The Sword and the Armour: science and practice in the brewing industry 1837-1914

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At the German Brewing Congress of June 1884, the redoubtable Max Delbrück, Director of the Experimental and Teaching Institute for Brewing in Berlin announced 'With the sword of science and the armour of practice German beer will encircle the world.'[1] It was no idle boast. In 1887 beer output in the German states exceeded that in the UK for the first time and Germany became the largest producer of beer in the world.[2] Fifty years earlier, when the 18 year old Victoria came to the thrown, it was unthinkable that Germany would hold such a position. Britain was the premier brewing nation, with London's massive porter breweries of 'a magnificence unspeakable' in the van.[3]

Porter Brewing

The 'power loom brewers' as Charles Barclay called them in 1830 operated on a scale unknown anywhere else.[4] The four biggest in 1837 were:[5] (i) Whitbread, at the White Hart Brewery in Chiswell Street; the first brewery to top the 200,000 barrel a year mark in 1796. (ii) The long established Truman, Hanbury & Buxton at the Black Eagle Brewery, Brick Lane, Spitalfields; the first brewery to appoint a professional chemist to its staff in 1831, when the number of such men in Britain could be counted in tens.[6] (iii) Reid's, at the Griffin Brewery, in picturesquely named Liquor-pond Street (now Clerkenwell Road); the first brewery to appoint a science graduate to its staff in the late 1830s.[7] (iv) Barclay Perkins, at the Anchor Brewery, Dead Man's Place, Park Street, Southwark. Barclay Perkins had the greatest output of any London brewery by 1809 and remained in the lead until the 1850s, passing the 300,000 barrel mark in 1815 and 400,000 barrels in 1839.[5 & 8]

Despite Charles Barclay's remark, which invited comparisons between the brewing industry and the textile industry, brewing differed from the latter in that it achieved large scale production without the benefit of water or steam power. Large output was achieved using horse power to drive the malt mills for example and manpower to do the mashing by hand with ores.

Whitbread brewed 122,000 barrels of porter in 1782, two years *before* they ordered a steam engine to grind malt and pump water.[9 & 10] A particularly impressive figure when one remembers that at that time the brewing season was restricted to the colder months, October to March, as summer brewing often gave unacceptable losses in spoilt beer. Once the steam engine became available, London brewers where understandably keen to adopt it. By the turn of the century the improved engines of Boulton and Watt and others had been installed in all but one of London's major breweries and horses and men were reduced in number.[11]

Quantitative measurement crept into brewing from the mid 18th century with the application of the thermometer by Michael Combrune, and then the hydrometer, in the form of the saccharometer, by John Richardson.[12 & 13] Figure 1 is a representation of these instruments taken from a brewing treatise published in 1802.[12] Shown as *Fig 1* is a brass saccharometer

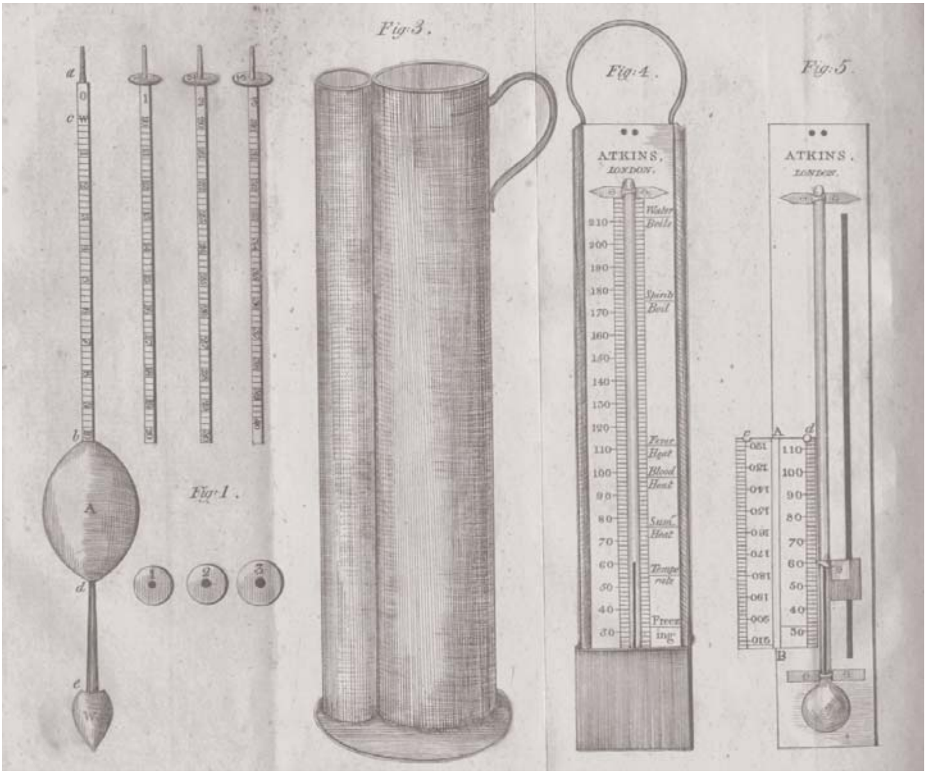


Figure 1. Saccharometer, assay jar and thermometers, from Alexander Morrice's A Treatise on Brewing*, first published in 1802.*

with its hollow ball and square stem graduated on four sides, which together with detachable weights allowed the determination of wort strength up to 40 pounds per barrel i.e. a specific gravity of up to 1.111. Shown as *Fig 3* is the copper assay jar with two communicating compartments to hold the saccharometer and the thermometer. *Fig 4* is a 'common brewer's thermometer' and *Fig 5* the intriguing 'blind thermometer', where the 'pocket scale' is detachable. With the blind thermometer the more secretive brewer could set the moveable 'index' or rider to the required temperature against the scale, then remove the scale and leave the instrument in the hands of a brewery worker to take the required action when the mercury rose to the point at which the index had been set. A blind thermometer was more expensive than the common model but remained popular well into the 19th century amongst a brewing fraternity jealous of the details of its process. Linking use of the thermometer with the saccharometer gave the brewer real advantage in process control. The measurement of wort strength and temperature allowed the brewer to determine the best 'mashing heat' to get the best yield from his malt and allowed comparison of different malts in this respect. One consequence of this new found knowledge was the discovery that it was cheaper to use pale malt with colouring and/or black malt rather than brown malt in the production of porter. The greater extract more than compensated for the extra cost of the pale malt and the beers matured more quickly allowing faster turnover. The brewers adopted this new technique with alacrity. Porter drinkers can hardly have failed to notice the difference in appearance and taste of their favourite brew, but far from reacting against the new form of porter they seem to have welcomed it.[15 & 16]

The great symbol of the porter brewing technology was of course the giant storage vats, necessary to mellow the flavour of the crude beer by long maturation. Porter was made from cheap ingredients and was easy to produce (which made it popular with the brewers) it kept well and

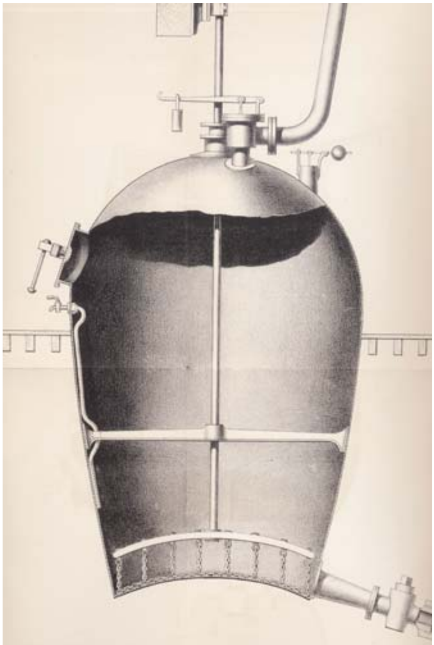


Figure 2. A a sixty barrel domed porter copper, from James Steel's Selection of Practical Points of Malting & Brewing*, published in 1878.*

didn't spoil easily because of the high level of hops in it (which made it popular with the publican) and it was flavoursome and undercut the price of competing beers by 25% (which made it popular with the drinker).[17] The size of their porter vats was something of a matter of pride amongst brewers. One such was Henry Meux, of the Horseshoe brewery in Bainbridge Street, St Giles, at the south end of Tottenham Court Road, where the Dominion Theatre now stands. This brewery contained some immense vats constructed with little knowledge of the forces they would have to withstand, and on the night of 17th October 1814 a tragedy occurred. Some of the metal hoops around the vessel snapped, the vessel gave way and 3,555 barrels of Porter flooded out. 'The flood swept away walls in the brewery, inundated the crowded basements in the vicinity and caused several tenements to collapse, with the death of eight people "by drowning, injury, poisoning by the porter fumes or drunkenness"'.[18] The total amount of beer lost was put at 7,664 barrels, for which the brewery petitioned Parliament for a refund of the duty and duly received a rebate - nobody else received any compensation! The incident did however cause the race for bigger vats to abate thereafter.

Figure 3. A Steel's Masher at Hook Norton brewery. Photograph courtesy of Roger Putman 2004.

Evolving Technology

The early decades of the19th century saw a number of technological innovations in brewing.[19] Attemperators with cold water circulated through copper pipes to maintain a steady temperature in fermentation vessels became widely adopted. The pipes could be fixed to the wall or base of the vessel, and such an arrangement may still be found in breweries today, or be portable such that they were dangled into the vessel from above as needed. Mashing machines, driven originally by horses and then by steam power, were used to rake the mash and came into general use replacing mashing ores. Domed coppers were introduced in the first decades of the 19th century but were slow to spread, an example from a brewing manual published in 1878 is shown in Figure 2. This particular example is fitted with a rouser to prevent the hops settling to the base of the vessel and getting burnt.[20] But covered as opposed to open coppers were not accepted everywhere, the giant Burton brewers persisted with open coppers into the 20th century. Indeed some brewers have yet to be convinced. Wadworth's of Devizes still have an open copper in use and also a domed copper. The latter seems to have been on trial for much of the last century. Steam heating as opposed to direct firing of the

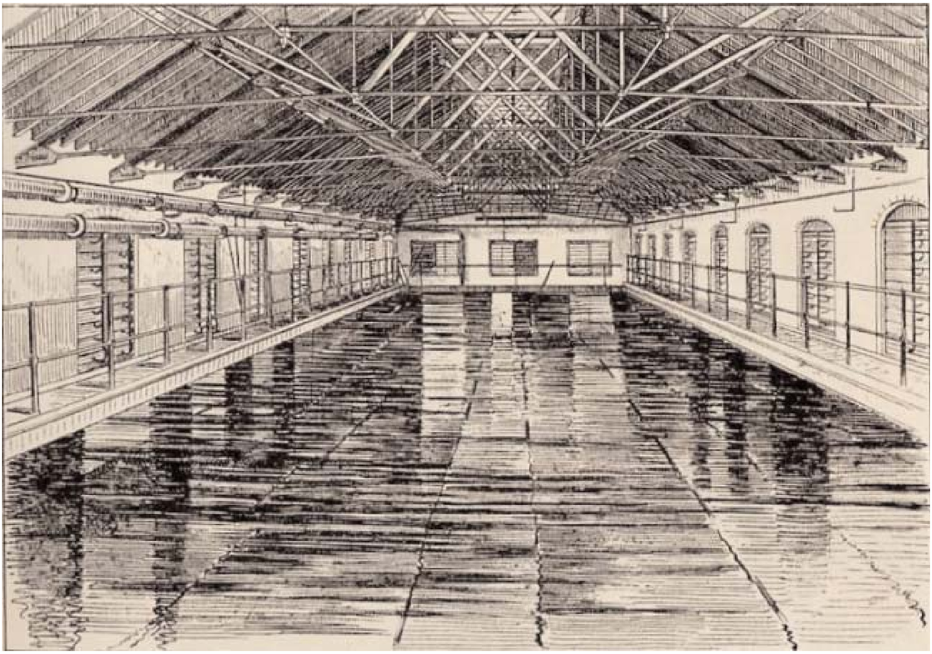


Figure 4. An open cooler at John Smith's brewery, Tadcaster, from Alfred Bernard's Noted Breweries of Great Britain and Ireland*, volume 3, published in 1890.*

copper was similarly slow in being accepted but is now the norm, although some direct fired coppers may be found around the world.

More readily accepted was the use of rollers to crush the malt which began to replace grinding stones as used in flour mills from mid century. External mashing

Figure 5. Advertisement for Robert Morton refrigerators 1880s.

Figure 6. Parachute at Daniel Batham's brewery, Dudley. Photograph courtesy of Roger Putman 2005.

machines also came into use at this time, the most popular version of which was associated with James Steel of Glasgow The Steel's masher was patented in 1853 and may still be found in almost unchanged form in a number of breweries [Fig. 3]. These devices complemented the internal rakes by acting as a mixer whereby incoming grist is intimately mixed with hot liquor on its entrance to the tun by means of an Archimedean screw. Sparging, which seems to have originated in Scotland,[21] in which the extracted grist in the mash tun is sprinkled with water rather than being re-extracted by immersion, spread form around 1800 and was accepted practice for most brewers by the 1860s. A shallow open cooler (coolship), for cooling hot wort from the copper, situated in a well ventilated room usually at the top of the brewery [Fig. 4], was a feature of Victorian breweries. The odd example may still be found today. Open coolers came to be complemented by refrigerators in which circulating cold water cooled the wort en-route to the fermenters [Fig. 5]. Initially these were horizontal, but took up much room and were to an extent replaced by vertical refrigerators, in which wort flowed down over the cooled surface. In larger breweries there would be banks of these refrigerators to facilitate relatively rapid processing

Fermentation Techniques

Fermentation vessels were generally quite small (10s rather than 100s of barrels), could be either round or rectangular, and be operated on various regimes depending upon the method used to remove the accumulated yeast from the fermented beer.[22] The skimming system was popular in which yeast was drawn off in an inverted cone placed just beneath the yeast surface. The yeast was passed via a pipe from this parachute as it was known to a vessel on the floor below. In rectangular fermenters the parachute was placed at one end of the vessel and the yeast swept towards it using a board which was dragged over the surface. Examples of parachutes are still to be found [Fig. 6]. The skimming system developed into the dropping system in which fermentation starts in a round fermenter and then perhaps 24 to 36 hours after pitching is dropped to rectangular shallower vessel on the floor below for skimming. This system had the advan-

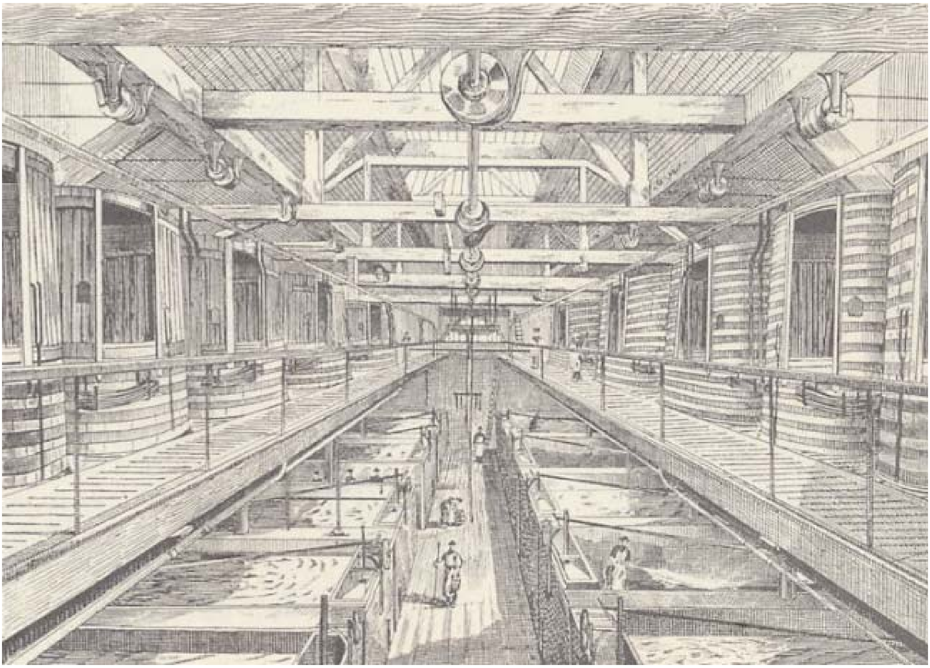


Figure 7. The dropping system of fermentation in operation at Jacob's Street brewery, Bristol, from Alfred Bernard's Noted Breweries of Great Britain and Ireland*, volume 2, published in 1889.*

tage of rousing the fermentation making it more vigorous and in leaving unwanted debris behind in the round prior to passing to the skimming vessel below [Fig. 7]. Another kind of yeast removal, or cleansing system, involves the transfer of actively fermenting wort to casks in which fermentation is completed. This developed into the best known such system, the Burton union system, which neither originated in Burton nor was peculiar to it, but became particularly associated with the town in the production of the high quality pale ales which were the great success story of Victorian brewing in Britain [Fig. 8]. In this system, fermentation starts off in relatively small rectangular vessels and half to three quarters of the way through the fermentation the fermenting wort is passed to the union casks for cleansing. In the union sets, linked casks are surmounted by a trough ('barm back') into which the fermenting wort rises via 'swan's necks'. From the gently slopping trough the yeast and beer flow into the 'feeder back', the yeast being thus removed with the progressively brightening beer flowing back into the casks. So it goes on gently gurgling away until the fermentation reaches completion and the yeast count is reduced to the required level for racking. The Burton

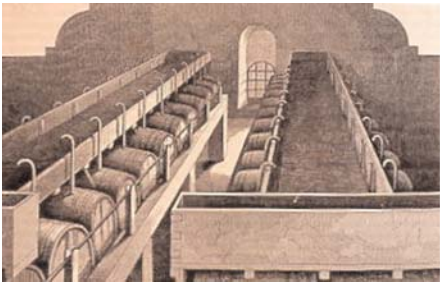


Figure 8. A Burton union fermentation set at Samuel Allsopp & Sons brewery, from Sheridan Muspratt's Chemistry as Applied to the Arts and Munufactures*, published in 1854.*

union system is of course still in use at Marstons in Burton. Another cleansing system with similarities to the Burton unions which was popular in London involved the use of pontos. These vessels were larger than union casks (six rather than four barrels in capacity) and were set up on their heads.[23] The yeast flowed over a sort of lip at the top, and dropped into a trough [Fig. 9]. Pontos were probably extinct by the 1st World War. Then there are Yorkshire squares. These vessels with capacities of 30 to 50 barrels were made of stone or slate slabs and had two compartments connected by an orifice, or manhole as it is called, with a raised collar through which the fermenting wort gushes, leaving the yeast on the top 'deck' of the vessel to be collected as the beer flows back into the main body of the vessel. Such vessels, now made of stainless steel, but operated much as they would have been in Victorian times may be found at Tetley's brewery in Leeds [Fig. 10] and elsewhere.

Figure 9.The Ponto system of fermentation in operation in an unnamed brewery, from Julian L. Baker's The Brewing Industry*, published in 1905.*

Figure 10. The Yorkshire square system of fermentation in operation at Joshua Tetley & Sons brewery, Leeds in the 1970s. Photograph from the author's collection.

The Tower Brewery

Here it is convenient to consider the arrangement of plant in a Victorian ale brewery. From the mid 19th century the classic tower brewery took shape.[24] In a tower brewery gravity was utilised to do the work once the water had been pumped and the malt lifted to the top of the brewery, with the processed wort and beer allowed to flow downwards in the various stages. Although in fact in most tower breweries it was not quite as simple as that. Pure gravity systems, were gravity does all the work, were really confined to small breweries.[25] Figure 11 shows a plan and elevation for a 5 quarter (c. 5000 barrels a year capacity) pure tower brewery.[26] The material flow is consistently downwards from the malt hopper, to mill (rolls), to grist case, to mash tun, to underback which received the sweet wort (not actually shown here), to copper were the wort is boiled with the hops, to the hop back were the spent hops are separated from the boiled wort, to the large open cooler then over the refrigerators, on to the fermenting vessels were the yeast is added, and then down to the cleansing casks. This system although superficially attractive was very inflexible, particularly if the brewery was to be extended at any time, and in fact most breweries of any size used the pumped tower system [Fig. 12]. Here again the goods and liquor go to the top

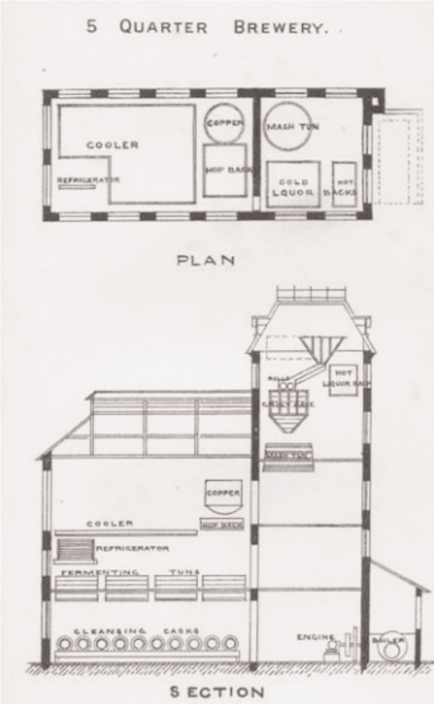


Figure 11. A pure tower brewery, from George Scamell & Frederick Colyer's Breweries and maltings: Their Arrangement, Construction, Machinery, and Plant*, 2nd edition published in 1880.*

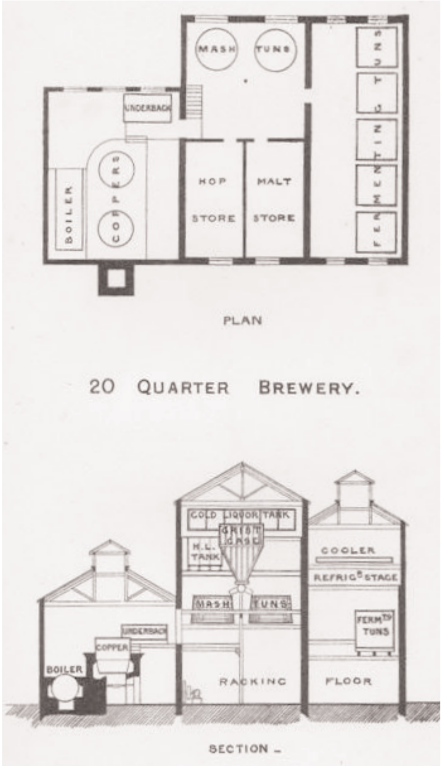


Figure 12. A pumped tower brewery, from George Scamell & Frederick Colyer's Breweries and maltings: Their Arrangement, Construction, Machinery, and Plant*, 2nd edition published in 1880.*

of the brewery, the grist case feeds the mash tuns, which in turn feed the underback and copper and hop back, but from the hop back the hot wort is pumped to the top of the fermenting house and the shallow open cooler; thence over the refrigerators and on to the fermenters etc. This system has the benefit of flexibility, is easier to oversee, has the open cooler at the well ventilated top of the brewery and lends itself to compartmentalising of the operations into three houses; the central brewhouse, the boiler house were the steam may be contained, and the fermentation house.

Lager brewing

Top, warm-fermentation of ales, where the yeast rises to the surface of the vessel, was of course not the only system in

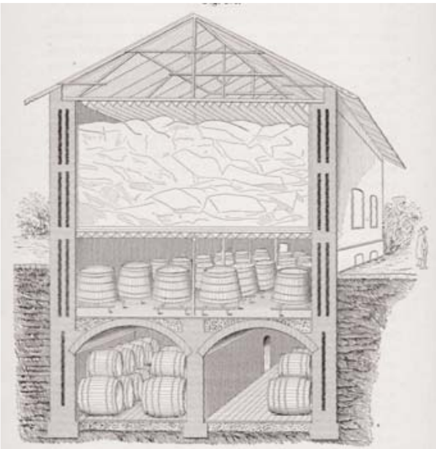


Figure 13. Lager fermentation and maturation in an ice-house, consisting of an underground store-cellar with a fermenting cellar above it, both cooled by the natural ice in the upper part of the building, from Julius E. Thausing's, The theory and practice of the preparation of malt and the fabrication of beer*, published in 1882.*

use in the period we are surveying. There was also fermentation carried out at lower temperatures with yeast which sank to the bottom of the vessel; what became known in Anglophone countries as lagers from the German verb lagern, to store. In this system, as operated in the mid 19th century, fermentation would typically be conducted in an ice-house [Fig. 13].[27] But it was not just in the area of fermentation that brewing practice in continental lager breweries differed significantly from that in Victorian British ale breweries. Brewhouse procedures were very different. This was because British and continental malts were very different. British malts were what is called 'well modified' i.e. produced in such a way that the starch and the protein in the malt were made easy to extract and degrade in the brewhouse. Continental malts on the other hand were 'undermodified' not so amenable to extraction. These continental malts therefore needed more extensive treatment in the brewhouse than their British equivalents. Continental practice reflects these differences as shown in Figure 14. The diagram shows the hopper (A), the grist case (B) and external masher (C) feeding a mash tun (D), but from then on things get more complicated than in a British brewery. About 1/4 to 1/3 of the mash is withdrawn during the brew and fed to a mash copper (E) were it is boiled and then added back to the mash tun, thus raising the temperature. This may be done 2 or even 3 times to give step changes in mashing temperature. The system is called decoction mashing. It was developed purely empirically but may now be seen as providing a range of temperatures in which the enzymes required for protein and carbohydrate degradation, which differ in their heat stability, can operate. At the end of the mash the contents of the mash tun is fed to another tun (H), the lauter or clarifying tun, which is usually wider than the mash tun proper and has a slotted plate false bottom through which the wort filters thus separating the wort from the spent grains. The wort is then fed to a wort copper (K) were it is boiled in the ordinary way. The arrangement is shown in practice in a nearly contemporary picture of a German brewhouse [Fig. 15] which clearly shows the four vessels.

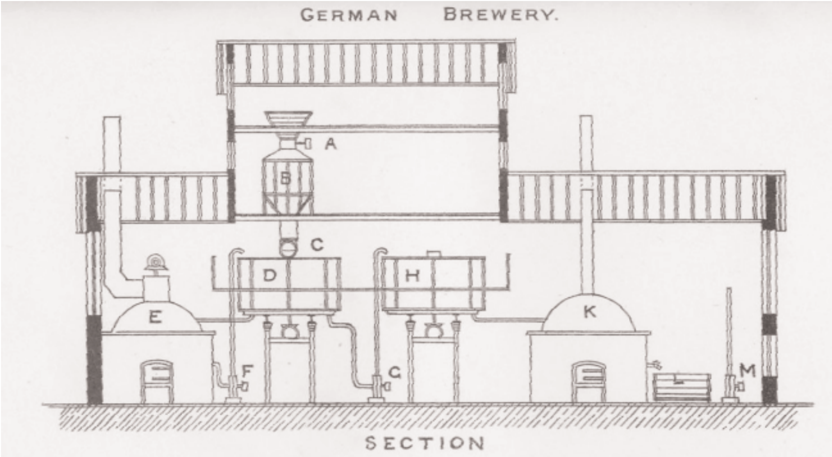


Figure 14. A German brewhouse from George Scamell & Frederick Colyer's Breweries and maltings: Their Arrangement, Construction, Machinery, and Plant*, 2nd edition published in 1880.*

Until the 1840s bottom-fermentation was unknown outside Bavaria and Bohemia (where it had been practised since about 1400). It was then, instigated to an extent by the efforts of Gabriel Sedlmayr jnr from the Spaten Brewery in Munich and Anton Dreher from his family brewery at Schwechater just outside Vienna, that lager began to spread [Fig. 16]. On a trip to Britain in 1833 the pair had indulged in what has been described as industrial espionage,[28] learning the use of the saccharometer and thermometer and the techniques of large scale brewing. They were not above rather underhand behaviour such as secretly taking samples in breweries using hollow walking sticks. On their return home Sedlmayr and Dreher became apostles for lager and applied what they had learnt in Britain's more advanced ale breweries to the production of bottom-fermented beers. The first pale straw coloured lager, for the product of Munich was dark brown in colour and that of Vienna a reddish brown, is usually ascribed to Josef Groll a German brewer working in Pilsen in October 1842. Lager was first produced in Norway in 1843 and

Figure 15. The brewhouse of the Hanover Brewery Company c. 1900 showing left to right, the mash copper, the mash tun, the lauter tun and the wort copper.

Figure 16. Gabriel Sedlmayer (left) and Anton Dreher in c. 1860.

more famously Jacob Christian Jacobsen made the long journey from Copenhagen to the Spaten brewery in 1845 and obtained some yeast which he carefully preserved in his hat box on the return journey and used it to produce his first lager (a dark one) in 1846. A year later he built a new brewery on a hill overlooking Copenhagen and called it after his young son Carl and its location: hence Carlsberg. Lager was making significant inroads in north Germany by 1850 and Gerard Heineken, seeing which way the wind was blowing, switched from ale to lager brewing in Amsterdam in 1869. Lager was to be found on the other side of the Atlantic from the 1840s. Frederick Pabst, Frederick Miller and Joseph Schlitz exploited Lake Michigan's ice for lager production. Bernard Stroh similarly on Lake Erie. Ebrehard Anheuser and Adolphus Busch utilized the cool caverns of St Louis. Adolph Coors the Colorado mountains. From the 1870s these German-Americans developed a new style of lager brewed with readily available cereals, notably maize (corn) and in Anheuser-Busch's case rice as diluants for the high nitrogen six-rowed barleys grown in the USA. These adjuncts were used unmalted and were gelatinised before addition to the malt mash. Although banned in Bavaria, there was nothing new in the use of unmalted adjuncts, but what was different from mainstream European practice was the high level of use. The Americans used them at levels of 50% or more of the grist. This coupled with the development of an accelerated brewing process where storage time was minimised and filtration used for clarification, led to the development of unique very pale coloured, delicate, beers.[29]

From the 1860s, the increasing availability of efficient artificial refrigeration freed lager brewers from the need for natural ice.[30] Lager and ale brewers alike adopted all year round brewing. Refrigeration was initially used to produce ice but was soon applied to direct cooling via expansion coils [Fig. 17]. Lager now became a world drink. The first successful commercial brewery in Japan, the Spring Valley Brewing Company set up in Yokohama by an American W. Copeland in 1869, evolved into the Kirin Company and brewed lager. German brewmasters brought brewing to China for the first time

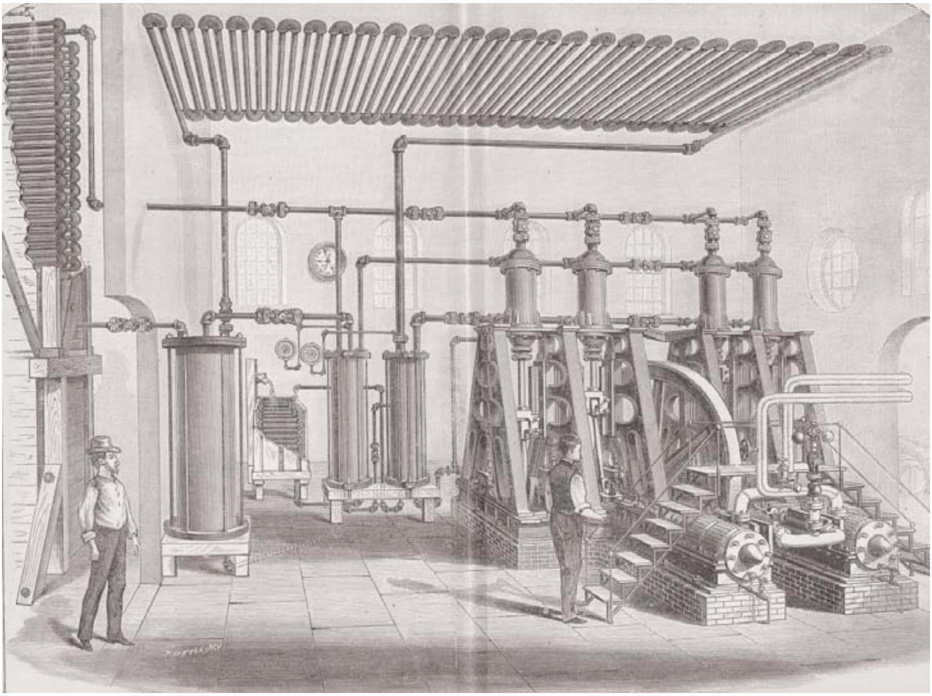


Figure 17. An ammonia compression refrigeration machine in a US brewery, from Julius E. Thausing's, The theory and practice of the preparation of malt and the fabrication of beer*, published in 1882.*

in the 1870s; Tsingtao lager from what is now China's biggest brewer, was an early product. Hampered by lack of suitable materials and the climate, local beer production in Australia only started to outstrip imports in the 1870s. Lager brewing reached the country in the late 1880s, with the American émigré Foster Brothers beer, brewed by the German brewmaster they brought with them using domestic cane sugar as an adjunct to malt, going on sale in Melbourne in 1889. Lager had been imported into Britain since about 1850 and the first tentative steps at brewing what at least was called lager, may have been taken place within a decade or so thereafter but the evidence for these early attempts is sketchy.[31] Experimental brewing of genuine lager took place at William Younger's Holyrood brewery in 1879 and what was probably the first purpose built lager brewery in the UK was built in Wrexham in 1882. Tennents started brewing lager in Glasgow in 1885. But it remained very much a niche drink in the UK (about one percent of the UK market in 1960, by which time lager made up c. 20% of the market in Scotland).

Concurrent with the spread of lager brewing came more emphasis on a scientific approach to brewing, the most famous early practitioner being Louis Pasteur. Until Pasteur carried out his investigations on wine and beer fermentations in the 1860s and 1870s and showed the importance of eliminating deleterious bacteria, there was little practically useful advice available to brewers on how to prevent their beers unaccountably going off. In a wider context, it was through the investigation of the production of wine, vinegar and beer that Pasteur established the importance of micro-organisms in causing disease. The far reaching significance of Pasteur's work on fermentation can thus not be doubted. What is less clear is the actual impact his work had upon fermentation practice and brewing in particular.[32] Pasteur's *Etudes sur la Biere* published in 1876 and translated into English as *Studies on Fermentation* in 1879, is often cited as revolutionising the industry. This is something of an exaggeration. The fermentation technology he devised, which essentially involved aseptic procedures in a closed vessel, found very limited application. His advocacy of the danger of aerial infection in breweries found more adherents, but in time it became clear that a greater hazard came from contact of wort with dirty surfaces and the drip of germ-ridden condensations.[33] Even the heat treatment technique which bears his name and which became so widely used was not recommended by him for use with beer on the grounds that it spoilt the flavour. It is in his advocacy of the practical utility of science which he communicated in a very high profile manner, rather than in the detail of Pasteur's work on beer where we may detect his real impact on the brewing industry. One undoubted practical outcome of Pasteur's work, however, was the growing adoption of that great Victorian gentleman's high tech. plaything, the microscope, for use in breweries [Fig. 18]. Pasteur was not the first to use a microscope in a brewery,[34] but it was certainly he who popularised it. A technology which was quickly accepted in most quarters of the brewing world was pure yeast culture introduced by Emil Christian Hansen at Carlsberg in 1883. Where Pasteur had identified bacteria as the causes of brewing problems, Hansen extended this to the presence of harmful yeasts. Pasteur had purified yeasts by acid washing to kill the bacteria. Hansen selected a single strain of yeast from the unreliable and variable mixed cultures then in use in the brewery and in so doing

Figure 18. The brewers' microscope as advertised in the Brewers' Journal *in 1882.*

Fermentation Type							
Bottom						Top	
Germany	67	Chile	5	Finland	1	Belgium	5
USA	17	Switzerland	4	Japan	1	France	5
Sweden	11	France	3	Mexico	1	Denmark	3
Russia	10	Argentina	3	Philippines	1	Germany	2
Holland	7	Uruguay	2	Poland	1	Holland	2
Norway	6	Australia	1	Spain	1	England	1
Denmark	5	Bolivia	1	Venezuela	1	Finland	1
Austria	5	Brazil	1				

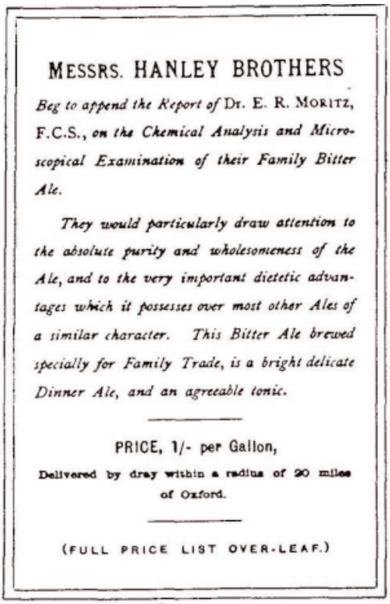
Table 1. Spread of Hansen's Yeast Culture Plants - Breweries with pure yeast culture plants in 1892. Number in each country by fermentation type

significantly improved the consistency of fermentations and the reproducibility of beer flavour. Table 1 shows the impressive spread of Hansen's pure yeast propagation plants around the world within ten years of his first demonstration of the technique. Only in Britain was there significant resistance; one British brewery, Combes, makes the list. There were various reasons for this; these go beyond mere English conservatism, and centre around the impossibility of producing English stock ale with a single strain of yeast, and the negative influence this had on the thinking of UK brewers.[35] In contrast to England, Germany was quick to adopt the new technique and easily tops the list.

Technical training and quality control

To be at the top of lists was typical of the German brewing industry by the closing decades of the 19th century. Trade and technical journals proliferated from the 1860s, with Germany having the earliest and most examples.[36] The first record of lectures being given on brewing is in Prague in 1818, but by the end of the century Germany provided the most widespread technical education at Weihenstephan (outside Munich), Nuremberg, Worms and most impressively in Berlin. These institutions did teaching and research, and provided an analytical service to brewers. No such institutions were established in Britain. The first brewing school in Britain to not arrive until

1899 at the newly established Birmingham University and then at Heriot Watt College in Edinburgh in 1904. But these were of little account in comparison. Training of brewers in the UK was, and continued to be, by a pupilage system, in which the trainee paid a fee for the privilege of on the job tuition by a brewer and/or consulting chemist. There was no institutional analytical service available to UK brewers, indeed attempts to provide such a service were opposed by the private consulting chemists who derived a steady income from the industry. By the 1880s there were many of these consultants to choose from. At least a dozen in London and others in provincial cities and of course in Burton. Particularly prominent was Edward Ralph Moritz, London born of German descent with a PhD from Göttingen, appointed Consulting Chemist to the Brewers' Society when only twenty-six he was the founder of what became the Institute of Brewing. Not all consultants had the credentials enjoyed by Moritz, the unregulated system encouraged quite a lot of quackery, and one must question the ability of even the most knowledgeable chemists to deliver quite what they promised.[37] Indeed Moritz was not above earning the odd guinea or two by having his rather overblown reports used to advertise his customers' beers. Figure 19 is an example, with much said about 'absolute purity … wholesomeness … tonic …' etc.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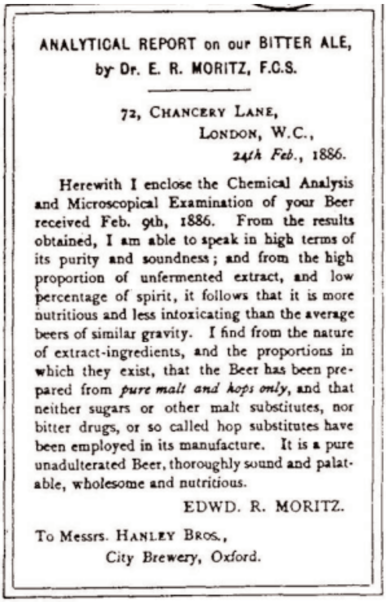
ANALYTICAL REPORT on our BITTER ALE,
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72, CHANCERY LANE,
LONDON, W.C.,
24th Feb., 1886.

Herewith I enclose the Chemical Analysis and Microscopical Examination of your Beer received Feb. 9th, 1886. From the results obtained, I am able to speak in high terms of its purity and soundness; and from the high proportion of unfermented extract, and low percentage of spirit, it follows that it is more nutritious and less intoxicating than the average beers of similar gravity. I find from the nature of extract-ingredients, and the proportions in which they exist, that the Beer has been prepared from *pure malt and hops only*, and that neither sugars or other malt substitutes, nor bitter drugs, or so called hop substitutes have been employed in its manufacture. It is a pure unadulterated Beer, thoroughly sound and palatable, wholesome and nutritious.

EDWD. R. MORITZ.

To Messrs. HANLEY BROS.,
City Brewery, Oxford.

Figure 19. An 'Analytical Report' used as a testimonial.

This raises the question of the nature of quality control in UK breweries. To what extent was in-house analysis carried out and who did it? The evidence is conflicting. Thus Edward Frankland, Professor at the Royal College of Chemistry in London testified to the Royal Commission on Scientific Instruction in 1871, that 'brewers … keep almost a constant stream of students passing through the College. They employ a considerable number of chemists in their breweries, some of them two in the same brewery … '.[38] Where-as Charles Graham, Professor of Chemical Technology at University College London, was able to tell the Royal Commission on Technical Instruction in 1882 that amongst breweries there was 'scarcely a laboratory anywhere else in England except at Burton'.[39] To make sense of this one must look at the context in which each statement was made. Frankland was trying to justify his position and show the success of his teaching. Graham on the other hand was eager to give reasons why he should start a new course at UCL.[40] More impartial information on the penetration of laboratories into late Victorian breweries in the UK may be drawn from the writings of Alfred Barnard who travelled all over the country in the late 1880s visiting breweries. He produced a four volume work on his travels which is now something of a collector's piece.[41] Barnard was no critic, virtually everything he came across was described in glowing terms, but he did record clearly what he saw and his work is much more than the 'coffee table' book it is sometimes dismissed as. The illustrations are undoubtedly somewhat sanitised from more disorderly reality, but we do get fairly detailed accounts of plant and equipment and the organisation of the breweries. The decline in the production of old vated beers like porter is clear, as is the rise of 'running beers', which were made to be brewed, packaged and drunk within 4 weeks.[42] The benefits derived from greater scientific understanding and measurement is something Barnard is particularly keen to make part of his accounts. From these descriptions a picture of the role of quality control in late Victorian British breweries emerges. Five levels of increasing sophistication can be detected in the 112 breweries Barnard visited.[43]:

Level 1: No mention of quality control, or if it is mentioned it is restricted to visual examination of barley, malt and hops by a north light window, the nosing of casks and the use of the saccharometer in brewery. 55 breweries meet this description.

Level 2: A bench in the brewers' office containing basic analytical equipment e.g. a microscope, colorimeter, simple glassware, perhaps a forcing tray for testing the microbiological stability of beer, and some scientific books. 21 breweries meet this description.

Level 3: A separate room set up as a brewers' laboratory with analysis carried out by one of the brewers. In addition to a microscope, colorimeter and forcing tray there would usually be water baths, a balance, extensive glassware and even sometimes a fume cupboard. 25 breweries meet this description.

Level 4: A chemist's laboratory with analysis carried out by a qualified dedicated chemist. In addition to the apparatus listed for level 3, equipment might also include photomicrography equipment, a polarimeter, ovens and incubators. Routine water, barley, malt, beer, and hop analysis would be the norm. Six breweries (Wm. Youngers (Edinburgh), Mann Crossman & Paulin (London), Ind Coope (Burton), Barras (Newcastle), Truman (London), Benskins (Watford)) meet this description.

Level 5: Chemists' Laboratories. A chemist and usually assistants in a laboratory with more than one room. There would often be a dedicated instrument room and balance room. Equipment would be as for level 4 but might also contain such sophisticated, and difficult to operate, apparatus as that required for combustion analysis of elemental carbon & nitrogen. Research activity was likely. Five breweries (Allsopp, Bass, Worthington and Salts, all of Burton and H & G Simmonds of Reading) meet this description.

Thus, scrutiny of Barnard goes some way to support Charles Graham's contention that there was ‘scarcely a laboratory anywhere else in England except at Burton’ but only if one ignores all but the most sophisticated laboratories. From the figures above, counting brewers' and chemists' laboratories, by the late 1880s there were at least thirty six breweries in Britain, one third of the total visited by Barnard, which had a laboratory. Nor is there any good reason to discount the brewers' laboratory which could be very well equipped, as in the example shown at Hanson's Kimberley brewery [Fig. 20]. It is also possible that Barnard missed the odd laboratory. Certainly it is strange that he notes Ind Coope to have a laboratory at Burton but does not mention one at Romford, even though other evidence indicates that the company were employing a chemist at the latter brewery in the 1860s/70s.[44] What is clear is that the presence of an in-house laboratory in the 1880s was not particularly determined by the size of the brewery. Certainly many of the smallest breweries lacked such a facility, but so did the biggest of them all, Guinness, which had no laboratory when Barnard visited Dublin and would not have one until the 1890s. Nor does Barnard note a laboratory in most of the big London breweries. Indeed, Courage, Reid, Meux, City of London, and even Whitbread with their much vaunted Pasteur connections, do not even have a bench in the brewers' office by Barnard's account. One wonders what had happened to the legendary microscope the directors of Whitbread are said to have bought after Pasteur's visit to the brewery in 1871?

The big Burton breweries were of course a special case and employed chemists from the 1840s. The significant export

Figure 20. The laboratory at Hanson's Kimberley brewery, from Alfred Barnard's Noted Brewerries of Great Britain and Ireland. Volume 3*, published in 1890.*

trade in India Pale Ale encouraged their early adoption, for the breweries could get drawback of duty on exported beer and needed someone technically skilled to carry out the distillations and weighings required to determine original gravities and thus substantiate a claim. Also the delicacy of IPA made it much harder to produce than dark rough beers like porter and a chemist was seen as useful. Four of Burton's brewers' chemists rose to particular distinction. In order of seniority we have: (1) At Allsopp's there was Peter Griess who was their chemist for 25 years until his death in 1888. He fulfilled a full role as a chemist in the brewery, but he also had an abiding interest outside the day job - synthetic organic chemistry on which he published over 100 original papers and became a world authority. He is regarded today by historians of chemistry as a chemist of the first rank, whose work laid the foundations of the dyestuffs industry. (2) At Bass there was Cornelius O'Sullivan, he spent 40 years with the company until his death in 1907. He made his name in carbohydrate chemistry, the enzymology of the mash tun, closely associated with his brewing work. (3) At Worthington there was Horace Brown, a botanist, who did ground breaking work on barley germination and worked for thirty years for the company before falling out with the redoubtable Arthur Manners. (4) Finally there was Adrian Brown, Horace's somewhat less talented younger half-brother, who specialised in problems to do with yeast, and spent 25 years with Salts brewery before becoming the first professor of brewing at the newly formed Birmingham University in 1899. All four men were elected Fellows of the Royal Society.

The spread of the brewers' chemist

The number, if not necessarily the quality, of brewers' chemists was gradually to increase as the 19th century drew to a close. Employment of chemists in breweries then received a boost, somewhat indirectly, by an unexpected consequence of the implementation of the 'Free Mash Tun Act' of 1880. This piece of legislation changed the basis on which duty was paid on beer. For the previous fifty years duty had been levied on the raw materials (primarily malt; sugar had been allowed since 1847 but was not particularly advantageous to use because of duty differentials), now it was to be levied directly on beer. Brewers were now free to use any wholesome source of extract they wished. This led them to employ 'malt substitutes' which soon made up around 20% of the grist for many beers. Flaked maize and rice were commonly used 'adjuncts', but many brewers preferred the added convenience of ready made processed 'brewing sugars'. In 1900, twenty years on from the 'freeing' of the mash tun, the use of brewing sugars from one particular manufacture, Bostock & Co., led to probably the greatest tragedy to affect the brewing industry in England. This came about when sulphuric acid contaminated with arsenic was inadvertently used in the production of glucose and invert-sugar. The sugar was used to brew beer over a period of some nine months before its effects were spotted. Seventy people died and at least 6000 others had symptoms of arsenic poisoning.[45] On the positive side, the affair led to the realisation that arsenic, at low but not negligible levels, was present in many batches of malt due to the fuel used for kilning. Indeed it is likely that arsenic poisoning from this source had been an unrecognised danger for generations before the poisonings of 1900. The Royal Commission appointed to investigate the matter established the concept of the maximum permitted level of materials in foodstuffs.[46] Arsenic being the first environmental hazard to be controlled in this way. The scare also led to much work for chemists, particularly consulting chemists who made a pretty penny out of it. But, it also led brewers increasingly to recognise the virtues of having a chemist on site to test materials for safety as well as brewing value. This also made sense in economic terms. The brewers had been stung by the amount they had needed to pay consultants during the arsenic scare, why not have their own man on site who may well be useful in other ways? The growth in the lighter running beers and bottled beer trade which required more attention added strength to this view. The comments of

Edwyn Barclay, looking back from 1910 reflect this:[47] '… the most far-reaching innovation was the starting of a laboratory in the brewery. Constant analysis of all materials has, of course, given an accurate knowledge which has led to many improvements and alterations'. There are no published data on the growth in the numbers of scientists employed in breweries. From examination of brewery archives, obituaries, trade and scientific journals, membership lists etc my provisional estimate is that in 1900 there were around 20 consulting chemists who specialised in brewing practising in the UK. By 1910 the numbers of consultants had not increased, but the number of dedicated brewers' chemists operating inside breweries had more than doubled to perhaps as many as eighty.[48]

Things to come

The seeds of many other changes were also laid as the 19th merged into the 20th century.[49] Chilled and filtered bottled ale, called non-deposit beer because it had no yeast sediment in it, came to Britain in 1897 via the USA.[50] Lager produced quickly using straight single temperature infusion mashing and minimal maturation time arrived two years later, with the launch of Allsopp's lager. This beer, while fermented with bottom-yeast at low temperature had a total production time from mashing to reaching the bar of only 3 weeks, as opposed to at least as many months for continental lager at the time.[51] It was, however, at least of continental strength at 5.5% alcohol by volume, unlike beers later sold in the UK under the name lager, both home-produced and imported, which had alcohol contents not much above half of that. The first brewery research laboratory in the UK was established by Guinness in 1901.[52] After five year's of allowing free publication when run by Horace Brown (ex Worthington's) this became a very secretive place, with Guinness banning its staff from publishing anything of their work. The ban lasted for 40 years. Mash filters [Fig. 21] were first used in the UK by Benskins in Watford in 1903,[53] followed a few years later by Vaux in Sunderland, but found few other takers in the country for another 90 years. What was effectively keg ale (although it was of course not called that), chilled, filtered and carbonated draught beer dispensed with CO_2 top pressure came to Britain in 1905, when William Butlers', Springfield Brewery launched it in Wolverhampton. They persisted with the experiment until 1914 but then dropped it because of consumer dislike of the product.[54] 'All foam and no flavour' was one comment at the time concerning chilled and carbonated

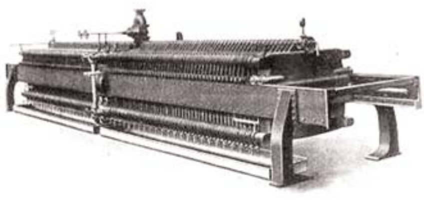

Figure 21. An Edwardian Mash Filter, from the Brewing Trade Review *1905.*

beer.[55] Breeding of hybrid strains of barley originated in 1905 with the crossing of the varieties Plumage and Archer by E. S. Beavan to give a new variety destined to dominate the malting crop from the 1920s to the 1940s.[56] E.S. Salmon's hop breeding programme which started the worldwide movement to improved varieties began at Wye College in Kent in 1906.[57] Also in 1906, Ludwig Nathan was granted an English patent[58] on a vessel with a ‘rigid cylindrical iron shell [and] a glass lining made up of curved glass plates' for use in brewing; the first step towards the cylindro-conical fermenter which sixty years latter would start to come into its own. Aluminium was used for fabrication of fermenters and storage vessels in Germany in 1909[59] and a year later in the UK; and the metal would have a certain vogue for a couple of decades until stainless steel took over. In 1911 Leo Wallerstein, a first generation German-American consulting brewers' chemist, noting the increasing propensity of Americans to store their beer in the icebox, came up with a method for chillproofing beer to stop it going hazy in the fridge by treating it with proteolytic enzymes in the brewery.[60] Walter Scott of Ansells in Birmingham patented his eponymous yeast plant in 1913.[61] In this system yeast is drawn off from an open fermenting vessel under vacuum, forced through a filter press and the filtrate returned to the fermenters. The economies thus provided were soon to have particular appeal to brewers when, as a consequence of the First World War, excise duties rose to unprecedented levels and stayed there.

Was Delbrück right?

To go back to where we came in. Was Max Delbrück correct in his prediction of 1884? Has the sword of science and the armour of practice enabled German beer to encircle the world? With over a hundred years of hindsight the answer is a qualified yes, but not quite in the way he meant. In the years that followed Delbrück's statement, German brewing scientists proved rather more adept at accumulating data than using it - to an extent handicapped by German practice, which was governed by the Reinheitsgebot, or 'commandment for purity', a consumer protection or trade protection measure depending upon your viewpoint, which restricted their freedom of action. On the other hand, German brewmaster's proved extremely influential across the world. If you go into any large modern brewery today, including those few which still brew ale, you will see equipment originally designed for use with bottom-fermentation and it is frequently manufactured by German firms. Lauter tuns are to be found everywhere. But all is not as it seems at first glance. Outside Germany and the Czech. Republic lauter tuns are seldom used in complicated decoction mashing regimes, rather programmed infusion mashing is the norm; you don't see many mash coppers any more. Mash filters for ultra swift processing are also increasingly replacing lauter tuns and they have their origins in Belgium. The ubiquitous cylindro-conical fermenter originates in Switzerland, not Germany; Ludwig Nathan was from

Zurich. But, there is no denying that lager, cold-produced bottom-fermented beer, has encircled the world. With sales buoyed by increasing consumption in developing countries, lager is truly the world drink. Even in the UK, which has steadfastly maintained volume ale production longer than anywhere else, over 70% of the beer sold is lager - and much of the ale and stout now served in pubs is dispensed at very low temperatures to make it seem more like lager! However, I doubt if Max Delbruck would recognise the lager of unrivalled blandness which now sells the most worldwide as having much to do with what he knew as German beer.[62]

Notes and References

1. Delbrück, M. (1884) 'Ueber Hefe und Gärung in der Bierbrauerei', *Bayerische Bierbrauer*, 19, p. 312. ‘Mit dem Schwerte der Wissenschaft, mit dem Panzer der Praxis, so wird Deutsche Bier die Welt erringen’.

2. Data from *The Brewers' Journal* 1891, 27, p. 315 & *The Brewers' Almanac* 1899, p. 145.

3. Pennant, T. (1793) *Some Account of London* (3rd Ed.). R. Faulder: London, p. 313. via Pearson, L. (1999) *British Breweries. An Architectural History*, Hambledon Press: London. p. 31.

4. Barclay, C. (1830) Parliamentary Papers, X: 16. ‘We are the power-loom brewers, if I may so speak’

5. Gourvish, T.R. & Wilson, R.G. (1994) *The British Brewing Industry 1830-1980*. Cambridge University Press: Cambridge. p. 610.

6. Bud, R.F. & Roberts, G. K. (1984) *Science versus Practice: Chemistry in Victorian Britain*. Manchester University Press: Manchester. pp. 14-15. Green, J.H.S. (1957) 'Robert Warrington (1807-1867)'. *Proceedings of the Chemical Society*, pp. 241-246.

7. The graduate was William Ferguson (1810-1869) who obtained a BA. degree in Dublin in 1833. Bud, R.F. (1980) *The Discipline of Chemistry: The Origins and Early Years of the Chemical Society of London*. Unpublished PhD thesis, University of Pennsylvania, pp. 137-138, 166. Anderson, R.G. (1992) 'The pattern of Brewing Research: A Personal View of the History of Brewing Chemistry in the British Isles.' *Journal of the Institute of Brewing*, 98: pp. 85-109, 86, 88. Burtchaeli, G.D. & Sadler, T.U. (1935) *Alumni Dubliniensis*. Alex Thom & Co.: Dublin.

8. Mathias, P. (1959) *The Brewing Industry in England 1700-1830*, Cambridge University Press: Cambridge. p. 552.

9. *ibid*. 551.

10. Ritchie, B. (1992) *An Uncommon Brewer. The Story of Whitbread 1742-1992*, James & James: London. pp. 28-29.

11. Mathias, P. *op cit*. 85. The odd brewery out was Trumans, which did not have a steam engine until 1805.

12. Sumner, J. (2001) 'John Richardson, saccharometry and the pounds-per-barrel extract: the construction of a quantity'. *British Journal of the History of Science*, 34, pp. 255-273.

13. Sumner, J. (2006) 'Early heat determination in the brewery'. *Brewing History. The*

Journal of the Brewery History Society, 121, pp. 66-80.

14. Morrice, A. (1802) *A treatise on brewing: wherein is exhibited the whole process of the art and mystery of brewing the various sorts of malt liquor; with practical examples upon each species*. H.D. Symonds: London. Appendix 181.

15. Corran, H.S. (1975) *A History of Brewing*. David & Charles: Newton Abbot. pp. 170-174. Mathias, P. *op cit*. pp. 76-78. Commercial brewers have by definition always sought to maximize their profits, but this is perhaps the first example of using instrumental data in order modify brewing technology purely on economic grounds. Certainly there seemed to be an indifference to porter flavour changes in adopting the new grist and the brewers got away with it. A precedent had been set.

16. Cornell, M. (2003) 'Porter myths and mysteries'. *Brewing History. The Journal of the Brewery History Society*, 112, pp. 30-39.

17. Anderson, Ray (2003) 'Microbes and the origins of porter'. *Brewing History. The Journal of the Brewery History Society*, 113, 27-30.

18. Mathias, P. *op cit.* (11) p. 62.

19. Corran, H. S. *op cit*.(15) pp. 183-211.

20. Steel, J. (1878) *Selection of the practical points of malting and brewing and strictures thereon for the use of brewery proprietors*. Privately published: Glasgow pp. 121-122.

21. Corran, H.S. *op cit*.(15) p. 191.

22. Hind, H.L. (1940) *Brewing Science and Practice*. Chapman & Hall: London. Vol. 2, pp. 808-817

23. Moritz, E.R. & Morris, G.H. (1891) *A Text-book of the Science of Brewing*. E. & F. N. Spon: London. p.391.

24. Pearson, L. *op cit*.(3) pp. 41-46.

25. Scamell, G. & Colyer, F. (1880) *Breweries and maltings: Their Arrangement, Construction, Machinery, and Plant*, 2nd edition

26. A note on terminology. A quarter is an English measure of malt and barley. Originally the quarter was a volume measure and it was assumed that 1 quarter of barley would yield (about) 1 quarter of malt. Later, quarters were defined by weight such that a quarter of barley weighed 448 lb. and a quarter of malt 336 lb. (See Briggs, D.E. (1998) *Malts and Malting*. Blackie: London. p. 80.). Thus the number of quarters of malt processed by a brewery is a measure of its capacity. The assumptions generally made when constructing a brewery to serve a given volume of trade were that: 1. Four barrels of beer was the average yield from a quarter of malt. 2. The plant brews once a day four days a week (thus leaving room for expansion if necessary by brewing on the fifth day without addition to the plant). 3. The brewery is in operation 50 weeks of the year. (See Bradford, W. (1891) 'Brewery Construction' *Transactions of the Institute of Brewing* (Laboratory Club), 4, pp. 110-111.). It follows therefore that a 5 quarter brewery would be designed to produce 5 x 4 x 4 x 50 = 4000 barrels per year and would have a capacity of 5 x 4 x 5 x 50 = 5000 barrels a year.

27. Thausing, J.E. (1882) *The theory and practice of the preparation of malt and the fabrication of beer with especial reference to the Vienna Process of Brewing*. Henry Carey Baird: Philadelphia pp. 556-604.

28. Teich, M. (1993) 'A case of industrial espionage in brewing', in *A Special Brew.*

Essays in honour of Kristoff Glamann, ed. Thomas Riis. Odense Univerity Press: Odense pp. 183-187

29. Anderson, R.G. (2003) 'Beer' in Blocker, J., Tyrell, I. and Fahey, D (eds) *Alcohol and Temperance in Modern History: An International Encyclopaedia*. Santa Barbara: ABC-Clio, Vol1., pp. 92-100.

30. Hård, M. (1994) *Machines are Frozen Spirit. The Scientification of Refrigeration and Brewing in the 19th Century - A Weberian Interpretation*. Campus Verlag: Frankfurt am Main.

31. Wilson, R. (1993) 'The Introduction of Lager in Late Victorian Britain', in *A Special Brew. Essays in honour of Kristoff Glamann*, ed. Thomas Riis. Odense Univerity Press: Odense p. 199.

32. Anderson, R.G. (1995) 'Louis Pasteur (1822-1895): An assessment of his impact on the brewing industry'. *Proceedings of the 25th European Brewery Convention Congress,* Brussels pp. 13-23.

33. Hind, H.L.. (1936) 'Progress in Brewery Fermentation during the last Fifty Years'. *Journal of the Institute of Brewing*, 42, p. 514.

34. In 1839 Robert Warington of Trumans was a founder member and sat on the first council of the Royal Micoscopical Society in London. Turner, Gerald L'E (1989) *God Bless the Microscope! The history of the Royal Microscopical Society over 150 years*. 16.

35. Anderson, R.G. (2006) 'One yeast or two? Pure yeast and top fermentation. Part1: A question of flavour and condition'. *The Brewer & Distiller*, 2 in the press.

36. Anderson, R.G. (2006) 'The transformation of Brewing: An Overview of Three Centuries of Science and Practice' *Brewing History. The Journal of the Brewery History Society*, 121, p. 9.

37. A jaundiced view of chemists is evident from James Steel's 1878 book on brewing (Steel, J. *op cit*.(20)) the preface of which contains this passage: ‘The chemist has hitherto been helpless in the brewery, because, not having learned the art of Brewing, he could have no theory, and having neither art nor theory, his presence has as yet done more harm than good’. Even Steel, however, who found fault with almost everyone, sounded a note of optimism when he continued: ‘When the chemist has been presented with the facts of the position and a base to operate from, he will doubtless become in the brewery, as elsewhere, of the highest utility’. Emollient words but not a particularly accurate prediction of future relations between practical brewers and chemists. Thirty years later, by which time chemists had something of a ‘base to operate from’, their ‘utility’ caused other problems. In 1908 the Operative Brewer's Guild was set up by ‘practical men’ who resented the influence of ‘scientific men’ in the brewery and sought to redress the balance. The lack of sympathy between the two factions was to rumble on to the end of the period we are reviewing and beyond (See for example, Editorial Notes. Practical or Scientific? *Journal of the Operative Brewers' Guild*, 1914, 1, pp. 29-30).

38. Royal Commission on Scientific Instruction I, 1872, C. 536 Minutes of Evidence,5834, p 369. The actual evidence produced by Frankland to the Commission showed that from a sample of 366 of a total of 1008 students trained at the college since its foundation in 1845, only twenty were pur-

suing careers in the brewing industry and of these eleven were known to be connected with three of the Burton breweries. (See Sigsworth, E. M. (1964-1965) *Economic History Review*, 17, 538.). Frankland may therefore have somewhat exaggerated his 'constant stream'.

39. Royal Commission on Technical Instruction III, 1884, c. 3981, answers to Q 1523/4, 145.

40. Anderson , R.G. (1992) *op cit*. (7) p. 94.

41. Barnard, A. (1888/1891) *Noted Breweries of Great Britain & Ireland*. Joseph Causton & Sons: London.

42. Baker, J.L. (1905) *The Brewing Industry*. Methuen & Co: London, p. 116.

43. There are 108 separate entries (chapters) covering brewing companies and 5 entries for malting companies in the four volumes of Barnard's work. Four of the brewing company entries (Charrington (London & Burton), Ind Coope (Romford & Burton), Mann (London & Burton) and Truman (London& Burton)) cover two production sites in two towns/cities. These are counted as separate breweries for the purposes of this comparison. Where companies have more than one production site in a single town/city (Allsopp (Burton), Bass (Burton), Wm. Younger (Edinburgh) and Steel, Coulson (Glasgow)) these are treated as a single brewery. Hence the figure of 112 used here.

44. Anon (1875). 'Obituary notices, Henry Medlock', *Proceedings of the Chemical Society*, 28, pp. 1317-1318.

45. Final Report on the Royal Commission appointed to enquire into Arsenical Poisoning from the consumption of beer and other articles of food and drink (1903). Cd. 1848, p. 5.

46. *ibid*. 50. ‘In our view it would be entirely proper that penalties should be imposed under the Sale of Food and Drugs Acts upon any vendor of beer or any other liquid food, or any liquid entering into the composition of food, if that liquid is shown by an adequate test to contain 1/100th of a grain or more of arsenic in the gallon; …’. Although the recommendations of the Royal Commission were not given statutory force until 1959, they came to represent good manufacturing practice and were accepted by the Courts (The Arsenic in Food Regulations, 1959, S. I. No. 831).

47. Barclay, E. (1910) 'Obituary Notices. Frederick Lincoln Bevan'. *Journal of the Institute of Brewing*, 16, pp. 67-68.

48. Anderson, R.G. ‘Gravity. Tint & Bitterness. The Rise & Fall of the Brewers' Chemist’ in preparation.

49. Anderson, R.G. (2006) 'History of Industrial Brewing' in *Handbook of Brewing* . Eds Fergus G. Priest, Graham G. Stewart. Second Edition. CRC Taylor & Francis: Boca Raton, London & New York pp. 1-37.

50. Van Laer, N. (1900) 'The Chilling and Filtering of Top-fermentation Beers', *Journal of the Institute of Brewing*, 6, pp. 439-450.

51. Anon (1899) 'Allsopp's Lager Beer Installation', *The Brewers' Journal*, 35, pp. 646-652.

52. Anderson, R.G. (1992) *op cit*. (7) p. 96. Although Guinness was the first to establish a research laboratory in the British Isles, a case can be made for it not being the first to employ a dedicated research scientist. In 1889 Arthur Landauer Stern went to work for Cornelius O'Sullivan when the latter was head brewer at Bass' New Brewery in Burton.

The appointment was to assist with research work in a private capacity for O'Sullivan and only some years later did Stern join the staff of the brewery.

53. Cannon, M.J. & Brown, H. (1906) 'The Filter Press in the Brewery' *Journal of the Institute of Brewing*, 12, pp. 11-27.

54. Anon (no date) W. Butler & Co. Ltd. Brewing-Room Note Book. 4-5. Coors Visitor Centre. Museum of Brewing. Uncatalogued archive material.

55. Smith, S.W. (1912) 'Notes on some problems concerning bottled beer' *Journal of the Institute of Brewing*, 18, p. 11.

56. Lancaster, H. (1942) 'Obituary. Edwin Sloper Beaven 1857-1941. *Journal of the Institute of Brewing*, 42, pp. 31-33.

57. Darby, P. (1998) 'A Century of Hop Breeding' *Pauls Malt Brewing Room Book 1998-2000*. R.H. Beach (ed), 57-61.

58. Nathan, L. (1906) 'Improvements in the Construction of Vessels for Use Particularly in the Sterilised Manufacture of Beer' English Patent 5619, 8th March 1906; via *Journal of the Institute of Brewing*, 1907, 13, p. 296.

59. 'B' (1909) 'Aluminium Fermenting and Storage Vats' Wochenschschrift für Brauerei 26, 361-362, via *Journal of the Institute of Brewing*, 1909, 15, pp. 716-717.

60. Wallerstein, Leo (1956) 'Chillproofing and Stabilization of Beer' *Wallerstein Laboratories Communications*, 19, No. 65, pp. 95-110.

61. Scott, W. (1913) 'Means of Handling, Skimming and Pressing Yeast' English Patent 21,925, 29th September 1913.

62. Adams, R. (2003) 'Busch case nipped in the Bud', *The Guardian*, 18th February, 16.