

# “A Most Exquisite Fellow” — William White and an Atlantic World Perspective on the Seventeenth-Century Chymical Furnace

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The seventeenth-century technologist and colonist William White (ca. 1600–73) has been cited as an alchemical tutor to Gabriel Plattes and George Starkey, and hailed as an early modern “wizard of industrial efficiency.” This study — the first that focuses on White individually — pays particular attention to White’s extraordinary reputation for furnace design and manufacture. By examining the sources of knowledge and social connections that enabled White to acquire and disseminate his knowledge of metallurgy, the authors develop a genealogy of furnacic design that extends from the continent to the Atlantic world and back again, connecting White to better known figures such as Cornelis Drebbel and Robert Boyle. By foregrounding, through White, the technology of early modern alchemy, the authors also hope to emphasise the importance of practical craft in the development of the chemical arts.

“Mr Whyte ... is a most exquisite fellow and the best in England for making all manner of furnaces and of divers other industries.”<sup>1</sup> As a description of Gabriel Plattes’s acquaintance, the seventeenth-century technologist and colonist William White (ca. 1600–73), this 1643 entry in Samuel Hartlib’s *Ephemerides* could hardly be improved upon, particularly in the emphasis it places on White’s abilities as a furnace-maker. References to him in the historiography of alchemy have been infrequent — Charles Webster identified White as a source of Plattes’s alchemical knowledge, while more recently William Newman and Lawrence Principe described him as a “wizard of industrial efficiency” who taught the arts of metallurgy, including furnace-making, to George Starkey, who imparted them in turn to Robert Boyle.<sup>2</sup> This paper will extend these insights by examining White’s sources of knowledge and

<sup>1</sup> Samuel Hartlib, *Ephemerides 1643*, in *The Hartlib Papers (a Complete Text and Image Database of the Papers of Samuel Hartlib) (C. 1600–1662)*. Held in Sheffield University Library, Sheffield, UK. (Sheffield, UK: HROnline, Humanities Research Institute, University of Sheffield, 2002), 30/4/93B.

<sup>2</sup> Charles Webster, *Utopian Planning and the Puritan Revolution: Gabriel Plattes, Samuel Hartlib, And “Macaria,”* Research Publications of the Wellcome Unit for the History of Medicine, Oxford, No. 2 (Oxford, UK: Wellcome Unit for the History of Medicine, 1979), 21; William R. Newman and Lawrence Principe, *Alchemy Tried in the Fire: Starkey, Boyle, and the Fate of Helmontian Chymistry* (Chicago: University of Chicago Press, 2002), 159–61.

social connections as a means of tracing the lines of influence acting on those more significant figures. We also hope that by foregrounding the technology of early modern alchemy, we will help to emphasise the importance of practical craft in the development of the chemical arts.

While scholars of seventeenth-century alchemy have tended to concentrate on the intellectual progression from magical and vitalist explanations of natural phenomena to the more materialist “mechanical philosophy,” it has also become apparent that the movement from alchemy to chemistry was a gradual one, and that the conceptual and practical roots of the work of major figures such as Boyle and Newton lay deep in the rich soil of alchemical practice.<sup>3</sup> A defining feature of the scientific method is that theory must proceed out of observation, and such diverse thinkers as Paracelsus and Bacon had emphasised the necessity of careful examination and measurement of the physical and natural world. Observation in the chemical sciences is, however, not technology-independent; many phenomena are not observable without some kind of intervention or enhancement on the part of the observer. Physical matter as it is experienced in the world is both complex and chaotic, and very few of what we now recognise as elements or compounds are actually met with in nature in a pure form. To even begin to approach their study, a complex technology of heating, burning, distilling, refining and combining is necessary, and it is precisely here that a major component of the alchemists’ contribution to the development of science can be found. While there is some evidence for the use of transmutation as a means of generating actual wealth, its primary significance probably lies in the promise of riches that created a flow of investment capital that funded, in turn, the technological experimentation and development from which an impressive body of empirical knowledge and expertise was assembled.<sup>4</sup> In the absence of research grants, professorships and Nobel Prizes, the desire to create gold from less valuable and more readily available metals was a powerful stimulant to research. William White’s history as an alchemical laborant in England and English America affords an insight into the relationship between alchemy and technological development. By concentrating on the evidence relating to White’s furnace-making activities, we suggest a line of transmission for fornacic design from the Dutch inventor Cornelis Drebbel at the start of the seventeenth century to Robert Boyle in the 1650s. We also describe some of the economic and social pressures, not to mention some of the very human factors, that shaped this process.

The known facts of William White’s life are relatively straightforward. He was English, born between 1600 and 1610 at the latest, and from the fact that his eldest daughter was married by 1647 (when she was convicted of stealing a dress), we can deduce that he had

<sup>3</sup> William R. Newman, *Gehennical Fire: the Lives of George Starkey, an American Alchemist in the Scientific Revolution* (Chicago: University of Chicago Press, 2003); Lawrence Principe, *The Aspiring Adept: Robert Boyle and His Alchemical Quest: Including Boyle’s “Lost” Dialogue on the Transmutation of Metals* (Princeton, N.J.: Princeton University Press, 1998); Bruce T. Moran, *Distilling Knowledge: Alchemy, Chemistry, and the Scientific Revolution* (Cambridge, Mass.: Harvard University Press, 2005).

<sup>4</sup> Carl Wennerlind, “Credit-Money as the Philosopher’s Stone: Alchemy and the Coinage Problem in Seventeenth-Century England,” *History of Political Economy* 35, Annual Supplement (2003): 234–61; Tara Nummedal, “Practical Alchemy and Commercial Exchange in the Holy Roman Empire,” in *Merchants & Marvels: Commerce, Science and Art in Early Modern Europe*, ed. Pamela H. Smith and Paula Findlen (New York: Routledge, 2002), 201–22.

probably married his wife Elizabeth by 1630. By the early 1640s, he had acquired an extensive repertoire of technical skills and a reputation as an expert furnace-maker, but like other similarly placed experts, he found the conditions prevailing during the Civil War insupportable. In 1645, he emigrated to Massachusetts in the company of Dr. Robert Child. Child had recruited him to work for the Company of Undertakers of the Iron Works in New England as an expert metallurgist, and he was employed at the Saugus Ironworks until a falling out with the manager, Richard Leader, caused him to leave at some time in 1647 or early 1648. Resident in Boston until August 1648, he supported his family through a variety of enterprises, which included a period of employment by the young alchemist George Starkey, whom he instructed in the arts of metallurgy. In July 1648, White travelled to Bermuda to work for the alchemist William Berkeley, and remained there until early 1655, when he returned to New England, probably having been recruited by John Winthrop Jr. for his projected alchemical campus at Fishers Island in Connecticut's Long Island Sound. Although White spent some time at Fishers Island, the enterprise did not proceed, and White moved to Rhode Island, where his daughter Elizabeth and her husband Benjamin Hearnden had settled. A falling out with Hearnden saw White return to Boston in 1660, where he remained until his death in 1673.<sup>5</sup>

The quotation with which this paper opens reads in full "Mr Whyte Plats special acquaintance [one] that lived for many years with Dr Evered who spent many hundred lb. vpon Chymistry is a most exquisite fellow and the best in England for making all manner of furnaces and of divers other industries." Samuel Hartlib, a German émigré to England who was actively involved in alchemy, scientific reform and education, recorded this report on White in his day-book, the *Ephemerides* of 1643, noting that the source of his information was "Plats."<sup>6</sup> Gabriel Plattes, a member of the Hartlib scientific circle, was the author of the anonymously published utopian tract *Macaria* and of books on mining, metallurgy, and agriculture.<sup>7</sup> In another entry in the 1643 *Ephemerides*, Hartlib further enlarges on White's

<sup>5</sup> *Records and Files of the Quarterly Courts of Essex County, Massachusetts*, 8 vols. (Salem, Mass.: Essex Institute, 1911), vol. 1, 137; *A Report of the Record Commissioners of Boston, Massachusetts 1630–1699* (Boston, Mass.: Rockwell and Churchill, 1883), 23; George Lyman Kitteridge, *Doctor Robert Child the Remonstrant* [Cambridge, Mass.: (Harvard) University Press, 1919], 16; William White to John Winthrop, 24 July 1648, in *Winthrop Papers* (Boston, Mass.: Massachusetts Historical Society, 1947), 239–40; William White to Robert Child, 8 May 1649, in *Hartlib Papers*, 15/8/6A–7B; William White to John Winthrop Jr., 14 February 1654/5, in *Winthrop Papers* (unpublished) (Boston, Mass.: Massachusetts Historical Society), 19:150; William White to John Winthrop Jr., 26 July 1656, in *Winthrop Papers* (unpublished) (Boston, Mass.: Massachusetts Historical Society), 19:150; *Early Records of the Town of Providence*, 21 vols. (Providence: Snow & Franham, 1892–), vol. 2, 11, vol. 2, 98, vol. 4, 9–11, vol. 15, 75–76; "Will and Inventory of William White, October/November 1673," *Suffolk Deeds* (1673), 343–6.

<sup>6</sup> Hartlib, *Ephemerides* 1643, 30/34/90A.

<sup>7</sup> Gabriel Plattes, *A Discovery of Infinite Treasure, Hidden since the World's Beginning: Vwhereunto All Men, of What Degree Soever, Are Friendly Invited to Be Sharers with the Discoverer, G.P.* (London: Printed by I. L. and are to be sold by George Hutton, 1639); Gabriel Plattes, *A Discovery of Subterraneall Treasure Viz. Of All Manner of Mines and Mineralls, from the Gold to the Coale; with Plaine Directions and Rules for the Finding of Them in All Kingdoms and Countries.* (London: I. Okes, for Iasper Emery, and are to be sold at his shop at the signe of the Eagle and Child in Pauls Church-yard next Watlin-street, 1639); Gabriel Plattes, *A Description of the Famous Kingdome of Macaria. Shewing Its Excellent Government*, (London: Francis Constable, 1641).

fornacis genius — “Mr White hase amongst [many] other things invented a new kind of Furnaces which will save charges and coales. For hee vndertakes to save one third part of the charges of fire in all Brew-houses dyers-Houses and all other Houses and employments where boyling of liquid substances cause the charge.”<sup>8</sup> Given the fact that Plattes and Hartlib were early advocates of both economic rationality in scientific investigation and of the need for increased technological efficiency, it is not at all surprising that Plattes would have told Hartlib about White’s achievements, or that Hartlib would have taken pains to record them for future reference.

The “Dr. Evered” referred to by Plattes as the person with whom White lived for several years was the antinomian minister Dr. John Everard, who had come to prominence in the early 1620s as an outspoken critic of the “Spanish match,” the proposed marriage of Prince Charles and the Spanish Infanta. In proclaiming his opposition, Everard well and truly established his credentials as a godly firebrand, and was imprisoned on a number of occasions. A few years later, however, a mystical experience led him to a radical rejection of all religious doctrine (except his own). Everard’s patron and protector (quite literally so at times) was Henry Rich, the Earl of Holland, who kept the church and secular authorities at bay and also afforded him a measure of personal comfort and an unusual degree of personal freedom. Everard emphasised individual spirituality in the present world at the expense of a “literalist” interpretation of scripture that situated spiritual rewards in the hereafter. The increasing outspokenness of his sermons alienated him from both the puritan party and the established church, so that when he came into conflict with the Laudian authorities in the 1630s, he had few allies outside his own direct supporters. Everard was eventually forced to recant his beliefs before the Court of High Commission in 1640, only months before his death.<sup>9</sup>

Everard’s interest in alchemical ideas is well documented. For him, transmutation was a mirror of the inner perfection achieved by the believer upon surrendering the Self to God. Everard was in contact with the Rosicrucian defender Robert Fludd in the 1620s,<sup>10</sup> and he went on to produce the first English translation of the *Pymander* of Hermes Trismegistus.<sup>11</sup> But for all his interest in chrysopoeia as a mirror of spiritual transformation and a way of understanding relationships within the microcosm, the Hartlib reference to Everard’s connection to White implicates Everard in more mundane chemical pursuits and the development of White’s technological efficiency.

William White’s connections to Plattes, and to Everard, enable us to draw some tentative conclusions about the social milieu in which he moved, and the possibilities that that milieu opened up for him. If, as seems most likely, White had not only lived with Everard for years, but had worked with him in implementing the prolonged programme of alchemical experimentation that cost, according to Plattes, “many hundred pounds,” that experience was also probably the work through which White developed and improved the efficiency of his furnace designs. Everard’s financial support, then, probably played

<sup>8</sup> Hartlib, *Ephemerides* 1643, 30/4/93B.

<sup>9</sup> David R. Como, *Blown by the Spirit: Puritanism and the Emergence of an Antinomian Underground in Pre-Civil-War England* (Stanford, Calif.: Stanford University Press, 2004), 219–65.

<sup>10</sup> Como, *Blown by the Spirit*, 222.

<sup>11</sup> John Everard, *Hermes Mercurius Trismegistus, His Divine Pymander. ... Translated Formerly out of the Arabick into Greek, and Thence into Latine and Dutch, and Now out of the Original into English; By ... Dr. Everard* (the Preface Signed J. F.) (London: Printed by J. S. for T. Brewster, 1657).

a significant role in developing White's practical skills and knowledge in the field of furnace-making. Furthermore, as a member of Everard's household, White may well have come into contact with other practising spagyrist, as well as people involved in the Puritan colonisation of America. Everard's patron, Henry Rich, was himself a director of the Providence Island company, and Rich's brother Robert, the Earl of Warwick, was actively involved in a number of Anglo-American plantations. These influences may have been instrumental in directing White's thoughts toward employing his spagyric talents in America, which by 1643, three years after Everard's death, he clearly seems to have envisioned doing.

We know this because of a far more detailed picture of White's extensive abilities that can be found in another document among the *Hartlib Papers*, one roughly contemporaneous with the earlier entries. The "Cattallogg of secrets good for a Common-welth or plantation" appears to be an advertisement for William White's skills as a furnace-maker and general artisan technologist.<sup>12</sup> It could be a manuscript for a handbill, although it is not known to exist in this form, and its inclusion among Hartlib's documents suggests that it may have been given to him in an attempt to solicit business from among Hartlib's connections. Although the phrase "Mr. White's Inventions" has been appended to the page by Hartlib, there is no need for us to assume that all of the technologies offered were of White's original invention — in the seventeenth century, "invention" could still be used with the older meaning of "contrivance" and without any implication of originality. In some cases, though, White does make clear that he is the originator of the product or process offered. White himself refers to his offerings as "Secrets" in the sense of specialised professional knowledge not known to the layman.<sup>13</sup> However they are categorised, White's list reveals an impressive range of interests and activities that makes this document worth quoting in full.

A CattaLogg of secretts good for a Common welth or plantation

1. As Biulding of stoues stills or any other furnases for the vse of phisitians Chimists and ApotheCaris Cooks hatters & diuers other Tradesmen sauing much fire & also time with the vses of most of them
2. meltinge pots and other vessells for phisicall Cimmicall & goldsmiths & many other trades in Case of wantinge of the ducthmens Ware & cheaper
3. also Iugg mettall; that will hold aquafotis as well as glase & will make heads boddys bottls Iuggs etc very nessesarie in all Countrys etc
4. A horisontall Windmill so Contriud: on the topp of a dwellinge house standing allways to the winde without tendence: & will alsoe doe many things with little tendance

<sup>12</sup> William White, "Catalogue of Inventions, Mr White," in *Hartlib Papers*, 63/11A–11B. The editors of the Hartlib Papers have given it this title, although the title of the document in White's hand is "A Cattallogg of secrets good for a Common-welth or plantation." "Mr White's Inventions" is written above this in another hand. Two items in the list of inventions can be used to date the Catalogue to the years 1642 or 1643. In the description of a portable oven, it is mentioned that one had been "lately made for the Kings vse," while the wording of "hand granads of Iugg earth against our foraine enemies: not at home" carries a clear hint that war in England was a clear danger, if not in fact a present reality.

<sup>13</sup> For a discussion of secrets, see William Eamon, *Science and the Secrets of Nature: Books of Secrets in Medieval and Early Modern Culture* (Princeton, N.J.: Princeton University Press, 1994), 11.

5. alsoe horsemills & handmills with ease added to them a newe way
6. Alsoe ouens of all sorts portable; good for trauellers by sea or lande or plantations on lately made for the Kings vse that will in 24 ours bake bread for a 1000 men: and followe the Army foote for foote: by a frenchman prised at ten thousand li.
7. Alsoe making of stous & stills portable: veri nesesarie[altered] for studdys Clossetts etc
8. A newe way by hime Contriued for making or buildinge of salt-worke to saue much fire & time good for all plantations= & at this time for England
9. Good ways for water works// Good for drye towns or drie or wett grounds
10. A good forte by hime soe Contriued that by the turning a horisontall wheele 50 men may keep out 2 or 3000= alsoe it is harde to be taken & with kare works vnder ground & 6 men will Remoue 12 smale ordnace at once & discharge them all at one place if need be
11. hand granads of Iugg earth against our foraine enemys: not at home
12. A newe deuised ploughe to inCounter with Mr plats setting Enginn
13. Good ways to Calcine & smelt all sorts of oares or mettalls etc
14. A deuise to make the Capp & Coppell or greate test soe that it may saue in walls: by Mr Roberts his Reporte one 1000li a Yeare
15. diuers sorts of bellows for maltinge for nipping vp glasses perfeuminge etc

White concluded the list with an explanatory comment — “These are enoughe to make some smale shoue of Ingnewetie and the[y] are no tricke but all profittable things= and who soeuer doth desire to be further satisfied he may haue any of them modelled for verry Resonable Consideration= with some Conditions.” White clearly intended his list to function as both advertisement and an investment prospectus; it is a description of useful products and inventions, and an offer to demonstrate their quality and efficacy by producing demonstrations for a reasonable fee, subject to certain unnamed conditions.

More than half of the items relate more or less closely to the practice of alchemy or other activities requiring the use of heat, and throughout, although usually indirectly, the emphasis on the efficiency of White’s furnaces is readily apparent. From one of the “secrets” in particular, though, we are able to make connections between White and other individuals and to locate him within a much broader pattern of technological development.

The reference to King Charles in invention number 6, the portable military oven, relates to his ill-fated invasion of Scotland in 1639. An almost identical description of an oven is to be found in Hartlib’s *Ephemerides* for 1639 — “Cufler hase an Invention of ovens for baking of bread, 20. of which shall doe as much as 300. of those which the P. of Orange vses to take along with him into the Leaguer. Id est by computation they shall bake so much as shall furnish an Army of 20. thousand men.”<sup>14</sup> Johann Kuffler was a Dutch immigrant who had married a daughter of the inventor Cornelis Drebbel in 1627 — his older brother, Abraham, had married another of Drebbel’s daughters a few years earlier. Johann Kuffler’s own description of his ovens, written after 1653, made their link to Charles I explicit and reconfirmed that they dated to 1639:

When as the troubles first arose in England by reason of Scotland, the King desired to knowe whether there was not an Invention, to carry baking ovens into all places about the Leger, wherebie they might at all tymes be provided with bread: Whereupon (though not with small

<sup>14</sup> Samuel Hartlib, *Ephemerides* 1639, in *Hartlib Papers*, 30/4/6B.



charges), I soe long practized, that I found out such an Oven consisting of yron and Copper plates (for the lightnesse of the weight sake) wherebie if it be but 2 foote greate or wide, & 3. foote high, I am able to bake in the space of 24 houres 1500lb weight in bread, which will suffice for a Regiment of souldiers, & be verie convenient every where to followe the Camp ... The King did not see the Invention, he being before that time departed from London.<sup>15</sup>

White's oven and Kuffler's oven were clearly closely related. In military purpose, portability, and even the number of men fed by a single oven — a thousand — the two furnaces were essentially the same. It is indeed difficult to escape the conclusion that White was, or had been, in contact with the Kufflers and learned about their portable oven. Given White's own reputation for furnace construction, it is possible that he helped to construct the original, and, on the basis of that experience, offered to replicate it for others.

When these early references to White's fornacic construction are linked to his subsequent involvement with George Starkey, a more detailed picture of mid-seventeenth century furnace development emerges; one that reveals the particular feature that made the furnaces of White and the Kufflers so impressive in the late 1630s. This new perspective includes not just Starkey, but the best known fornacic expert of the seventeenth century, Johann Rudolph Glauber.

William Newman and Lawrence Principe have concluded that William White was in Boston in 1648, teaching the young American alchemist George Starkey the secrets of metallurgy.<sup>16</sup> After studying with White, Starkey travelled to London, where a reference in Hartlib's *Ephemerides* for 1651 establishes the young Starkey's fornacic credentials beyond doubt. Hartlib compared the youthful New England émigré with the most prominent furnace-maker of the time — "Hee [Starkey] hath admirable skil in making all manner of furnaces, and hath lighted vpon the same fashion that Glauber makes before hee had seene any of his."<sup>17</sup> Hartlib was impressed with what he perceived as Starkey's and Glauber's independent generation of the same fornacic technology, a comparison that, by implication, favoured the younger inventor from the remote colonial setting. However, with our knowledge of Starkey's tutelage under William White, the man Hartlib had described as the "best in England for making of all manner of furnaces," we are perhaps better able to surmise how Starkey had acquired his remarkable fornacic abilities. If Starkey was able to make furnaces in the fashion of Glauber, the chances are that he learned how to do so from William White.

Starkey certainly practised oven construction in New England. In August 1648, Starkey informed John Winthrop Jr. that "I have built a furnace, very exquisitely but want glasses."<sup>18</sup> (The contemporary meaning of the word "exquisite" was "accurate or precise" — Hartlib had used the same word to describe White himself.) In a later autobiographical note describing his emigration to London, Starkey spoke of furnace construction again. "Leaving New England, I came to London in the year 1650, around the beginning of winter, in the month of November, and towards February I began to labor, equipped with a better furnace that I had learned of in the previous year, so that the tedium of the coals was

<sup>15</sup> Johann Kuffler, "Copy Extract on a Portable Baking Oven," in *Hartlib Papers*, 39/2/115A–16B. A reference to the "Lord Protector" dates this document to 1653 or later.

<sup>16</sup> Newman and Principe, *Alchemy Tried in the Fire*, 160.

<sup>17</sup> Samuel Hartlib, *Ephemerides 1651*, in *Hartlib Papers*, 28/2/6A.

<sup>18</sup> George Starkey, "Letter to John Winthrop Jr., 2 August 1648," in *Winthrop Papers V* (Boston, Mass.: New England Historical Society, 1947), 241–42. The "glasses" that Starkey lacked were chemical glassware.

reduced.”<sup>19</sup> This was the furnace that Hartlib judged to be “state-of-the-art.” Starkey’s own reference to learning of the furnace the year before he emigrated confirms that he brought the knowledge of how to build such a furnace with him from Boston. To be sure, Starkey had previously complained about the unsuitability of New England furnaces for the work that he hoped to do, but, like most alchemists in the colonial environment, Starkey was constantly challenged by the absence of or poor quality of materials. The instant boost in furnace function that Starkey achieved once in England presumably came about because he had known the *technique* of furnace-making back in America, but had lacked the *means* to bring it about. Since this paper is arguing that Starkey learned fornacic design from William White, we need to determine by what means White knew about Glauberian furnace design. Could there in fact be a technological genealogy that spanned the Atlantic world, linking the ovens and furnaces of White, Kuffler, Starkey, and Glauber?

The German alchemist Johann Glauber had published his *Furni Novi Philosophici* in the period 1646–49; an English translation appeared in 1651.<sup>20</sup> If we are to take seriously the assertion that White’s furnaces — whose design features were passed on to Starkey — were not only as good as those of Glauber but were essentially identical to his before the publication of *Furni Novi Philosophici* (by which time White was living in America), we must consider the possibility of a connection between White and Glauber prior to White’s emigration to America. Although a direct link between the two men cannot be discounted, there is no positive evidence for it; by the time that Glauber had come to the attention of the Hartlib circle, White was already in America, and, although they could have been aware of one another in the later 1640s through a common connection like Robert Child, by this time both of them were on record as being expert furnace-makers. Instead of this direct influence, a consideration of Glauber’s and White’s furnaces supports the prospect of a common source of their innovations. The traditional tendency of science history to deal in innovations and “breakthroughs” often disguises the fact that technological change is incremental and complex, involving much informal experimentation and discussion before a new “invention” bursts onto the documentary record.<sup>21</sup> *Furni Novi Philosophici* is a case in point. The major fornacic innovation that it advances is found in the Fourth Part, where Glauber describes the use of smokestacks to create draught:

Let there also be a round hole in the furnace, having the third part of the intrinsecall diameter of the furnace, appointed for the flame and smoak; to which if you will use a very violent fire, put to it a strong iron pipe of the height of 5, 6, 8, or 12 feet; for by how much the higher you set your pipe, the stronger fire may you give.<sup>22</sup>

This has been accepted as the earliest description of the use of “chimney draught” in furnace construction and a milestone in the development of the air furnace.<sup>23</sup> Chimney draught

<sup>19</sup> Newman, *Gehennical Fire*, 251.

<sup>20</sup> Johann Rudolf Glauber, *A Description of New Philosophical Furnaces, or, a New Art of Distilling, Divided into Five Parts* (London: Printed by Richard Coats, 1651).

<sup>21</sup> For a discussion of continuity in technology, see George Basalla, *The Evolution of Technology* (Cambridge: Cambridge University Press, 1988), 26–63.

<sup>22</sup> Glauber, *A Description of New Philosophical Furnaces*, 234.

<sup>23</sup> R. Jenkins, “The Reverbatory Furnace with Coal Fuel, 1612–1712,” *Transactions — Newcomen Society for the Study of the History of Engineering and Technology* 14 (1933): 67–81, on 77; J. N. Goldsmith and E. W. Hulme, “History of the Grated Hearth, the Chimney and the Air-Furnace,” *Transactions — Newcomen Society for the Study of the History of Engineering and Technology* 23 (1942): 1–12, on 4.



utilises the differential between the density of the heated air inside the chimney and the cooler air outside to create a flow of air that increases in speed proportionately to the height of the chimney and the heat of the fire. Air entering the furnace beneath the grate provides oxygen to the fire and obviates the need for a bellows to generate the high temperatures needed for metallurgy. Temperature could be varied by controlling the volume of air entering the furnace through the use of a “register,” and the result was a furnace that made highly efficient use of fuel, produced little or no smoke, and required minimal intervention by the operator. White had been credited in 1643 with the invention of a furnace “which will save charges and coales,” a description which would fit the Glauberian air furnace exactly and offers a further reason to support the argument that White’s and Glauber’s new furnaces were, at the very least, closely similar.

Perhaps the similarities between White’s and Glauber’s furnaces derived not from their mutual acquaintance, but rather from their having learned the design principles that they employed from a common source, Johann Kuffler’s father-in-law, Cornelis Drebbel. The Dutch–English inventor Drebbel had moved from Holland to England in 1604, and by 1607 was in the employ of James I, for whom he created a perpetual motion machine; his other works included lenses for telescopes and microscopes, refrigeration, and, most spectacularly, a submarine that travelled for some distance underwater in the River Thames. After his death in 1633, his Kuffler sons-in-law promoted Drebbel’s claims as an inventor so vigorously that they may have been guilty of attempting to exaggerate his reputation.<sup>24</sup> Drebbel has been described in the present era, perhaps unfairly, as an inventor of novelties who did not make “a significant lasting impact on technology.”<sup>25</sup> It might be more charitable — and accurate — to view Drebbel as a visionary whose reach exceeded his grasp and whose spectacular innovations were rooted in good empirical science.

In the field of heat technology, Drebbel is today well known for his thermostatically controlled oven, in which the draught was controlled by adjustable dampers regulated by the expansion and contraction of a mercury column in a glass tube.<sup>26</sup> As the dampers regulated an existing flow of air, the operating principle behind Drebbel’s thermostat could only have been chimney draught, which provided a steady supply of oxygen to the fire, the amount of which could then be varied to regulate the intensity of the fire and the temperature of the oven or furnace. Drebbel’s thermostatic control did not become established as a standard feature of furnaces and ovens (it may have been too complex or unreliable to move beyond the prototype stage), but the use of controllable chimney draught can be considered a necessary component of the thermostat’s operation. In 1602, two years before he left Holland, Drebbel was granted a Dutch patent for the design of “a chimney with a good draught,”<sup>27</sup> and while not hugely significant in itself, this patent forms the first link in the

<sup>24</sup> F. W. Gibbs, “The Furnaces and Thermometers of Cornelis Drebbel,” *Annals of Science*, no. 6 (1948): 32–43, on 36–37; H. A. M. Snelders, “Drebbel, Cornelis (1572–1633),” in *Oxford Dictionary of National Biography*, ed. H. C. G. Matthew and Brian Harrison (Oxford: Oxford University Press, 2004), 900–2.

<sup>25</sup> Richard S. Westfall, “Science and Technology During the Scientific Revolution: an Empirical Approach,” in *Renaissance and Revolution: Humanists, Scholars, Craftsmen, and Natural Philosophers in Early Modern Europe*, ed. Judith Veronica Field and Frank A. J. L. James (Cambridge: Cambridge University Press, 1993), 63–72, on 71.

<sup>26</sup> Lawrence Ernest Harris, *The Two Netherlanders: Humphrey Bradley and Cornelis Drebbel* (Cambridge: W. Heffer, 1961), 191, 219.

<sup>27</sup> Harris, *The Two Netherlanders*, 131.

chain of evidence connecting Drebbel to the air furnace that Glauber was to write about in 1646. A passage from Sir Francis Bacon about the need for the control of temperature in alchemy appears to be a reference to Drebbel:

And here we call to mind that we knew a Dutchman, that had wrought himself into the belief of a great person by undertaking that he could make gold, whose discourse was, that gold might be made; but that the alchemists over-fired the work: for [he said] the making of gold did require a very temperate heat, as being in nature a subterrany work, where little heat cometh; but yet more to the making of gold than of any other metal.<sup>28</sup>

The need to produce temperate heat would have presented a significant challenge to the pyrotechnician — it is easier, perhaps, to cause a fire to burn intensely than to control its heat output in the manner suggested — and additional evidence that Drebbel had thought about this problem, and had in fact perhaps solved it, can be found in the claim that he had developed an incubator for hatching chicken and duck eggs,<sup>29</sup> a challenge to temperature control if ever there was one.

A set of references from 1635 in the *Hartlib Papers* under the heading *Drebbelii et Cufflerianae* confirms Drebbel as the ultimate source of the Kuffler's ovens and that he was indeed capable of maintaining temperature control over extended periods of time by utilising chimney draught.

The Inventions of the Ovens are excellent good for the drying of Malt as likewise for Clothworkers to dry their Clothes in winter. [Malt is dried slowly at a moderate temperature.]

When Tobacco is taken in a roome <the ovens> wil draw all the smoake to their holes out of it. [Air is being drawn out of the room into the oven.]

The Selfe-same Ovens which Drebbel et Cuffler have made formerly of Irons are now made in the Low-Countries between the Hage and Leiden of lome (thonn) which will serve as well for all those Uses for which the iron served. They will bee as strong as the Iron ones and lasting. 2. Not stinke. 3. not smoake. 4. Cheaper of 10. shillings price perhaps. [Smoke is expelled from the chimney rather than being drawn into the room.]

It will save the hangings (Cufflers ovens) etc. from dust which is raised by the ordinary blowing of the fires. [Bellows were not needed to provide oxygen to the fire.]<sup>30</sup>

Although these passages relate to domestic ovens, there is little doubt that the air furnace principle had been well established. In any case, the difference between an oven and a furnace was largely one of purpose, and William White himself was later to write of the use of ovens for baking biscuits.<sup>31</sup>

The intriguing question arises of the relationship between Drebbel's development of the air furnace at some time prior to his death in 1633 and Glauber's publication of its description in 1646. While Glauber did not acknowledge any external source of his new furnace, he was certainly the most eloquent of those who praised its virtues:

<sup>28</sup> Francis Bacon, *The Works of Francis Bacon* (Stuttgart: Friedrich Frommann, 1961), vol. 2, 449. The identification of the Dutchman as Drebbel is based on the assumption that the "great person" was James I.

<sup>29</sup> Snelders, "Drebbel, Cornelis (1572–1633)."

<sup>30</sup> Samuel Hartlib, *Ephemerides 1635*, in *Hartlib Papers*, 29/3/56A–B. These three passages are proximate but are interspersed with other entries.

<sup>31</sup> William White to John Winthrop Jr., 14 February 1655.

And by the help of this furnace, with Gods blessing, I found out my choicest secrets. For before, and indeed from my youth I under went the trouble of those vulgar labours performed by bellows, and common vents, not without loss of my health, by reason of the unavoidable malignant and poysonous fumes, which danger this furnace was without ... I thought to melt; but seeing I could not melt such things being very hard to be melted, without the helpe of bellows (which I had sold) I began to consider the matter with my self more seriously, and so I found out this furnace, and being invented, I presently built and proved it, which in tryings I found so good, that I did again take hope of my labours, and would no more despair.<sup>32</sup>

Glauber's statement that he "*found out* this furnace, and *being invented*, I presently built and proved it" are ambiguous, perhaps deliberately so, on the question of Glauber's personal responsibility for the air furnace.<sup>33</sup> It would not have been difficult for him to have acquired the secret of chimney draught and the air furnace; both Drebbel and the Kufflers maintained close links with The Netherlands, and if earthenware versions of the furnaces were in fact being manufactured there as early as 1635, he would have had ample opportunity to observe and use them. The purpose of this paper is not, however, to examine Glauber's activities except insofar as they cast light on the line of technological influence running from Drebbel and the Kufflers through William White to Starkey; Hartlib's linkage of Glauber to Starkey in reference to Starkey's furnaces is the clinching piece of evidence that makes the technogenealogy credible. Questions of intellectual property were not irrelevant in the early modern era,<sup>34</sup> and indeed William White was later to be troubled by them, but to determine the identity of the real inventor of the air furnace, even supposing that this were definitively possible, is also beyond our present task. It is enough for present purposes to note the important role played by Cornelis Drebbel and the possible connections between Drebbel, the Kufflers, and William White.

That evidence of the subsequent transmission of this innovation is less clear-cut is due in no small part to the reticence of chymical practitioners to disclose in writing the technical details of their craft, but it is nonetheless apparent that by the mid 1650s the "Glauberian furnace" had become widely adopted. Newman and Principe have described the largely unacknowledged appropriation of Starkey's ideas and skills by Robert Boyle,<sup>35</sup> and there is every reason to assume that this would have included knowledge of the air furnace. White himself had emphasised the utility of his furnaces for chymists, especially the use of portable ovens and stills in domestic surroundings, and Starkey had established such a laboratory by early 1651, before his highly influential collaboration with Boyle had commenced. In fact, given the extensive nature of the experimental undertaking revealed by Starkey's notebooks, it is reasonable to assume that his activities would have been seriously curtailed by a reliance on the use of bellows, and he even appears to have considered patenting the "continual blast" process.<sup>36</sup>

<sup>32</sup> Glauber, *A Description of New Philosophical Furnaces*, 235–36.

<sup>33</sup> The authors are reliably informed that the same ambiguity between discovery and invention exists in the original German text. Johann Rudolf Glauber, *Furni Novi Philosophici: Oder Beschreibung Einer New Erfundenen Distillir-Kunst ...*, 5 vols. (Amsterdam: J. Fabel, 1646–49).

<sup>34</sup> Newman and Principe, *Alchemy Tried in the Fire*, 27–33.

<sup>35</sup> Newman and Principe, *Alchemy Tried in the Fire*, 22–25.

<sup>36</sup> Samuel Hartlib, *Ephemerides 1656*, in *Hartlib Papers*, 29/5/86B.

Another practitioner to benefit from Starkey's skills and knowledge was Hartlib's son-in-law Friedrich Clodius, who gained something of a reputation as a furnace-maker during the 1650s. Almost immediately after his arrival in England, Clodius began to make free use of Starkey's ideas and techniques to impress Hartlib, and even after the two men fell out, he continued to receive the young American's secrets from Boyle.<sup>37</sup> He made specific claims to Glauberian furnace construction,<sup>38</sup> and when Hartlib set out to promote Johann Kuffler's portable oven after that man's return to England in 1655, Clodius made an unsubstantiated boast that he possessed superior pyrotechnic abilities.<sup>39</sup> His erstwhile mentor Johann Moraien was unimpressed by these claims, but there was presumably some real basis to Clodius's assertion of fornacic skill that his access to Starkey's (and Boyle's) laboratory technology would be likely to account for.

While the emphasis of this paper has been on the links between White, Drebbel and Starkey as evidenced by the air furnace, it would be a mistake to limit our survey of his accomplishments to this area alone. The range of interests revealed in the Catalogue extends to mining, industrial metallurgy, milling, drainage, weapons production, and military engineering. He was anxious to reassure doubters that they were "no tricke but all profitable things," and certainly a close examination reveals them to be, at the very least, credible. Invention number 3, for example, was for "jugg mettall; that will hold aquafotis as well as glase." Aqua fortis, or nitric acid, is an extremely powerful solvent that was used to dissolve silver in alchemical experiments; highly corrosive of iron and other metals, it needed to be stored in more expensive and fragile glass vessels. Cast iron containing a high proportion of silica, however, is very resistant to corrosion by nitric acid, and could have been produced by mixing common sand with the iron during the smelting process.<sup>40</sup> Similarly, the reference to making grenades from "jugg earth" possibly relates to the production of saltpetre from the guano left by roosting (or "jugging") birds.<sup>41</sup> The horizontal windmill is particularly interesting, and it is notable that the first illustration published in an English book of such a device driving a bucket and chain pump appeared within a decade of the Catalogue.<sup>42</sup> Such a device would have been able to operate with the wind blowing in any direction — while the efficiency of energy conversion is considerably less than for a windmill operating in the vertical plane, enough power could have been generated to pump water, and horizontal windmills were used for this purpose until comparatively recent times.<sup>43</sup> White specifically mentions that his horizontal windmill was to be mounted on top of a house, which suggests its use as a domestic power source. Since a primary purpose of the Catalogue was to adapt

<sup>37</sup> Newman and Principe, *Alchemy Tried in the Fire*, 263–65.

<sup>38</sup> Samuel Hartlib, *Ephemerides 1655*, in *Hartlib Papers*, 29/5/6B.

<sup>39</sup> J. T. Young, *Faith, Medical Alchemy, and Natural Philosophy: Johann Moraien, Reformed Intelligencer and the Hartlib Circle* (Aldershot: Ashgate, 1998), 54.

<sup>40</sup> *Kirk-Othmer Encyclopedia of Chemical Technology* (New York, N.Y.: John Wiley & Sons, 2000).

<sup>41</sup> *The Oxford English Dictionary*, 2nd ed., 20 vols. (Oxford: Oxford University Press, 1989). Entry for "jug."

<sup>42</sup> Walter Blith, *The English Improver Improved, or, the Survey of Hvsbandry Surveyed Discovering the Improueableness of All Lands Some to Be under a Double and Treble, Others under a Five or Six Fould, and Many under a Tenn Fould, Yea, Some under a Twenty Fould Improvement* (London: Printed for John Wright, 1652).

<sup>43</sup> Richard Leslie Hills, *Power from Wind: a History of Windmill Technology* (Cambridge: Cambridge University Press, 1994), 11–23.

technology to a projected colonial environment, however, it is most likely that any direct experience he had had with wind power would have been in its use in drainage. It is noteworthy that two of White's New England associates, Richard Leader and John Winthrop Jr., were later involved in a windmill-powered salt evaporation project in Barbados.<sup>44</sup> Improved efficiency in salt-making through the use of his furnace was, of course, another of White's "inventions," and he mentioned salt works explicitly in his 1654 letter to Winthrop Jr., some years before the Barbados venture.<sup>45</sup> Invention number 12 relates to Gabriel Plattes's seed-setting engine, which, he had claimed, would produce a twenty-fold increase in productivity and "excell the old way in expedition, even as the Science of Printing doth excell writing."<sup>46</sup>

The significance of some of the other inventions is more difficult to decode. Improvements to alchemical equipment (number 2), calcinations (number 13) and cupellation (number 14) are in line with his known activities, but nothing further can be divined from their brief descriptions. Horse mills and human labour (number 5) were used in fen drainage,<sup>47</sup> and this seems to have been the most likely context in which White would have been exposed to this technology — Drebbel had been involved in drainage work in the later years of his life. Similarly, the rather spectacular invention that allowed a fort to withstand a siege through the automation of ordnance fire (number 10) echoes Drebbel's military interests. The following entry in Hartlib's *Ephemerides* may be relevant:

Engelbert Bows to short [i.e. shoot] Granadoes will keepe of any siege. Hee had a Pension of a 100. marke allowed vnto him but was forbidden to reveale the Invention to others by Queen Elizabeth's Councell who had nothing to object against it but that it would spoile the Art of Warre. There were 1000 of them of such steele bows in the Tower but they were all sold according to the valew of the steele. One of them is yet in Southwarke to bee seene and Mr Plats could make them if need were.<sup>48</sup>

The information is attributed to Gabriel Plattes, and the passage is immediately followed by the entry, also attributed to Plattes, about White's portable ovens. William Engelbert, Plattes's patron, appears to have been inventor of the steel bows. White had stated that "by the turning a horisontall wheele 50 men <may> keep out 2 or 3000," and it is not difficult to imagine Englebert's steel bows delivering the grenades described by White as "small ordnance" — while conclusive proof is lacking, the entries dovetail very neatly.

Later documents confirm the extent of White's activities in the years before his departure to America, and there is a strong vein of consistency running through them. His 1648 letter to John Winthrop refers to his having experience with mining in Derbyshire, while his letter to Robert Child, written in the following year, contains a salutation to the "noble Doctors and Apothecaries," suggesting that these may have been among the customers for his furnaces. He refers to a number of locations in London, confirming the view that this was the primary seat of his operations. The letter of 1654/55 contains a succinct summary of a number of his principal interests that had changed not at all since the Catalogue — mines, distilling, stoves, and salt works — while the 1656 letter is concerned with largely

<sup>44</sup> Walt W. Woodward, "Prospero's America: John Winthrop Jr., Alchemy, and the Creation of New England Culture, 1606–1676" (Ph.D. dissertation, University of Connecticut, 2001).

<sup>45</sup> William White to John Winthrop Jr., 14 February 1655.

<sup>46</sup> Plattes, *A Discovery of Infinite Treasure*, 50.

<sup>47</sup> Blith, *The English Improver Improved*, 56–57.

<sup>48</sup> Hartlib, *Ephemerides* 1643, 30/4/89B.



agricultural matters and brickmaking. Although little detail is known of White's activities during his English years, it is safe to say that he left that country with an unusually large bag of technological skills among his luggage. As Roger Williams remarked of him, "he hath skill in most worcks."<sup>49</sup>

William White has survived in a handful of documents and letters, and at first glance might appear to be of interest only through the significance of his acquaintanceships and the vigour of his prose, but when the proper connections are made, as this paper has attempted to do, a figure of some substance emerges. We have also been able to track the transmission, and perhaps the progressive refinement, of Drebbel's chimney technology, a critical tool in the technology of science, to Robert Boyle and beyond, and to suggest that the development of this technology must be considered alongside the parallel development of scientific ideas. In the case of chemistry, such a conclusion would be entirely fitting, as it, perhaps more than any other branch of science, combines the habits of observation and logic of the natural philosopher with the practical hands-on skills and precision of the artisan. It was this very fusion of practical advancement with intellectual purpose that made alchemy the "key" to understanding God and nature for so many people in the seventeenth century, and which now brings William White, an "attendant lord" on an international stage, into the spotlight at last.

#### Notes on Contributors

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<sup>49</sup> Roger Williams to John Winthrop Jr., 15 February 1655, in *The Correspondence of Roger Williams* (Hanover: Brown University Press, 1988), vol. 2, 247.