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John Richardson, saccharometry and the pounds-per-barrel extract: the construction of a quantity†

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Abstract. This paper uses the work of John Richardson, an eighteenth-century brewing theorist, to explore the view that physical quantities, though they appear 'natural' or 'given', are actually contingent entities constructed to serve particular aims. It focuses on the pounds-per-barrel extract, a brewery-specific quantity which, in a reversal of the familiar position, seems self-evidently constructed to the general reader yet came to be accepted as 'natural' among its users. Central to Richardson's work in achieving this acceptance was an instrument, the saccharometer, which, by providing measurements of the quantity, legitimated it. Richardson presented both instrument and quantity as tailored to serving the particular needs of his fellow brewers, at the same time emphasizing their separateness from parallel work in distillery assessment, which had made Richardson's innovation possible but now threatened his projected consensus. Richardson's overall project encompassed the direct proportionation of material costs, retail prices and Excise duties to extract values as defined by the saccharometer, which he sought to monopolize. The scheme was not wholly successful, yet Richardson's quantity remained in brewery use into modern times. The end result, I contend, shows how a quantity, by becoming naturalized, may survive the loss of its initial theoretical underpinning.

Introduction

John Richardson of Hull, a brewing theorist of the late eighteenth century, is unlikely to be familiar to many historians of science. Within his own profession, however, he is remembered for establishing the 'pounds-per-barrel extract', a quantity employed as a standard measure of the value of beer through most of the nineteenth and twentieth centuries. My aim here is to analyse Richardson's activities in the light of the interpretation, now widespread in the history and philosophy of science, that quantities are contingent entities, constructed, preserved and modified by their users.

The work of Harry Collins has been particularly influential in dispelling the assumption that quantities can be taken for granted as 'naturally occurring' or 'intuitively obvious'. Quantities pass into use, change in meaning and are ultimately discarded; that we perceive them as self-evident, Collins argues, results from their 'entrenchment' within our society's overall pattern of assigned properties. They are like ships in bottles: their chief virtue is

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that they seem always to have existed in their present configuration, yet they must in reality have been brought into being at some time and by some agency.[1] Richardson's 'extract' therefore presents an interesting case study. As a quantity defined only in a highly specialized, commercial context, it may strike the general reader as quite obviously constructed and contingent, yet examination of Richardson's work shows him striving to establish it as the fundamental component in an overarching theoretical interpretation of brewing.

If quantities are contingent rather than 'natural' categories, their pioneers must work to secure their adoption in several ways. Most immediately, the very act of picking a quantity out has to be justified. The quantity must be represented as a coherent conceptual entity; this inevitably requires some theoretical innovation, but is most easily achieved by building on some pre-existing idea of a distinct property, already entrenched in practitioners' minds. The quantity must also be represented as 'reliable'; this demands a demonstration not only of self-consistency, but of broad agreement with pre-quantificatory understandings. Finally, the quantity must be shown to be useful. Again, it must be tied to some pre-existing notion of usefulness in order to be accepted; at the same time, however, it must provide new benefits to justify the work involved in its imposition. Quantifiers, then, must present themselves as both radical and conservative, promoting a new programme of understanding – usually justified by an increase in 'precision' or 'certainty' – but at the same time carefully embracing established shared expectations. Quantification is inalienably social, because the quantifier's ultimate goal is to achieve consensus in the discipline to which the quantity will belong.

One existing account which illustrates these principles is Simon Schaffer's interpretation of the emergence of eudiometry in the 1770s. The 'goodness' of air, as measured by Joseph Priestley's nitrous-air apparatus, was not quite equivalent to any established property. Priestley justified it, however, with reference to the readily understood concept of the air's fitness for breathing, at the same time stressing the new certainty and precision imposed by his scheme.[2] My aim here is to treat Richardson's conceptualization of 'extract', which emerged around the same time, in parallel fashion. Common to both cases is the presence of a wider agenda driving the project of quantification. Priestley developed the nitrous-air test in support of his underlying theory of an aerial economy of 'virtue', grounded in his theological concerns. Richardson's agenda focused on an economy of another kind: he sought the adoption of a system tying beer strength, taxation and the cost of raw materials to a single numerical standard. The extract was planned as the centrepiece of a universal scheme of value determination, which would safeguard the brewer's profits in a hitherto uncertain climate.

Of crucial significance to Richardson's project was his introduction of the 'saccharometer', a purpose-built instrument by which his quantity was to be measured. It is now widely held that instruments have a role in defining, publicizing and reifying the quantities which, ostensibly, are conceptually prior to them and determine their construction. In a forthcoming publication, Graeme Gooday challenges the view that

1 H. Collins, *Changing Order: Replication and Induction in Scientific Practice*, London, 1985, 5–18.

2 S. Schaffer, 'Measuring virtue: eudiometry, enlightenment and pneumatic medicine', in *The Medical Enlightenment of the Eighteenth Century* (ed. A. Cunningham and R. French), Cambridge, 1990, 287–8, 290.

mensuration requires a 'clear conception' of the relevant quantity to pre-exist: using the example of teaching practices in nineteenth-century electrical physics, he suggests that students were required to undertake measurement work as a way of naturalizing unfamiliar and 'ontologically problematic' concepts in their minds. A first-principles explanation might leave the sceptical apprentice unconvinced that, say, electrical resistance actually existed in any worthwhile sense; after a couple of years of painstaking laboratory work with resistance boxes, however, it would seem as real to him as his right arm – the ship, if you like, would be in the bottle.[3] In much the same way, Richardson exploited the saccharometer to entrench his quantity's status among fellow professionals.[4]

This paper is divided into three sections. The first, in keeping with what has been said about pre-quantificatory understandings, discusses notions of value in brewing before the appearance of the saccharometer, and the roots of gravimetric determination in the parallel field of distilling. The second analyses Richardson's work in establishing the saccharometer as an instrument distinct from this distillery context, and the third explores the wider aspects of Richardson's quantificatory scheme. I conclude with a brief discussion of how subsequent events indicate the success, in a limited sense, of Richardson's quantificatory endeavour.

The prehistory of Richardson's work

Before the second half of the eighteenth century, the strength of beer was not considered as a quantity in the modern sense. That is not to say that differences in strength were not intended or appreciated: on the contrary, beer's dual function as an intoxicant and a source of relatively unpolluted water meant that brewing to different alcoholic strengths had been commonplace for hundreds of years. It was precisely this notion of a divergence, however, which had shaped the understandings of the public and, in particular, the Excise authorities: although stronger beers, using more malt, did attract higher overall taxation through a separate malt tax, the finished beer itself was classed into two (or, for some years from 1782, three) very broad strength categories, each attracting a flat Excise duty per barrel. In principle, Excise officials categorized beer on the quantitative basis of either the volume of malt used or the price at which the brewer sold the beer: the traditional demarcation between 'strong' and 'small' beer was a retail price of six shillings per barrel exclusive of duty.[5] In effect, it was assumed that the distinction would be qualitatively obvious. Officially, and also in the public understanding, beer strength was not a continuum, but a system of two or more distinct zones representing different styles and purposes, as maintained by law.

3 G. Gooday, *The Morals of Measurement: Accuracy, Irony and Trust in Late Victorian Electrical Practice*, forthcoming, Chapter 2.

4 Some recent work has discussed how official bodies, in applying quantification, seek to engender trust and prevent conflict with practitioners by appealing to the 'objectivity' or 'neutrality' of the numbers produced. See in particular T. Porter, *Trust in Numbers*, Princeton, 1995. Richardson's case is rather different. He presented his quantity as designed primarily to benefit, and to be applied by, his fellow practitioners themselves, rather than agents of the legislature. The appeal for trust here, therefore, rested less on the quantity's abstract nature than on its broad conformability to pre-existing understandings, coupled with its practical utility.

5 P. Mathias, *The Brewing Industry in England 1700–1830*, Cambridge, 1959, 110, 369.

The brewers themselves, however, did not necessarily share the assumption of a clear-cut distinction. The inevitable borderline cases were generally resolved by an Exciseman tasting the beer and pronouncing on the basis of his individual judgement, an approach which understandably led to disputes. During the wars of 1689 to 1697 and 1701 to 1714, the significance of this problem increased dramatically: unprecedented duties were loaded onto beer, widening the divergence between 'strong' and 'small' and making accurate demarcation a crucial matter.[6] Furthermore, the brewers found they could take advantage of the growing disparity in taxation by brewing exceptionally strong beer, paying duty at the uniform 'strong' rate, and then diluting it with small beer to give a product which would pass for 'strong' but which had been taxed partially at the much lower 'small' rate. Although prohibited, this practice was undetectable unless actually witnessed by attentive Excisemen, and as such quite commonplace.[7] Nonetheless, the system of broad bands persisted through the eighteenth century in the absence of any clear alternative. Before the development of canal and rail freight, the low mercantile value of beer made it uneconomical to transport, and brewing practices were thus strongly localized. Standardization, or any form of determination more precise than the established Excise bands, seemed a logistical impossibility.[8]

A contrasting situation existed in the distilling industry. The economic feasibility of transporting spirits naturally caused much comparison of different manufacturers' wares, and spirits, unlike beer, were generally produced for the purpose of intoxication alone; the notion of the 'value' of a sample of spirit was therefore much more keenly defined and observed. Distillery practices also contributed to the emergence of an interpretive framework very different from that established in the brewery. The process of extraction and purification necessitated the concept of an absolute, a most 'highly rectified' form of spirit which could not be purified any further; this 'pure spirit' was identified with the principle of intoxication, since the effect of drinking a given volume increased with the degree of purification.[9] Consequently eighteenth-century distillers interpreted the value of spirits in terms of a continuum representing the relative proportions of 'pure' alcohol and water (which chemical analysis, derived from distillation practice, showed to account for almost all of any spirit's volume).

Acceptance of this continuum conception ultimately became mandatory through its adoption by the Excise authorities. Like the levy on beer, spirit duty was customarily charged in wide, uniform bands, and qualitative methods were often used in demarcation. With the shift towards use of the Excise as the government's key revenue-raising tool after 1713, and following a moral panic over the incidence of spirits drunkenness resulting from

6 The cultural history of the brewing profession appears to show a distinct consciousness of, and sense of injustice against, the sharp duty increases concentrated in the period from 1690 to 1710. A pseudonymous polemic of 1760, the 'Obadiah Poundage letter', protesting the general deterioration of the brewers' condition since the 1690s, was widely drawn on or plagiarized in subsequent literature, and forms the basis of many, ostensibly neutral, accounts. H. Corran, *A History of Brewing*, Newton Abbot, 1975, 110–6.

7 Mathias, op. cit. (5), 346; Corran, op. cit. (6), 175–6.

8 Mathias, op. cit. (5), p. xxii; T. Gourvish and R. Wilson, *The British Brewing Industry 1830–1980*, Cambridge, 1994, 41.

9 C. Wilson, 'Water of life', in *Liquid Nourishment* (ed. C. Wilson), Edinburgh, 1993, 142–5.

the rising price of beer, spirit duties too were subjected to a hefty increase.[10] Just as in the brewery case, accurate demarcation now became a matter of great economic significance. However, the pre-existing notion of a continuum meant that the broad duty bands were increasingly undercut by attempts to define strength in precise numerical terms. Building on the existing arbitrary reference standard of 'proof', the Excise authorities established a numerical scaling whereby samples were rated as so many degrees 'above' or 'below proof'. Distillers henceforth had no choice but to consider the strength of their product in terms of its position on the proof scale. Excise duties were increasingly determined by the results of proof assessments, and by the mid-eighteenth century there were suggestions of replacing the broad bands with a direct proportionation.[11]

The Excise officials, who travelled between distilleries making regular assessments on the premises, therefore needed a means of assessing spirit content which was not only reliable but also rapid and, above all, portable.[12] The device which best seemed to meet these needs was the spirit hydrometer, first developed by John Clarke in the 1720s. This instrument exploited the fact that pure alcohol is considerably less dense than water: to use the contemporary natural-philosophical expression – retained to this day in the language of brewing – it has a much lower gravity. The hydrometer, which indicated the gravity of a sample, could thus be used to discover the proportion of alcohol present. It typically consisted of a long hollow stem made to float upright by a weighted bob at its base, to which additional weights might be attached. A sample of liquid was placed in a trial vessel, and the weighting on the hydrometer adjusted until it would just float in the liquid, with part of its stem above the surface and part below. The total weighting required rose in proportion to the gravity, and a conversion factor could be determined by calibration from direct mass and volume measurements. With most models, the density could be found more precisely from the depth to which the hydrometer sank: the mass of the stem was usually designed to coincide with the smallest weight difference available, and the determination made by reading off a scale (again established by precalibration), etched into the stem, at the point where it cut the surface of the liquid.

Clarke worked closely with the Excise authorities, to whom the establishment of a single, trustworthy standard was essential in minimizing conflict with the distillers. However, as Will Ashworth has recently recorded, this measure was only ever partially successful. There was doubt over the reliability of gravity measurements as a guide to spirit content: if a sample contained, besides spirit and water, sugars or other matter in solution – as all, in practice, did – this would raise the gravity and make the spirit content appear lower than it really was. From the Excise perspective, it was thus possible for

10 For the move away from reliance on the formerly dominant Land Tax, and increased use of the Excise and other means of indirect taxation, see J. Beckett, 'Land Tax or Excise: the levying of taxation in seventeenth- and eighteenth-century England', *English Historical Review* (1985), **100**, 285–308; J. Brewer, *Sinews of Power*, London, 1989, 95–101.

11 For the history of spirits taxation see F. Tate, *Alcoholometry: An Account of the British Method of Alcoholic Strength Determination*, London, 1930, pp. ix–xviii.

12 For the structure and day-to-day operations of the Excise, see Brewer, op. cit. (10), 101–14; but see also W. Ashworth, '"Between the trader and the public": British alcohol standards and the proof of good governance', *Technology and Culture* (2001), **42**, 27–50, on hostility towards the institution and the specific problems (discussed here below) faced in the spirits assessment case.

distillers to defraud the assessors by adulteration; the distillers responded that a certain proportion of sugary matter was naturally present in the unadulterated product, and contributed to the flavour and quality as perceived by the public. The ongoing controversy over this point culminated, in 1780, in what became a test case. Under charge of adulteration, the brandy merchants Steele and Co. mounted a strong challenge to the authority of the device, and although the verdict went against them, successfully highlighted the instrument's vulnerability. Ashworth goes on to discuss the steps taken by the Excise to shore up the hydrometric project: in 1787, as a provisional measure while a more reliable device was sought, the established model was enshrined in law as providing definitive readings.[13]

The situation was greatly complicated by rival instrument-makers who, following Clarke's death in 1746, were conspicuous in proffering numerous alternative devices, thereby weakening the intended consensus. One such was Benjamin Martin, a man seldom slow in spotting a new market or opportunity: he was at various times a philosophical lecturer, microscopist, philologist, magazine editor and spectacle-maker.[14] In 1762 Martin made a concerted play for the 'official' hydrometry market by dedicating to the Customs and Excise a work entitled *Theory of the Genuine Hydrometer*, in which Clarke's instrument was compared unfavourably to his own.[15] It was Martin, in fact, who lodged the first influential claim for the application of hydrometry to beer, in what appears, curiously, to have been a swiftly regretted piece of advertising hyperbole.[16] 1768 saw Martin, having failed to gain Excise support, and doubtless seeking sales outside the relatively small market of the distillery, advertising in very general terms his instrument's usefulness 'in discovering the strength of beer, ale, wine and worts'.[17]

At least two brewers, Richardson and James Baverstock of Alton, were sufficiently enthused by this claim to make experiments with Martin's hydrometer, and communicated with him on the subject. Both brewers found, oddly enough, that Martin himself had since abandoned the project: in Baverstock's words, 'having made his experiments on different sorts of *beers* instead of on unfermented worts, [Martin] found himself so bewildered and in such a labyrinth that he had abandoned the pursuit'.[18] The problem which raised

13 Ashworth, op. cit. (12), 36–48. Ashworth's account is informed by Theodore Porter's (op. cit. (4)) view of how a public body – in this case the Excise – may seek to exploit the apparent objectivity and precision of quantitative measurements to achieve particular ends – in this case the gathering of a huge Excise revenue with as little trouble as possible. It was this objectivity which in 1781 was placed on trial.

14 For Martin's life, and the topography and culture of the Fleet Street instrument trade of which he formed a part, see J. Millburn, *Benjamin Martin*, Leyden, 1976.

15 Ashworth, op. cit. (12), 35–6.

16 One known earlier account is a description, in W. Reddington's *A Practical Treatise on Brewing* of 1760, of a home-made gravimetric device intended for worts. It is unlikely, however, that the later brewers who developed the saccharometric project were aware of this innovation. Mathias, op. cit. (5), 70.

17 Quoted in J. Baverstock, *Treatises on Brewing: By the Late James Baverstock, Esq.* (ed. J. H. Baverstock), London, 1824, pp. xiii–xiv.

18 Baverstock, op. cit. (17), p. xiv (original emphasis); J. Richardson, *The Philosophical Principles of the Science of Brewing*, York, 1788, 116–17. This text contains Richardson's *Statical Estimates*, unaltered from 1784, with other works. Richardson deliberately omits Benjamin Martin's name from his account; that his 'late celebrated philosopher' is indeed Martin is, however, clear from Baverstock's son's account of the episode. See J. H. Baverstock in Baverstock, op. cit. (17), 256.

controversy in the distillery case was apparently of fatal proportions here. Beer, since it does not pass through a distillation process, unquestionably contains a very large proportion of dissolved, unfermented matter, which contributes its 'body' and flavour. In all practical cases this more than counteracts the gravity reduction due to spirit content, so that the gravity of beer is *higher* than that of water. By itself, the final gravity of a beer tells us nothing about its alcoholic component; this, if we believe Baverstock, is what Martin failed to grasp.[19]

A possible solution, however, was successfully explored by both Baverstock and Richardson. The gravity of wort – unfermented beer – is much higher than that of the finished product; wort is also much sweeter-tasting. It was therefore widely assumed that, during fermentation, most of the sugary materials dissolved in the wort were somehow converted into alcohol, with a corresponding falling-off in gravity – the thinning-out or 'attenuation' of the beer. If the gravity fell proportionately as the alcoholic concentration rose, then the difference between the original and final gravities would give a value which indicated the strength of the beer.

The route by which this mode of hydrometry became a standard practice among common brewers in the last years of the eighteenth century is obscure. Baverstock was undoubtedly the first to promulgate the principle privately. In 1770, besides communicating a long essay full of practical results and theoretical justifications to Martin, he attempted to interest major London brewers in the device, engaging the attention of a leading porter brewer, Henry Thrale.[20] Yet Baverstock's account, which suggests the device became generally popular in 1780, tellingly overlooks the significance of the first published text on hydrometric brewing, Richardson's *Statical Estimates of the Materials for Brewing*, which did not appear until 1784. This work discussed many principles which Baverstock had elaborated independently in the early 1770s, and which most of the brewers to whom he had communicated them privately had ignored. Obviously feeling the need to assert his priority, Baverstock himself published in 1785 a text, *Hydrometrical Observations and Experiments in the Brewery*, which (according to his son's testimony) was substantially equivalent in content to the sheaf of observations Baverstock had sent Martin back in 1770.[21] It is Richardson, however, whom brewers principally remember as the driving force behind the importation of hydrometric practices.[22]

Why were brewers more receptive to Richardson's entreaties in the 1780s than to Baverstock's in the 1770s? Economic factors must not be ignored. Peter Mathias, in his

19 Baverstock, op. cit. (17), 6–7.

20 Baverstock, op. cit. (17), 191. The major London breweries producing the brown beer known as porter were huge concerns in the eighteenth century, orders of magnitude greater in terms of plant and output than most provincial common breweries. We might assume that their systematic, industrialized operations and need for standardization made them natural candidates for the saccharometric approach: it should be noted, however, that Baverstock first approached Samuel Whitbread, whose brewery was the very largest of its kind, and was firmly rebuffed.

21 Baverstock, op. cit. (17), p. xx.

22 The tendency among brewers to consider Richardson's contribution as pre-eminent is exhibited in, for instance, T. Glendinning, 'A short account of the brewers' saccharometer', *Journal of the Federated Institutes of Brewing* (1900), **6**, 358. It is evidently widely dispersed in the secondary literature and can also be found in accounts not specific to the brewery. See for example J. Yeats, *The Technical History of Commerce*, London, 1871, 234.

substantial economic history of brewing in the period, draws attention to the steady rise in the price of raw materials over the intervening period, which forced brewers (whose retail prices were effectively fixed) to seek economies.[23] However, other differences need to be considered. Richardson went further than Baverstock in fashioning a distinct identity for the hydrostatical brewery instrument, tying it closely to the circumstances of its operation; this would have the additional advantage of distancing it from the ongoing confusion and controversy over the distillers' hydrometer.[24] At the same time, he worked to define a quantitative notion of value applicable to beer, for which his vision of the instrument could serve as a standard measure. The considerable delay in publication may well be attributable to the work needed to establish reliable results in support of this wider strategy.

The definition of the saccharometer

Richardson's publication of the *Statical Estimates* was accompanied by the unveiling of a new hydrometrical device, designed according to Richardson's own specifications and manufactured by a sole instrument-maker, John Troughton of Fleet Street. It is not known exactly what prompted the connection, though we should certainly see nothing odd in a provincial brewer's business association with a London-based maker of philosophical instruments. Richardson advertised himself not only as a practising commercial brewer, but also as a consultant advising others on efficient methods. A member of the Hull Literary and Philosophical Society, he was typical of a generation of professional men whose increasing literacy promoted a theoretical, 'scientific' approach to practical problems, often contrasted in print with the apparently hidebound attitudes of more traditional contemporaries.[25]

Richardson was not a Hull native: he was born in rural Cambridgeshire in 1743 and apparently lived for some time in Liverpool before moving to Hull, where around 1783 he took on the North Brewery, Wincolmlee, in partnership with John Dobson, a former merchant, probably a Liverpool acquaintance. It is Richardson's London connection, however, which is most significant for us. Local historians have suggested that Richardson served his apprenticeship in one of the major London breweries: a metropolitan background seems probable in view both of his obvious familiarity with London practices and of his firm's activities within the local market.[26] Richardson's was the first brewing firm in Hull systematically to build up a pub estate: at the time, most public houses in Yorkshire were independent, each brewing on a small scale for its own use, whereas in London, the south-east and East Anglia, the pattern had shifted towards large 'common

23 Mathias, op. cit. (5), 71–2.

24 I am grateful to an anonymous referee for raising this suggestion.

25 For rhetoric of this kind in Richardson's work, see for instance Richardson, op. cit. (18), 83–5.

26 P. Aldabella and R. Barnard, *Hull and East Yorkshire Breweries*, East Yorkshire Local History Society, 1997, 9, 80–1. The authors mention an advertisement for one of Richardson's early works, published in 1777 (prior to his move to Hull), which gives as contact address a coffee-house in Fleet Street. There was thus a period for which Richardson was based, or at least had regular business, in close proximity to the hub of London's philosophical instrument trade – although John Troughton did not take up premises in Fleet Street until 1782.

brewers' supplying most of the local trade.[27] By the 1800s the North Brewery was probably the largest in Hull. It was still nowhere near the size of the huge London porter concerns, but this intermediate position may have worked to Richardson's advantage, allowing him to appeal simultaneously to modernizing metropolitans and aspirant rural victuallers.

As we shall see, Richardson was aiming to create a monopoly over hydrometry in the brewing world, establishing his own instrument, methods and interpretations as the sole authorities. Yet in 1784 the hydrometer was already a firmly established device; if it was not necessarily known among traditional brewers, it was certainly familiar to natural philosophers, Excisemen and distillers as an instrument with a considerable historical pedigree. Richardson plainly could not present the hydrometer to the brewing world without acknowledging this history, and so could not make the case for sloughing off all the interpretations, practices and controversies which had already surrounded it. He therefore performed a neat terminological sidestep: the device Richardson presented to the world was described not as a hydrometer but as a saccharometer.

Did this coinage truly describe an instrument distinct from the hydrometers of Martin and Clarke? The new device measured gravity by its weighting and depth of fall according to the established principles and, to judge from the frontispiece illustration in the *Statical Estimates*, looked very much like the hydrometers in use at the time. Yet Richardson was adamant that his device was conceptually separate from what had gone before, and quite specifically characterized his application of hydrostatic principles to beer-brewing as a new development. His justification was that no hydrometric project before his own had satisfactorily met the needs of the brewers in particular, for want of adequate specialization.[28] This assertion was backed by several features of the instrument itself and of the account Richardson gave of it.

One key property supporting the distinction was the saccharometer's effective range. The brewing and distilling industries both began their processes with the extraction and fermentation of sugary substances, so the upper limits of gravity measurement might be similar in both cases. Only distillers, however, would need a measure for those values below the gravity of water: the lowest gravity value a brewer should encounter in normal practice would be that of water, and he would be most concerned to have trustworthy readings for his original gravities. In fact, any hydrometer could be made to give readings in a particular gravity region, given the appropriate set of weights; the question was how reliable the device would be in that region. This was determined by how much attention had been paid to the instrument's calibration within that region at the time of its construction: a device purpose-built by someone with an understanding of the brewer's needs might therefore be expected to function more reliably in a brewery setting.

Richardson accordingly devoted some space in the *Statical Estimates* to describing his early experiments in calibrating a hydrostatic instrument. He began by establishing a zero

27 The estate-building project was imitated by other Hull brewers, with the result that the port became noticeably anomalous within Yorkshire, where individual on-site brewing remained the norm well into the nineteenth century. In the 1850s and 60s around eighty per cent of excised malt in Hull was brewed by large common breweries, as against fifty-eight per cent in York, nineteen per cent in Sheffield and twelve per cent in Leeds. See P. Clark, *The English Alehouse 1200–1830*, London, 1983, 265–7; K. Allison (ed.), *A History of the County of York*, *East Riding*, Oxford, 1969–, i, 'The city of Kingston upon Hull', 266, n. 84.

28 Richardson, op. cit. (18), 116.

for it in distilled water, then applied it to a sample of his wort, adding weight until the zero was regained. He then weighed half-barrels of the water and the wort, presumably with a large beam balance, and established the difference between them. Tests on other worts confirmed that this difference rose linearly with the weight required to sink the saccharometer.[29] This account drove home the point that his device was a brewer's innovation through and through, rather than, as we might alternatively consider it, an adaptation of a distillery tool well-known to instrument-makers, distillers and Excisemen. An anonymous 'friend' who performed more precise experiments on Richardson's behalf – detailed in a letter to Richardson added as an appendix – tells us explicitly that he planned, at one point, to investigate the gravity region particular to the spirits trade, but did not consider 'the necessary toil of wading through liquors, comprehending such a variety of density' worthwhile, given the limited market presented by the distillery as compared with the brewery.[30]

We might also consider Richardson's choice of instrument-maker. The firm of John Troughton (later J. & E. Troughton) was one of the most renowned in the London trade, with a particular reputation for engineering accurately divided scales, chiefly for astronomical instruments. John's brother Edward Troughton, who ran the business alone following his brother's death in 1807, was generally acknowledged to be London's foremost instrument-maker after 1800.[31] The prestige of the Troughton name would certainly have been helpful to Richardson's purpose, and does not go unmentioned in his account of the instrument,[32] but we might speculate as to the possible relevance of another factor. The name of Troughton had not, unlike those of several other leading makers, been conspicuous in the fraught and sometimes unseemly scrambling for position associated with the spirits hydrometer.[33] Richardson's choice arguably gave him additional insurance against negative comparisons, while the Troughtons for their part gained early access to a largely unexplored market for gravimetric devices.

The Richardson–Troughton device also possessed one undeniable novelty, the 'regulator'. This was a sliding attachment designed to correct mechanically for local

29 Richardson, op. cit. (18), 95–102. The account is puzzling: the device under discussion is seemingly the finalized saccharometer itself, made to Richardson's own instructions, yet he also presents himself as discovering the instrument's properties for the first time in this calibration process. Perhaps the narrative is in truth based partly on his earliest experiences with the Martin hydrometer: Richardson would naturally have sought to downplay the significance of the precursor instrument.

30 Richardson, op. cit. (18), 324. The identity of this 'friend', who wrote from London and whose initials were given as 'W. D.', seems to be lost; Glendinning (op. cit. (22)) remarked on the mystery in 1900. The content of W. D.'s letter suggests him to have been a non-brewer, well versed in hydrostatic theory and skilled in the manipulation of instruments. We might reasonably speculate that he was himself an instrument-maker: however, I have not as yet uncovered any likely suspects bearing these initials (which are not, of course, necessarily genuine).

31 For the Troughtons, and their place in the London instrument trade, see A. Skempton and J. Brown, 'John and Edward Troughton, mathematical instrument makers', *Notes and Records of the Royal Society* (1972–3), **27**, 233–62; A. McConnell, 'From craft workshop to big business – the London scientific instrument trade's response to increasing demand, 1750–1820', *London Journal* (1994), **19**, 36–53. Note that John Troughton did not die in 1784, the year of the publication of the *Statical Estimates*, as some secondary sources suggest.

32 J. Richardson, *Philosophical Principles of the Science of Brewing*, York, 1805, 457.

33 The Troughtons did, however, later submit an instrument (without success) in response to an 1802 call for a new device to serve as the official Excise spirit hydrometer. Tate, op. cit. (11), 8.

variations in the gravity of the water used for brewing, so that dissolved mineral salts were not counted as part of the extract. Before first using the saccharometer, the brewer would float it in a sample of the water he planned to use, and manually adjust the regulator until the waterline corresponded to a zero mark. The instrument was now appropriately localized as the 'equipoise or representative' of the water.[34] The regulator evidently served the useful purpose of demonstrating that the saccharometer was not just a hydrometer and, specifically, signalling to potential buyers that its inventor was informed of the particular needs of the brewery. This, in fact, was probably the regulator's primary purpose: it is hard to see why else Richardson would have put Troughton to the considerable effort of engineering to acceptable precision this mechanical correction factor, when a simple numerical operation could have been used for the same purpose. Indeed, Richardson's original plan was to add a further sliding regulator to deal with the dependence of the readings on temperature. The addition of a further mechanical correction, besides taking the device further away from the standard perception of the hydrometer, would have introduced even more adaptation to brewery conditions; as Richardson's 'friend' points out, however, technical difficulties overcame this scheme.[35]

Not only did Richardson's monopolistic scheme make him the creator of the saccharometer and, via Troughton, its sole supplier; he also sought, by means of the *Statical Estimates*, to become its sole interpreter. Unlike many technological innovators, Richardson was manifestly unconcerned with presenting simplicity as a point in the instrument's favour. The claim that the new-style, saccharometric brewer must be literate and 'scientific' accommodated the construction of a highly complex set of rules for the best operation of the saccharometer. The *Statical Estimates* prescribed when and where in the brewing process it should be used, how the readings should be corrected and how initial results could be used to determine – via painfully laborious arithmetical digestion – the best practice for the remaining part of the brewing operation. Copious use was to be made of Richardson's numerous tables which corrected for temperature, the effects of evaporation and so forth.

The tables were supplied in a book with the saccharometer, as were 'Directions for using the instrument'; even with these in his possession, however, the inexperienced brewer would have found the operation of the instrument a rather opaque business without the detailed procedural explanations in the *Statical Estimates*. Equally, the relevant passages of *Statical Estimates* were written with exclusive reference to the Richardson saccharometer's construction and scale, and so each effectively required the other; indeed, the book might well be viewed as an extended advertorial for the instrument. A description of the device, with the price quoted as three guineas, appears at the close of the book, with Troughton's address and a note that 'Country brewers may be supplied by means of their booksellers, who have correspondents in London'.[36]

The neologism 'saccharometer' itself, finally, helped to engineer the distinction. We should note that other specialized hydrometers were similarly christened by other

34 Richardson, op. cit. (18), 97.
35 Richardson, op. cit. (18), 322 n.
36 Richardson, op. cit. (18), 345.

innovators – the 'lactometer' for milk, 'acetometers' for vinegar, and so forth.[37] Richardson's choice of term perhaps requires a little more explanation than these. In making his device a 'sugar-measure', he emphasized the divide between the brewers' and the distillers' use of gravimetric methods: whereas the distillery (and the Excise) were chiefly concerned with the finished product and its state of rarefaction relative to pure water,[38] the brewers made their most important measurements before the fermentation process had even begun, and hence were concerned not with alcohol itself but with the sugary solubles which went to produce it. As will be discussed later, Richardson made the quantification of these solubles central to his whole philosophy of brewing.

On a variety of fronts, then, Richardson worked hard to define the saccharometer as both distinct from the distillery hydrometer, and solely under his authority. In doing so, he furthered the construction of the quantity measured by his saccharometer as a distinct conceptual entity, forestalling the kind of controversy which had arisen in the spirits case by establishing a single device as the universal standard – not only at the Excise level, but among the brewers themselves. This was, at the time, a far more important matter than asserting the gravimetric accuracy of the device (which was considered at length in the anonymous appendix but barely addressed in Richardson's own text): once the saccharometer was suitably entrenched as an authority in its own right, it need not be justified by appeal to the hydrostatic principles which had spawned it.

The contingency of Richardson's approach can profitably be illustrated by comparison with Baverstock's equally evangelical efforts in the same field. No doubt as a result of the aforementioned discontent over priority, Baverstock defined a conceptual agenda just as strong as that of Richardson himself, first expressed in an appendix to his 1785 text. Carefully unpicking Richardson's work of establishing the separateness of the saccharometer, Baverstock first criticized the regulator – 'the only novelty of it as a hydrostatical contrivance' – as both unnecessary and prone to errors caused by slippage, wear and tear and possibly leakage. A more serious problem, Baverstock contended, was Richardson's method for obtaining the desired strength of worts on the basis of saccharometric readings. This potentially required long evaporations to provide the required concentrations, and depended on a laborious calculation process. Baverstock, who recommended a rather simpler scheme involving the mixing of worts, considered the evaporation method impractical, unreliable and superfluous, and cast the calculation procedure which directed it in the same light. In doing so, he worked to divorce the saccharometer from the *Statical Estimates*, breaking down Richardson's monopolistic dependence relation.[39]

Its regulator aside, Baverstock raised no objections against the saccharometer as a measuring device. In fact, it well suited his purpose not to, but rather to stress his

37 A. Morrison-Low, 'Hydrometer', in *Instruments of Science: An Historical Encyclopedia* (ed. R. Bud and D. Warner), New York, 1998, 311–13; J. Burnett, 'William Prout and the urinometer: some interpretations', in *Making Instruments Count* (ed. R. Anderson, J. Bennett and W. Ryan), Aldershot, 1993, 242–54.

38 No term other than 'hydrometer' was ever in common use to describe the British distillery instrument. A French device constructed by Gay-Lussac, which gave direct percentage readings of alcohol by volume, was dubbed the 'alcoholometer'. W. Garnett, entry for 'Hydrometer', *Encyclopædia Britannica*, 1910, 164.

39 Baverstock, op. cit. (17), 96.

impartiality as to the claims of different instrument-makers, and therefore to place the saccharometer on a level with any other hydrometer.[40] The *Hydrometrical Observations* contained a section on the question of variation between hydrometers, in which Baverstock argued that the only true distinction was in the scale used. Even this was 'a matter of the most perfect insignificance': Baverstock claimed to have tested five hydrometers then on the market, and to have developed simple arithmetical conversions between their readings.[41] We may question the degree of his success in conforming the different devices to each other, but it is clear that he believed the future of measurement in brewing lay in this project of conformation, rather than in the privileging of a single device. An 'Advertisement' added to the text later in 1785, prompted in part by some remarks (not extant) of Richardson's concerning the appendix, proclaimed, '*All* the hydrometers now made, those intended merely for spirits excepted, *speak a language* expressive of the superiority or inferiority of worts to each other; and that, besides shewing the difference in water, is all that a brewer has to require of the instrument.'[42] The issue of differing degrees of accuracy in different gravity regions was not discussed.

Richardson, ultimately, did not achieve his aim of establishing sole control over the saccharometer. One drawback to Richardson's reliance on a neologism was his inability to control it: the term 'saccharometer' was rapidly applied, by various established hydrometrists, to numerous instruments with a greater or lesser degree of brewery specialization. Lacking even the limited protection afforded to Clarke by the official sanction of the Excise, Richardson was powerless to prevent other makers cutting in on a market he was chiefly responsible for opening up.[43] Yet Baverstock's contention that all gravimetric devices are effectively interchangeable was not accepted either. The interpretation which developed among later brewers – that the saccharometer represents a special case of the hydrometer, adapted to the brewer's purpose – can be seen as a middle ground between the two theorists' positions and demonstrates that Richardson's rhetoric concerning the idea of a dedicated brewery appliance did lodge itself in the brewing community's mindset. To fully understand the appeal of Richardson's scheme of measurement, we must now consider in more detail the quantity which was being measured.

40 Baverstock, op. cit. (17), 96.

41 Baverstock, op. cit. (17), 61–4. The Curtis museum in Baverstock's home town of Alton, Hampshire, has an Atkins hydrometer once in the possession of Baverstock and presumably used in this project. Both Atkins and Benjamin Martin also attempted conformations with other makers' instruments, evidently with a view to capturing their trade. Martin (who presumably influenced Baverstock) created a correspondence table relating his values to Clarke's, whilst Atkins sometimes sent his devices out with specially made scales which would read in the units of both Clarke and another leading hydrometrist, Dicas.

42 Baverstock, op. cit. (17), 101. Original emphasis.

43 Perhaps because the Troughtons' interests lay primarily in other directions, the reputation for the production of the most accurate saccharometers settled early in the nineteenth century on the firm of Dring and Fage, already a powerful force in hydrometry since they were now the official manufacturers of the Excise-approved Clarke device; see Tate, op. cit. (11), p. xviii. Nineteenth-century accounts typically praise Richardson's theoretical contribution whilst downplaying the contemporary value of his instrument; see for example F. Accum, *A Treatise on the Art of Brewing*, 2nd edn., London, 1821, 104–23; A. Morrice, *A Practical Treatise on Brewing the Various Sorts of Malt-Liquor*, 7th edn., London, 1827. Dring and Fage themselves appear to have acted as agents for Morrice's book, which strongly advocated their device.

The saccharometric extract

The units in which Benjamin Martin's hydrometer was scaled were meaningful only within the distillery. Baverstock, who used the Martin device exclusively in his early work, retained these units and did not seek a more brewery-specific scaling.[44] It was important to him only that gravity had been quantified; the units employed were arbitrary, and might reasonably have no material significance at all. The more conceptually territorial Richardson took an opposite course. His saccharometer measured on a scale of 'pounds-per-barrel extract', later known simply as 'brewers' pounds': this system had a major effect on brewing and the scale remained in quite general use well into modern times.[45]

The operational description of the instrument's calibration in the *Statical Estimates*, mentioned earlier, indicates how the scale came about. By direct weighing, Richardson established that a barrel of the first wort sampled was thirty-nine pounds heavier than a barrel of distilled water. He therefore proclaimed that the weighting needed to sink the saccharometer in a sample of that wort was the 'representative' of this increase of thirty-nine pounds per barrel.[46] Since the gravity of wort increased linearly with the load on the saccharometer, he thereafter expressed all gravity values on the pounds-per-barrel scale. The actual physical masses of the weights loaded onto the saccharometer were, as far as the brewer was concerned, immaterial; again, here, we see the instrument, and the values it produced, being established as independent from its hydrostatic roots.

Note that Richardson's system focused the user's attention on the additional density found in worts: that is, on the extent of the positive contribution made by the mashing process, in which the malt was infused in water. Habituating the brewer to the pounds-per-barrel scale facilitated interpretation with reference to the extract, the soluble sugary material extracted from the malt during mashing. Richardson's overall goal was to establish, in the brewers' minds, the readings from his saccharometer as a quantification of the 'value' contained in a wort. He achieved this by defining value exclusively in terms of the extract, an apparently uncontroversial but hugely significant step. Extract, crucially, was something tangible: it was possible – though not a common analytical practice – to evaporate off the water from a sample of wort, leaving the extract behind as a sweet-tasting mass. The weight of this 'dry' extract and the brewers'-pounds measure of liquid weight increase were not, in fact, equivalent quantities (a point Richardson elaborated, but which seems to have given some confusion to 'brewery pupils' as much as a century later);[47] they were, however, linearly proportionate, and this was sufficient for Richardson's purposes.

The pre-existing concept of the extract performed much the same role for saccharometry as had the 'breathability of air' for eudiometry: it was an entrenched idea, familiar to all the interested parties, with reference to which the benefits of a quantitative treatment could be spelt out in practical terms. Yet Richardson's quantification scheme entailed a subtle shift in priority. The pre-saccharometric notion of extract was needed to justify the

44 Baverstock, op. cit. (17), 256–7.

45 Corran states that the scale has 'not yet in 1974 become obsolete'; more recently it has lost ground to the conventional specific gravity scale. Corran, op. cit. (6), 136.

46 Richardson, op. cit. (18), 98–9.

47 Glendinning, op. cit. (22), 363.

pounds-per-barrel measurement; once the proportionality was established, however, the precedence was reversed. The directly quantified extract itself – the mass of sugary material – never appeared in Richardson's operational procedures; 'extract' could now be determined, and hence was exclusively defined, by the instrument's reading.

Perhaps the most important conceptual principle in the *Statical Estimates* is Richardson's building up of the extract as a replacement for the only pre-existing quantity available to the brewer in determining the strength of his beer: the volume of malt used in the mash. It was well understood that this did not correlate particularly well with the evidence of taste or intoxication: the quality of malt was affected by growing climate, malting procedure and a host of other unseen factors. However, volume was easily quantified, and seems to have been relied on as a tolerably accurate guide – Richardson at one point discusses the apparently familiar case of a brewer attempting to emulate the beers of another region on the basis of malt volume data.[48] Richardson sought to sweep away not just this practice but the whole notion of a 'guide' to strength. The saccharometrically determined extract was not merely a 'better' means of assessment: strength, under the definitions Richardson imposed, is precisely that quantity recorded by the saccharometer. To borrow Schaffer's term, strength was 'elided' into extract, just as the extract had been elided into the quantity defined by the hydrometer.[49]

Richardson gives us a colourful account of exactly the kind of brewing mentality he sought to overturn. He cites the example of two samples of 'the same kind of barley, under the management of two different maltsters'. Saccharometry revealed a difference in extract per bushel of nine per cent,

> and yet these two parcels of malt would have passed, among common consumers, with this [*sic*] simple observation that *this sample is freer than that*; the difference in sale, would not, perhaps, have exceeded a shilling per quarter; and the brewer would have thrown them indiscriminately into the mash tun, drawing his usual length from each, to the positive loss of 9 per cent. either in the quality of his liquor from the latter parcel, or in the obtainable profits of his trade from the former; which ever might happen to tally with the general quality of the malt he used.[50]

Critically, there was in this analysis the notion of a pre-existing standard: each brewer aimed to brew his beer to a specific strength to be sold for a specific price. This standard of strength would certainly be more closely determined than the Excise category in which it fell, but it would still be rather broadly defined. The variation in the quality of malt inevitably caused the strength to fluctuate: if it rose too high the brewer would realize he was making an undue expenditure on malt, and if it fell too low the customers would object; with only the evidence of taste as judge, there would be a broad band in the middle within which both parties were satisfied. With the introduction of the saccharometer, however, 'strength' was redefined as a rigorous and replicable quantitative standard. Richardson's technology imposed a sharply defined optimum of strength: any deviation from this value worked to the brewer's disadvantage, entailing either the certainty of customer dissatisfaction or a determinable waste of materials. Once established, then, the saccharometric standard had to be maintained. Whereas, in the spirits case, the proof scale

48 Richardson, op. cit. (18), 289–90.

49 Schaffer, op. cit. (2), 288: 'Respirability elided into dephlogistication, dephlogistication into health, health into virtue'.

50 Richardson, op. cit. (18), 164–5. Original emphasis.

embodied by the Clarke hydrometer became an inevitable part of practitioners' lives through brute force of legislation, with all the difficulties that implied, the inevitability Richardson projected in the brewery rested on an appeal to the brewers' own interests.[51]

Richardson's next step further extended the appeal of his scheme to the brewers. By analysis of extract values, he submitted the above-mentioned variation in malt quality to a quantitative determination. Brewers and maltsters were already in the habit of grading malt on the basis of its physical appearance, which provided a rough guide to quality. Richardson proclaimed that there were even greater 'invisible' differences in extractive potential: he advanced results suggesting that some apparently 'indifferent' barley was more extractible than 'well-made' samples produced in different years or locations. Brewers could now abandon qualitative judgements 'to which no positive idea can be fixed, because they are relative to no standard of comparison'.[52] Richardson claimed to be able to 'estimate the intrinsic worth of every kind of malt, to the very great precision of the one-thousandth part of the fermentable matter extracted from every quarter employed'. This revealed 'a great variety in malts, which, but for these discoveries, would scarcely have been deemed of different value'.[53] In downgrading the evidence of the brewer's own eyes, Richardson aimed to install the saccharometer as the chief arbiter of quality, and extractibility as the chief criterion for selection; at the same time, by tying the extract to the concept of economic value, he strengthened the prospect of its adoption.

Richardson was very explicit on how the value of malt might be standardized. Presumably proceeding from his own more general experience, he nominated a standard reference value, '82 pounds [per barrel] produce' to represent 'what is now termed *good malt*', and calculated the values of the several malts included in his survey relative to this figure. He also nominated the term 'par' to express malt values, by direct analogy with the concept of 'proof' in spirits, a sample of malt being described as so far above or below par. He even sketched out a plan for a possible

> apparatus for ascertaining the value of malt to the purchaser or maker, independent of the consumer; in order that the buyer and seller of that article may adopt a clear and explicit language, conveying definite ideas which by common usage may become as familiar to each other, and as well understood, as the terms used by the importers and dealers in spirits.[54]

Richardson's message was one of empowerment for the brewer, who was no longer reliant on maltsters' claims regarding the efficacy of their practices; the judgement of the saccharometer could be applied in deciding the merits not only of individual samples of malt, but of entire customs of malt-making. Richardson noted with interest the consistently

51 The saccharometric project is interesting as a case where practitioners were driven to seek greater precision than the legislature had imposed. More commonly, as in the spirits case, the legislature appeals to the precision of its methods in imposing a quantificatory scheme (see notes 4 and 13 above). We might speculate that the serious difficulties which transpired in the distillery influenced Richardson against presenting his scheme directly to the Excise.

52 Richardson, op. cit. (18), 171.

53 Richardson, op. cit. (18), 158–9.

54 Richardson, op. cit. (18), 170–1. Richardson never constructed, or at least never marketed, such an instrument, although the proposition evidently provoked interest. The third and final edition of his collected work, published in 1805, contains a footnote: 'Enquiries having been addressed to me on the subject of this apparatus, I think it right to say that an atention [*sic*] to more material avocations has hitherto prevented my prosecuting the idea, which, however, is not entirely relinquished'. Richardson, op. cit. (32), 253.

low extracts from malts made by the procedure characteristic of Ware in Hertfordshire. Ware brown malt was produced mainly for the London market and was the principal choice of the major porter brewers, commanding the highest prices: 'credibility would be staggered' at the idea that this premium product could be so inferior, wrote Richardson, 'were it not mathematically demonstrable'.[55] This was the nub of Richardson's argument: 'mathematical demonstrability' would, he boldly stated, be sufficient to turn the popular prejudice on its head and price would become a function of extractibility.

On this matter, there is evidence that Richardson's scheme came to fruition. Brewing in the eighteenth century had been characterized by the rise of the major industrial porter breweries, which predominantly used brown malt. This was dried at high temperatures, usually over wood fires, and tended to be scorched, smoky and dark in colour. In general, the higher grades of barley were reserved for the more delicate process of making pale malt, often dried over the more expensive coke, and used in fine ales. Brown malt was cheaper than pale, but was assumed to be correspondingly less extractible. The saccharometer provided the first quantitative interpretation of this long-established understanding: following up his observations on Ware malt, Richardson found that the extractibility of brown malts in general was lower than the price differential suggested.[56] Richardson collected new extract results for each year's malts and published them cumulatively in succeeding editions of the *Statical Estimates* to 1805.[57] Mathias attributes principally to Richardson's activism a major shift in the porter brewers' practices as they saw the economic sense of demanding and using the more extractible pale malts. To preserve the characteristic colour and flavour of porter, small amounts of much darker malt were added: 'Disguised as far as possible initially from the consumer – who wanted porter to taste as he had known it always to have tasted – hidden changes in manufacturing occurred as the saccharometer came into use'.[58]

We can draw an important point out of Mathias's summary. So keen was Richardson to standardize the extract as a determinative criterion that all other factors were sidelined: in his analysis, a beer was truly determined by the original gravity of its wort. Other, apparently defining features, such as colour or bitterness, were virtually ignored. This was in spite of their obvious economic significance: London porter, the distinctive colour and taste of which were defined by brown malt, was effectively a badge of identity for the drinkers of the metropolitan working class, to whom pale ales carried associations of the countryside or of undue refinement. The 'hidden changes' effected by the brewers can therefore be viewed as their means of reconciling Richardson's stark, reductionist

55 Richardson, op. cit. (18), 161.

56 Richardson, op. cit. (18), 163–4; Mathias, op. cit. (5), 414–16.

57 Richardson, op. cit. (32), 249–52. Mathias perhaps overstates the case in referring to Richardson's 'proving conclusively' (op. cit. (5), 415) the superiority of pale malt over the years. The figures in the 1784 edition, and those for 1787 and 1788, do give clear support, but after this date there is often little difference between Richardson's values for 'pale' and for 'brown and pale mixed'. Richardson's accompanying text in the 1805 edition problematizes the figures somewhat: his claim for the superiority of pale malt is unamended. The figures later produced with reference to the same point by F. C. Accum (see below), also mentioned by Mathias, are similarly ambiguous.

58 Mathias, op. cit. (5), 72–3. See also Baverstock Jr.'s comments: J. H. Baverstock in Baverstock, op. cit. (17), 189–90.

efficiency lessons with the need to retain their customers' goodwill. Later writers, such as the chemist F. C. Accum – whose 1820 work on brewing theory reiterates many of Richardson's points, also invoking saccharometric data in their support – take this into account: Accum suggests the use of burnt sugar to obtain the correct colour.[59] In the beginning, however, some limitation in scope was plainly necessary in order for Richardson's overall project to be established: the clarity introduced by his single-minded privileging of the quantified extract was arguably crucial to its intelligibility and hence to its ready adoption.

Having painstakingly constructed his own system of assessment, Richardson allowed himself a few remarks, in the introduction to the *Statical Estimates*, on that operated by the Excise authorities. We should not be surprised to find Richardson roundly derisive of the 'darkness' in legislative thought represented by the uniform duty bands, the reliance on the Exciseman's sensory powers and the 'ridiculous restrictions' preventing the mixing of beers. Richardson's saccharometric extract measurements, in contrast, could be taken to express both strength and commercial value, which permitted – indeed, were defined by – a convenient and authoritative means of determination, and gave precise quantitative figures to which taxation might be proportionated. 'Were the duties shaped according to the gravity of the wort', Richardson wrote, 'these altercations would immediately vanish, the revenue would be increased, the brewer would be at liberty to make, alter, or compound his liquor into as many and as various sorts, as he has palates to please, without subjecting himself to the interference of the officer, or the lash of the law'.[60] So neatly is the argument woven, it is hard to escape the conclusion that this final extension had been in Richardson's mind throughout the project's development.

Of course, it was not in Richardson's power to proclaim a change in the Excise legislation. Yet developments in the spirits case suggested a strong commitment to the principle of gravimetric assessment and it seemed plausible that the economically powerful brewing lobby might exert sufficient pressure to force a change. Richardson provided plentiful inducements: as he described it, the saccharometer would not only put a stop to costly legal disputes and facilitate the tailoring of strength to customer demand. It would also ensure revenue was drawn from the brewer in direct proportion to the known value of his raw materials, since all the relevant quantities were rated directly to the saccharometric standard. The unified system, at least in theory, would have obviated most of the unknowns and irregularities which made brewing an economically fraught, and often perilous, business. This, then, was the ultimate vision Richardson offered to his trade, and its acceptance rested squarely on the acceptance of his quantity, the pounds-per-barrel extract, as measured by his instrument, the saccharometer.

Conclusion

Richardson's followers had a long wait before his dream of a direct Excise levy on the saccharometrically determined gravity of worts came true. The vagaries of the British legislative process, coupled with parliamentary desires to keep various interests besides

59 Accum, op. cit. (43), 27.
60 Richardson, op. cit. (18), 87–9.

those of the brewers satisfied, led to a peculiar and drawn-out sequence of events, whereby the uniform duty bands persisted until 1830 and were then replaced by a tax proportionated to the volume of malt and other materials used, invoking the very quantification Richardson had sought to discredit. Although Richardson's pounds-per-barrel scale and saccharometers of various kinds were by then in universal use among the common brewers, the legislature ignored the possibility of gravimetric assessment for a further half-century; then, in 1880, the malt duty was swept away, to be replaced by a levy in direct proportion to the original gravity of worts, roughly along the lines Richardson had suggested.[61] This arrangement persisted, through various modifications, until 1993.

This result, I would argue, serves as testament to Richardson's ultimate success in at least one of his aims: the enshrining of the pounds-per-barrel extract as a fundamental unit. This is only accentuated by the fact that, a hundred years on from the *Statical Estimates*, most of Richardson's theoretical work in privileging the extract had fallen by the wayside. As we have seen, Richardson made careful use of pre-existing brewery interpretations, playing on his fellow brewers' economic concerns and sense of identity, and thereby divorced the project from the distillery context which had made it possible. Most other brewing theorists – including Richardson's rival Baverstock – tended to the distillery-derived view that alcoholic concentration represented the sole principle of intoxication, and was therefore a potential marker of economic value; because Richardson's extract-based criterion was not proportional to alcoholic content, he could not accept this claim, and was led to develop an awkward theoretical compromise which he could not realize to his own satisfaction.[62] Over the course of the nineteenth century brewing chemists steadily deconstructed Richardson's notion of 'extract', identifying separate constituents which would ferment at different rates, some being directly converted to alcohol, others providing 'body' and other features which held no place in Richardson's analysis.

Yet, in 1880, a measure directly proportionate to Richardson's pounds-per-barrel extract became the sole criterion for Excise duty: the legislators, it was made clear, interpreted the 'value' of beer as subsisting unequivocally in the matter dissolved in the wort which produced it, rather than the intoxicating effect it would produce.[63] This, it seems to me, can only be understood when we appreciate that the pounds-per-barrel measure, having been in customary use among brewers for most of a century, was now so firmly entrenched in the brewery context as to require no justification: it was simply a given, a fundamental indicator of value in its own right. Richardson's ship had long ago entered its bottle.

61 Mathias, op. cit. (5), 73; J. Nettleton, *A Study of the History and Meaning of the Expression 'Original Gravity', as Applied to Beer, Worts and Distillers' Wash*, London, 1881, 3–6.

62 Richardson, op. cit. (18), 251–3. Richardson's resolution – invoking the gas present in beer as an additional principle of intoxication – presents an intriguing case which I hope to discuss further at a later date.

63 Nettleton, op. cit. (61), 7. Assessment on the basis of original gravity persisted with various minor modifications until 1993, when it was replaced by the alcohol-by-volume scale traditionally associated with the distillery. This final legislative abolition of the saccharometric scheme perhaps reflects the increasing marginalization, in Great Britain, of the brewery culture Richardson stood for, and would repay further study. For a summary account of the complex issues and interests involved, see P. Ogie, 'UK beer duty: a brief history', in *Beer, Glorious Beer* (ed. B. Pepper and R. Protz), London, 2000, 112–14.