any brewhouse process (eg excessive wort boiling) Over enthusiastic mixing in other brewhouse vessels such as conversion vessels also has a negative effect on flavour stability. The leading brewhouse manufacturers all offer their own interpretation and development on the latest available brewing knowledge and science.

## Milling

There are three main options for milling. Dry milling normally uses six roller mills and is still popular with breweries using lauter tuns. The milling is independent from the mashing process and therefore a lower rated mill can be used so that the milling operation can utilise the conversion vessel cycle-time, whereas 'continuous steep' milling requires milling to take place in 20 minutes of the mashing process. It is also reckoned that mill adjustments available on the three sets of rollers give a better opportunity for optimisation of extract and run off.

Hammer milling is only used in conjunction with the mash filter in order to get the 30% fine flour required, power consumption is up to three times that required by wet milling systems. Noise and explosion risks also need to be taken into consideration.

Continuous steep milling is recommended by Steinecker (Variomill) and Huppmann (Millstar) and can be used in conjunction with any lauter tun. Conditioning of the whole malt grain in a continuous warm water steep increases the water content of the husk to approx 15 % before milling. Advantages over dry milling are said to be better and faster wort separation with opportunities for increased lauter tun loading, less equipment and less explosion risk (no dry ground grist), less oxygen uptake due to mashing taking place at the same time as milling (Fig.3).

Ziemann have recently developed their innovative "Dispax" dispersion mashing/milling system which is a compact 'wet' option mainly for use with mash filters (Fig.4)

## Mash Conversion

The key here is the choice of infusion/temperature programmed mashes and whether mash boiling and cereal cooking are part of the desired brew recipe. All manufacturers feature on low oxygen pick up, efficient mixing, heat transfer with latest design mixers and temperature control. Ziemann and Steinecker (ShakesBeer) have introduced dimpled heat surfaces inside the vessel (Fig.5) which gives improved heat transfer and hence faster temperature rises for programmed mashes. Along with hot water injection, heat rises of over 2°C/min as against 0.5– 0.9°C/min for a conventional conversion vessel can be achieved. This would be important to any brewery whose mash cycle is the rate determining step in their brewhouse. For a temperature programmed mash starting at 45°C and rising to 75°C, an overall time saving of 30–50 minutes is very significant. Note that any operation using mash boiling or decoction will include more complex plant as well as increased energy costs.

## Wort separation

The big debate continues on the use of lauter tuns and mash filters. Historically mash filters had a brief rise in the late 1970s, but improvements in lauter tun design reasserted their ascendancy until the introduction of the Meura 2001 membrane mash filter (Fig 6). Ziemann continue to offer modern mash filters and lauter tuns. The Ziemann TCM (Thin layer Chamber Mash filter) produces up to 16 brews per day, the largest version taking a 21 tonne grist. At present there is no clear winner, except that each brewer must make the decision based on its own requirements. Breweries using unmalted adjucts and high gravity brewing often opt for mash filters, as do breweries with a low number of wort streams requiring fast throughput and high extract yields. Lauter tun manufacturers, Briggs, Ziemann, Steinecker (with Pegasus) and Huppmann (with Lauterstar) have continued to develop their equipment to increase loading (up from a "norm" of 160kg/m$^2$ to over 200kg/m$^2$) while reducing cycle times and increasing extract. An emphasis has been put on decreasing down time (like spent grain removal) with improvements in rake design, automated raking and run off control improving the

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*Figure 7: The underside of a modern lauter tun – take note of the number of wort run off pipes – photo supplied by Huppmann*

wort flow itself. A significant step forward has been to increase the number and positioning of run off ports incorporating a conical design (Fig.7). This has resulted in faster run off with an even extract recovery across the whole bed and less vacuum produced.

Without getting into detail, the main differences between a lauter tun and mash filter include the following. The lauter tun is more flexible for loading – charges of + 50% to -30% are claimed with the mash filter only able to handle +10% to -20% of optimum loading. Smaller breweries with a large number of beer brands are more likely to favour lauter tuns because of this.

*Figure 8: The Symphony external wort boiling system – supplied by Briggs of Burton.*

The cycle time of the mash filter of 90–120 minutes has been consistently better than the lauter tun, although using the latest run off technology twelve brews per day on a bed loading of 200 kg/m$^2$ can be achieved with a lauter tun. Whatever mash separation device is used, the malt quality is vital to good performance, especially levels of beta glucans, with β-glucanase addition to the mash often used to maintain consistent run off performance on mash filters.

A recovery of 100–101% of laboratory extract from a mash filter compared with say 98.5% on an optimised lauter tun can mean a saving in malt of around £150,000 per year at a brewery producing one million hectolitres of wort. There is, however, a debate about how much the extra 3–4% extract is of positive value from a beer flavour and quality perspective.

Capital costs of lauter tun systems are claimed to be about 70% of an equivalent mash filter. The maximum size for a single mash filter has been around 11 tonnes of grist (approx 600 hl of high gravity wort) compared with up to 25 tonnes for a single lauter tun, although the 21 tonne Ziemann mash filter is catching up fast.

Operating costs for mash filters are also higher. This is mainly due to higher maintenance costs, cleaning costs (cleaning required every 50–60 brews), replacement of filter sheets (every 2,000–3,000 brews) and membranes (every 5,000 brews). Unlike the Meura 2001, the Ziemann TCM has no membranes to maintain or replace.

## Wort Boiling

As energy costs rise, wort boiling will continue to be an area of increased attention. Modern understanding of wort boiling has enabled manufacturers to look at wort volatile reduction and protein denaturisation/ coagulation as separate processes. The idea of applying a minimum temperature difference between the heating medium and the wort by effectively increasing heating area and inducing two phase liquid/vapour bubbles in the wort means that wort evaporation can be reduced from over 8% to 4–5%. Different approaches have been made by manufacturers, with some opting for a separate volatile reducing step after wort boiling.

Beers produced have similar fermentation characteristics and volatiles as well as reduced DMS levels. Reduced thermal stress on the wort also predicts an increase in flavour stability, although results supplied by manufacturers are difficult to assess and compare because they are often from different tests and analyses. With flavour stability and beer freshness attracting more focus, relying more on tasting beer and using better understood analysis would be helpful. Reduced evaporation from less and lower heat input also results in improved beer foam. Less fouling of the heating surface also has the benefit that cleaning frequencies can be reduced. The introduction of a natural thermosyphon during boiling is becoming a feature in all modern wort boilers.

There is a choice between internal and external wort boiling. The latter is a development of Briggs external wort boiling system and is called ‘Symphony’ (Fig.8) This involves increasing the specific heating surface of the boiler to 0.43m$^2$/hl which is five times more than for a typical internal heater, and twice as high as a standard external wort boiler. By using this increased area, the steam temperature and pressure can be reduced and a two phase, liquid/vapour driven thermo-syphon is produced. The wort, which is circulated eight to ten times during the boil, is returned to the copper in a tangential manner to reduce foaming and minimise trub break up. This arrangement of external wort boiler and tangential inlet to the copper is easily arranged into a combination copper/whirlpool.

Other suppliers have developed efficient internal copper heaters. A ‘dynamic’ or ‘low pressure’ boiling technique has been introduced by Huppmann (Fig.9) which involves heating wort under pressure of 150 mbar, equivalent to a boiling temperature of 103°C. When this pressure is reached, it is rapidly reduced to 50mbar and the temperature drops back to 101°C. This takes place at least six times during each boil and the effect produces a flash evaporation with the formation of foam and bubbles within the wort kettle which strips unwanted volatiles and aids coagulation of hot break particles. In order to accommodate the flash evaporation, the copper volume needs to be 30% greater than for a standard system and the wort is circulated 20–30 times per hour.

Ziemann offers a similar technology. The internal wort heater as applied by Steinecker (Stromboli) creates a large heating surface within an internal heater which enables wort volatile removal and precise protein coagulation at low thermal load. The heater has a specially designed two part spreader for the heating and boiling part of the cycle. A natural thermo-syphon via a “jet pump” above the central tube enables the heat input to be reduced(Fig 10,11) As with the Briggs Symphony system, fouling of the heater is reduced, resulting in a lower cleaning frequency( Fig 12,13) Huppmann introduced an internal heater with a natural thermosyphon called Jetstar in September 2005.

## Volatile stripping from wort after boiling

German manufacturers have developed equipment to improve energy efficiency, beer quality and flavour by stripping volatiles after the copper. This allows copper evaporation to be reduced to 3–5%. DMS and precursor reduction takes place after the copper, but before wort cooling.

The Steinecker system, called ‘Merlin’ is a vertical cylindrical vessel with a steam heated, coned shaped interior over which a thin film of wort is pumped before it goes the whirlpool (wort evaporation is 1–2%) (Fig.14). Ziemann offers a different approach using a vacuum technique working at approximately 0.4 bar underpressure to strip out volatiles between whirlpool and wort cooler (Fig.15).

## Energy saving and wort boiling

With UK gas prices reaching a peak of £1.40 per Therm (£0.013/MJ) in November 2005, the requirement to save energy moves from a financial “nice to do” to a definite “must do”. It would be sensible for any brewer to look at retrofitting energy saving equipment whether or not a full brewhouse development is being considered.

Brewers should be as focussed on energy usage as they are on malt extracts. Large energy savings are possible, especially if energy recovered from a vapour condenser is used for preheating wort going to the copper. This technique involves installing an energy storage system, which comprises a hot water storage tank and heat exchanger for taking

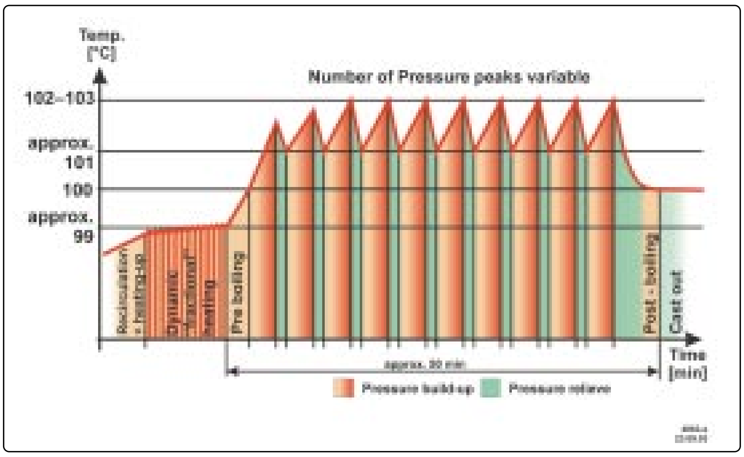
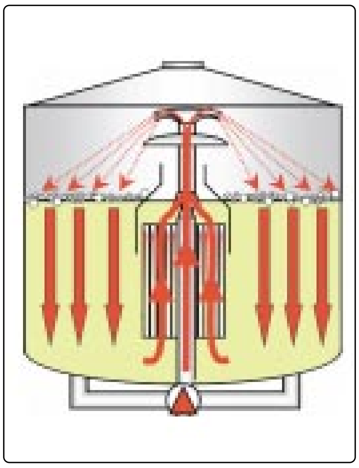
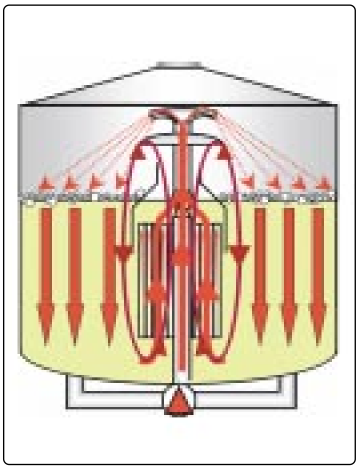


*Figure 9: The temperature/pressure chart of “dynamic/low pressure boiling” process – supplied by Huppmann.*





*FAR LEFT: Figure 10: The “Stromboli” internal copper heating wort up to boiling temperature. –*

*LEFT: Figure 11: The “Stromboli” internal copper heating system in boiling mode including thermosyphon. Diagrams supplied by Steinecker.*

*FAR LEFT: Figure 12: The tubes of a conventional internal wort heater after 8 brews.*

*LEFT: Figure 13: The tubes of a Stromboli internal wort heater after 80 brews – notice how the less intensive heating regime has reduced fouling considerably. Photos supplied by Steinecker.*

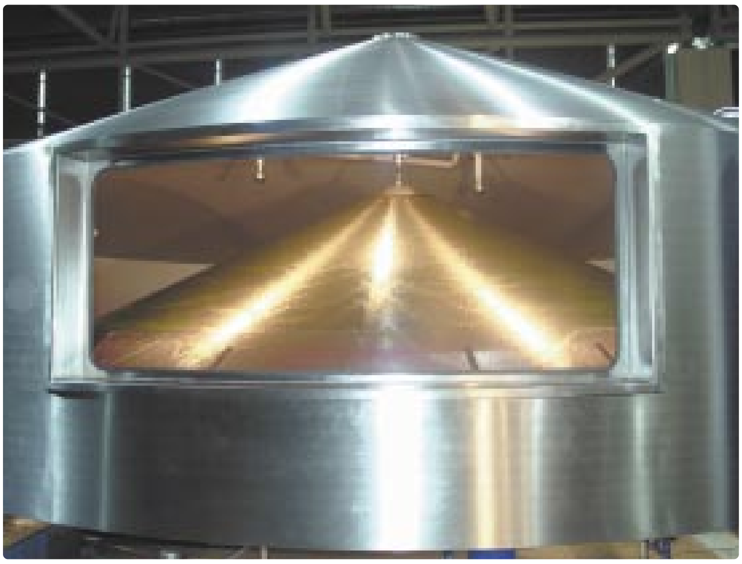


*Figure 14: The inverted heating surface cone of a Merlin boiling/ wort stripping system seen in an exhibition mock up – photo supplied by Steinecker.*

*Figure15: A Ziemann vacuum wort "stripping" system positioned after the whirlpool but before wort cooling – photo supplied by Ziemann.*

wort from approx 75°C after the wort separator to 95°C+ in the copper (Fig.16).

## Trub separation

The whirlpool remains the most popular and simplest method for separation of hot trub from boiled wort. The workings of whirlpools have been studied extensively with many theories and calculations showing the best design. A vessel height to diameter ratio of around 0.5, copper casting time of ten minutes, tangential inlet velocity of 3–4 metre/sec and stand time of 20 minutes normally works effectively.

An often overlooked consideration is solids loading. In order to get good trub separation, it is said that hop pellet loading should not exceed 2.0kg/m$^2$. Hop pellets also retain extract, so increasing or decreasing hop pellets and hop extract ratios can make a difference in yield. There are many designs for the run off system, floor shape, and trub removal, all of which are important to consider as long as the basic design gives a good result. Converting hop backs in traditional breweries to effective whirlpools is often easily achieved with minimal expenditure.

Combined copper-whirlpools have been successfully installed in recent years, these tend to be a compromise in optimum design, Vessel configuration and the hop grist must be fully considered along with all other criteria. An advantage of a copper whirlpool is that a vessel to vessel transfer is eliminated, there is less trub particle size reduction, and it allows a faster start up of wort transfer to fermenter. The copper/whirlpool is a natural development from the Briggs Symphony system involving a tangential inlet to the copper and is branded as 'Symphony Plus'

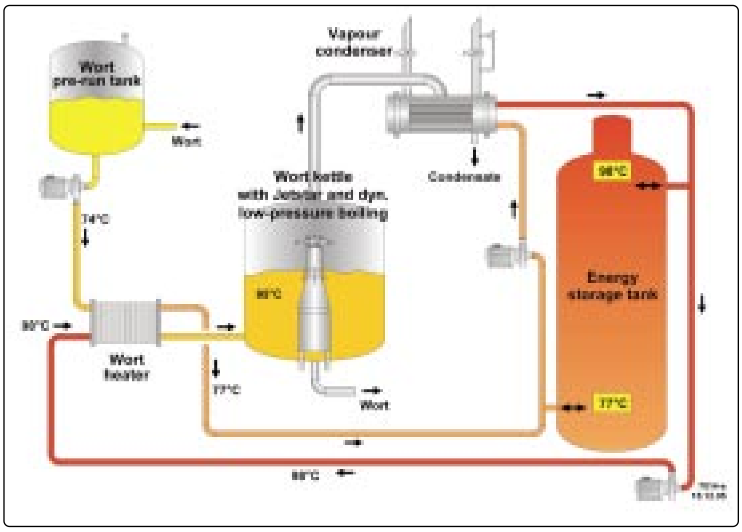


*Figure 16: Schematic of a brewhouse 'energy store system', with heat recovered by a vapour condenser used to preheat wort on its way to the copper – diagram supplied by Huppmann.*

## A final word

It is easy to get carried away with new plant, but a dedicated project team and detailed planning needs to be in place from the beginning. Bringing the new plant on stream is not always as straight forward as first thought and a logical step-wise programme of trials to ensure beer flavour and quality match the specifications is fundamental.

There should also be a comprehensive blending operation in place until all 'stakeholders' are satisfied with the result. It is important that the Marketing and Sales functions are included in this process and the success criteria for a successful flavour match is agreed beforehand, so there is no dispute when the time for the final sign off comes. ■

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● The author would like to acknowledge the help of the following for supplying information, diagrams and photographs for this article. Briggs of Burton (Paul Dowd), Krones/Steinecker (Peter Gattermayer), Huppmann (Thomas Bühler) and Ziemann Group (Volker Mewes).

**● The author**

After a long career with Whitbread and Interbrew, including time as Head Brewer of Boddingtons and Stella Artois Brewmaster, **Paul Buttrick** has started his own independent consultancy Beer Dimensions. Paul has an MSc in Brewing Science from Birmingham University and is one of only a handful of British brewers to have studied at Weihenstephan (T.U. Munich).

*Table 1 shows the order of magnitude of costs for wort pre-heating and boiling for a one million hectolitre brewery (volume brewed) at both 5% and 10% evaporation as the cost of fuel doubles.*

**TABLE 1**

| Operation | Approximate Energy usage MJ/hl | Cost per 1 million hl per Therm brewed with gas cost at £0.65 (£0.00616 per MJ) | Cost per 1 million hl brewed with gas cost at £1.4 per Therm (£0.0133 per MJ) |
|---|---|---|---|
| Wort pre-heating from 75°C to 95°C | 12 | £73,900 | £159,200 |
| 5% wort evaporation | 12 | £73,900 | £159,200 |
| 10% wort evaporation | 24 | £147,800 | £318,400 |

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