125th Anniversary Review: Some Recent Engineering Advances in Brewing and Distilling

J. M. H. Andrews[1,*], J. C. Hancock[1], J. Ludford-Brooks[1], I. J. Murfin[1], L. Houldsworth[2] and M. Phillips[1]

ABSTRACT

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Some of the more important engineering advances of the last 25 years in brewing and distilling are reviewed. The modern mash filter is compared to lauter tuns. Wort boiling systems, cross-flow or membrane filtration, yeast propagation, and process improvements are considered. Approaches taken to reducing energy, water and effluent are highlighted, as is by-product usage. The impact of computers, software, and digital technology on process control, automation, engineering design, and project implementation are reviewed.

Key words: brewing, distilling, energy, engineering, technology.

INTRODUCTION

The basic processes of brewing and distilling have remained largely unchanged over the last quarter century with new technologies being introduced incrementally and with an adoption timescale of typically ten years to become widely accepted. The main drivers for change have been capital and revenue cost, reliability and repeatability, enhanced product quality, particularly stability, security and safety, and environmental impact. This paper reviews the most important advances in engineering and project implementation in these areas.

MASH FILTRATION

Mash filters have been used in breweries for over a hundred years[24] but until about 20 years ago their application was limited, often handling materials too difficult for conventional lautering, such as sorghum. This changed with the advent of the Meura 2001 mash filter system whose key features were the reliable and effective membrane system (made possible by modern materials) and the process control methodology, which ensured fast mash filtration and sparging, maximising extract recovery and minimising spent grain moisture at high throughputs[21,25].

The mash filter can process mash from grist which has been reduced to a fine powder by hammer milling. The extract performance approximates to the fine grind of laboratory analysis. The lauter tun grist is the result of roller milling, which normally produces an extract performance at, or slightly below, the coarse grind of laboratory analysis. For typically modified malt the difference is of the order of 2%, a significant revenue saving.

Furthermore, modern mash filters have been developed to achieve up to 14 brews per day. The original gravity of the resulting wort, at typically 20°P and 100% extract, means that the volume of brewing water is reduced by at least 20% compared with lauter tuns. This water is not "saved" as it must be used to dilute the product either pre or post fermentation to bring the ensuing beer to sales gravity. However, this process saves significant energy because it does not have to be heated. Also, the brewhouse vessels can be reduced in size for the same overall beer output. Because the spent grains are much drier, at about 70% moisture, than lauter tun spent grains, which are typically 78–80% moisture, the effluent from mash filters is reduced, giving a potential cost reduction.

Mash filter development has emphasised the importance of mash filterability and wort quality presented to the filter which, in turn, benefits lauter tuns[36]. Consequently, development of the mash filter spurred other suppliers on to rapid improvement in lauter tun design and performance, closing the gap on mash filter performance. The beginning and end of the lauter process have been optimised to maximise lautering time, with gains in extract recovery. Lauter tun performance improved from typically 8 brews/day at 98% extract recovery in the 90s, to 10 brews/day + at >99% extract recovery, with excellent wort clarity, <10 EBC for 80% of wort collected[2]. This has been achieved by developments including: overlapping of mash-in and recirculation; grain out and underplate flushing; reduced underplate volume; larger grain port area and more effective grain discharge systems; and a combination of thinner, higher lift lauter knives and responsive lauter automation. Table I shows commissioning data from an installation of both a mash filter and a lauter tun.

Currently, it is estimated that 25% of world beer output is from breweries using modern mash filters[2]. The selection decision is a finely balanced one depending on the trade-off between a higher capital cost and lower revenue cost for the mash filter, which in turn is influenced by the overall volume output, the number of recipes and brew lengths and the quality of raw materials.

[1] Briggs of Burton PLC, Staffordshire, U.K.
[2] Briggs Automation Limited, Cheshire, U.K.
[*] Corresponding author. Email: john.andrews@briggsplc.co.uk

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Table I. Comparison between two installations with results during commissioning[2].

	Brews/ day	Brew length	Wort gravity (Plato)	Turn around time (Min)		Yield		Haze (EBC)		Spent grains moisture (w/w)	
				Target	Actual	Target	Actual	Target	Actual	Target	Actual
Lauter tun – 9.5 tonne malt charge	10	625 hL	16	144	136	>98.9%	99.30%	<40	5.3	<80%	80%
Mash filter – 10.5 tonne malt charge	12	420 hL	19	120	116	>100%	102.44%	<10	1.45	<75%	71.50%

Fig. 1. A recent membrane filter installation (Coors Brewing Company, Shenandoah, Virginia, USA).

WORT BOILING

Wort boiling accounts for between 20% and 40% of all thermal energy utilised in a brewery. This is a complex process which attempts a number of key objectives in one step[3]; wort concentration, wort stabilisation, protein denaturation and coagulation, hop isomerisation and volatile removal.

The desire to reduce energy consumption has led to a plethora of approaches to wort boiling aimed at reducing the evaporation of water, which typically accounts for 60% of the total energy used in wort boiling. It should be noted that evaporation is only required for the removal of volatiles, as all other process objectives can be met by the application of temperature and time. Some systems have been developed whereby undesirable volatiles are removed under vacuum, or by gas or steam stripping, either of which can reduce volatile concentrations at lower energy input.

Over the last 25 years, external wort boiling systems coupled with Thermosyphon recirculation[16] during the boil have reduced energy consumption and shear stress on the wort while allowing a larger heat transfer area than can be accommodated by an internal heater, resulting in several benefits as follows:

- Lower temperature differences between the heating medium and the wort resulting in lower thermal stress,
- Lower colour pick-up,
- Lower fouling and increased brews between cleaning cycles (CIP).

In the early 80s, when internal heaters were used, 6–8 brews could be achieved before the heating surfaces required cleaning, compared with 35–40 brews with external heaters today. In some cases this has been increased further (up to 85 brews) by using even larger heating surface areas. Traditionally, total evaporation and boil time during wort boiling have been the only criteria applied to determine a successful boil[3].

As energy prices have increased, so too has focus on the question of evaporation rates – how much is enough? Extensive work by most major brewers has resulted in the total evaporation being reduced from 7–8% 10 years ago to a more typical 4–5% today. The balance has been to reduce evaporation without raising volatile concentrations above acceptable/detectable levels.

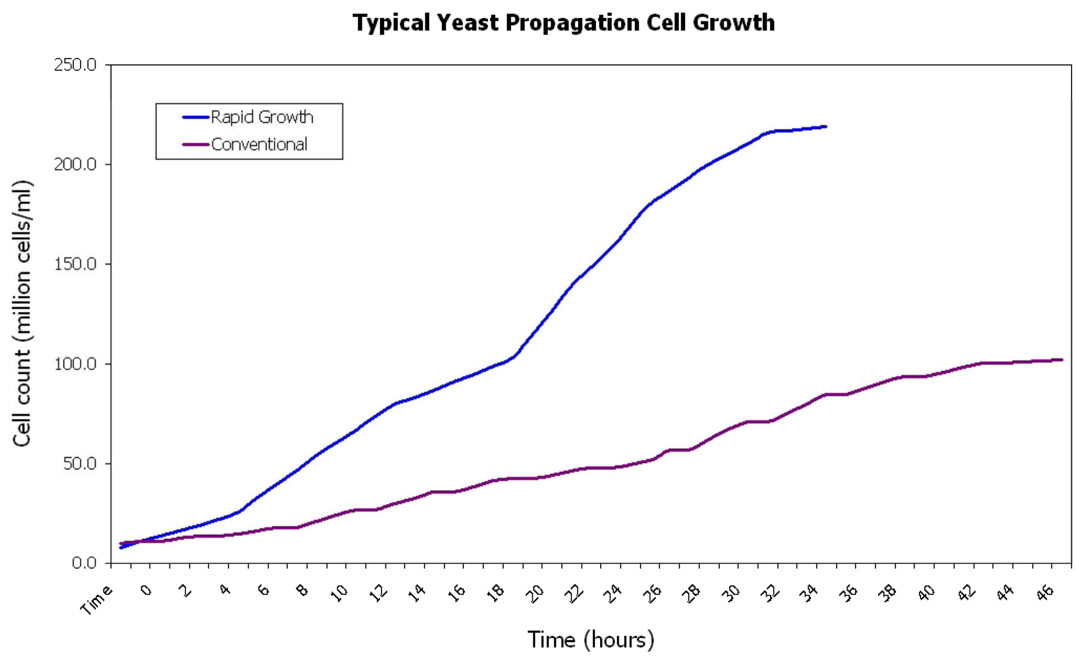

Fig. 2. Comparison between current yeast propagation rate and traditional rate.[11]

Work by Sommer and Hertel[31] indicates that in atmospheric boiling conditions, overall evaporation determines the final concentration of volatiles, provided their concentration is known before boiling commences. In the future, evaporation rates may be set according to changes in the incoming malt specification.

More recently, rectification of wort during the boil has been attempted in order to raise the efficiency of volatiles removed during the boil[18]. Regardless of the success of this patented technology, the future of wort boiling will be dictated by systems that increase the efficiency of volatile removal above that of standard atmospheric wort boiling systems.

CROSS FLOW FILTRATION

Until 2000, all beer clarification methods were based on the use of diatomaceous earth (DE). These included plate and frame filters, vertical/horizontal leaf filters and candle filters.All these filtration methods, whilst functioning admirably, have challenges in operation. The carcinogenic nature of the powder leads to handling concerns and disposal of the spent powder to land fill is increasingly expensive. Product losses during brand changes and at the end of filter runs are relatively large. It is also time consuming to establish a filter bed and to re-establish it in the event of a power cut or pressure shock.

In the last decade, three suppliers have developed cross flow filtration systems using semi-permeable membranes. Two of these suppliers utilise centrifuges to remove the bulk of the solids. The third supplier bleeds the larger solids from the system and collects them in a retentate tank. The case for the centrifuge seems sound as the load on the filter is reduced, but there is increased concern about capital costs, reliability, temperature, and dissolved oxygen pickup. The membrane filter suppliers report improvements in flavour stability and emphasise their environmentally sound credentials[10,14].

A main consideration for selection of a filtration system will always be the balance between capital cost and operational expenditure. It is not immediately clear which is the cheaper system in terms of total cost of ownership. The lifespan of the membrane filter cartridges is currently relatively short at approximately 500 filter runs (this would equate to approximately two years normal operation), but it seems likely that improvements in durability in the near future will firmly tip the balance in favour of membranes. A typical recent membrane filter system is shown in Fig. 1.

YEAST PROPAGATION

Yeast propagation developed relatively little until 1995. It was a batch growth system with 5 to 10× multiplication per stage, usually with simple pulsed aeration and without agitation. These systems had a lengthy growth period, reaching typically 100×10^6 cells/mL, and often required three stages to pitch production wort volumes, with a total cycle time of up to two weeks[7,33]. Recent developments have concentrated on rapid growth and production of high viability yeast suitable for pitching production wort volumes, with representative beer quality and good yeast growth during production (Fig. 2).

Systems have been developed following work by Boulton and Quain[8], with rapid yeast growth reaching up to 220×10^6 cells/mL within 36 hours per stage, at viability >98%. Flow profiled oxygen sparging is used, linked with controlled intensive agitation to produce effective and extremely rapid yeast growth, while controlling foam generation.

Other systems have been based around recirculation rather than agitation, with oxygen injection but less sophisticated oxygen flow control. For the most part these are limited to yeast concentrations around 120 × 10^6 cells/mL in two to three days per stage. Another system uses recirculation, together with membrane technology, to achieve a cell concentration of up to 200 × 10^6 cells/mL[26].

PROCESS IMPROVEMENTS

Shear force reduction has become much more important over the last twenty years as it has become apparent that the effect of shear forces in the production process impacts on downstream processes and the quality of the final product, with a significant influence on shelf life. This is partly because it is difficult to separate oxygen pick-up from high shear, as they often occur simultaneously. The impact of dissolved oxygen on beer shelf life has been well documented[5,32].

It has become established over the last twenty five years that the quality and handling of mash prior to mash filtration, whether by lauter tun or mash filter, can have a significant impact on mash filtration. In the 1980s, mash may have been handled using conventional agitation systems, through standard centrifugal pumps and at relatively high velocity, through tortuous transfer pipework, and finally distributed at high level within the lauter tun[23], impacting first on the spreader plate and finally on the false bottom. All of these stages introduced unnecessary shear into the mash, resulting in poor filterability and slow run-offs.

Mash pre-mashing and mash agitation systems producing gentle handling of mash are well established, but selection of suitable low speed, low shear solids handling pumps, together with careful pipework design is just as important. Lauter tun bottom mash entry reduced mash oxidation and, to some extent, shear forces. However, the rapid change of direction through bottom entry ‘poppet’ valves can cause shear damage, especially at the start of mash transfer, something which is avoided by side mash entry.

Similarly, perhaps the most critical factor affecting whirlpool trub separation is that the wort/trub stream fed into the whirlpool must be readily settleable[11]. This is overwhelmingly influenced by trub particle size. Essentially this is primarily influenced by effective wort boiling, by vigorous boiling with a large vapour liquid interfacial area to promote trub floc formation, followed by gentle handling both in wort kettle recirculation and in transfer to the whirlpool.The development of thermosyphon wort boiling systems has allowed wort circulation without pumping during the boil, substantially reducing shear forces during pumped recirculation[22].

The combined kettle/whirlpool system, particularly where there is no separate boil and whirl, totally eliminates transfer, and helps to minimise damage to trub flocs. When combined with thermosyphon circulation, there are further benefits in shear reduction promoting effective trub separation. The benefits of low shear brewhouse technology continue downstream to beer filtration, and beyond, to the finished beer.

ENERGY USAGE

Increasing energy prices, concerns over security of supply, together with existing and emerging climate change legislation have all added urgency to the constant need to drive down energy usage and operating costs. All major brewers have developed corporate sustainability statements detailing significant energy reduction as a key production target with positive results[1,13,17,28,30]. Wort boiling continues to be targeted for energy saving, using many different methods including vapour heat recovery, thermal/mechanical vapour recompression and absorption refrigeration. Implementation of these systems is heavily dependent on payback with relatively high capital investments. Recently, installed vapour heat recovery equipment at Molson Coors Burton Brewery saves 96% of the previous wort preheating energy required prior to boil.

Two recent projects by Diageo demonstrate a commitment to become more self-sufficient in energy use and to rely less on outside supplies. Diageo Roseisle Distillers in Scotland utilises a combination of biomass combustion and anaerobic digestion to recover 8.6 mW of energy for re-use in their operations, equivalent to 84% of the total steam load required by the plant. Meanwhile at the Cameronbridge Distillery in Fife, anaerobic digestion and a combined heat and power (CHP) plant powered with biomass will account for 80% of site electricity and 98% of the total steam demand[20].

Energy is increasingly being sourced from sustainable supplies. The Sierra Nevada Brewing Co. in Chico, California, utilises solar panels on the majority of its exposed brewery buildings to produce 1.4 MW of sustainable energy for brewing operations[15,29].

Energy efficiency is not just confined to large manufacturing operations. Hobsons Brewery in Shropshire, UK, utilises a very innovative ground source heat pump system for heating and cooling, saving 80% on previous electricity bills. In addition, a wind turbine contributes 40 kW of the 180 kW needed to operate the brewery.

A move towards continuous brewing would appear to yield significant benefits in the future for energy usage (Table II), both in investment in capital equipment and for

Table II. An installed energy comparison[27] for batch and continuous 3 million hL brewery at 12°P.

	Batch brewhouse	Continuous brewhouse
Capacity	12 brews/day, 400 hL cold wort at 20°P	200 hL/h cold wort at 20°P
Pumps	Mash: 1,500 hL/h – 15 kW	Mash: 180 hL/h – 5.5 kW
	Wort: 3,600 hL/h – 30 kW	Wort: 225 hL/h – 4 kW
Utilities	Steam peak flow: 14 T/h	Steam peak flow: 3 T/h
	Water peak flow: 650 hL/h	Water peak flow: 220 hL/h
	Electricity installed: 375 kW	Electricity installed: 250 kW
	Electricity peak: 300 kW	Electricity peak: 200 kW
	Peak cooling power: 4,650 kW	Peak cooling power: 2,200 kW

the elimination of peak demands associated with current batch processing. A recently installed microbrew system at Martens Brewery in Belgium is the first to try this new approach[6].

WATER SAVING CASE STUDY

The assessment of water consumption, together with its associated availability at a production plant, can impact several aspects of the overall process and operational model including:

- Production capacity constraints,
- Availability of water supply,
- Environmental discharge,
- Site variable operating costs,
- Optimum process mass and energy balances.

Although a quantitative study into water consumption and availability at any particular production plant may only focus on improving one or two distinct subject areas, there is the potential to indirectly affect several others simultaneously. It is therefore advantageous to consider water consumption of production plants in their entirety, to ensure that an improvement in one area will not adversely affect another.

Every production plant and its associated availability of water is different, meaning that a solution to improve water consumption at one site is unlikely to yield the same benefits at another. Similarly, solutions to improve water consumption are also likely to be different if an existing plant is to be modified or a new plant is designed from first principles. An example that demonstrates this type of water consumption study is found at Diageo's Cameronbridge Distillery in Fife, where an existing system has been optimised to reduce overall water consumption within the site.

Bore water, which is an accumulation of water below the earth's surface in aquifers, is used on site for a variety of processes including the manufacture of product, indirect cooling/condensing fluid and for the flushing of physical equipment. Generation of this water using bore holes and associated pumping systems was deemed to be a major constraint on alcohol production and was required to be removed as part of a continuous improvement project. After analysis of the major bore water consumers on the site, the existing wort cooling process was identified as the principle unit operation in which bore water consumption could be significantly reduced. Reducing water consumption in this area alone would have the net effect of increasing the alcohol production capacity of the site. Cold bore water was passed through a single pass wort cooling heat exchanger to produce wort at a desired pre-fermentation temperature. The wort cooling process generated warm water in a quantity that far exceeded other process requirements of this product. This resulted in the discharge of excess liquid to a local water course.

A detailed study of the existing equipment and systems on this particular site determined that there was excess cooling capacity within the closed circuit water ring main and an inactive heat exchanger. By using this dormant heat exchanger to pre-cool wort using the excess cooling capacity within the water ring main meant that consumable cold bore water would only be used for subsequent trim cooling of the wort to the pre-fermentation temperature, using the original wort cooler.

An overall mass/energy balance of the wort cooling system, used in conjunction with the design characteristics of the heat exchangers, determined that a significant reduction in bore water consumption could be made as shown in Fig. 3.

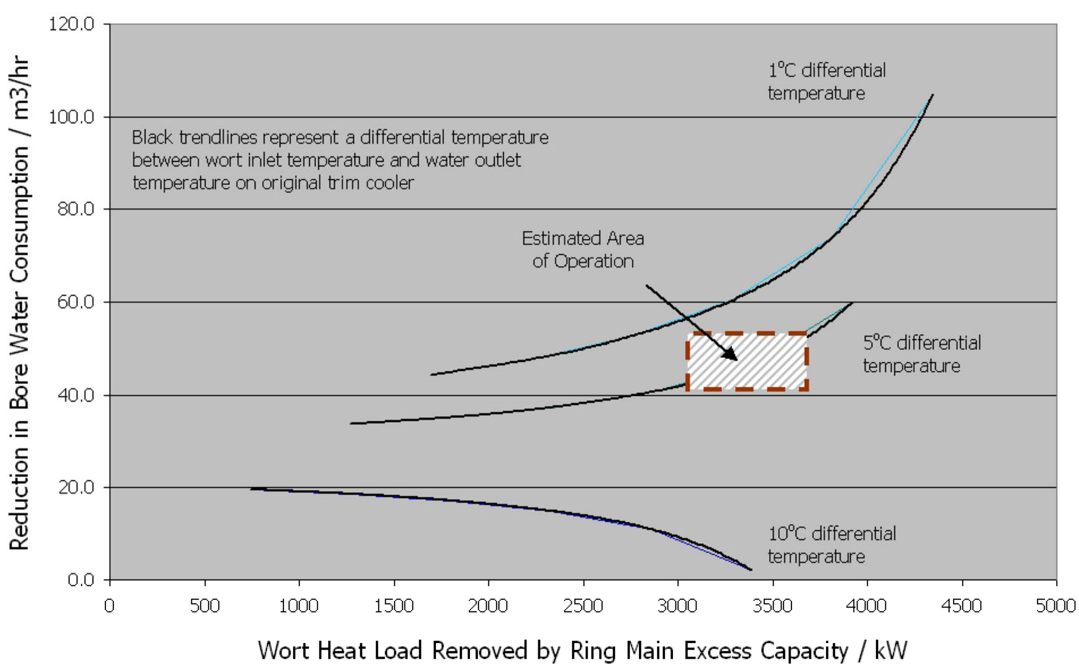

Fig. 3. Theoretical water consumption reduction in a distillery using process balances and equipment data. (Diageo Cameronbridge Distillery, Fife, UK).

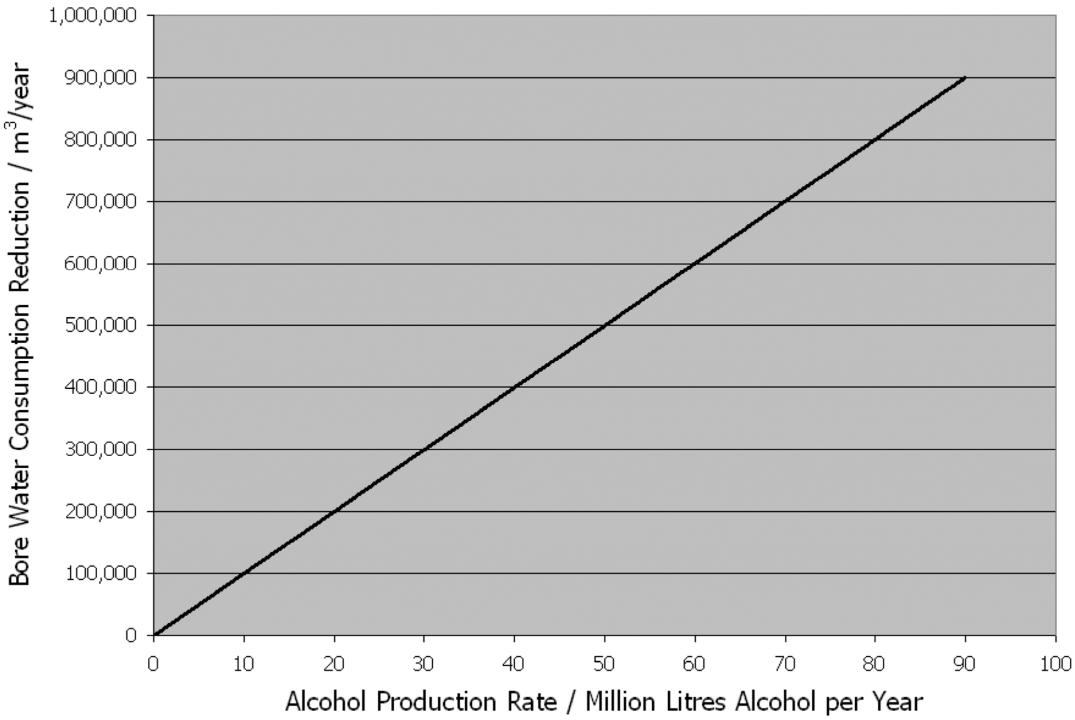

Fig. 4. Net water consumption reduction as a function of site production rate in a distillery. (Diageo Cameronbridge Distillery, Fife, UK).

By implementing these relativity simple changes, the overall site water consumption was reduced by 10 litres for every litre of alcohol produced on the site. The resultant annual net water consumption reduction as a function of plant production capacity is shown in Fig. 4.

The primary goal of this project was to remove an alcohol production capacity constraint. However, the project also realised the additional benefits of reducing the amount of effluent, generated a more favourable process balance and eliminated the capital and variable costs associated with installation of an additional bore hole system that could have been implemented to solve this particular problem.

CLEANING IN PLACE (CIP)

There has probably been more development in CIP technology, operation and particularly in the emphasis on CIP as an integral part of the brewing process, than there has been on the process itself. CIP has increasingly played a more important role in new developments, with CIP being built into new and upgraded facilities as a key and integral part of the design, rather than as an afterthought. Advances in double seat mixproof valve technology have allowed systems to be designed with great flexibility, while guaranteeing complete and effective CIP coverage of all (vessel and mains) contact surfaces, with safe separation between product and CIP, and full automation.

Demands for increased levels of 'sterility' and separation of, for example, different yeast strains has led to greater use of single-use CIP sets, where there is no re-use of rinse water or detergent. More recently, environmental concerns have emphasised the advantages of effective recovery CIP systems, where detergent, rinse water and detergent interfaces are recovered, with a reduction in water, energy and chemical usage. Effective recipe-based automation has allowed the CIP program to be optimised for each CIP route, and the effectiveness of the CIP to be monitored by return flow, conductivity and, in some cases, by return rinse water quality.

High pressure, low flow, high impact, rotating CIP spray heads have allowed very effective CIP of large fermenting vessels and brewhouse vessels, with low CIP flows, reducing water, energy and chemical costs, as reflected by eligibility for the UK Government Enhanced Capital Allowance (ECA) Scheme[34]. The use of pre-rinse, being effectively a dilute detergent wash using recovered rinse water, both reduces water usage and makes the detergent stage much more economic by maximising soil removal prior to detergent, thereby extending detergent life. By these means, together with high pressure rotating spray heads, it has been possible to re-use caustic even following its use in the brewhouse for cleaning purposes, as compared with older systems that relied on total caustic disposal at the end of the clean with no pre-rinse. Use of membrane technology to recover heavily soiled caustic has also been developed.

BY-PRODUCT HANDLING

Spent yeast, grains and trub from the brewing process are still largely sold as animal feed today. These products, once considered as inconvenient waste in the past, are now being considered and sold as products in their own right. Trub can be recycled to the mash filter provided wort quality is not compromised, or it may be discharged via lauter tun spent grains, increasing the protein content in the animal feed.

Active research is progressing to re-use brewers' and distillers' grains to produce more alcohol by fermenting with organisms capable of digesting lignocellulosic material and the ethanol produced can be used as fuel or contribute to the overall alcohol yield from a distillery. One such example is a thermophilic bacterium (TM242) developed by TMO Renewables Ltd, to convert a wide range of biomass-derived sugars efficiently into ethanol at high yields and temperatures. The process was developed and has been testing feedstocks for potential clients since the summer of 2008[4].

EFFLUENT

Brewers and distillers have been seeking to reduce water usage and more technologies are being employed to recycle water with less reliance on discharging effluent to municipal water treatment and fresh water supplies, thus reducing cost. Water recycled in breweries and distilleries is still typically reused for CIP, boiler feed and cooling tower applications rather than direct use for product manufacture. Until the late 1970s, effluent treatment was usually aerobic. This required large plant footprints and generated large sludge volumes which then required disposal.

The Upflow Anaerobic Sludge Blanket (UASB) reactor, which dramatically reduces the volume of sludge produced, was developed and first applied to brewery effluent at the Bavaria Brewery and Maltings in the Netherlands in 1984[12]. It is now the most widely applied anaerobic reactor system used in breweries in the world today.

Following the success of the UASB[35], successive generations of reactors such as the Expanded Granular Sludge Bed (EGSB) and Internal Circulation (IC) have provided continued footprint reductions and improved throughputs, albeit for a considerable increase in height. IC technology was the first used by Heineken in Den Bosch in 1990 and occupied 41% of the market share of anaerobic systems employed in breweries by 2003[12]. Where water is discharged to a water course, or the intent is to reuse it within the brewery, anaerobic pre-treatment followed by aerobic post treatment systems are the preferred solution[9].

Activated sludge is still the most frequently applied technology for the treatment of industrial effluent. However, recently airlift reactors, which were first used by the Grolsch Brewery in Enschede in the Netherlands in 1996 and operate at much higher volumetric loading rates, have been used. In conjunction with Dissolved Air Flotation Units (DAF). This allows the enhanced removal of solids and Chemical Oxygen Demand (COD). A combined IC/Airlift and DAF system occupies 150 m^2/hL compared to a traditional aerobic activated sludge system at 1,000 m^2/hL[12]. Another advantage of anaerobic systems is the production of biogas. This can be used to supplement fuel in steam boilers or in gas engines and CHP plants to produce electricity.

A more recent development is the use of biogas in fuel cells. Sierra Nevada, Kirin, Asahi and Sapporo Breweries all use fuel cells to generate electricity on site using natural gas. Sierra Nevada substitutes between 25–40% of its natural gas supplies with biogas obtained from their anaerobic digestion plant – generating steam and electricity for operations in the process[29].

AUTOMATION IN THE BREWING AND DISTILLERY INDUSTRIES FROM 1985 TO 2010

Technology has progressed at a very rapid rate over the last 25 years and the world of industrial automation has enjoyed the benefits of this across a wide range of industries. Although various electronic controllers were developed in the late 1950s, the first Programmable Logic Controller (PLC), the workhorse of most brewery and distillery control systems, can be traced back to a request from General Motors for a standard machine controller, resulting in the first MODICOM PLC in 1969. In 1975, Honeywell and Yokogawa both released their first Distributed Control Systems (DCS).

By 1985, the Siemens S5 PLC was already seven years old and Rockwell was about to release its PLC5 processor. These two systems were the PLCs of choice for the brewing industry and this remains true to this day with their modern day equivalents the Siemens S7 and Rockwell Control Logix. Typical automation at this time used PLCs with a mimic made up of lamps and push buttons. Towards the end of the 1980s, Supervisory, Control and Data Acquisition (SCADA) type operator interfaces, such as the Siemens WF470 and Rockwell Control View, were becoming more commonplace. At this time though, electrical panels with standalone control loops and temperature indicators were still being used.

Generally, this period saw a steady progression of control systems providing greater functionality, greater capacity and reduced development time for a given functionality. The first DCS supplier to adopt UNIX and Ethernet networking technologies was Foxboro in 1987. This networking of the various control system components was an important progression.

From the early 1990s, Microsoft's dominance in the computer industry extended into industrial automation and alternative operating systems disappeared, leaving virtually all SCADA type systems running on Microsoft operating systems. PLCs also began to be programmed on standard PCs rather than on the bespoke programming terminals that preceded them, helping to reduce development time. Microsoft had a procession of operating systems including Windows 95, Windows 2000, Windows NT and various versions of Microsoft Server. The longest survivor was Windows XP and remains the operating system of choice for SCADA nodes eight years after its release. The SCADA level of the control system running on standard PCs with standard operating systems has allowed control systems to freely exchange data and to be integrated with the site network that now exists in almost all organisations.

In the mid 1990s, digital input/output (I/O) networks such as Profibus DP, Profibus PA, ControlNet, ASi and Foundation Fieldbus emerged and enjoyed a very quick uptake. These allowed for large amounts of I/O with reduced installation costs, quicker installation and increased

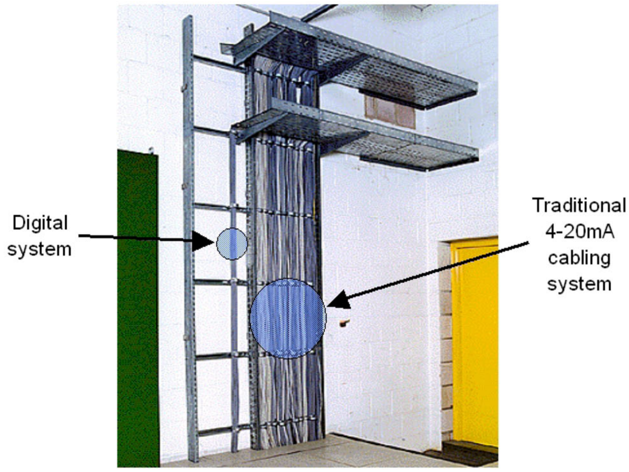

Fig. 5. Comparison between traditional and digital system cabling. (Coors Brewing Company, Shenandoah Virginia, USA).

diagnostics. Wireless I/O networks are also available and Ethernet type I/O networks have now been introduced. Correspondingly, as these networks were introduced so too were compatible field devices such as automatic valves with intelligent control tops and instrumentation with built in hardware to communicate on the new networks. Very large reductions in installation costs and much improved reliability were achieved with a compareson of cabling shown in Fig. 5.

As power electronics technology progressed, it allowed for more capable and cheaper Variable Speed Drives (VSD) to be developed, allowing them to be used where previously either a mechanical or motor winding switching arrangement would have been necessary. The ability to finely control motor speed provides the opportunity to improve product quality by precisely controlling to the most appropriate speed for a particular task.

The prevalence of the Internet now means that remote access for monitoring and maintenance of control systems is rapid and can be easily achieved. Web based plant reports are now becoming more common. Security remains a concern with such technology.

In 1995, the International Society of Automation (ISA) produced the S88 Batch Standard and its structured hierarchical approach to engineering is now common in most control system solutions[19]. The batch engine aspect of S88, which provides a more flexible system, can be seen on a number of installations around the world, although it remains relatively rare.

Today's control system architecture is typically a number of PLCs and SCADA nodes (or the equivalent DCS components) communicating over Ethernet. Plant data is likely to be archived in a database (usually MS SQL). The database will also allow for the storing of recipes and report data, and facilitates an interface with high-level Management Execution System (MES) and Enterprise Resource Planning (ERP) systems. Other Microsoft products may be used for generating and publishing reports. The control systems I/O will be achieved using a variety of I/O networks. This typical architecture has been in place for almost 15 years.

There is, however, an increased interest in what might be termed DCS style systems. The brewing and distilling industry has traditionally used PLC/SCADA systems as opposed to DCS, particularly in the UK. Both these systems have their traditional markets and brewing has always fallen in-between. As the markets evolve, the DCS suppliers are incorporating more PLC/SCADA type features and the PLC/SCADA suppliers are incorporating more DCS type features, resulting in the differences between the two types of system becoming less significant. Both PLC/SCADA and DCS can now achieve user objectives, although there are many subtle pros and cons for each system type. Regardless, there is however a trend towards trying to engineer all the components of the control system into an integrated software environment so as to provide standardised solutions with reduced system development time.

ENGINEERING, PROJECT MANAGEMENT AND DESIGN INNOVATION

Engineering solutions rely on the application of scientific knowledge, mathematics and innovation, of which the underlying principles have changed little during the last 25 years. Dramatic advances have been witnessed in digital and electronic technology and communications, coupled with computer capacity and internationally accepted standards that have had enormous influence on engineering outputs. Rapid developments in these areas continue to drive organisational and process changes, resulting in engineers executing their design and building tasks at a far more cost effective and efficient pace.

Advances in computer aided design software (CAD) integrated with powerful database applications ensure the production of very high quality engineering design information and construction drawings in a shorter time cycle. This technology was emerging during the late 1970s, with specific applications in the aviation industry, but was restricted by computer hardware capacity. Following the introduction of "AutoCAD release1" and other similar products in the early 1980s, incremental improvements in software and hardware capacity have facilitated a migration from two-dimensional (2D) orthographic and isometric engineering drawings to complex three-dimensional (3D) models. Currently the Autodesk 2011 product is at "release 25" and is widely accepted as an international platform and standard for engineering drawing, model and information outputs.

Today 3D models can be readily accessed via "free to view" sample visualisation software on most standard desktop or laptop computers. Client operations and project teams can visualise the layout and ergonomics of their future plant and equipment, which is often very large and complex in nature, before it is constructed and make valuable observations and contributions to engineering design. Detailed design analysis can also be completed using the 3D models without the expense of creating physical prototypes. Finite Element Analysis (FEA) traditionally required complex mathematical equations to determine important engineering design criteria, particularly associated with elasticity, thermal, and structural properties of construction materials. A number of FEA software packages can now be integrated to 3D modelling systems offering increased accuracy and alternatives and, again, contributing to a much less expensive design cycle. Figure 6 shows the comparison between a computer 3D model and the actual installation.

Electronic file formats to international standards make integration from multiple project contributors simple to combine into one 3D model. Detection of conflict between the various engineering disciplines can be identified and corrected at the design phase, hence saving valuable time and cost during construction.

Vast quantities of technical data can now be stored, managed and accessed to display specific fields of information or report formats using standard data base applications such as Microsoft Access. Recorded change control provides multi disciplined engineering team access to input and to extract data specific to their requirements.

The entire project lifecycle can utilise the same database from early design input through equipment specification, selection, purchasing, procurement, inventory control, installation, operational qualification and asset care. The use is further extended to include input and output generation for automated programmable logic controllers (PLC). Database outputs can be utilised in the PLC avoiding lengthy duplicated manual tasks.

Electronic mail has been in existence since the early 1970s but became more globally accessible with the introduction of simple mail transfer protocol (SMTP) via the Internet in 1982. Email has revolutionised international communication. Originally a text-only communication medium, it has developed to carry multipurpose internet mail extensions (MIME), which allows the engineer and others to transfer large volumes of technical information and particularly drawings, images and 3D model files around the globe.

File transfer protocol (FTP) allows multiple project contributors to securely copy large and complex files to a project host client server under password protection. This enables more efficient access to technical design data and drawings from multiple suppliers and users worldwide. Concerns with confidentiality and intellectual property are protected and managed with file and area access restrictions.

Introduced during the mid 1990s, web conferencing is now frequently used to conduct live meetings via the Internet. This technology has created a visual and verbal interactive platform for the engineer to undertake detailed design reviews with numerous attendees simultaneously from around the globe. Each attendee can interact to the information being presented onscreen whilst the rest of the audience can respond verbally via normal telephone communication.

With the global drive to improve energy efficiency and reduce overall dependence on the world's valuable natural resources, there is increasing pressure on engineers to provide solutions to these challenges. Together with the long established engineering disciplines, specialised sectors are developing rapidly around computer technology, energy, genetics, medicine and biosciences to help deliver solutions to meet increasingly demanding timescales and lower costs.

Electronic and digital communication has significantly improved technological and economic efficiencies in engineering during the last 25 years without compromising quality outputs.

CONCLUSIONS

Over the last 25 years, there has been a succession of small improvement steps in the brewing and distilling industries, resulting in lower labour, reduced consumption of raw materials, energy, and water, together with innovative solutions to effluent and by-product treatment. Process design and project implementation tools have benefited from powerful portable computers and ever more sophisticated software giving engineers the possibility of solutions, which could only be dreamed of at the beginning of the 1980s, together with reduced project timescale and overall engineering man-hours.

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