AMBIX, Vol. 54, No. 1, March 2007, 5–29

Michael Combrune, Peter Shaw and Commercial Chemistry: the Boerhaavian Chemical Origins of Brewing Thermometry

JAMES SUMNER

University of Manchester

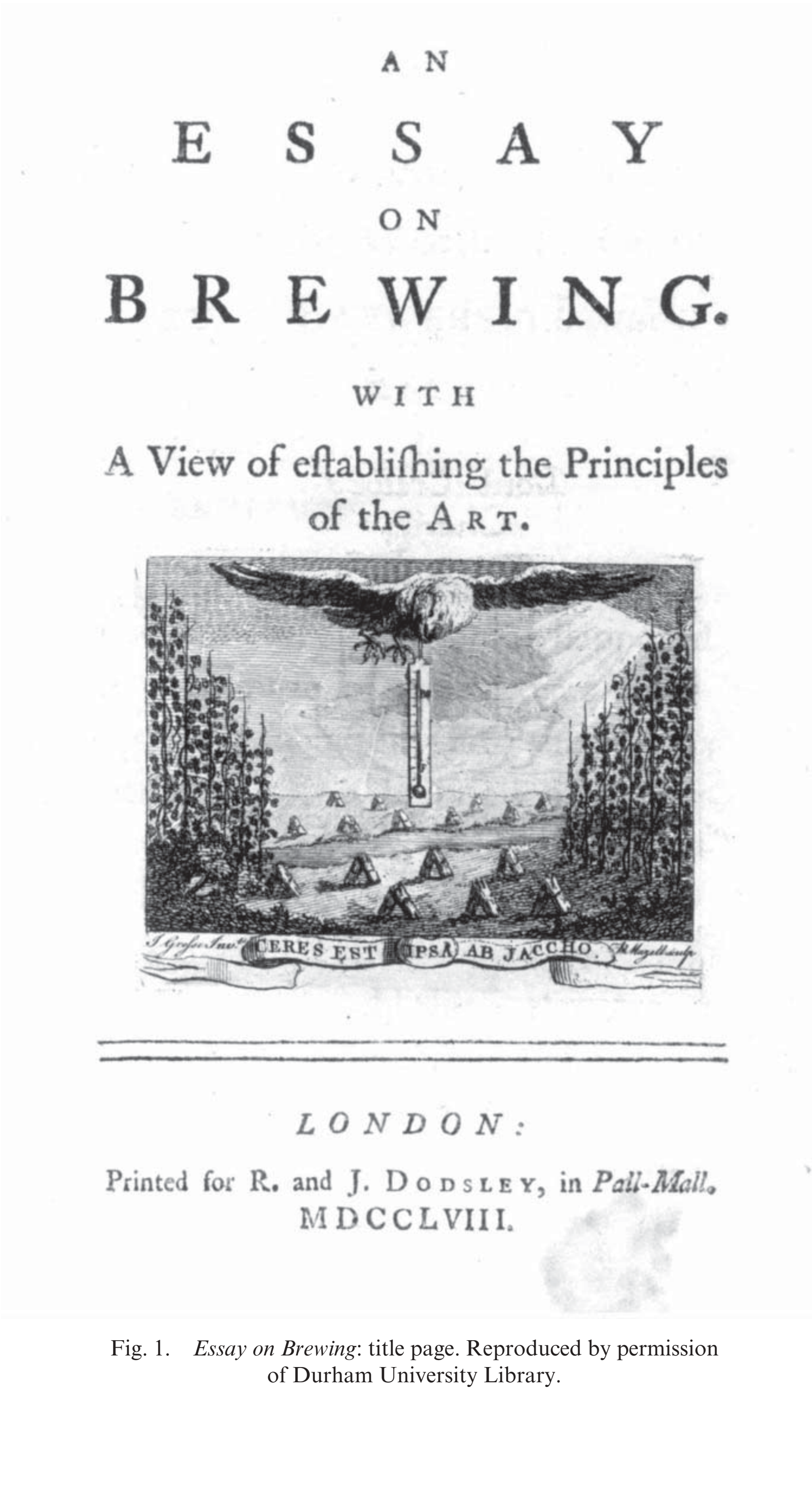
Recent work by David P. Miller indicates how the chemical activity of a much-studied figure, James Watt, has been obscured by the retrospective assigning of heat studies in general to physics. This paper applies a similar analysis to the work of Michael Combrune, a philosophically inclined brewer of the mid-eighteenth century; remembered chiefly within the brewing profession as a pioneering thermometrist, Combrune understood the thermometer as the central diagnostic tool in a chemically derived system of management that is now largely forgotten. In the course of retrieving this scheme, I display its origins in the chemistry of Herman Boerhaave as mediated by his unauthorised translator Peter Shaw, Combrune's intellectual patron, whose association with the gentlemanly representatives of artisanal trades derived from his concern to establish "commercial chemistry." I next demonstrate Combrune's considerable conceptual independence and forcefully reductive quantitative agenda, and finally outline three reasons why later practitioners abandoned his scheme: the displacement of its supporting authorities, the affording of independence to users, and the acceptance of its practical outcomes as simple givens — all circumstances that might befall a "mainstream" as easily as a "marginal" theory.

Introduction

In 1758, Michael Combrune, owner of an ale brewery at Hampstead (then a village outside the metropolis of London), published a small work entitled *An Essay on Brewing, with a View of Establishing the Principles of the Art.* The proposed means to this end are strikingly revealed in a title-page engraving, the work's sole illustration, presenting a curious symbolic scene (figure 1). A field dotted with stooks of barley is framed on either side by hops trailing up their poles, so as to present the two principal materials of the brewer's art. The motto *Ceres est ipsa ab Jaccho*, borrowed from Lucretius, hints obliquely at the creation of wine from barley.[1] Above the field, the sun breaks strongly through a cloudy sky, presumably

[1] Michael Combrune, *An Essay on Brewing* (London, 1758), title page. In classical mythology, the goddess of agriculture, Demeter/Ceres, associated particularly with the cereal crops, is the mother of Iacchus, who is sometimes identified with Bacchus/Dionysius, the god of wine. I thank David Levene and George Macdonald Ross for clarification on this point. The source is *de Rerum Natura*, iv, line 1168: "at tumida et mammosa Ceres est ipsa ab Iaccho." The motto has in fact been sundered rather drastically from its original, less wholesome context. Lucretius is commenting sardonically on how infatuation may affect a man's judgement of a woman's appearance: the tone is well captured by the translation, "The fat girl with enormous breasts is 'Ceres suckling Bacchus.'" Lucretius, *On the Nature of the Universe*, trans. R. E. Latham, rev. John Godwin (London: Penguin, 1994), 125.

 DOI: 10.1179/174582307X165452



A N

E S S A Y

O N

B R E W I N G.

W I T H

A View of eſtabliſhing the Principles of the A R T.

CERES EST IPSA AB IACCHO.

L O N D O N:

Printed for R. and J. DODSLEY, in *Pall-Mall.*
MDCCLVIII.

Fig. 1. *Essay on Brewing*: title page. Reproduced by permission of Durham University Library.

signifying the light of reason penetrating longstanding uncertainty. In the foreground, flying straight towards the reader, is a huge, spread eagle; and from the eagle's beak, rather incongruously, dangles a thermometer with a Fahrenheit scale.[2]

The *Essay* is the first significant brewery text to recommend the thermometer, and Combrune enjoys a pioneer's reputation in the internal history of the brewing profession.[3] His relationship to contemporary natural philosophy, however, has been little regarded, despite the influence of some notable figures. Combrune professed himself a follower of Herman Boerhaave, perhaps the preeminent chemical and medical authority of the early eighteenth century; in 1762, Combrune published an enlarged work under the guidance of Peter Shaw, the physician and popular lecturer responsible for the most influential English translations of Boerhaave. Combrune evidently considered himself a practising chemical philosopher, and the centrality of the thermometer in his work depends directly on its nomination as the sole diagnostic instrument in a broad, modified Boerhaavian theory of chemical action.

The first goal of this paper is to explain how a procedural manual on the traditional craft of brewing came to be modelled on the plan of a philosophical treatise — in fact an entirely unsurprising development once we understand the role of Shaw, whose project of "commercial chemistry" explicitly bridged the worlds of philosopher and artisan. The next is to interpret the scheme itself, in which the thermometric quantity becomes directly representative of chemical state. The final goal is to establish why, even as the name of Combrune rose to prominence, and the use of the thermometer almost to ubiquity in British commercial brewing before 1800, investment in the chemical scheme that had underpinned its introduction collapsed. Shaw's patronage notwithstanding, natural-philosophical contemporaries barely engaged with Combrune's work; among the brewers, the thermometer's utility was increasingly accepted as a self-evident given. This instrumental ethos was later projected back onto Combrune's innovation itself, to the extent that its predominantly chemical nature has been obscured.

Beyond shedding useful light on activities at the perceived boundaries of eighteenth-century natural philosophy, recovering Combrune's case helps to illustrate an emerging theme in the historiography of chemistry. Recent work by David P. Miller presents some of the iconic activities of James Watt — including the steam-engine research, begun around the time of Combrune's publications, which led to the separate condenser — as specifically chemical in character; the designation of this and other work on heat as a part of "physics" is an artefact of a revision process, beginning in the early nineteenth century, that culminated in the view that heat phenomena, including thermometric activity, were reducible to and underpinned by thermodynamics.[4]

[2] The bird is, beyond reasonable doubt, intended to be an eagle, although the accuracy of the representation is limited: I am grateful to Helen Macdonald for guidance on this point. The eagle was a familiar stock symbol, designated the king of the birds (much as the lion was of beasts), and is the bird most often found in heraldry. The sun as "glory" or "halo" is likewise a heraldic convention.

[3] See, for example, H. S. Corran, *A History of Brewing* (Newton Abbot: David & Charles, 1975), 131–32.

[4] David P. Miller, "True Myths: James Watt's Kettle, his Condenser, and his Chemistry," *History of Science* 42 (2004): 333–60, esp. 334, 350–52; "Seeing the Chemical Steam for the Historical Fog: Watt's Steam Engine as Chemistry" (paper presented at the British Society for the History of Science Annual Meeting 2005, University of Leeds, 17 July 2005; based on an unpublished manuscript, September 2004).

In the case of brewery heat management, we must be all the more wary of this anachronistic tendency, given the rather better-known heat researches performed by another English brewer a century after Combrune. Otto Sibum's work on the tacit, "gestural" skills acquired by James Joule, in the course of work at his family's brewery in Salford, reveals how a specifically early-Victorian brewery environment newly concerned with standards, scientific instrumentation and the recording of numerical data created Joule's unparalleled thermometric precision and accuracy.[5] My account is not incompatible with Sibum's — indeed, he acknowledges antecedent thermometric developments[6] — but his focus is on those precise, legislatively enforced applications that arose decades after the instrument had entered general use, such as its application to determine "standard heats" for Excise hydrometry.[7] The initial rise of the thermometer, by contrast, must be viewed in the context not of Victorian thermodynamics but of Georgian chemical philosophy. Let us begin, then, with the circumstances in which Combrune's project was inspired.

"Commercial Chemistry" and the Brewery Context

By the eighteenth century in Britain, adequate heat management was generally understood, among those who brewed for profit, to be critical at several stages in the process. Malted barley had to be dried by heating, which would determine both the colour of the product and the yield of fermentable sugars, while fermentation itself could be speeded or slowed by changes in atmospheric temperature. Most crucially, heat had consequences during *mashing*, the infusion of malt in water to extract the fermentables, producing the sugary solution known as wort. If the water (*liquor* in brewery parlance) was too cold, the mash would be inefficient, giving an understrength wort; if it was too hot, the mash would become *set*, clotting into a paste that retained most of the fluid. Warnings against the "set mash" appear in most brewery literature, couched in essentially unchanging form across more than a century.[8]

Our recovery of early techniques employed to prevent this catastrophe is limited by the small number of surviving descriptions; we must exercise particular caution, given that commercial brewing insiders had a strong incentive to preserve the "mystery" of their craft, whereas outsiders promoting new, and hence atypical, practices, such as the autodidact food reformer Thomas Tryon, were most inclined to publish.[9] The surviving evidence tends to confirm Sibum's emphasis on sensory engagement, dubbed "gestural" in his work,

5 H. Otto Sibum, "Reworking the Mechanical Value of Heat: Instruments of Precision and Gestures of Accuracy in Early Victorian England," *Studies in History and Philosophy of Science* 26 (1995): 73–106; H. Otto Sibum, "Les gestes de la mesure. Joule, les pratiques de la brasserie et la science," *Annales Histoire, Sciences Sociales* 53 (1998): 745–74; H. Otto Sibum, "An Old Hand in a New System," in *The Invisible Industrialist: Manufactures and the Production of Scientific Knowledge*, ed. Jean-Paul Gaudillière and Ilana Löwy (Basingstoke: Macmillan, 1998), 23–57.

6 Sibum, "Gestes de la mesure," 757.

7 Sibum, "Reworking the Mechanical Value of Heat," 87–88.

8 Compare, for instance: *Directions for Brewing Malt Liquors* (London, 1700), 12; Combrune, *Essay on Brewing*, 50; William Reddington, *A Practical Treatise on Brewing* (London, 1760), 13; John Richardson, *Statical Estimates of the Materials for Brewing* (York, 1784), 194–97; and Alexander Morrice, *A Practical Treatise on Brewing*, 7th ed. (London, 1827), 137–38.

9 Thomas Tryon, *A New Art of Brewing Beer, Ale and other sorts of Liquors* (London, 1690), 21.

although given the absence of a demonstrative aspect, we may prefer to term it "bodily" in the sense applied by Graeme Gooday.[10] An "hour-glass" tradition, whereby liquor for mashing was boiled and then cooled for a timed period before use, apparently gave way after 1700 to judgement based on the brewer's expert eye; in the most widely reported method, after heating the water to near boiling, the brewer allows it to cool until the steam subsides to the point where he can see his own face reflected in the surface.[11] Alternatively, cold and boiling water could be mixed in given proportions; however, it was made clear that this quantitative method should not overrule the qualitative judgement of the brewer, whose (incommunicable) expertise remained the final authority in managing an intrinsically variable process.[12]

Michael Combrune, on his own account, began to consider the possibility of a thermometric approach in 1741:[13] this was probably some years prior to his involvement with the well-connected Peter Shaw, elected a Fellow of the Royal Society in 1752 and subsequently physician-in-ordinary to both George II and George III.[14] The circumstances of their introduction, and the exact extent of their relations, are unknown. Certainly — as I have noted elsewhere, concerning the brewing theorist John Richardson's relations with the Troughton family[15] — we must avoid the automatic assumption of some problematic social or economic gulf between "philosophers" and "artisans": Shaw's father was master of a grammar school, and Combrune's was a wealthy Huguenot refugee whose bequests provided substantial capital.[16] Combrune's Huguenot background, in fact, provided a common context with several leading members of London's natural-philosophical elite, most obviously John Theophilus Desaguliers (also the son of refugee parents), the writer and instrument-maker often identified as the primary "disciple" of Isaac Newton. Recent work by Jean-François Baillon points to a specifically Huguenot element in the construction of Newtonianism in England and on the Continent during the first third of the eighteenth century.[17]

[10] Graeme Gooday, "Spot-watching, Bodily Postures and the 'Practised Eye': the Material Practice of Instrument Reading in Late Victorian Electrical Life," in *Bodies/Machines*, ed. Iwan Rhys Morus (Oxford: Berg, 2002), 165–95, esp. 166.

[11] John Lightbody, *Every Man His Own Gauger* (London, 1698?), 42–43; William Ellis, *The London and Country Brewer*, 1st ed. (London, 1735), unpaginated preface and 31, 38, 95–96.

[12] William Ellis, *The London and Country Brewer*, 4th ed. (London, 1742), 221; Reddington, *Practical Treatise*, 11–12.

[13] Michael Combrune, *The Theory and Practice of Brewing* (London, 1762), ii.

[14] Shaw has received surprisingly little study in the history of science, given the wide dissemination of his works. The principal source remains F. W. Gibbs, "Peter Shaw and the Revival of Chemistry," *Annals of Science* 7 (1951): 211–37; the most recent discussions are: Jan V. Golinski, "Peter Shaw: Chemistry and Communication in Augustan England," *Ambix* 30 (1983): 19–29; and John Christie, "Historiography of Chemistry in the Eighteenth Century: Hermann Boerhaave and William Cullen," *Ambix* 41 (1994): 4–19.

[15] James Sumner, "John Richardson, Saccharometry and the Pounds-per-Barrel Extract: the Construction of a Quantity," *British Journal for the History of Science* 34 (2001): 255–73.

[16] Anita McConnell, "Michael Combrune (d. 1773)," *ODNB*; Jan Golinski, "Peter Shaw (1694–1763)," *ODNB*.

[17] Patricia Fara, "John Theophilus Desaguliers (1683–1744)," *ODNB*; Jean-François Baillon, "Early Eighteenth-century Newtonianism: the Huguenot contribution," *Studies in History and Philosophy of Science* 35 (2004): 533–48.

Another shared context for Combrune was freemasonry. Owing in part to the networking activities of Desaguliers, many influential members of the Royal Society were also masons, and perceived a common agenda. The scope for patron–client relationships provided by such spaces is typically represented in terms of philosophers' access to the high-born or well-capitalised; but philosophical credibility could be a patronage resource in its own right. Around 1740, Combrune certainly encountered in his masonic life both Desaguliers and the medic William Graeme; Graeme had worked closely in Edinburgh with George Martine, who was at that time presenting work on thermometric scaling that ultimately found its way into Combrune's writings.[18] We need not, however, attempt to prove a sustained relationship between Combrune and any of these individuals. It is sufficient to confirm that spaces existed for interaction between established natural philosophers and the representatives of artisanal crafts; when philosophers promoted their work via public lectures and publications aimed at lay audiences, while simultaneously seeking programmatic mastery of artisanal knowledge, such interactions became inevitable. This was true above all in the case of Peter Shaw.

Shaw was deeply concerned with the relationship between natural philosophers and practical operators. His chief totem was Francis Bacon, whose philosophical works he translated. Jan Golinski summarises Shaw's interpretation of Baconian method as follows: the philosopher stands in a position of intellectual dominance over the artisan, handing down to him the rules for the best conduct of his labour; however, the philosopher cannot formulate those rules unless guided by knowledge that only the artisans themselves can provide.[19] Accordingly, Shaw made it his business to collect and distribute information on technical practices, seeking in particular "to extend the Business of Chemistry, and render it applicable to the improvement of Philosophy and Arts"[20] and to persuade more writers to address chemical subjects. He marketed a portable laboratory, which might be set up in the homes of those seeking to make their own investigations.

In 1731, Shaw presented in London a course of twenty lectures outlining elementary chemistry "with a view to practical philosophy, arts, trades and business."[21] The concluding lecture sets forth his programme of "Commercial Chemistry," aiming to increase national productivity and create a surplus for exportation; to better prepare commodities for transportation; and to supply "chemical necessaries" to those who travelled and developed the international trade routes. Shaw contended that, with better chemical organisation, England could undercut other nations in the world market.[22] Such an agenda evidently

[18] Graeme and Desaguliers were, respectively, Grand Master and Deputy Grand Master for the year immediately following Combrune's service as a steward to Grand Lodge: James Anderson, *The Constitutions of the Antient and Honourable Fraternity of Free and Accepted Masons* (London, 1756): 228–31. For Graeme and Martine, see Roger L. Emerson, "The Founding of the Edinburgh Medical School," *Journal of the History of Medicine and Allied Sciences* 59 (2004): 183–218.

[19] Golinski, "Peter Shaw," 23–24.

[20] Peter Shaw, *Philosophical Principles of Universal Chemistry* (London, 1730), preface; quoted in Gibbs, "Peter Shaw," 217.

[21] Gibbs, "Peter Shaw," 217–18.

[22] Peter Shaw, *Chemical Lectures, Publickly Read at London, In the Years 1731, and 1732* (London, 1734), 418–19. Shaw also distinguished philosophical, technical and oeconomical (i.e. domestic) branches of chemistry.

chimed with the interests of Michael Combrune.[23] Combrune's family connections were geographically diffuse and predominantly mercantile: his brother, James, married into the Huguenot merchant family of Arbouin, and traded in the British Factory in Lisbon; two further brothers were in partnership as Blackwell Hall factors (agents in the London cloth market) in the 1750s; and Michael's daughter, Ann, married John Glen King, chaplain to the British Factory in St. Petersburg.[24]

Shaw, correspondingly, was inclined to address in particular the production of alcohol: drink in the eighteenth century constituted a staple of the popular diet, a widely exported commodity subject to much competition in international trade, and a matter of increasing economic significance as governments began to raise excise duties in preference to the land tax.[25] When, in 1731, Shaw published a set of linked essays intended to exemplify his plan for the theoretical and practical development of chemistry, the case studies discussed were Georg Stahl's doctrines on the distillation of spirits, and the concentration of wines to demonstrate Stahl's theory of fermentation.[26] Of Shaw's twenty public lectures, four were concerned largely or wholly with malting, worts, vinegar, wine or spirits.[27] In the delineation of "Commercial Chemistry" in the concluding lecture, Shaw's specific examples were the production of malt spirit to undercut the Dutch, and the supply of wines and vinegars in the colonies (presumably from sugar).

Shaw's texts refer typically to "wines," but it is evident that the reference is not intended to be specific to the product of the grape. Shaw's lectures emphasise the claim that all products of alcoholic fermentation are subject to the same rules; indeed, Shaw himself claimed to have discovered "as an *Axiom*" that the basis of wines was not anything specific to the nature of the grape, but only "a *saccharine Substance*",[28] an interpretation that also appeared in the work of Boerhaave around the same time.[29] Shaw's demonstration of vinous fermentation in the *Chemical Lectures* uses raisins; he immediately comments that the experiment "is universal," and can with only superficial changes be applied to malt, as to honey, apples and so forth.[30] Given all this, it should not be surprising that Shaw responded to Michael Combrune's "View of establishing the Principles" of brewing chemically, nor

23 Michael Combrune, "An Historical Accompt of the English Brewery" (unpublished manuscript, 1767; Beinecke Library, Yale University, Osborn c603): 42 in particular demonstrates Shavian influence, although Shaw is not mentioned.

24 McConnell, "Michael Combrune"; Henry Wagner, "The Huguenot Refugee Family of Combrune," *The Genealogist*, new ser., 24 (1907–8): 194–95; London Metropolitan Archives, Acc. 339/14 and Acc. 339/17 (Blackwell Hall partnership).

25 For changes in taxation policy, see J. Beckett, "Land Tax or Excise: the Levying of Taxation in Seventeenth- and Eighteenth-century England," *English Historical Review* 100 (1985): 285–308.

26 Gibbs, "Peter Shaw," 218.

27 Shaw, *Chemical Lectures*. Lecture 7, on "Fermentation and Putrefaction," discussed the production of wine, vinegar and inflammable spirits; Lecture 10, on "Vegetable Curation," discussed malting and beer-worts; and Lectures 11 and 12 were specifically devoted to "Wines and Spirits" and "Distillation."

28 Shaw, *Chemical Lectures*, 120.

29 Shaw's lectures were first read in 1731. As Gibbs points out, Boerhaave first presents the doctrine in the *Elementa Chemiae*, which was ready for press in 1729 but not published until 1732; hence we cannot say for certain whether Shaw borrowed his axiom from Boerhaave, or evolved it independently. Gibbs, "Peter Shaw," 222.

30 Shaw, *Chemical Lectures*, 117–18.

that Shaw's name would have found its way to Combrune as that of a likely and well-connected champion.

Combrune and Shaw were in personal correspondence by 1758, and the text of Shaw's lectures, published in 1734 as *Chemical Lectures, Publickly Read at London* . . . and reprinted in 1755, served as a compositional model for Combrune's *Essay on Brewing*.[31] Shaw received the *Essay* to look over in manuscript, and praised it in a letter reproduced, with his permission, in a preface to the published version: Shaw notes that he "should be glad to see some other Trades as justly reduced to Rule, as you have done that of *Brewing*."[32] The successor volume, completed in 1761 under the title *Theory and Practice of Brewing*, contains a dedication to Shaw, stating that the enlarged treatise, "if it can boast no other merit, has that of having been undertaken and finished by your advice and counsel."[33] At the same time, however, the *Theory and Practice* shows other influences. Combrune is keen in particular to present his Boerhaavian induction as direct, rather than mediated by Shaw's intellectual patronage, as an examination of his thermometry makes clear.

Combrune, Boerhaave and the Introduction of Thermometry

Combrune's account of the origins of the thermometer, first published in the 1758 *Essay*, derives in many respects from Shaw's treatment in the published *Chemical Lectures*. Shaw addresses in some depth the question of "how to regulate and ascertain the Degrees of Heat in Chemical Operations; so as to produce the Effects required in every Case": traditional chemists' receipts, he notes, "are full of Uncertainty; their first, second, third, and fourth Degrees of Heat, meaning no precise Degrees, measured by any Standard." The reliance on qualitative distinctions, proclaims Shaw, might be changed by the adoption of the thermometer, guaranteeing "the necessary Accuracy" in heat determination. Yet, despite the existence of established devices at this time, the project is presented as wholly conjectural; Shaw hints at a graduated scale, with limits at some freezing point and at the boiling point of quicksilver, but introduces no numerical values.[34]

Combrune, by contrast, advocates the Fahrenheit thermometer and its associated scale in all his published work, and so other influences beside the *Chemical Lectures* must have been in play. Although several makers and scalings were widely known by 1730, none is discussed by name in Shaw's text; Shaw's demonstrator during the public lectures was the instrument-maker Francis Hauksbee the younger, who had marketed a thermometer bearing his own (the so-called "Royal Society") scale, and we might conjecture that this was the device used.[35] Yet Combrune, carrying out his research in the 1740s and 1750s, did not

[31] Combrune's inclusion of a glossary of technical terms, for instance, parallels the *Chemical Lectures* directly, with a couple of entries borrowed verbatim: Shaw, *Chemical Lectures*, vii–xv; cf. Combrune, *Essay on Brewing*, 1–19. Elsewhere, substantial portions of text clearly have their origins partially in Shaw, as in the account of the thermometer discussed below.

[32] Shaw to Combrune, 20 July 1758; quoted in Combrune, *Essay on Brewing*, vii. Emphasis in the original.

[33] Combrune, *Theory and Practice*, unpaginated front matter.

[34] Shaw, *Chemical Lectures*, 36. This material was unaltered in the 1755 reissue.

[35] Shaw, *Chemical Lectures*, 46–47; Gibbs, "Peter Shaw," 218, 220. For Hauksbee's thermometers and the supposed Royal Society endorsement of the scale, see W. E. Knowles Middleton, *A History of the Thermometer and Its Use in Meteorology* (Baltimore: Johns Hopkins Press, 1966), 58–62.

consider any scale but Fahrenheit's, which he held to be "the most perfect, and the most generally received."[36]

This may be traced to Combrune's desire to be seen specifically as a disciple of Boerhaave, whose name, achievements and doctrines are cited frequently throughout his work. Boerhaave had been a notably keen and influential thermometric proponent from the first decade of the century, recommending the device to his students in lectures, and writing of its diagnostic merits in detecting the onset of fever. Boerhaave's favoured maker was Daniel Gabriel Fahrenheit, who by the 1720s was making a name for himself (doubtless thanks partly to Boerhaave's patronage) both in the Low Countries and in England, securing election to the Royal Society in 1724.[37] As the name "Fahrenheit" came to be applied first to any instrument constructed on his model, and then to any bearing his scale, it became the dominant specification in both regions.

The centrality of the thermometer to Boerhaave's chemistry has been well characterised by Jan Golinski. Boerhaave construed heat in terms of a subtle elemental fire, the medium for all chemical action: the fire was "an agent of change *revealing* the chemical components of bodies and their properties." A device that could indicate the quantity of this fire, then, might be applied in the analysis or regulation of any chemical process: "the thermometer was thus a crucial instrument, key to the mastery of fire. It was, so to speak, a second-order instrument, the artefact that gave humans the control of the cosmic instrument of fire that was the basis of chemistry's claim to the status of an art."[38] Combrune, as we shall see later, became utterly committed to this worldview. In the most elaborated version of his system, *every* quantity, except volume, is rendered expressible in degrees of Fahrenheit's thermometer.

The dissemination of Boerhaave's work into English was, as both Golinski and John Christie point out, a complex episode in which Peter Shaw played a significant role. Shaw published English-language translations, with much original commentary, of both the 1724 pirated edition of Boerhaave's chemical lectures and of Boerhaave's official text, *Elementa Chemiae*, published to forestall the pirates in 1732.[39] When Combrune, however, cites material from the *Elementa*, his reference is not to Shaw's 1741 edition, but to the earlier translation made by Timothy Dallowe, released with Boerhaave's approval in 1735.[40] It

[36] Combrune, *Theory and Practice*, 26.

[37] Jan V. Golinski, "'Fit Instruments': Thermometers in Eighteenth-century Chemistry," in *Instruments and Experimentation in the History of Chemistry*, ed. Frederic L. Holmes and Trevor H. Levere (London: MIT Press, 2000), 185–210, on 191–92; G. A. Lindeboom, *Herman Boerhaave: the Man and his Work* (London: Methuen, 1968), 294–97; Middleton, *History of the Thermometer*, 66, 76–77, 79.

[38] Golinski, "Fit Instruments," 190–91. Italics in the original.

[39] The first text, prepared in collaboration with Ephraim Chambers (afterwards compiler of the seminal *Cyclopaedia*), appeared as *A New Method of Chemistry* in 1727. The other, translated by Shaw alone and published in 1741, was marketed as the "second edition" of the *New Method*, somewhat disingenuously, given that the sources were distinct. Many of the notes, however, were carried through from the first translation to the second; the annotation is in places voluminous and discusses many rival theories to Boerhaave's, to the extent that Shaw's editions are often considered less as translations than as commentaries: Gibbs, "Peter Shaw," 216; Golinski, "Peter Shaw," 24–25; Christie, "Historiography of Chemistry," 4–12.

[40] Combrune, *Theory and Practice*, 169: "[T]he same author, in his *Elements of Chemistry*, vol. I, page 195 to 199, clearly proves . . ." The title and pagination are consistent only with Dallowe's edition.

seems plausible, then, that Combrune came to be acquainted with Shaw through a prior knowledge of Boerhaave, rather than the other way around.[41] Certainly, Combrune shows little awareness of Shaw's other influences. Georg Stahl, whom Shaw also translated at length and invoked as an authority, is not mentioned in Combrune's work, notwithstanding Shaw's Stahlian exposition of fermentation and distillation elsewhere.

Presumably, then, it was in Dallowe's Boerhaave that Combrune first saw the thermometer — and with it, inevitably, the name of Fahrenheit — illustrated and commended in the following terms: "Of what infinite use . . . are *Fahrenheit*'s mercurial Thermometers? How certainly do they point out to us the danger that arises from the Heat in acute Diseases?"[42] This could almost be a description of the thermometer's diagnostic role in brewing at the fermentation stage, when a fluctuating or excessively high temperature could be ruinous to the operation.

Combrune must to some extent have kept abreast of developments in thermometry after the publication of his known sources. While the *Essay* borrows almost verbatim from Shaw's text, prepared around 1730, on the "very vague and indeterminate" degrees of heat traditionally recorded by "chymists," the characterisation is prefaced with the words "till of late," indicating that it is now obsolete. Combrune appends a thorough account of the Fahrenheit thermometer and the principle of its numerical scaling, by which "we are enabled to regulate our fires with the utmost precision." A list of heats of notable circumstances and transformations, based partly on Shaw's six degrees, now cites an individual value or range, on the Fahrenheit scale, for each case up to the boiling point of quicksilver (around 600 degrees), thus fulfilling Shaw's project up to the practical limit that he had perceived.[43]

Combrune's revisions, then, oblige us to dismiss any notion that a brewer's involvement in natural philosophy, in the period in question, could amount to no more than the parroting of undigested theory. Combrune does resort in places to verbatim borrowing; this, however, was then a widespread and relatively legitimate device, and there is evidence elsewhere not only of the integration of sources, but of the independent innovation of theory, relating specifically to the brewery, on the broadly Boerhaavian chemical basis that Combrune had received from Dallowe and Shaw.

Unlike its predecessor, and almost uniquely among published works specific to brewing, the 1762 *Theory and Practice* is a quarto volume. The choice of format would have sent a clear message to the readers of the day: here was not a cheap, portable manual of practical advice aimed principally at the literate artisan brewer, but (at least in intention) a bona fide

[41] Peter Mathias, *The Brewing Industry in England, 1700–1830* (Cambridge: Cambridge University Press, 1959): 66 suggests that Combrune "first took the hint to employ the thermometer in his own brewery from Dr. Peter Shaw . . . following the re-publication of his *Chemical Lectures and Essays* in 1755"; as previously noted, Combrune himself claimed to have begun thermometric research in 1741 (*Theory and Practice*, ii). While Combrune certainly might have known of Shaw's work early in his thermometric career, I have found no evidence to suggest this.

[42] Herman Boerhaave, *Elements of Chemistry*, trans. Timothy Dallowe (London, 1735), vol. ii, 245. Italics in the original. Lindeboom (*Herman Boerhaave*, 295, n. 3) draws our attention to one mystery: the Fahrenheit device depicted in the *Elements* "seems to end at 96°," which, unless Fahrenheit's scale was not then in its final form, represents normal body heat; thus, this particular instrument would be adapted neither to "acute Diseases" nor to the brewery.

[43] Combrune, *Essay on Brewing*, 25–28.

philosophical treatise, fit to grace the shelves of a gentleman's library. Combrune was bidding to be seen, not as a communicator of philosophical ideas, but as a philosopher in his own right.[44] To understand this contention, we must examine the chemical system developed in Combrune's published works.

Thermometric Chemical Theory in the *Essay on Brewing*

The thermometer, as the title page makes clear, is central to the *Essay on Brewing*. Combrune notes the utility of the device in determining not only mashing heats — "a point of the utmost importance with regard to brewing" — but also hop rates, the amount of yeast to employ, and the correct boiling times for worts.[45] Nowhere, however, are invariant values prescribed. Echoing the pre-thermometric writers' articulation of the expert brewer's ultimate authority, Combrune states that the mashing heat, for instance, "must be properly varied according to the driness and nature of the Malt; to its being applied either in the first or last mashes; and in proportion also to the time the beer is intended to be kept."[46] Yet a crucial change is implied: the brewer is to be guided in managing this variation not by bodily experience, but by the evidence of thermometric measurement conducted throughout the beer-making process. Combrune's aim was to refound traditional understandings about the relationship between the character of malt, the heats of mashing and the period of maturation on a thermometric basis; the 1758 essay is not a volume of practical thermometric advice, but a preparatory text developing the theoretical principles of this relationship.

Combrune's expectations for the applicability of the thermometer are very broad, resting on his conviction that the state of the malt, mash or wort, at any stage, can have appointed to it a direct thermometric representative. Note, for instance, the following speculation:

> If curiosity should lead us so far, we might . . . determine, by [the thermometer], the particular strength of each Wort, or of every Mash; for if Water boils at 212 degrees, Oils at 600, and Worts be a composition of Water, Oil and Salt, the more the heat of a boiling Wort exceeds that of boiling Water, the more Oils and Salt must it contain, or the stronger is the Wort.[47]

Combrune, probably in imitation of his chemical sources, uses the term "salt" to refer to sweet fermentable matter (what most later writers termed "sweets" or "saccharine"). Here, then, we have an intimation of a scheme to quantify wort strength instrumentally: not by density, as theorists of the following generation proposed,[48] but by the thermometer.

This radical extension of the thermometric quantity is understandable when we consider that Combrune, like all commercial brewers, lived in the shadow of the Excise: his site and routines were subject to constant intervention and examination by the peripatetic

[44] I am much obliged to Jon Topham for guidance on this point. Contemporary catalogues and review literature give a price of 10s. 6d. for the *Theory and Practice*, as against 3s. 6d. for the 1758 *Essay* and, typically, 2s. 6d. or 3s. for the handful of octavo and duodecimo brewing treatises published by others in the 1760s.

[45] Combrune, *Essay on Brewing*, 44–45, 67.

[46] Combrune, *Essay on Brewing*, 44–45.

[47] Combrune, *Essay on Brewing*, 69.

[48] Sumner, "John Richardson," provides a detailed characterisation of this approach.

gaugers who maintained the mammoth project of indirect tax-gathering.[49] It was these mathematically trained officials' responsibility to develop a comprehensive volumetric determination of each brewer's production, applying known formulae to reduce the whole diversity of brewing apparatus into forms that could be gauged using a few simple instruments, suitable for mobile use; so, perhaps, Combrune sought to bring the *intensive* properties of his product under the sole authority of the thermometer.

To establish a basis for determining the value of malt thermometrically, Combrune turns to an analogy with grapes, applying the universalising fermentation theory — *Ceres est ipsa ab Jaccho* — of Boerhaave and Shaw. Combrune's Boerhaavian conception of vegetable matter holds it to be composed chiefly of acids and oils, intermixed to a greater or lesser extent. Unripe grapes are very acidic, but, as the growing season progresses, higher temperatures have the effect of drawing out oily principles: the acids are "smoothed over" by oils, producing the sweet, fermentable "acid salts."[50] Malting, says Combrune, is an artificial analogue of this process. Ungerminated barley, "viscous and replete with acids," is ill-suited for the brewing of sound liquors, the nature of acids promoting uncontrollable fermentation leading to putrescence.[51] The malting and drying of the barley provides "the proper means for setting the constituent principles of the grain in motion . . . [thus] the grain hath fewer acids in proportion to its Oils; and, at the different stages of dryness, obtains different properties; in the first stage resembling the fruits ripened by a weaker sun, and, in the last, exceeding the growth of the hottest climate."[52]

Combrune begins to explore this process by finding thermometric values for the lowest and highest heats of drying that will produce malt. Experimentally, he establishes a certain heat below which the steeped barley is prone to regermination and spoiling, but above which it effervesces in water and cannot regerminate. It "first shews this act of effervescence, when it has been thoroughly impressed with a heat of 120 degrees . . . consequently this may be termed the first or lowest degree of drying this Grain for Malt."[53] To fix the upper limit, Combrune reasons once again from his chief chemical authorities. Given Shaw's assertion that alcohol is produced from vegetable matter alone, and Boerhaave's doctrine that inflammable bodies remain inflammable only so long as they contain alcohol, or some principle like it, it follows that alcohol resides latently in vegetable bodies,[54] and that their nature can be changed by heating only so long as the alcohol within them endures. The highest degree to which the malt may be taken, therefore, corresponds to the point at which alcohol boils and flies away from its receptacle — 175 degrees of Fahrenheit's thermometer.[55]

The next objective is to "determine and fix the properties of the intermediate spaces" between these limits, a process that we might compare to Fahrenheit's initial fashioning of the temperature scale.[56] Combrune devotes several pages to a procedural account of an

49 William Ashworth, *Customs and Excise: Trade, Production and Consumption in England 1640–1845* (Oxford: Oxford University Press, 2003), esp. 117–130, 209–222.

50 Combrune, *Essay on Brewing*, 76, 78.

51 Combrune, *Essay on Brewing*, 137.

52 Combrune, *Essay on Brewing*, 145, 151.

53 Combrune, *Essay on Brewing*, 181, 167. Elsewhere in his work, Combrune occasionally gives 119° in place of 120°.

54 An apparently widespread view that was subsequently attacked in, for instance, John Richardson, *Theoretic Hints on an Improved Practice of Brewing Malt-Liquors* (York, 1777).

55 Combrune, *Essay on Brewing*, 168–70.

56 Middleton, *History of the Thermometer*, 71, 74.

experiment in which a pan full of pale malt was gradually heated, with constant stirring, over a charcoal fire. He draws attention to the colour change, through orange and brown to black; as the thermometer showed 180°, he notes, the heap "grew black apace," and he judged all the truly malted grains to be thoroughly charred; yet he pushed the fire on until most of the heap was reduced to cinders. On the basis of his observations, Combrune draws up a table relating colour to temperature of drying, such as would allow the brewer to assess the value of the malt that he purchased.[57] The observation that some of the corns are entirely black at 175° is taken to give reasonable support to the latent alcohol theory. As a further confirmation, Combrune records, the sensory effect of performing this experiment "greatly resembled the case of inebriation," as would be expected if boiling spirit from the malt were escaping into the surrounding air.[58]

Working from the acid–oil chemical theory, Combrune presents this range of thermometric malting values as having considerable practical significance for the brewer: it determines the times at which beer made from the various malts will fall into — and out of — a drinkable condition. The palest malt, at 120°, is dominated by acid principles and ferments rapidly, so that the beer is ready to drink in two weeks; if stored much beyond that point, however, it will become putrid and sour. Drying to a high brown colour at, say, 152°, on the other hand, draws out oils to retard the fermentation, so that the beer may remain in a preserved state for many years; and yet, for the same reason, it may take fifteen months of maturation before it becomes drinkable. Given that different traditions, locations and contingencies promoted a wide variety of different storage periods, various malting heats might rationally be sought.

To this end, Combrune provides a table, "shewing the Age Beers will require, when properly brewed from Malts of different Degrees of Dryness."[59] The approach is finally extended to cover the beers' propensity to become *fine* (clear), as the matter causing cloudiness drops out of solution. When the malt is dried to between 119° and 138°, the beer will fine itself spontaneously as it comes into drinkable condition; from 138° to 166°, the beer can be artificially fined with additives such as isinglass; above this level, even artificial methods may not work.[60] The *Essay*'s "principles of the art," then, centred on a relationship between malting heat and maturation time, with reference to which the informed brewer could manage his overall production.

Combrune later stated that this theoretical innovation had "engaged the attention [and,] I may add, the favor of some good judges [who] have allowed my principles to be, at least, plausible."[61] The reviewing press, through which a gentlemanly audience would first have become aware of the work, showed no consensus on this point. While the notice in the *Critical Review* lauded enthusiastically the project and its execution, quoting Combrune at length, the *Monthly Review* was unconvinced and the *Gentleman's Magazine* positively scathing:

> [The author] has scarce given one practical direction for brewing, in any part of the process . . . he has told us that the whole success of the brewing depends upon the heat of the first mash, but he has no where told us what degree of heat that should be . . . His principal

[57] Combrune, *Essay on Brewing*, 183.
[58] Combrune, *Essay on Brewing*, 171–78.
[59] Combrune, *Essay on Brewing*, 188.
[60] Combrune, *Essay on Brewing*, 199.
[61] Combrune, *Theory and Practice*, ii.

> design (besides making and selling a book) seems to recommend the thermometer, which might as well have been done in 10 words as in 214 pages, of which number this work consists, and in which nothing is discovered, except that the brewers sometimes poison their beer to make it drinkable.[62]

This was followed by a summary of the book's "only propositions from which any practical truth can be inferred," a list of forty-nine points so tersely expressed as to cover less than three pages. Although both sarcasm and synopsis were common enough devices in periodical reviews of the time, the *Gentleman's Magazine* reviewer seems specifically to have been aiming to convict Combrune of impractical, airy verbosity. The contrast with Shaw's endorsement of Combrune's "right application of philosophical knowledge"[63] could not be greater.

What might explain the disparity? There is a concealed barb in the reviewer's reference to a lack of concrete directions. Combrune was the first English-language writer to publish a brewery-specific text while being an active commercial brewer; the *Essay* was dedicated to the Worshipful Company of Brewers and published with their permission. The implication is that, while seeking the profits of publication and the glory of discovery, he jealously hid away his "trade secrets," so safeguarding his own livelihood, and scrupulously maintained the traditions of the closed brewery community to avoid antagonising his peers.[64] Combrune had unwittingly exposed a vulnerability in Shaw's agenda: the commercial value of chemical data could be seen to work against the natural-philosophical ethos of openness (which, however little it was in practice observed by senior adepts, had at least to be projected as an ideal by those whose credibility was less secure). The tilt is more explicit in a 1763 comment, also in the *Gentleman's Magazine*, on an account of brewing published, in line with Shaw's programme, by the Society of Arts:

> The success of brewing depends wholly upon the heat of . . . the first mash; it is therefore to be wished that those who brew would determine this heat by something more definite and certain than the direction here given: If a thermometer was used the first time, and the brewing succeeded, the great point would be ascertained with the utmost precision, and the first trial that succeeded would become a standard for ever. This is the arcanum which the brewers, by profession, keep to themselves, and which a late treatise on brewing, that explains every other particular of the process, leaves wholly undetermined.[65]

To the brewer, however, this objection would have an obvious flaw. Even establishing a given thermometric value as trustworthy in a given situation would not make it "a standard for ever": materials and postmashing conditions were intrinsically variable, depending on the malt and hop supplies, brewery utensils, atmospheric conditions, Excise duties and procedures, tastes of the drinking public, and a myriad of other factors. The brewers among Combrune's readership would immediately have recognised the local and contingent nature of a numerical mashing heat; so, probably, would Shaw, whose methodology demanded attention to such practical considerations.

62 *Gentleman's Magazine* 29 (1759): 59–61, on 59. Cf. *Critical Review* 8 (1759): 219–28, and *Monthly Review* 20 (1759): 227–28.

63 Shaw to Combrune, 20 July 1758; quoted in Combrune, *Essay on Brewing*, vii.

64 Cf. Mathias, *Brewing Industry in England*, 66; Sibum, "Reworking the Mechanical Value of Heat," 85.

65 *Gentleman's Magazine* 33 (1763): 592.

Any concrete figures, then, could be no more than exemplars of the method. Once this is taken on board, it seems plausible that the absence of figures in the *Essay* is due not to "trade secrecy" but, once again, to the imitation of authority: although Boerhaave recorded thermometric data for his own use, and encouraged others to do likewise, there is (to a modern commentator) a conspicuous absence of numerical values in the *Elementa* or in his medical works.[66] This supposition is borne out by the fact that Combrune *did* publish exemplary figures in the wake of the periodicals' response. The very title of the *Theory and Practice of Brewing*, published four years after the *Essay*, could be specifically designed to head off the *Gentleman's Magazine* criticisms. "Theory" and "Practice" occupy separate sections: the first consists of the *Essay* in largely unamended form; the second is entirely new, laying out explicit, arithmetical computations of the relationships between malt character, mashing heats, hop rates and fermentation times on a basis which is entirely thermometric.

Combrunian Thermometric Management in Practice

The *Theory and Practice* makes one key modification to the chemistry of the original *Essay*: malt-drying heat is no longer deemed the sole determinant of longevity. Returning to the grape analogy, Combrune notes that the fermentability of the fruit depends on the range of temperatures that they receive over the whole of their growing season: those that undergo the greatest rises in temperature from spring to summer ripen the most. In the grain case, therefore, the representative quantity must reflect the whole process of brewing, including the mash.

In the *Essay*, the Fahrenheit figure that Combrune tabulated against each maturation time was a straightforward malt-drying temperature; in the *Theory and Practice*, it is a composite, later dubbed the "governing medium heat,"[67] which expresses "not only the degrees of dryness in the malt, but also those of heat in the extracting liquor, to the medium of which the degree of power in the hops is likewise to be added."[68] By "medium," Combrune here intends a straightforward arithmetical mean of the Fahrenheit values for the heat to which the malt is dried and the heat of the water in which it is mashed. The "power of the hops" is a correction factor: in Combrune's system, hop value may also be assessed in Fahrenheit degrees. While still displaying Boerhaavian influences, Combrune has stepped beyond anything found in the natural philosophy of Boerhaave or Shaw (or indeed any alternative authority), towards a radically thermocentric programme of malting and brewing chemistry.

Being an arithmetical mean, the governing medium heat that determines maturation time is affected equally by changes in mashing as in malting heats; but this symmetry does not hold in determining colour, taste or strength. Malting heat alone determines whether a

[66] Lindeboom, *Herman Boerhaave*, 296.

[67] The composite quantity does not in fact receive a name in the 1762 *Theory and Practice*. It becomes "governing medium heat" only in a revision undertaken at an unknown later date and published posthumously: Michael Combrune, *The Theory and Practice of Brewing*, new ed. (London, 1804). As "governing medium heat" is the only term ever nominated by Combrune, however, I have employed it for the sake of clarity in my account.

[68] Combrune, *Theory and Practice*, 135.

beer will be pale or brown, or whether it will have the characteristic taste of a high-dried brown malt; for strength, the optimum malting heat is at the bottom end of the permitted range, whereas the mashing heat must be carefully steered between the familiar, traditional danger zones of inefficient extraction and the "set mash."[69] These differences impose enough arithmetical constraints to allow "right mashing heats" to be determined from the character of the beer desired. In a typical calculation, the malting heat is chosen according to the desired colour; the governing medium heat is found from the requisite maturation properties of the brew; and the mashing heat, the unknown quantity, can then be established arithmetically from the two knowns.

Combrune presents such calculations for four distinct modes of brewing, which between them cover all the main beer styles then in use: thus, all the common practices of the day are presented as rational consequences of Combrune's chemical theory. The delineation of mashing heats for pale keeping beer, for instance, is digested numerically in a column of figures that may be summarised as follows.

- "From its name" (and also to maximise strength), the palest malt is used, giving a malting heat of 119°.
- The intended governing medium heat is the highest permitting spontaneous fining, 138°.
- Beer in this style must be well hopped: Combrune specifies 10 lb of fine hops and, presumably proceeding empirically, states the "value of the virtue of the hops" at 3°, which reduces the governing medium to 135°.
- The mean mashing heat should thus be 151°, 135° being the mean of 119° and 151°.[70]

It should be noted that, conventionally at this time, brewers subjected each load of malt to *several* mashings, at different temperatures; Combrune's initial formula indicates only the mean of these values. The variation from coolest to hottest mash is determined by a further set of calculations that sometimes lack clear justification in Combrune's narrative (see box). It is to be doubted whether many readers followed these highly involved workings in any detail: what is most important to note, however, is that concrete figures result (138° for the first mash, and 164° for the last).

For porter, the same arithmetical process is applied with different constraints. The beer is darker, so a malting heat of 138° is specified. The governing medium heat must also be higher, since this style of beer is customarily fined artificially: assuming a typical maturation period of eight to twelve months, Combrune selects 148°. Porter has a high hop rate, which Combrune takes as equating to 3¾ degrees: the corrected governing medium heat is then a little over 144°, giving a mean mashing heat of 150°. Combrune's rules for mash variation (see box) establish the first mash at 144° and the last at 162°, an ad hoc addition of 2° being made to both values "for what is lost in [the extracts'] parting from the malt."[71] In the section on small beers, more empirical corrections are added to take account of the heat of the air, determined thermometrically, since these beers are the most acidic in nature and prone to spoilage in hot weather. A table lists the appropriate malting and mashing heats for atmospheric temperatures ranging from 35° to 60°.

The system features several empirically derived or wholly unexplained correction factors, and would evidently be difficult to routinise. We cannot assume, however, that

[69] Combrune accounts for "setting" as the result of excess heat causing the air present, "which is a principal agent in resolving the malt," to be expelled: Combrune, *Theory and Practice*, 9.

[70] Combrune, *Theory and Practice*, 138–40.

[71] Combrune, *Theory and Practice*, 156–57.

Combrunian Calculation of Mashing Temperatures

Combrune's theory states that the interaction of oils drawn out by heat with the malt's acids renders it not only fermentable but "saponaceous" (referring to the soluble sugar, or "sapo," of the malt) and hence transparent. The difference of 38 "saponaceous degrees" between the lowest heat of malting (119°) and the onset of blackness or charring (157°) is deemed to represent the greatest divergence in heats that should be applied across the brewing process "for any intended purpose" (Combrune, *Theory and Practice*, 135–36).

Combrune's formula to find the lowest mashing heat, which invokes this divergence, is especially difficult to follow in the worked example for pale keeping beer, since certain distinct variables have equal values. The computation invokes, obscurely, the chosen governing medium heat figure *without* the correction for hops, i.e. 138°: since the malting heat is 119°, the mash heat that would theoretically give this medium of 138° is 157°. This figure is named as the "highest saponaceous extract"; subtracting the above-mentioned 38 saponaceous degrees from 157° gives the "lowest saponaceous extract" of 119°. The "middle sapo" or mean of these two values, namely (once again) 138°, is nominated as the heat of the first mash. Since the mean of the mashing heats for this beer has to be 151°, the highest mashing heat is thus 164°.

In the example for porter, the process is as above, except that porter possesses less than the full 38 "degrees of saponaceousness": from another empirical table, Combrune gives a value of 32°. The uncorrected governing medium is 148°, which, with the malting heat at 138°, entails a theoretical highest mash of 158°. This is the highest saponaceous extract: a range of 32 saponaceous degrees gives us a lowest saponaceous extract of 126°, and a middle sapo (the mean of 136° and 158°) of 142°. Thus 142° should be the lowest mashing heat, and 160° (to give a mean of 151°) the highest. As discussed in the main text, however, Combrune makes an ad hoc addition of 2° to each value, giving 144° and 162°.

Combrune *did* intend any imitable demonstration of how to derive the relevant heats: to satisfy both his critics and his own original intent, it was necessary only to provide a concrete list of thermometric mashing heats for each mode of brewing, and a plausible explanation for the reliability of those heats in natural-philosophical terms. In Combrune's numerous arithmetical demonstrations — presented in a columnar form that probably echoes familiar brewery book-keeping conventions — the mashing heats tend to appear in the middle steps of calculations, rather than on the bottom line, as if to confirm that the chief intent is not to explain their derivation, but to convince the reader of their validity.

Combrune assumes an audience unfamiliar with algebra,[72] and the formula for determining an unknown mashing heat directly is never given. Performing the necessary rearrangement would, in fact, produce the following:

$$\text{mean mashing heat} = 2 \times (\text{governing medium heat} - \text{value of hops}) - \text{malting heat}$$

This relationship illustrates an important point. Brewery tradition had it that heat ("fiery fumiferous particles") was impressed upon, or stored within, the malt, in proportion to the

72 At one point in the revised edition, Combrune does present a simple algebraic equation: its symbols are heavily glossed, and its import translated into worked arithmetical examples over several pages. Combrune, *Theory and Practice*, new ed., 271–75.

heat applied to dry it, and that consequently the higher-dried malts would require lesser mashing heats.[73] Combrune, in fact, dismissed this belief as incompatible with chemical reasoning: fire is of a highly "subtile" nature, prone to flying off from solid bodies, and cannot be contained for any length of time even in much "closer" materials than malt.[74] However, notwithstanding this objection to the traditional view, Combrune's method conspicuously preserves its operational consequences: for any given governing heat, higher-dried malt is still best managed by a cooler mash.[75] While the heat itself could not be preserved in the malt, the Boerhaavian, oil–acid chemical effect of its application could; and, in Combrune's scheme, the latter betokened and was elided into the former.

This ambiguity may be read as a legacy of the fundamental disagreement, among natural-philosophical authorities, as to the nature of fire or heat. Boerhaave, and many other continental writers, held it to be a fluid; Bacon, Boyle and their English-speaking descendants considered it to be a mode of motion, and therefore fundamentally different from any quality that could, even in principle, be impressed in matter. If Combrune ever consulted Shaw's 1741 edition of Boerhaave on this matter (as seems overwhelmingly likely, given Combrune's evident knowledge of Dallowe's Boerhaave, his correspondence with Shaw, and the much wider distribution of Shaw's text than Dallowe's),[76] he would have found the translation of Boerhaave's writings on the nature of fire to be buttressed with a prodigiously long footnote pointing out this disparity, and describing in detail the rival mechanical view, largely with reference to the works of Boyle.[77] This tendency is typical of the book and, in John Christie's view, "massively undercuts" its function as an exposition of Boerhaavian theory.[78]

Recapturing the traditional relationship did not, however, mean that Combrune was obliged to promote it: by his formula, it holds only so long as the governing medium heat (and thus the intended mode of brewing) is unchanged. Porter, although brewed with brown malt, conventionally had distinctly *higher* mashing temperatures than pale keeping beers. This is no problem for Combrune's system, since its governing medium is also higher; neatly, several of the identifying features of London porter (heavy hopping, long storage, artificial fining) were bound up in its governing heat. Some aspects of this identity were a matter of a few years old when Combrune began his researches; perhaps, then, his scheme was deliberately developed to accommodate newly developed urban practices that seemed to go against traditional wisdom.[79] Although following an unprecedentedly prescriptive agenda, then, Combrune was still careful to be seen to echo the full range of brewers' gestural or bodily practices.

[73] Ellis, *London and Country Brewer*, 1st ed., 14, 71.

[74] Combrune, *Theory and Practice*, new ed., 87–88, 98–99.

[75] It is only in the New Edition that the use of higher mashing temperatures to offset the characteristics of lower-dried malt is prescribed explicitly: Combrune, *Theory and Practice*, new ed., 177.

[76] Lindeboom, "Boerhaave and Great Britain," 56–57.

[77] Herman Boerhaave, *A New Method of Chemistry*, trans. Peter Shaw (London, 1741), i, 206.

[78] Christie, "Historiography of Chemistry," 6.

[79] For the identity of London porter, see: Oliver Macdonagh, "The Origins of Porter," *Economic History Review* 16 (1964): 530–35; and James Sumner, "The Metric Tun: Standardisation, Quantification and Industrialisation in the British Brewing Industry, 1760–1830" (unpublished Ph.D. dissertation, University of Leeds, 2004), esp. 120–58.

The Reception of Combrune's Chemical Thermometry

Despite the significant innovation present in Combrunian chemistry, little by way of response can be retrieved from the more familiar spaces of natural-philosophical discussion. If Combrune aspired to nomination for a Fellowship of the Royal Society, or to induction into the broader natural-philosophical community (as was obtained a generation later by Josiah Wedgwood, similarly an "artisanal" thermometrist), he was to be disappointed. However, there is no evidence that this was the case. The credibility of the *Theory and Practice* rested substantially on the intellectual patronage of Shaw, and Shaw's programme of knowledge-building explicitly did not legitimate any role for Combrune beyond his commercial experience and expertise. Although evidently keen to be accepted as a philosopher, Combrune was perhaps contented with the status of "philosophical brewer." His later known writings, also brewery-specific, tended mainly to target economic and legislative concerns, arguing for controlled retail pricing and reform of the Excise system.[80]

We should therefore assess the success of Combrunian chemistry more in terms of its dissemination in the brewing community itself. Early reactions were certainly not overwhelmingly receptive. A text of 1765 states that suitable materials, rather than rules of management, should be the brewer's chief concern; another, two years later, classes Combrune's research as laudable yet "more philosophical than practical," and ignores thermometry in favour of the old face-visibility criterion.[81] Similar judgements are found in the reviewing press. The author of the *Monthly Review*'s response to the *Theory and Practice* (in contrast to the *Gentleman's Magazine* contributor of 1763) keenly comprehends the variability and contingency of the brewing process, but sees these as grounds for holding the art to be entirely separate from natural philosophy:

> The principles of the sciences are permanent; and no advances in them are valid, farther than they are warranted by positive data, and established rules. Here, and here only, truth is visible to conviction . . . [The] mechanic arts . . . are liable to such infinite variations from contingent circumstances, and none more so than those of the Brewery, that no general rules can be universally applicable to them; and particular ones will be too numerous for retention, and for application, consistent with proper dispatch of business.[82]

Thus, while Combrune's scheme might be valid, and indeed a useful contribution to the knowledge of the (gentlemanly) "public," it was unlikely to be taken up as an aid to brewing practice: "calculations and rules *so philosophically, so critically, nice*" would baffle the less adept, while the "expert artist" would find them far more time-consuming that his tacitly established, "mechanically shorter" modes of management.[83] The life and attainments of the

[80] Combrune, "Historical Accompt," and cf. an earlier draft: Michael Combrune, "An Historical Account [*sic*] of the English Brewery" (unpublished manuscript, 1762; Beinecke Library, Yale University, Osborn c. 602); Combrune gave statistical evidence to a Commons enquiry into the consumption of barley and malt in the year before his death: *London Magazine* 43 (1773): 116–17.

[81] "A Well-Wisher to his Country," *The Complete Maltster and Brewer* (London, 1765), xvi–xvii; George Watkins, *The Compleat English Brewer* (London, 1767), 3, 70.

[82] *Monthly Review* 26 (1762): 122–23, on 122.

[83] *Monthly Review* 26 (1762): 123. Italics in the original.

artisan brewer, the reviewer argued, were simply too different from those of the philosopher: "good natural parts, and the exercise of their professions" on a constant basis, gave him "an intuitive dexterity" — unquestionably Sibum's "gestural knowledge" — that more than compensated for any lack in theoretical finesse. Therefore, it was "feared that in brewhouses where any considerable business is carried on, the introduction of a thermometer to regulate every transaction, will be considered rather as an impediment to their operations, than as the means of assisting and forwarding them."[84]

This "fear," of course, was not necessarily founded on any direct brewery experience; houses of "considerable business" were apparently among the earliest to adopt the thermometer. As Peter Mathias's extensive survey revealed, its arrival is difficult to recapture from surviving sources.[85] Combrune himself, in an unpublished manuscript, states that other brewers experimented with thermometry as part of a general push for quality around 1740, but that it failed to catch on at that time; a 1766 text by the instrument-maker Benjamin Martin refers with little elaboration to the "Brewer's Thermometer," suggesting that a specialised instrument was established at that early date.[86] The balance of evidence suggests that this development stemmed chiefly from Combrune's efforts and that this was recognised at the time. The anonymous manual *Every Man His Own Brewer* of 1768, for instance, appears to have been revised before publication in the light of Combrune's innovations.[87] Combrune is mentioned by name, and occasionally quoted verbatim, and a table paraphrases (with occasional alterations) his values for the relationships between malt dryness, colour, time taken for the beer to be in order, and precipitation potential.[88] The writer comments that "[t]he thermometer recommended as the best, is said to be formed on the projection of Fahrenheit," and employs exclusively the Fahrenheit scale.[89]

This was the first in a series of brewing and malting manuals by diverse brewers, hacks and chemists, mostly drawing on their predecessors, which — undoubtedly alongside the unrecapturable word-of-mouth route — established thermometry and the degree Fahrenheit as general among all but the smallest brewers by 1830. The survival of Combrune's name alongside them was assured when substantial quotations from the 1758 *Essay* were produced with full acknowledgement in the second and third editions of the *Encyclopaedia Britannica* (1778–83, 1797), by then beginning to establish itself as a credible reference source.[90] Although encyclopaedia literature and the works of nonbrewing "speculative Men" were treated with increasing circumspection by commercial brewers in the nineteenth century,[91] it is notable that even those most keen to demonstrate a "practical-minded"

[84] *Monthly Review* 26 (1762): 122–23.

[85] Mathias, *Brewing Industry in England*, 66–67.

[86] Combrune, "Historical Accompt," 18–19; Benjamin Martin, *A Description of the Nature, Construction, and Use of the Torricellian, or Simple Barometer* . . . (London, 1766), 19–20.

[87] *Every Man His Own Brewer* (London, 1768), 44–45, 58–59, 108–11, 180–87.

[88] *Every Man His Own Brewer*, 37.

[89] *Every Man His Own Brewer*, 184.

[90] *Encyclopaedia Britannica*, 2nd ed. (1778–1783), vol. ii, 1378–85. The entry is a typical piece of scissors-and-paste journalism derived from three sources: unacknowledged, the brewery material from the *Cyclopaedia* of Shaw's co-translator Ephraim Chambers (probably a hack production itself); Combrune's *Essay*; and (also acknowledged) John Richardson's *Theoretic Hints* of 1777. For the organisation and rather shaky early history of the *Britannica*, see Richard Yeo, *Encyclopaedic Visions* (Cambridge: Cambridge University Press, 2001), 170–87.

[91] George Lloyd Worthington, *The Brewer's Guide: a New Work* . . . (London, 1812), iv.

attitude, based on long experience at the copper-side, were straightforwardly thermometric by 1820.[92]

Furthermore, a variety of nineteenth-century work that followed the posthumous[93] publication of the revised *Theory and Practice* demonstrates that some brewers were inspired not only to reproduce but to extend Boerhaavian or Combrunian chemical ideas.[94] One brewer, George Blake, acquired a copy of Shaw's original translation of the pirated Boerhaave, and was so taken with the treatment of "the mysterious nature and wonderful effects of Fermentation" as to reproduce it in full in his 1817 treatise.[95] John Levesque, a brewer claiming over 40 years' experience in 1836, developed his own Combrune-derived scheme of gradations of malt colour (six are nominated), which he also nominated as a basis for mash heat calculations.[96] Levesque's devotion to the "rule of proportion"[97] was such that, in one of his numerous tables, relating hop rate to atmospheric temperature, the proportionation is developed in a way that effectively takes the Fahrenheit scale as absolute — the number of pounds of hops required is a simple multiple of the number of Fahrenheit degrees.[98]

Overall, however, such writers were distinctly in the minority. The thermocentric, Boerhaave-inspired chemical scheme fell by the wayside, even as the thermometric culture that it had underpinned was enshrined as "normal" brewing practice. Commercial brewers' texts often simply ignored it; Friedrich Accum and Michael Donovan, nonbrewing chemists writing on brewery topics, reproduced it in the interests of demolishing its validity. Donovan, chemist to the Company of Apothecaries in Ireland, assailed both the experimental procedure and the whole theoretical basis of Combrune's central malt-drying investigation:

> The management of the heat has been considerably misunderstood . . . it was believed that the degree of heat is what decides the hue [of malt]: now, however, it is ascertained that it is not the degree of heat, but the period of time employed to communicate this degree, that determines the colour. A heat of 175°, slowly applied, will leave the malt pale; while the same

[92] The clearest example is John Tuck, *The Private Brewer's Guide to the Art of Brewing Ale and Porter* . . ., 2nd ed. (London, 1822).

[93] The significantly posthumous 1804 publication of the New Edition awaits explanation. Family involvement seems plausible, given that the manuscript must have survived intact for at least thirty years. The Hampstead brewery had not survived, but Michael's nephew and former apprentice, Gideon Combrune, had gone on to a successful career as an ale-brewer in metropolitan London, serving as Master of the Brewers' Company; Gideon had died in 1802, but at the time of publication the brewery was still trading under the Combrune name, probably under the control of his widow Anne (it was sold shortly afterwards).

[94] J. S. Forsyth, *The Farmer, Maltster, Distiller, & Brewer's Practical Memorandum Book* (London: D. Cox, 1823?); E. N. Hayman, *A Practical Treatise to Render the Art of Brewing More Easy* (London: Longman, 1819).

[95] George Blake, *Theoretical and Practical Remarks on G. Blake's System of Malting and Brewing* (London, 1817), 50–70; cf. Herman Boerhaave, *A New Method of Chemistry*, trans. and ed. Peter Shaw and Ephraim Chambers (London, 1727), 115–25.

[96] John Levesque, *The Art of Brewing and Fermenting and Making Malt*, 4th ed. (London: J. Leath, 1847), 119.

[97] Levesque, *Art of Brewing*, vii.

[98] Levesque, *Art of Brewing*, 79.

> degree, quickly applied, will scorch it quite brown. Unacquaintance with this fact led Mr. Combrune into the mistake of supposing that, at this temperature, malt is blackened and burned; and the mistake led him into a variety of others.[99]

The Fahrenheit scale and thermometer, then, could *not* be appointed the representative and determinant of colour. Donovan unpicks — and almost inverts — the crucial relationship between malting and mashing temperatures:

> [I]f the malt has been exposed to a high heat . . . the starch is more or less scorched . . . [and so becomes] more soluble in hot water without thickening it . . . The higher the temperature at which the malt has been dried the hotter the water made use of for mashing may be, and the less must be the possibility of its setting.[100]

However, roughly sixty years separate the chemical worlds of Combrune and Donovan (a fact of which Donovan was probably unaware: his source was the 1804 New Edition, whose presentation misleadingly suggests it as the work of a living author). Chemical investment in Boerhaave's conception of heat, never unrivalled at any time, had dwindled severely across this period; much of what Donovan finds "complex, obscure and affected" is simply Boerhaavian.[101] For instance, Donovan objects that if a direct heat of 175° were enough to char the malt, as Combrune claimed, the typical mashing process (at a similar temperature) would have the same result. Combrune would have had an answer to this in terms of the Boerhaavian doctrine of action through a menstruum, a concept that Donovan does not address.

Jan Golinski, in his piece on the thermometer, neatly covers the relevant aspects of the move away from Boerhaave. Joseph Black's work on heat capacities around 1760, by establishing the conceptual distinctness and nonproportionality of heat content and bodily expansion, altogether undermined the belief that chemical activities and fermentative motions could be codified in terms of the instrumental action of heat alone. An acceptance fatal to Combrune's theory, that the rise and fall of a thermometer could not provide a quantity directly representative of chemical state, thus arose from what was, as David Miller points out, a contribution to a thoroughly chemical debate.[102]

In rather different ways, the oxygen–caloric theory of Lavoisier, which begins to appear in brewery texts after 1800, also helped to exclude Combrunian thinking. The brewer George Adolphus Wigney, for instance, is keen in the 1830s to overturn the view that the malt's character "is effected [*sic*] by heat alone," stressing the role of atmospheric oxygen in the relevant chemical action: citing the analogy of rust and arterial blood, he ascribes to oxygen the direct colorific responsibility that Combrune applied to thermometric heat.[103] Thus the principal cause of the disappearance of Combrune's theory was not resistance to natural philosophy by brewers, but changing beliefs among chemists themselves.

[99] Michael Donovan, *Domestic Economy*, vol. 1: *Brewing, Distilling, Wine-making, Baking, &c.* (London, 1830), 86. Cf. Fredrick [Friedrich] Accum, *A Treatise on the Art of Brewing*, 2nd ed. (London, 1821), 31–32.

[100] Donovan, *Domestic Economy*, 145–46.

[101] Donovan, *Domestic Economy*, 146.

[102] Golinski, "Fit Instruments," 193–200; Miller, "Seeing the Chemical Steam."

[103] George Adolphus Wigney, *A Theoretical and Practical Treatise on Malting and Brewing*, 2nd ed. (Brighton, 1835), 65–66.

Conclusion: a Chemist Vanishes

Combrune's name, of course, survived to be admired: professional brewing science, codifying itself as a laboratory-based discipline from around the 1850s, needed foundational heroes. The thermometer was ubiquitous by this point, and merely yoking the individual to the device was sufficient to secure acceptance. As we have seen, however, the whole project of imposing the thermometer as representative of chemical state had by this point collapsed; the Boerhaavian worldview had lost ground to the extent of seeming arcane, and Combrune's attachment to it had drawn criticism from within and outside the brewery. In consequence, Combrune's pioneering reputation is in no sense chemical.

The historiographical pressures from outside the brewery are much as depicted by Miller: just as Watt was claimed (anachronistically) as a founding thermodynamicist, so Combrune — to his far more specialised constituency — mutated into the protoscientific representative of practical, distinctly physical instrumentation. This development exacerbated another pressure internal to the brewery: the rise from the 1780s of gravimetric determination, as promoted by James Baverstock and John Richardson, which I have discussed in a previous paper.[104] Although both were "philosophical brewers" in very much the style initiated by Combrune, and zealously thermometric, their processes made thermometry subservient to the application of hydrostatic instruments. Establishing the hydrometer or saccharometer as the chief representative of value in brewery contexts entailed displacing the thermometer from that position: hence the conspicuous absence of Combrune's name from Richardson's work, and the quiet unpicking of some of his key principles.[105] In the later nineteenth century, a symmetry was constructed between Combrune's innovation and Richardson's, the two being bracketed together as part of a progression towards quantitative science.[106]

The loss of Combrune the chemist did not, we must realise, follow inevitably from the decline of Boerhaave; but it was, perhaps, inevitable, given the strategy adopted by Combrune to promote his thermometric innovation. My previous work has noted how John Richardson adroitly tailored his saccharometric project to practising brewers' existing interests, with the result that understandings and practices distinct from those in the philosophical mainstream became entrenched in brewery culture. I emphasise the distinctly commercial nature of Richardson's agenda: he sought to establish a single-instrument model (via his monopoly relationship with the Troughtons) as valid, and himself as its sole interpreter. Combrune was less proprietorial: while promoting a sole theoretical scheme, he did not seek to control or redefine the thermometer itself.

While Combrune devotes some space to the history of the thermometer, its present state is treated very much as a simple given: no specific maker is recommended, and the various operational matters that might have been elaborated upon (where to position the bulb, time needed to obtain a stable reading, care of the device when not in use) are absent. This is unsurprising: Combrune has in mind a gentlemanly audience, whether engaged in brewing or not, seeking edification rather than manual directions. But the effect is to make Combrune's chemical underpinning optional: the early *Gentleman's Magazine* objection, that recommending the thermometer "might as well have been done in 10 words," ultimately retains some of its force. A practising brewer, skilled in the use of sometimes

[104] Sumner, "John Richardson."
[105] See n. 54.
[106] John Yeats, *The Technical History of Commerce* (London, 1871), 234.

delicate equipment, and inured by the unloved Excise to a regime of endless gauging and tabulation, would certainly have found a means to apply the thermometer without precise directions; but the mode of this application might have been entirely different from what Combrune intended.

The thermometer and its "standard" degree scale in fact admitted of intensely localised practice. A brewer might set the heat of his wort using the old-established methods of his choice, record a value on the thermometer scale, and, if the result was successful, bring the heat to the same value for the next brewing; if this failed to give similar results, the brewer would make a judgement based on his established understanding of the broader situation, and modify his figure or actions accordingly. Thus, thermometers were *not* the basis of a revolution in practice, but were assimilated into the brewer's array of bodily knowledge; correspondingly, the constant term "thermometer" belies an ongoing process of mutual reconstruction of theory and artefact. Adjustments occasionally became codified in print, as in the case of Combrune's correction factors: they serve as numerical echoes of the pre-thermometric writers' appeal to the authority of the traditional brewer.

Here, then, we see why thermometers came into general use while Combrune's chemical underpinning was neglected. Yet such is the fate of most underpinnings, as habituation leads users to accept quantities and procedures as trusted givens, while basic research promotes new understandings of established practice. In the early stages, Combrune's scheme *was* essential to the acceptance of the device among gentlemanly brewers — first by securing the brewery as a valid site for new philosophical techniques, through its positioning as a response to Shaw's agenda, and second by garnering publicity through the review journals. The scheme's survival was evidently dependent on the worldview that inspired it, and it endured as long as could be expected.

In the historical record, however, Boerhaave survived as a chemical as well as a medical adept, as did Peter Shaw; Combrune did not. To be a "philosophical brewer" was not to be an object of general philosophical concern or memorial. Yet it is instructive to note the ease with which Combrune's vanished chemical status can be restored to visibility — an ease that depends directly on his commitment to the philosophical standards and establishments of the day, which have left the historian with well-preserved quartos, periodical reviews and intriguing graphical symbolism to address. It is likely that parallel cases in other "marginal" fields, if similarly recovered, could significantly reshape our understanding of past chemical cultures.

Acknowledgements

In addition to those thanked in relation to specific points in the notes, I would like to thank: John Christie, Graeme Gooday, David P. Miller, Greg Radick and Anna Simmons; the staff of the Beinecke Rare Book and Manuscript Library, Yale University, and of Archives and Special Collections, Durham University Library; and the *Ambix* reviewer for comments and assistance.

Notes on Contributor

James Sumner is a lecturer in the history of technology at the Centre for the History of Science, Technology and Medicine (CHSTM), University of Manchester, UK. He has broad interests in technology and its relationship to the sciences from the late eighteenth century to the present day; his doctoral work considered the case of beer-brewing around 1800 to demonstrate the tensions and power-struggles that arise as quantitative techniques, using instruments such as the thermometer, are imported into “traditional” craft-based activities. He is also associate director of the National Archive for the History of Computing, and is involved in a nascent research project on the role and image of the computer in everyday British life. Address: CHSTM, Second Floor, Simon Building, Brunswick Street, University of Manchester, Manchester M13 9PL, UK; Email: james.sumner@manchester.ac.uk.