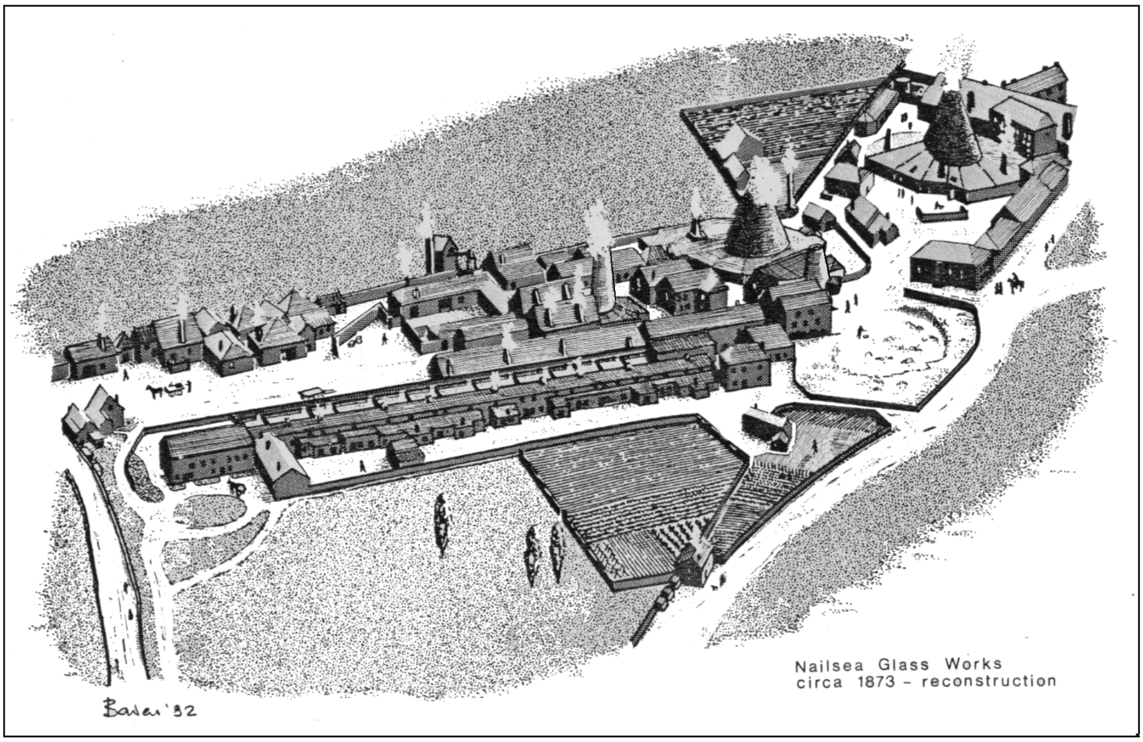
The Nailsea Glassworks,

Nailsea, North Somerset

A Review of the Technology

Nailsea Glassworks Study 2004 - Part 3



on behalf of:

Tesco Stores, Limited.

Andrew F Smith,
Avon Archaeological Unit

The Nailsea Glassworks,

Nailsea, North Somerset

A Review of the Technology

Andrew F Smith, BSc, MA, CEng, MIEE
Avon Archaeological Unit,
Bristol
April, 2004

"After destruction, reconstruction."
The cover illustration is an overhead view, looking approximately south-west, of the southern part of the glassworks holding, drawn as a re-construction by Mr Trevor Bowen of NDLHS in 1982. Reproduced by kind permission of Mr T Bowen.

CONTENTS

LIST OF FIGURES

Acknowledgements:

In general these are all covered in the main Introduction to the Study. However in this Part, particular thanks are due to Dr Justine Bayley and Gareth Hatton of the English Heritage Centre for Archaeology for permission to reproduce their report on the analysis of residues from the Nailsea Glassworks site.

I am very grateful to Dr David Watts, Editor of *The Glass Circle*, for the information reproduced in Appendix 2, as there seemed to be very little information on sizes as cut from a crown table. In this connection I am also grateful to the Margaret Thomas, who mentioned the Massachusetts Historical Society copy of a price list (Thomas, M 1987, p.30). The resultant web search revealed the details of the 1804 price and size list, reproduced here as Appendix 3, thanks to permission from the Massachusetts Historical Society.

Likewise I am indebted to Mrs B Knutson, at Nailsea Library, for permitting, and to Mr T Bowen of NDLHS for leading, the re-examination of C T Coathupe's notebook in order to achieve a more reliable transcription than that which had previously been used extensively.

Copyright

The copyright to the original Coathupe Notebook transcription is not certain, but it would appear to have been made in the early stages of the excavation works in the 1980s. Appendix 1 is an amendment of that transcription, with some editing, following the re-examination of the notebook, mentioned above. The notebook itself is currently in the safekeeping of Nailsea Library, but unfortunately is now rather fragile. It will probably be sent to the Somerset Record Office for conservation. [In the documents associated with the SMR 2397, most of which will end up at the Museum in Weston-super-Mare, its location has variously been given as three other places entirely.] Similarly the location of the original documents deriving from John Eyres and Frances Mountain, reproduced in Appendices 5 and 6, are not known. Both are in typescript form in SMR 2397 Folder E, but it is not certain that these are complete. The copy of Mountain has a note stating that the original is in the Bristol City Museum, but the staff there have not been able to locate it. All three documents have been included because of their great interest as eyewitness' accounts and the detail that can be gleaned from them. They appear to have been transcribed and photocopied several times, and attempts have been made to determine the originator. If copyright has been infringed by the further transcriptions herein, the author can only apologise now, and correctly acknowledge the situation in a future edition.

The copyright of Figure 3.29, the 1804 price and size list reproduced in Appendix 3, is held by the Massachusetts Historical Society.

Picture Credits

The cover illustration is an overhead view, looking approximately south-west, of the southern part of the glassworks holding, drawn as a re-construction by Mr Trevor Bowen of NDLHS in 1982. Reproduced by kind permission of Mr Bowen.

Figure 3.5: New House Cone Nailsea, showing ancillary buildings and onset of dereliction, Figure 3.6: View to Offices and Brick kiln in early 20th. Century, and Figure 3.7: Crucible furnace and Old Office, [?] are all © from the M. J. TOZER COLLECTION.

Figure 3.9: *Changing a pot at the Red House Cone* is a photograph by the author of part of a display board at the Red House Cone, Stourbridge, and is reproduced by kind permission of the Broadfield House Glass Museum, Kingswinford. It is thought to date from 1984.

Figure 3.10: *Furnace cross-section, derived from C T Coathupe's dimensions* is based on a copy in the SMR documentation, modified by the present writer. It has been established, late in the day, that the original was drawn by Mr T Bowen.

Figure 3.29: ©, Courtesy of the Massachusetts Historical Society.

Appendix 9: Figures 1 and 2 from *Scientific American*, 2nd December 1876, with thanks.

All other figures and photographs are by the author or derived from material held in the archive or in the North Somerset SMR, unless credited to the contrary in the text or adjacent to the Figure(s)/photograph(s) in question.

Particular exceptions are those photographs in Appendix 7 which are © English Heritage, and those identified as '© Bristol Museums & Art Gallery'. A condition of photographing material there is the transfer of copyright to the Museum.

INTRODUCTION

The Nailsea Glassworks has been noted as one of the most significant glassworks in the UK, so a review of the technology employed is appropriate. It is also believed that the New House Cone was the last to be built in the UK.[1]

It is clear from his patent of 1805 (see Part 1) that Lucas was conducting experiments at Nailsea, in the production of cylinder glass especially, that were ahead of the generally accepted chronology. It is doubted that much of interest will now ever be verified or disproved, due to the loss of the bulk of the firm's records during the 1939-45 war in an air raid on Plymouth[2]. They had, ironically, apparently been sent there for safekeeping. [Chance, 1968, gives Bristol, rather than Plymouth.]

Fortunately, one of the partners, C T Coathupe, in 1836-7 kept a small notebook, and even more fortunately, having been apparently discarded in a cupboard, it was eventually recognised for what it was and as a result we have an intriguing snapshot of the production processes, and more. It is reproduced, as an up-to date transcript, in Appendix 1. Reference will be made to this in due course. The accuracy of the original transcription was questioned, with justification.

Reference will occasionally be made to the BRO copies of the plans of the glassworks dated to the 1830s, and also that of 1870. These have already been reproduced earlier, but are again reproduced here, the latter with its schedule, as Appendix 4 and Appendix 5 respectively, for greater convenience. (In the text, building numbers referring to the 1870 plan are enclosed thus:- { }.)

Appendix 6 considers the chemistry, and will give the formulae for, and derivation of, some of the terms commonly used. In this way general readers will not need to be distracted by this detail. In association with this is Appendix 7, from Gareth Hatton for the English Heritage Centre for Archaeology, Portsmouth. It was debatable whether this should be associated with the archaeology or the technology, but it was felt that it had greater relevance to the latter.

Francis Mountain, probably working at Nailsea from the mid-1850s, wrote a "History" of the works in 1915, when he was aged 72. This is reproduced from SMR 2397 papers as Appendix 8. Appendix 9 give some information on the Frisbie furnace feeder, while Appendix 10 is a letter to H St George Gray from John M Eyres, at the works as a young man through most of the 1860s. Eyres and Mountain have not been quoted extensively, as it was felt that by including their notes verbatim they would make a much more coherent body of evidence. There is part of an autobiography by Eyres, reproduced as Appendix 1 in Part 4, as it has more "people" information than technical.

A formal glossary has not been included, but some terms will be explained in the body of the text, where appropriate. Allen, p.58 and Vose, p.196 each have one. Vose refers to British Standard 3447:1962 (*Glossary of Terms used in the Glass Industry*) and also to the *Standard Definition of Terms Relating to Glass and Glass Products (American Society of Testing Materials C162-71)*.

It is intended in this section to follow a chronological path as far as possible, starting with a brief look at the origins of glassmaking.

---

[1] T Bowen, *pers. comm.*

[2] Vincent, p.19

1. HISTORICAL NOTES

Prehistoric

The information in this chapter is derived largely from Vose, R Hurst, 1980, Harden, D B, 1968-71, and Adkins, L & Adkins, R, 1998. It is necessarily somewhat superficial, only aiming to give a general background.

Broadly speaking it seems that glass, initially in the form of a glaze on pottery, appeared in China in their Bronze Age, somewhere around 2000 BC, and even earlier in the Near East, the third millennium BC being quoted by Harden and Vose. In this case it was in the form of beads. A very large lump of blue glass dated to c.2000 BC (Harden) from Eridu in Mesopotamia is taken as evidence that the manufacture of glass was taking place there "many centuries before the earliest known factories in Egypt in the latter half of the 18th dynasty." The earliest vessels appear to come from the Asiatic Near East in the late 16th century BC, about a century before they appear in Egypt.

Production then spread through the islands and to Greece and the Aegean area, and was apparently flourishing until the 13th century BC. It then appears that there were a series of problems in the area, and glass production dwindled, the reason given being economic and market failure as a result of "the downfall of the rich monarchies and their cultures." Harden, 1968. It seems that production of small items continued to keep the techniques alive, namely, building round a core using a trail of molten glass, casting in open or closed moulds, shaping from a solid block, and building from sections of rod in a mould and heating to fusion.

This continued from the late 9th to earlier 4th centuries BC, when glass vessels again came in to production on the Syrian coast and in Mesopotamia. There is also some evidence of an Italian industry in the 8th century BC. No vessels were yet blown.

From about this time there is evidence of glass beads being imported in to Iron Age Britain from the continent. It also appears that blocks of glass as a raw material were also imported in the late Iron Age, but no evidence seems to have been found of manufacturing artefacts from this glass in Britain.

With the start of what has been called the Hellenistic age in the later 4th century BC, there was still no real change in techniques, and this state of affairs continued for a further three centuries. There were improvements in the techniques and increasing sophistication in the design and manufacture of the products of the industry. Now the main production areas seemed to be the Syrian coast and Alexandria. Sometime towards the end of the 3rd century increasing demand from Rome led to glass production starting in Italy, but it seems it was Alexandrian-led.

The archaeological evidence shows that in the latter half of the 1st century BC glass-blowing was invented, and that it occurred in Syria. By the 1st century AD Syrians had settled in northern Italy, and it appears that they continued to import Syrian sand.

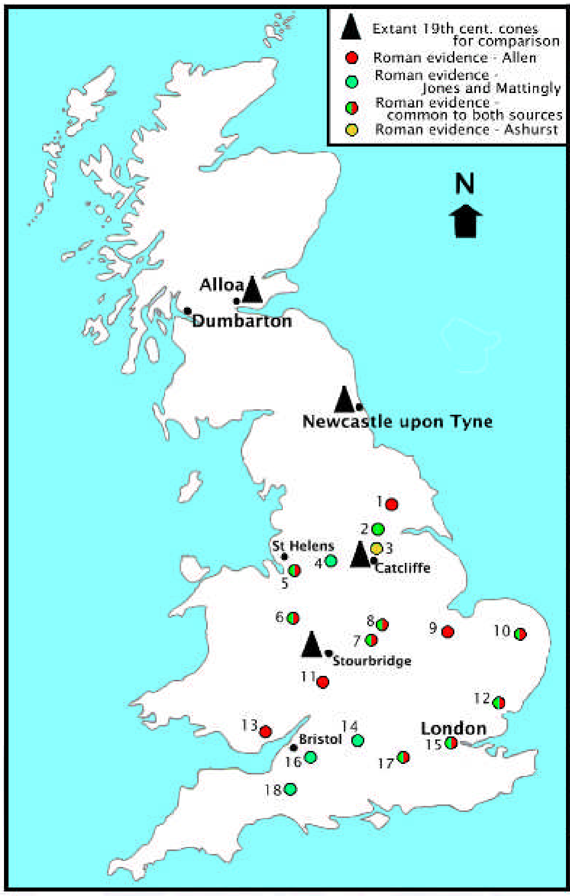
Roman

The expansion of the Roman empire, and the undoubted technological skills developed in the culture ensured a rapid expansion through the then known world, taking an Eurocentric view. As well as free-blown vessels, mould-blown vessels also came in to being, with the advantage to the latter that certain surface decoration could be integral with the mould. [The glass blower introduced the blowpipe, with an appropriate gather of hot glass on the end, into a suitable multi-part mould, and blew the bubble of glass to expand to fill the mould.] Indeed, very soon some mould–blown vessels were appearing with the maker's name incorporated in the mould and therefore on the finished product. It appears that the Egyptians persisted for some time with their traditional techniques, until the 2nd century AD at the earliest.[3]

By the middle of the 1st century AD mould blowing was well established in northern Europe[4]. In time, Roman glassware achieved a high degree of sophistication and complex forms were created.

There is evidence of glass manufacture in Britain in Roman times, broadly speaking from the start of the 2nd century AD on present data, although the production seems to have concentrated on simple blown shapes and window glass. It appears that the window glass was at first cast in plates, but during the 2nd century AD, "but not widely adopted until 300 AD"[5], the practice was introduced of forming a larger bulb and swinging it to and fro to form a cylinder, which was then cut open and flattened to form panes.

The sites at which evidence has been found are shown in Figure 3.1, below. The data derive from Allen, 1998, p.15, Ashurst, p.7, and Jones & Mattingly, 2002, p.216.



Site No.	Site Name/location
1	York
2	Castleford
3	Templeborough
4	Melandra (Glossop)
5	Wilderspool
6	Wroxeter
7	Mancetter
8	Leicester
9	Castor/ Water Newton
10	Caistor-by-Norwich
11	Worcester
12	Colchester
13	Bulmore, Caerleon
14	Wanborough
15	London
16	Combe Hay
17	Silchester
18	Ilminster

Figure 3.1: Roman sites in Britain with evidence of glassworking/production - compiled from Allen, 1988, Ashurst and Jones & Mattingly, 2002

The positions shown in Figure 3.1 are necessarily approximate, given the scale. The attribution of the evidence for the inclusion of these sites is given in Table 3.1 below. By way of amplification, Templeborough is on the south-west of Rotherham, Wilderspool is on the south side of Warrington, Caistor-by-Norwich is more usually associated with Caistor St Edmund, while Bulmore, now little more than a name on the 1:50000 OS map, is the site of a fortlet and

[3] Vose, R Hurst, 1980, p.43
[4] Allen, D, 1998, p.11
[5] *Ibid.*, p.56

settlement a couple of kilometres east of Caerleon, itself the site of a legionary fortress. The remainder are locatable using a reasonably large-scale road atlas gazetteer.

Table 3.1 - Romano-British glassworking sites – evidence for

Site	Author	Evidence
York	Allen	Crucible fragments
Templeborough	Ashurst[6]	Furnace, glass drips, runs & clippings
Wilderspool	Allen Jones & Mattingly	Possible glass furnaces "At least five glass furnaces & probably one annealing oven"
Wroxeter	Allen	Sand for glassmaking, glass-blowing waste
Mancetter	Allen	Furnace, glass-blowing waste
Leicester	Allen	Furnace, glass-blowing waste
Castor/Water Newton	Allen	Furnace and crucible
Caistor-by-Norwich	Allen Jones & Mattingly	Tank furnace "Relatively small number of furnaces, annealing ovens and working hearths"
Worcester	Allen	Crucible fragments
Colchester	Allen	Glass-blowing waste
Bulmore, Caerleon	Allen	Glass-blowing waste
London	Allen Jones & Mattingly	"more than 16 sites associated with glassworking, including furnaces, glass-blowing waste" "Glass factories ... existed on the south side of the forum."
Silchester	Allen	Furnace and crucible fragments

Post-Roman

For Britain there was a marked decline in the use and quality of glass once the period of Roman cultural and political ascendancy declined. For the rest of the world, the same step-change did not necessarily occur, and the picture becomes rather more complex. However, we will now focus largely on Britain where Saxon glassware is known, but many of the better pieces are largely believed to be continental imports. It appears from Harden, 1971 that Anglo-Saxon glasses were to be found in Britain from the 5th century AD through to the 7th. For example a specific type of glass cup, known as "bag-beakers", from their shape, were produced in Kent, from the 6th century AD, but no production site has been identified.

[6] Although his identification of Templeborough with Roman "Morbium" is not supported by either Rivet & Smith, 1981, or the OS Map of Roman Britain, 1994

He refers to documentary evidence, subsequently confirmed by excavation, that in 675 AD and in 758 AD continental glassmakers were invited to Monkwearmouth to make lamps and vessels as well as window glass, although again, while the production area has been identified, no furnace remains appear to be known. However, there is some evidence from Glastonbury Abbey that "window glass was being made in Britain towards the end of this period."[7] Harden, 1971, p.87, amplifies this information, and additionally mentions vessel glass in this context, thought to be 9th–10th century. By this time, some secular buildings were utilising window glass, which seems to have been made by the cylinder method.[8]

It appears that about this time, in the north and west of Europe, the Roman use of soda-lime glass was abandoned, and potash became the more common alkali, rather than soda. However it seems that in the Near East, under Arab influence, the use of soda-glass continued, and for some time that area led the field in both the artistic and technical aspects.

Medieval

Adkins and Adkins state (p.195) that in the early part of the period window glass continued to be manufactured by the cylinder method, but crown glass manufacture was introduced, probably from Normandy, at some time. From the 13th century both forms of manufacture are found in Britain. However, Ashurst, p.38, writing about the early (mid-late seventeenth century) South Yorkshire glassworks production of window glass states [but gives no authority] that, "It was made in the traditional 'crown' glass method of the Lorrainer immigrants (as opposed to the alternative cylinder method of the Normandy immigrants)." Vose, p.60, gives exactly the opposite attribution to Ashurst, [again giving no authority] adding Burgundy and the Rhineland to Lorraine as cylinder glass specialist areas. Burgoyne & Scoble, p.3, similarly attribute the Lorraine glassmakers (who apparently settled in the forests of the Weald some time after 1567) with using "a blown cylinder method known as the broad glass process." Without trying to resolve the difference, as not directly relevant here, this is therefore a suitable point at which to describe both processes, not in detail, but sufficiently for the methods to be understood.

The 'cylinder' method of glass manufacture, which has also been referred to above as starting in Britain in Roman times, is not the later form of cylinder glass, but its antecedent. Indeed, it is described by some writers (e.g. Burgoyne and Scoble, p.3) as the "Broad Glass" technique. It is also known as 'muff' glass because of the resemblance to a lady's muff. Briefly, it involves creating a cylindrical bubble by initially 'gathering' a suitable blob (the 'gather') of molten glass on the hollow tubular blowing iron, or pipe, blowing and marvering[9] and then repeating the operation until a suitable sized gather had been made. It would then be blown out to enlarge it. With repeated re-heating, blowing and being swung to and fro the required length and diameter would be achieved. It would then be pierced at the end and opened out, and after further manipulation, including shearing along the length, it would be flattened and allowed to anneal. Apparently the technique was "virtually obsolete in Great Britain by 1700."[10] This seems to be because there were often distortions in the glass, and it could be affected on one side by the surface on which it was left to flatten.

Figures 3.2 and 3.3 below illustrate the process, recreated with slight variations, by Harry Prior, assisted by Andrew Hay, at the English Antique Glass works at Bordesley Hall, near

[7] Adkins, L & R, 1998, p 164
[8] *Ibid.*
[9] "Marvering" is rolling the gather of glass on the end of the blowing iron on a smooth iron plate, the "marver", to get the required initial form. Also used to combine e.g. different coloured glasses in to a homogenous form.
[10] Burgoyne and Scoble, p.4

Birmingham. Their technique is virtually the same except the newly opened cylinder is annealed and then cut with a conventional glass cutter, is heated slightly to open the cut and then passed through another kiln for flattening. The glass in these pictures is red on clear.

Figure 3.2: 'Broad' or 'muff' glass blowing at the English Antique Glass Co. 1st series

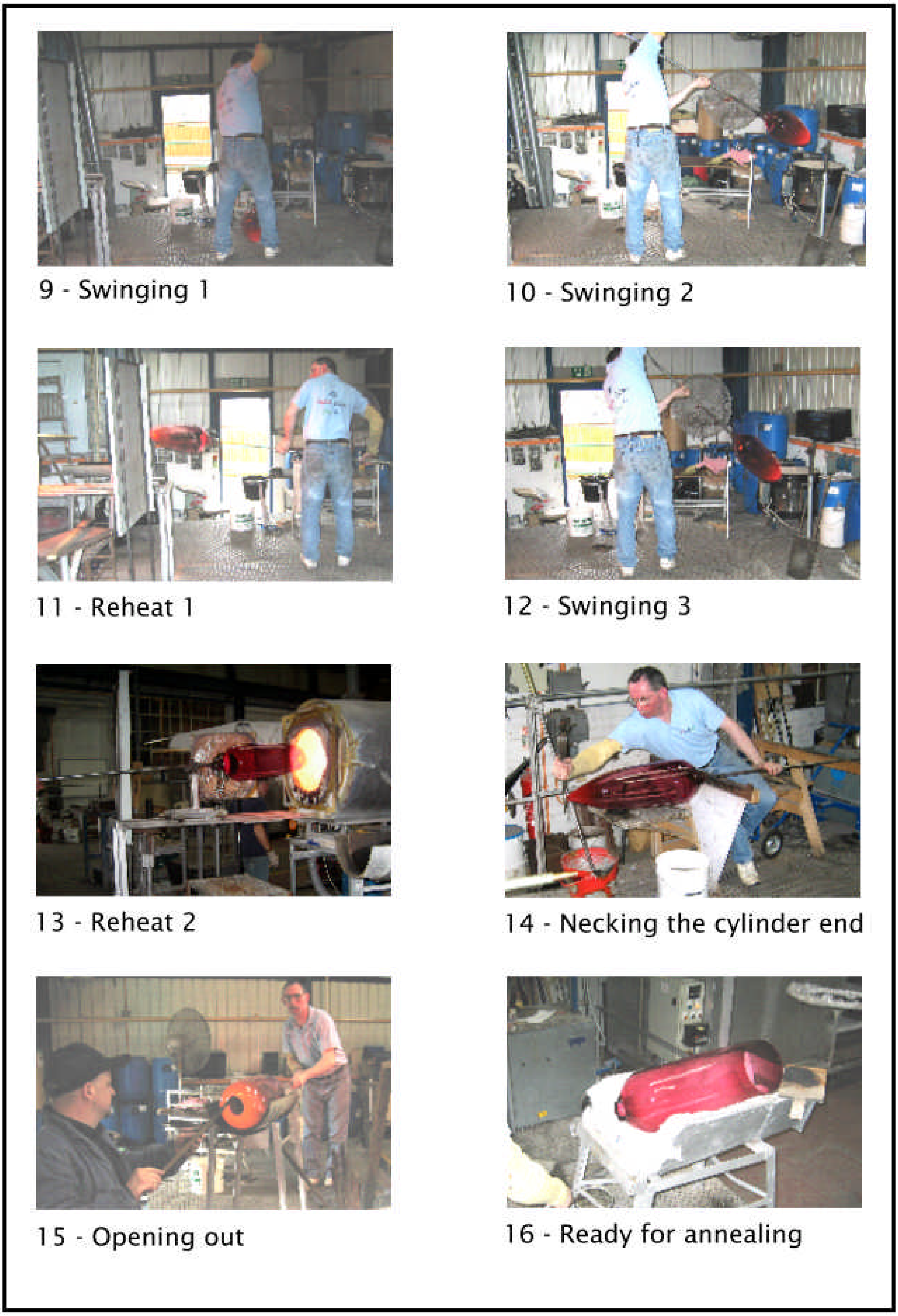


Figure 3.3: 'Broad' or 'muff' glass blowing at the English Antique Glass Co. 2nd series

The 'crown' method commenced in much the same way as the cylinder method. The principal difference came once an appropriate pear-shaped bubble had been achieved. At this stage, a solid punty, or pontil, rod would be attached to the centre of the wider end by means of a blob of molten glass, and the blowing iron would be broken off from the narrower end. The glass would then be reheated at the furnace via one of the openings, being continuously rotated the while. The centrifugal forces thus generated would result in the glass initially adopting a sort of mushroom shape finally ‘flashing’ [opening] out under the continuing application of heat and rotation to form a circular “table” in the order of a metre and a quarter in diameter. It would be kept rotating until no longer malleable. The pontil rod would be broken off, leaving the characteristic “bull’s-eye” in the centre and the glass would be annealed in an annealing kiln, both surfaces being “fire polished”, racked on ‘drossers’. Rectangular panes would then be cut from the circular table to get the least wastage. The off-cuts would then be used as cullet in due course.

Unfortunately, while Burgoyne and Scoble, p.5, show a well-known illustration of a marked-out table, it is only about half the size of those actually described by Coathupe in his *Notes*. Equally unfortunately, while he mentions what are obviously various different sizes on pages 104-109, he does not say what those sizes are; see Appendix 1. However, Col. Seddon (Royal Engineers, Retd.) published some information, reproduced in Appendix 2. Furthermore, the Massachusetts Historical Society holds a copy of an 1804 price list for ‘Crown Window Glass and bottles’ from Nailsea. (See Appendix 3). [At the very last minute, so not followed up, references have been found via the ‘www’ to an 1809 version of the price list, and to a *Crown glass cutter and glazier’s manual*, by William Cooper, 1835. Both are in the Koerner library of the University of British Columbia as microforms.]

[Thomas, 1987, p.20 states, “The glassworks at Nailsea made only crown glass; it never produced flint or enamel glass ...”, which seems to infer that crown glass was a recipe, rather than a method. This seems to be supported by the Concise Oxford Dictionary, but has not seemed to be interpreted in this way by other writers. It is clear from later passages that Thomas knew that the cylinder method was also used at Nailsea, and that bottles, and, later, plate glass was also made. This apparent confusion may just have come about from careless use of the terminology by writers using a convenient shorthand description. Vose, p.60, and Harden, (1969, p.83) agree that the first window glass produced by the crown method was in the east in around the fourth century AD, whence it translated to Italy and much later to north-west Europe.] Coathupe, p.111 expected that, “a well made table of glass should be 50 inches in diamr. and weigh $9\frac{1}{3}$ lbs. it then contains 101.915 cubc. ins.”

To return to the chronology, Vose, p103 *et seq.* suggests that there is some documentary inference for glassmaking in Britain from this time, and the picture gradually becomes clearer. This is, initially, mainly from documentary evidence (inventories, orders for glass and the like), rather than archaeological, but the latter fairly quickly comes in to its own.

For example, from Vose, p.104, we learn that about 1420 Staffordshire white glass was bought for York Minster and that in the late fifteenth century Salisbury Cathedral had its own “glashous”. This leads conveniently in to the next phase, as it appears that production was still mainly small-scale, often close to the fuel source, which was primarily still wood. Production was, therefore, still in small units of a house size, possibly hence the term “glasshouse”. In the woodland especially, it would appear that these could be fairly temporary in nature, it apparently being cheaper to move the glasshouse than to transport the fuel when the local woodland was exhausted. It also appears in some cases that the operation of the furnaces may have been seasonal, to some extent. (Vose, pps.60, 137.)

Ashurst, p.9, from Crossley (1967, p.65), refers to, “two tons of wood billets being required to produce eight crowns of window glass” in Sussex. Eight crowns might weigh about 75 pounds [a little over 34 kilograms]. At this point it is appropriate to mention that according to Vose, p.137, the glassworks at Knightons, Alford, Surrey (excavated by Eric Wood in 1973 and dated to the 1550s) had an annealing furnace "designed to take crown window glass sheets, the first example of crown glass manufacture in England."

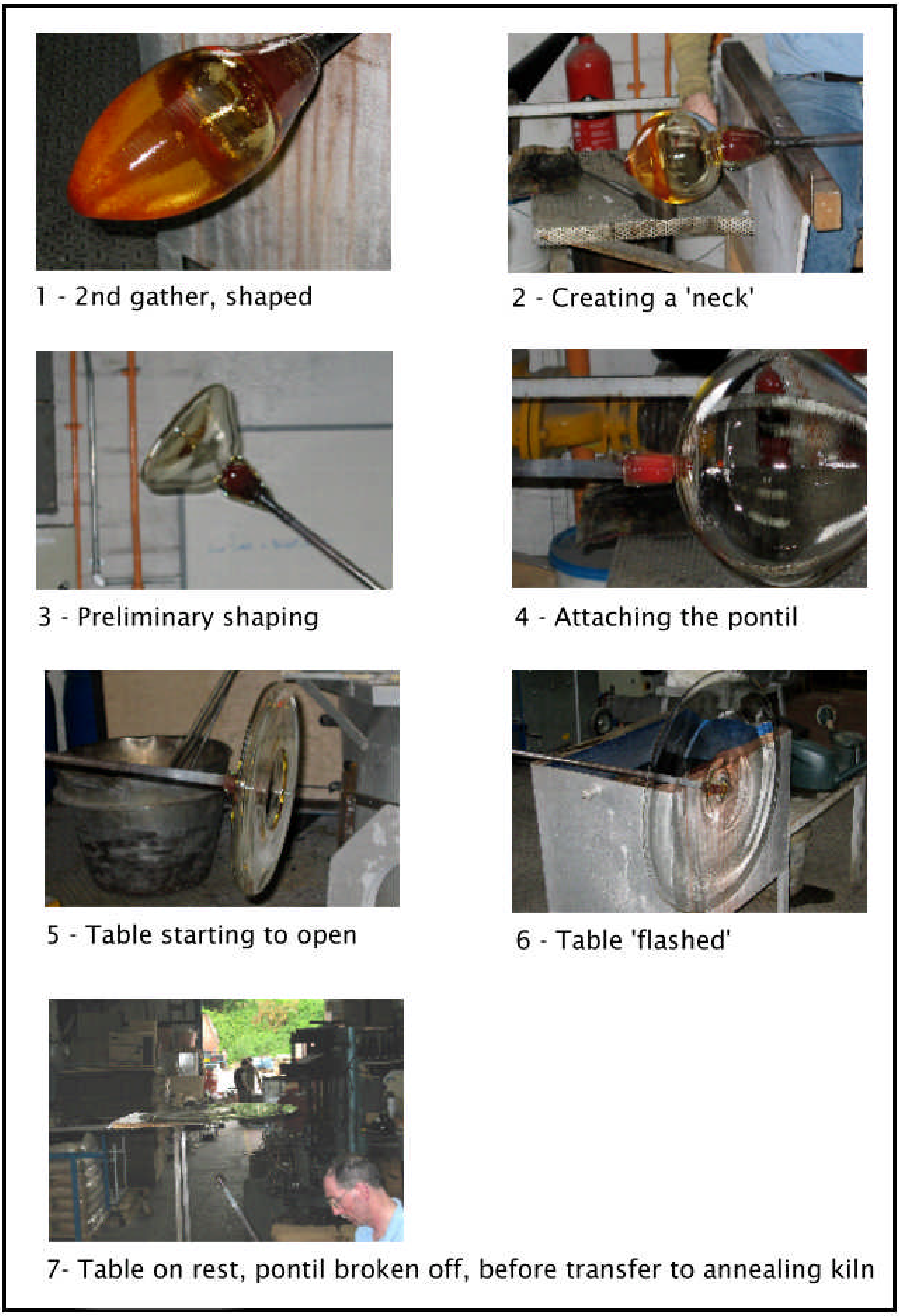


Figure 3.4: Crown table manufacture at the English Antique Glass Co.

Very good examples of clear crown glass window-panes, with orange-brown glass borders, may be seen on the first floor at Longleat House, Wiltshire, in the "Upper West Corridor, though the pot metal yellow borders do figure elsewhere in the House. This glass (with the armorial panels in the Grand Staircase lantern and the collection of early roundels etc formerly in the Chapel) were all introduced into the House when Sir Jeffry Wyatville was making his extensive alterations to the building for the 2nd Marquess of Bath in the early 19th century. The main glass supplier was Joseph Miller."[11]

Figure 3.4, above, attempts to capture some of the stages in the production of a modest sized table at the English Antique Glass Co. There is a detailed description, with a sequenced set of drawings, in Parkin, pps. 22-25. Other writers also give similar descriptions and there were probably certain local variations.

Post-medieval

Production seems still to be in the Weald and Staffordshire, primarily, but South Yorkshire made a tentative start early in the seventeenth century. While fine glassware still seems to be coming from outwith Britain, it is evident that window glass consumption is increasing. Its use is moving progressively down the social scale, and on p 105 there is an interesting paragraph on the use of window glass in Bristol in the first two-thirds of the sixteenth century[12].

Furnaces continued to be wood-fired, and competition for the fuel from the developing iron industry, in the form of charcoal, was becoming a consideration. Wood firing, due to the longer flame from wood, required a simpler furnace construction, the wood being fed in to a trough between the sieges that the pots sat upon in the furnace.

In 1614, James I and VI issued a patent to Sir Edward Zouch to use coal as a fuel to make every type of glass, and which prohibited the use of wood as a fuel and withdrew all previous patents. James went to the length supporting the prohibition by issuing a proclamation on 23rd May 1615 (Vose, p.115), to the effect that the way had been found to make glass, using coal as fuel, that was equally as good as that previously made by burning wood.

This use of coal lead to a change in design of the furnaces. Coal burnt with a shorter flame than wood, so the fire had to be brought much nearer the pots, or crucibles. This was done by the introduction of iron bars forming a grate to support the fire just below the siege floor level. In addition a stronger draught was required. The result was the development of large airways below the furnace, to beneath the grate, often designed in a funnel shape, into the prevailing wind, and indeed, there is a reference to a 'wind furnace' in Vose, p.143.

We are now approaching industrialisation proper, rather than small, localised, enterprises. By the late seventeenth century the glass cone seems to have been developed to enhance the draught, and at the same time to provide a working area around the furnace itself. The sieges, or seats, where the pots sat seem to have been, more often than not, rectangular in British practice. This was an earlier deviation from the usually circular siege structures of the Continent, and writers there regarded this, together with the cone, as a peculiarly British form of glass house. Some were indeed house-shaped, with a fairly attenuated cone coming up through the roof. Although later (late 1880s) and larger, Pilkingtons' No. 9 Tank House shown in Krupa and Heywood, 2002, p.2, Plate 3, gives some idea of the general outline of these early 'houses'.

---

[11] Information kindly supplied by Dr Kate Harris, Curator Longleat Historic Collections. (Pers comm.)

[12] Vose, 1980. This derives from Neale, F, 1974:Thesis on the topography of medieval Bristol, University of London

It must not be imagined that the change to coal as a fuel was painless. Coal, as mentioned above, needed more oxygen, therefore more air, for combustion and its smoke was heavier and dirtier, resulting for a while at least in more difficult working conditions. Not applicable at Nailsea, it is thought, but certainly for "lead crystal" glass this quickly led to virtually closed pots to exclude smoke and ash and ensure the clarity of the glass.[13] However, the problems were not insoluble, and while the process by which this came about does not seem to have been documented it obviously happened.

In consequence it meant that there would be economies to be gained from transferring glassmaking from the forested areas of the country to those with a good supply of suitable coal. During the seventeenth century this clearly happened. It also appears that sometimes the geology of the coal measures brought further benefits in terms of other raw materials, for example sands and clays, being readily to hand.

It also seems that in the longer term this enforced change to coal as a fuel gave British glassmakers an edge over those on the Continent, who persisted in using wood for a much longer period. Presumably with more heat available a faster melt and therefore increased production for a given number of workers was possible. A bigger cone would mean a greater draught and greater space for more workers around a larger furnace. The mathematics have not been investigated, but it is likely that something between a square and a cube increase in capacity with change in linear size would be not unreasonable.

That this was in fact the case is suggested indirectly in Buchanan and Cossons, p.146: "It is reported that there were fifteen glasshouses in the city in 1761, and 'about twelve' in 1794. Arrowsmith's *Dictionary* of 1884 states that all the Bristol bottle factories had merged into one house ... although: 'Their output equals very nearly that of the whole glass manufactories of the 18th century.'" Previously they pointed out that the competition from "larger-scale enterprises in the North and elsewhere during the nineteenth century" had led to the gradual demise of the industry in Bristol

How the cones were constructed, and especially in the case of Nailsea by whom, has not been determined, but presumably some kind of centring/formwork and working from an internal scaffold would have been employed. It is apparent from various illustrations of cones that the size and number of openings at the base circumference were not by any means standardised.

The two principal methods of flat glass making have already been described, but crown [glass] was the method of choice for manufacture of window glass as the industry went in to the eighteenth century, although plate glass had made a recent appearance in 1688[14]. This was made by pouring the molten glass on to an iron table and rolling it out in to a thick uniform plate, much like rolling pastry. See Appendix 8. This would result in two faces that had not been 'fire-finished', so were generally less clear than was desirable. After annealing the glass would therefore be ground and polished, often to about half its original thickness, so the result was a luxury product, used principally for mirrors and coach windows.

Crown glass in the late 1820s at least, was sold in five classifications: "Firsts, (an ideal ...), seconds, thirds, fourths and CC, the last being described as 'the worst glass ever made'. ...The inferior quality of glass that was disposed of in Ireland was sold much more cheaply. For that market there were only four categories: A, B, C and CC."[15] Prices for a given grade varied, depending on the part of the country for which it was destined.

---

[13] Ashurst, p.37, states, "This is usually attributed to Thomas Percival between 1611-1614...."
[14] Burgoyne and Scoble, p.10
[15] Barker, p.47

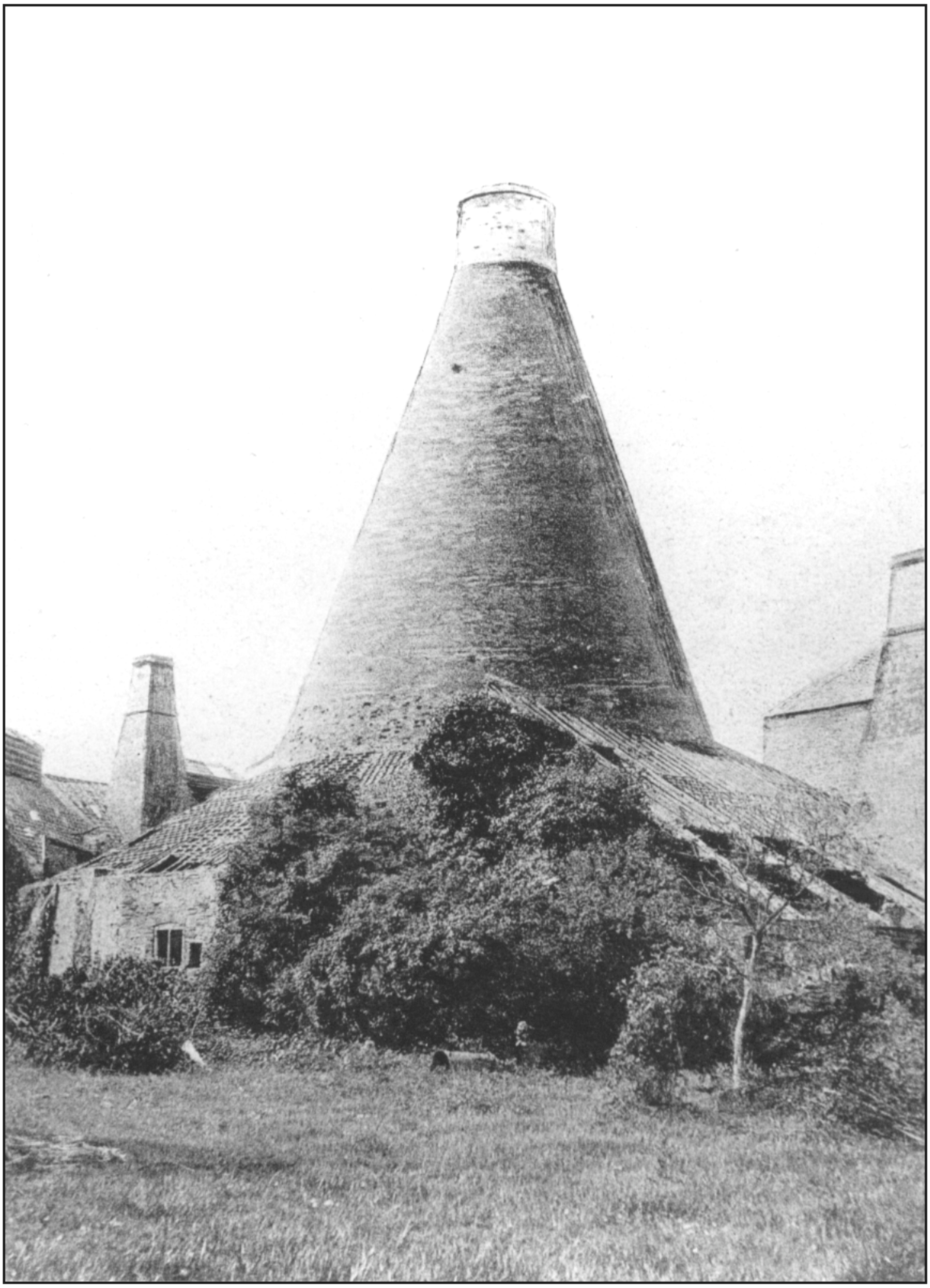


Figure 3.5: New House Cone Nailsea, showing ancillary buildings and onset of dereliction
(© M J Tozer collection)

However, although cylinder glass in its ‘broad glass’ form had gone out of fashion it was not exactly forgotten. It seems that the technique had been further developed in Germany, because the term ‘German sheet glass’ was applied to the ‘improved’ cylinder method (Burgoyne and

Scoble, p.5). This involved the gathering and blowing of a larger bubble than the broad glass method, and instead of merely swinging the cylinder to and fro a greater application of centrifugal force was achieved by swinging the cylinder right round overhead in a complete circle. This entailed the construction of 'swinging pits', over which the blower would stand on a platform giving sufficient clearance for the large cylinder to be swung. By careful re-heating, a thinner, more uniform product would result, in a larger sheet, in the order of twice the size of that from the crown method. It is at this point that, apart from the size and the swinging technique, the main change from the broad glass method now occurs. Instead of the cylinder end being opened out and the cylinder opened up longitudinally with shears while the glass was still malleable the 'improved' cylinder was allowed to cool (annealed) before further work was done. It was then cut with a diamond so that the rounded end and the end that had been attached to the blowing iron came away. The remaining open-ended cylinder would then be scored with a diamond to allow the glass to open up in to a flat sheet when it was reheated in a special kiln on a hard polished surface. This meant that there should be little or no damage to either face of the sheet. There is some debate about when the technique was introduced in Britain. See Part 1. Angerstein mentions swinging pits in 1755. Barker writes, "As early as 1758 the Excise commissioners were aware of the manufacture in England of an improved form of broad glass 'appearing to be of a quality and colour greatly superior to common Green Glass and of as good colour as some crown glass and being judged to be Crown Glass by several Glass-makers and glaziers'. In 1777 when the excise duty on glass was doubled, special provision was made for 'Glass now called German Sheet Glass' ..." [16] It seems unlikely that Lucas would have gone to the expense of devising a novel method and then taking out a patent on it in 1805 if there was not a good commercial reason for so doing. In fact, he actually states in the patent registration, the text of which is reproduced as an Appendix to Part 1, the Desktop Study, "this is the method I use."

The manufacture of fine glassware of many different forms does not come within the scope of this review, not being a significant commercial operation at Nailsea as far as is known. However, for the opposite reason, bottle manufacture should now be considered.

It is apparent from archaeology that bottle making has been practised for a long time. Indeed, bottles in one form or another were probably one of the first artefacts to be produced following the invention of the blowing technique.

Generally speaking it seems that the bottle would be blown either freehand or by blowing and rotating the gather into a half mould to produce a more consistent size. Marvering would have been used as necessary. Once the required size was reached a pontil would be attached to the base which may have been flattened, or alternatively pushed in to a greater or lesser extent, or even left as a 'bag-end'. The blowing–iron would then be broken off and the neck formed in a number of different ways, depending on the period in question and/or the expected use of the bottle. In the simplest case the neck would probably merely be smoothed by heating and manipulating.

According to Vose, p.129, multi-part moulds "were apparently used by Carré's Lorrainers in England in the 1590s, but the use of moulds in bottle-making appears to have died out in the mid—seventeenth century." On p.130, Vose notes that by 1696, Houghton, who analysed English glass manufacturing in that year, listed "around forty-two bottle houses, producing nearly three million bottles annually ...". It seems that from the mid-seventeenth century until 1821 there was "little change in the techniques of bottle making", (*Ibid.*, p.130), although Weeden (p.26) states that, " by the early part of the next century [18th], the straight sided bottle

[16] Barker, 1977, p.58

began to replace the bulbous shape, and to obtain regularity in shape moulds began to be used. These were simple in construction and formed only the body of the bottle." The neck and shoulder still had to be formed by hand, so there were still irregularities in the product.

To overcome this, Henry Ricketts, son of Jacob Wilcox Ricketts (the founder of the Portwall Lane glassworks in Bristol) took out Patent No. 4623, dated 5th December 1821. In effect this added a two-part mould for the shoulder and neck to the earlier type of mould, so that the complete bottle was made in one operation. In addition he also designed a false bottom to the mould so that the one mould could form bottles of different heights and therefore of different capacities. The 'push-up' of the bottle bottom could also be formed by a suitably shaped bottom to the mould, which could also carry the makers name and any other information required. This standardisation of sizes was of great help to traders and customers alike.

We have now reached the time when the glassworks at Nailsea were in production, and we should consider how the technologies for glass manufacture that have been considered were applied there, and indeed how they were developed. This will be the subject of the next section. As well as the primary function of glass production the technologies applying to ancillary processes will also be mentioned. In many cases it will necessarily be speculative at times because of lack of direct evidence.

2. NAILSEA GLASSWORKS - 1788 - 1873

Buildings

The date for the start of the glassworks is consistently given as 1788. The inference drawn from the various documents is that the move was carefully thought out and planned by J R Lucas. For example, it seems he was already involved in mining interests in Nailsea. However, production could not have started at once, as a finite time is required to build the works, hire staff etc. Trying to put oneself in the place of Lucas, the guess of the present writer is that the first construction would have been the bottle house. This is on three premises. The first is that it is the nearest cone to the mineshaft on the edge of the site. Secondly, while it is labelled 'Cone No. 2' on the 1830 plan, it is shown standing squarely, the building with 'Cone No. 3' (the Lilly Cone {55} in 1870) appears to wrap around its north-western corner. Its outline coincides with {49} on the 1870 plan – 'Open spaces where old bottle house stood'. Thirdly, it would probably have been a relatively simple building to construct, and he had staff available with the necessary skills from either or both Bristol and Stanton Wick. We are too early at this stage for any mechanised assistance with the bottle production, but this would start money flowing in to the business.

It is then thought that the Lilly Cone would have been the next to come in to production, on the basis that, as already mentioned, its associated building appears to have been built up against the bottle house. It has been noted that Lucas had advertised his Bristol interests for sale in *Felix Farley's Bristol Journal* of 2nd August 1788, stating that he wished to "confine himself solely to the Crown Glass and Bottle Manufacture"[17]. The assumption therefore is that this small, slender cone was the next to be brought in to use to produce a familiar product, namely window glass using the 'crown' method. Again this would bring money in to the business and help the cash-flow situation. The raw materials might not have been processed at the works at this stage, because of his existing business connections. It is imagined that the construction of the Old House Cone, a major undertaking, together with other ancillary buildings would have been progressing as quickly as possible in parallel with getting the earliest, simplest products out of the developing works.

---

[17] Thomas, 1987, p.2

It would appear that this stage might have been substantially completed by 1790. The *Bristol Gazette* of 6th May that year reported, "on Thursday last a fire broke out in the new glasshouse at Nailsea belonging to Mr. J. R. Lucas which burnt part of the roof; but by timely assistance the other parts of the buildings belonging to both Crown glass-houses were preserved."[18]

It must be emphasised that no direct documentary evidence has been found, either written or cartographic to support the above inferences. As can be seen in Part 2, the archaeological investigations came nowhere near elucidating the structures of the Lilly cone and what remained of the bottle house.

The initial rank of housing for the workers was built around the same time, because these were mentioned by Collinson, 1791, and certainly occupied when Hannah More visited in 1792 (See Part 4.) By 1822 the row on the opposite side of the High Street had also been built.

It appears that all this initial development took place on land that was available for lease, from an earlier enclosure from the Heath and any further extension was inhibited by the often quoted hostility of Nailsea parish vestry towards further enclosure of the Heath. Whether or not they eventually recognised the value of the works to Nailsea, gave way to *force majeure* from other local landlords, for some other reason, or a combination of them all, it seems that enclosure eventually took place in 1814. Lucas was thus able to start to develop the western portion of the site up to what became the present site of 'The Royal Oak', including building the New House Cone. It is clear that this took place probably from 1826. (See Part 1.)

Coincidentally, the St Helens Crown Glass Company [eventually to become Pilkington] was also building its first cone in 1826. This was 120 feet high and with an internal diameter of 66 feet. It has been stated that it was modelled on one of the cones at Dumbarton, and was built during the last nine months of 1826 for about £8,500.[19] It was therefore slightly larger than the New House Cone at Nailsea, the remains of which have an internal diameter of 60.6 feet, and an outside diameter of 68.63 feet. This is slightly smaller than the Old House Cone.

We now have the snapshot of the 1830s plan, (that might be as early as 1829 – see Part 1, para. 5.35) when a butcher's shop fronted on to the High Street. This had gone by 1870, and further buildings had been erected to the boundaries. From the limited cartographic evidence it would appear that this was probably a gradual process. The evidence from these two plans, as well as the archaeological evidence, supports this and also demonstrates changes in use. These will not be detailed here, but may be derived from the plans and the 1870 schedule.

The New House Cone has been shown earlier (Figure 3.5 above): in the view, looking approximately south-west, it is believed that the two tapering, rectangular-section structures to the left and right are the chimneys for the furnaces associated with the two larger sets of 'blowing holes', or 'swinging pits', {7}. In the right background is part of the six-storey building {6}.

The two illustrations below show buildings in both brick and/or stone, with slate or pan-tiles as roofing material. The buildings in the first (Figure 3.6), looking approximately east-north-east, are clearly identifiable, from left to right, as {3}(Smith's shop - totally overgrown), {2}(Two French kilns), {1}(Offices), {72}(3-storey building – cutting packing and assorting rooms – another, later, picture (not reproduced) shows that this is so more clearly. There is a ramp up to the first floor doorway, and there are wide arched openings to the ground floor. Then there is the brick kiln, {27}, partly behind {30}, the stone dressing room.

[18] *Ibid.*, p.12
[19] Barker , T C, p34

The brick kiln is mentioned by Mountain. The map information is not sufficiently clear to be conclusive, but the inference could be drawn from Mountain's description that it was probably established quite early on in the life of the works. Bricks stamped "COATHUPES & CO. NAILSEA NEAR BRISTOL", therefore from the 1840s, were found, with other refractory bricks from various Stourbridge makers; there are drawings from 1983 (File 'A').

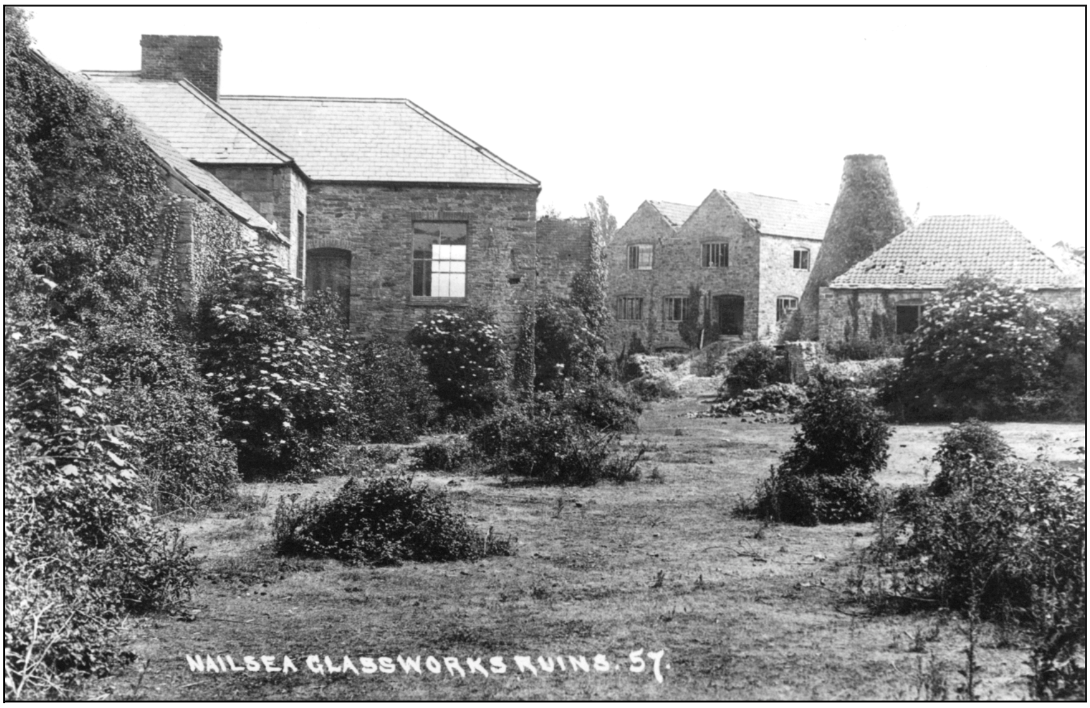


Figure 3.6: View to Offices and Brick kiln in early 20th. Century

© M J Tozer Collection

It is believed that Figure 3.7, below, looking almost due east, probably shows, again left to right, buildings {18}, Crucible furnace, and {17}, Old office, with {22}, the Old Watch House, behind, with chimneys associated with the Old House Cone (collapsed at the time of the photograph) behind that, and the corner of the building containing {15, 16}, pot arches, on the extreme right.

The 1870 schedule refers to {60}, Store room for centres. It is believed that these 'centres' would have been formwork used for building the crown of the furnaces, and other arches, and that they were stored rather than remaking as needed for repairs.

The only surviving building (other than the housing) associated with the works is the long building {10} on the western boundary. In 1870 it contained French Kilns, but Eyres' letter indicates that in the previous decade it had contained, or replaced, "large Acid Chambers." However, considering Brown's plan (see Figure 1.6) and comparing it with the 1870 plan, it is clear that there was a significant rebuild to the west and south-west of the New House Cone, presumably when the alkali works closed.

It is clear from the above that while the technology was not advanced, considerable building skills in both pennant and dressed stone, as well as brickwork, joinery and roofing in slate and tile were required on the site to a considerable extent over a considerable time. Building was up to six storeys, with several of three storeys (excluding the cones themselves, which were in a class of their own, the two larger probably being in the order of at least 30m high).

Figure 3.7: Crucible furnace and Old Office, [?]

© M J Tozer Collection

Ancillary trades

By examination of the two major plans it becomes apparent that there were several of these, so that the glassworks was fairly well self-sufficient, even including a butcher's shop in the 1830s. Blacksmiths, carpenters and joiners all had their own shops, while there must have been all the trades associated with having horses for transport, and people with the necessary skills to run and maintain the engines and boilers providing motive power for certain processes, such as a saw-mill and roller-crushers.

Figure 3.8:Composite of a crate and barrels, all on display at the Red House Cone

The presence in the 1830s of a pole shed and stave yard, combined with Coathupe's reference (Appendix 1, p.98) to making crates from poles leads one to presume that barrels and crates were made on site.

Chemical works

The disposition (other than it seems they were at the western boundary of the site) and detailed layout of these is not known for certain. It is presumed that Brown's plan (Figure 1.6) might show them, where it differs from the 1870 plan. It would appear that the works produced much of its own chemical requirements certainly from the later 1830s under Coathupe until about 1865, when according to Mountain a tall stack associated with the chemical works was demolished as unsafe. We have already seen above that the acid chambers in a smaller {10} were replaced by French Kilns at the latest by 1870, and the schedule gives no indication of any chemical manufacture at that date. (See Appendix 11 for a billhead vignette.)

The only indication of chemical processing not directly involved in the glassmaking process on the 1830s plan is one room identified as "Room for breaking kelp".

The various writers, including Eyres and Mountain give various sources for the primary raw materials. The study by Gilberton and Hawkins of sand in the locality is comprehensive, and concludes that there was significant extraction in the area, but that it was "probably largely the sands of aeolian origin dating from the last glacial stage of the Pleistocene which acted as the main source of the quartz." After further discussion, "Such local supplies, however, cannot have sustained an active industry for long and after a very short period, if not immediately, increasing reliance must have been placed on the importation of better quality sand from further afield." See Table 3.2 below.

Table 3.2 - Sources for raw materials

Item	From	Authority
Sand	Phippard's, Wareham, Dorset Portishead, via Bristol Isle of Wight Easton Failand Ridge	Eyres Mountain Coathupe Coathupe Gilberton & Hawkins
Lime[stone]	Walton, Weston-in-Gordano Wraxall to Clevedon – many kilns on the ridge.	Eyres Thomas
Saltcake	Netham Chemical Works, Bristol	Eyres, Mountain
Coke	Bristol Gas Works	Mountain
Kelp	Possibly Ireland as a return load to Bristol, in view of the considerable trade between them.	Author
Seaweed	Isles of Scilly Wales	Thomas Angerstein

Some idea of the chemistry involved will be found in Appendix 6, and from Coathupe's notebook – Appendix 1, pages 1-21. On page 20 of the notebook there is a reference to Sulphte. Burita. [Much later:this was from the earlier transcription: in the original it is not clearly legible and may read "Barita", but it is not thought that it will change the following.] This has been translated by both Michael Cable and Dr David Watts as 'Barium Sulphate'. The latter was intrigued to find it being referred to by Coathupe, as his initial response was that it was normally used later, particularly in the context of pressed glassware generally. However he subsequently advised that, "The chemistry of Barium and purification of the metal was well worked out by 1835, as indicated in *The Penny Cyclopedia* of that date, Vol. 3, pps.452-454. Its function is to improve toughness, brilliancy and the speeding-up of setting times.[20]

Material preparation

The sand, depending on its source probably would require washing and drying before use. The lime would probably have been ready for use from the limekilns.

Before the works went over to producing its own alkali, etc, the evidence from the 1830s plan indicates that the kelp would be broken up and then calcined in the 'calcining house' to reduce it to ash. [Angerstein, writing in June, 1754, about glass bottle manufacturing in Bristol describes kelp as, "a kind of soda or barilla, burnt from seaweed in Wales. This is quite salty on the tongue, and serves as a flux for the other ingredients."] A 'mill' is shown alongside the 'room for breaking kelp'[21], but it is not known whether this was to further mill down the kelp before burning, or whether it was part of the subsequent process. Taking the evidence from the 1870 schedule it might also have been for breaking down some of the other raw materials. Either way, once all the necessary raw materials were available they would first be measured by weight in the required proportions in to a rotatable wooden drum, and thoroughly mixed to form 'batch'.

This would then be 'fritted', that is partly fused together, by heating in an oven called a 'calcar' ('caulker' on the Nailsea drawings/schedule). By taking the batch to a temperature somewhat below 800º C, this would tend to reduce the production of gasses in, help to burn off any impurities before introduction to, and reduce the energy required in, the main furnace. [Coathupe refers to a calcar (p.94).] To make it more manageable it may well have been subsequently milled to give a more uniformly sized product. With the addition of an appropriate amount of clean cullet the resultant mix would then be added to a pot for melting. Whether the terminology, as opposed to the process, had been changed by 1870 is not known, but in 1870 there is a reference to a 'Sand caulker" {12}: this may have functioned as a drying oven, the sand having been washed first, as it is next to the 'Mixing Room' {13}. An alternative might be that by then 'sand' was a colloquial term for the mixed ingredients.

Cullet is not a 'raw' material, but it is a significant aid to the process of making glass, and therefore should be considered. This seems an appropriate place and I am grateful to Mr Mike Noble, factory manager at United Glass Limited, Alloa, for drawing it to my attention. He asked if there was any indication of the source(s) of the cullet used, as this is a question that has interested him. Obviously nowadays the ubiquitous 'bottle-bank' is an obvious source, as well as in-house waste, but he has wondered if in the past there were people who collected scrap glass (c.f. scrap merchants for scrap metal) or even if there were works whose principal product was cullet, rather than finished goods. The current study has not provided answers, and a close reading of Coathupe's notes does not provide any clarification. Cullet is obviously important because it is referred to a significant number of times. On p.24 he gives 336 lbs. of cullet to 448 lbs. Sand for the "S.S. Standard Mixture" and the same weights, using dry I.o.W. sand, for a 'carbonate' mixture on p.25. He confirms this ratio on p.40, as well as giving additional quantities of cullet used. On p.41 he quantifies cullet in the forms of 'Skimmings' [the scum/contaminated glass floating on the surface of the molten glass in the pot and skimmed off], 'Moils' [the glass remaining on the end of the blowing iron], and 'Pontys' [the glass remaining on the pontil rod after it had been detached from the finished item], as weights per

[20] Angus-Butterworth, p.36-7

[21] It seems more likely to have actually been kelp in its natural form at Nailsea, as there was a suggestion in 2001 (GT 1/01)of a possible drainage channel from the building, possibly indicating washing before processing.

found. On p.42 he gives the values of cullet as 5 shillings per cwt. if "Thin, picked and washed", and as 3 shillings per cwt. for "Ladlings and skimmings". This does not make it clear whether this is the value for selling or buying, but it is felt that the condition infers that it is being bought in at that price. On p.89 he states, "Wt of Cullet used **:** Wt. of cullet retd. from the Cutting Room as 1 **:** .0332, when we supply not so much cullet as we use." A further series of 'Cullet' ratios follow on p.90. One of these, "Total of Cullet used **:** Total of Sand used as 1 :1.08." appears to be at variance with the 3 **:** 4 ratio quoted above, unless it is including cullet used for glazing etc. The reference to "Brazling Cullet" on p.37 of Coathupe, as transcribed, drew the following comment from Michael Cable, "It could therefore mean the heinous practice of calcining cullet." [Pers. comm., with useful comments on cullet via David Crossley.] [The late access to the original of the notebook now gives an alternative reading of "Crazling"; the initial letter is rather ornamented, and not entirely clear. This is not helpful.]

By 1870 there were two rooms reserved for coloured cullet, {35} and {43}.

The presence of an 'Engine Room' {46} in 1870, with, for example a saw mill {45}, two clay mills, {40} and {50}, and a 'Limestone & Salt cake Mill' {39} in proximity indicates that a degree of mechanisation had been installed: when is not known.

Pot making

This was one of the most important trades in the works, as the pots, or crucibles, played an integral part in the glass-making process. The clay came from Stourbridge, being highly suitable for the purpose, as molten glass is very corrosive. Transport was relatively easy by boat down the Severn. Coathupe covers 'Pots' from p.60 to p.73 in his notebook: being reproduced as Appendix 1, much of the detail may be read there.

The pots were made on site, straight-sided, 'flower-pot' shaped (rather than closed), by the method, dating back to the Neolithic only on a much larger scale, of building up coils to give the required form and dimensions. Considerable manipulation of the clay was necessary to ensure a homogenous texture, clear of any air bubbles, and it would be 'tempered' by the addition of a certain amount of finely ground clay from used pots. This was in the ratio of 7:1 (Coathupe, p.60). Several would be worked on at once, to encourage stability by partial drying once a new ring had been added, but the top edge would be kept damp by sacking to ensure a good bond to the next ring when the turn of that pot came round to have a further ring added. "If very carefully dried, they may be used in from 5 to 6 months." (*Ibid.*, p.61.)

It is understood that once the pots were sufficiently air-dried they would be transferred to a pot-arch for drying out at a higher temperature and would be brought up to furnace temperature before being 'set' in the furnace itself.

It can be seen that while not requiring a large labour force it would have been virtually a continuous production process. While referring to the closed pots in use there, the Red House Cone booklet states that, "Each pot took about two months to build."

It does, however, give some idea of the time that would be involved to finish up with a pot with an external diameter at the top of 56 inches (132 cms), an overall height of virtually 41¼ inches, an external bottom diameter of 40 inches and a wall thickness of 1¾ inches. (Coathupe, p.61).

For whatever reason, it appears that no crucible fragments were found or, if found not retained, from any of the archaeological investigations. There is a reference to crucible fragments in the 1983 report (File 'A'), but none were found during a comprehensive search of the finds stored at the Museum at Weston-super-Mare. [The profile of the pot has been established by use of the figures in Coathupe, (p.73).]

Mountain, writing in 1915, aged seventy-two, recalled that, “The pots were about 5 feet in height, 3-4 inches in thickness and about 70 inches across from brim to brim.” It is not clear that this applied specifically to the Lilly cone furnace which he states held only four pots, or whether in fact the pot size changed after Coathupe’s time.

J F Chance, 1919, writing about Nailsea, states that, “Furnaces at the works were three in number, two for sheet glass, with eight 65-inch pots, and one for rolled plate, with four.” It seems that pot sizes varied with time, and in general it does sound as if pots got bigger.[22] Parkin, p.36, comments on the increase in pot sizes.

Figure 3.9: Changing a pot at the Red House Cone
© Broadfield House Glass Museum, Kingswinford

Once set in the furnace and the wall rebuilt, the pot would be glazed by ladling molten glass, it has been suggested, from an adjacent pot in order to coat the whole of the inside with a layer of glass (Coathupe, p.63). An alternative would seem to be by introducing a charge of cullet to the pot and using that. (Coathupe, p.40.) This would have the effect of sealing the clay surface before introducing the raw materials and commencing a melt. Vose, p.161, however, categorically states, “It should also be remembered that crucibles and the furnace interior are never purposely glazed, but become so owing to the heat of the furnace, which causes an exudation within the refractory.” The writer is grateful to Mr Mike Tuffey of the English Antique Glass Co. for confirmation that the pots are indeed glazed internally once they are in the furnace, before batch is introduced. He also confirmed that because of the siliceous nature of the refractory there is an exudation from the furnace interior.

Associated with the pots were ‘rings’. Some fragments of these rings, believed to be made of the same Stourbridge clay, which floated on top of the molten glass, were found. Of various cross-sectional areas and radii of curvature, [therefore possibly relating to different sized pots and different periods], they were more like a fine sandstone in texture, the clay being so dense and having been so highly fired. The function of the ring in the open pot was to keep a clear area on the surface of the melt from which the blower could gather the glass, having been skimmed clear of any impurities. As has already been mentioned, these are a drawback to using open pots when coal is the fuel. [Dr David Wardle of Pilkingtons, (*pers comm.*),

[22] Chance, J F, p.106

mentioned that the "Sodium Sulphate" mixture itself gives rise to a considerable amount of scum, that needs to be removed.] The reference to "skimmings" as waste, by Coathupe, implies that the ring would form a controlled area at the surface of the glass that would be skimmed periodically with some sort of ladle to ensure it was kept clear, rather than functioning automatically, as has been implied elsewhere.

A glassworks at Smethwick, Birmingham, was taken over by Robert Lucas Chance, nephew of John Robert Lucas, in 1824, and, according to J F Chance, rings were introduced by German workers there sometime before they left early in 1834 (due to a disagreement about working practices). By the end of that year, after trials, they "were in partial use in all the houses."[23] A footnote to that sentence states, "The dates are interesting, since Bontemps[24] in the *Guide du Verrier*, p.118 says that the rings, owed to Germany, had only lately – that is not long before 1868 – been adopted in England." This is of interest, because, as mentioned above, Coathupe quite clearly makes reference to rings in his notebook (1836-7).

Furnaces

From the archaeological evidence we have some idea of the layout within the two major cones at Nailsea, but due to the clearance of the site the exact configuration of the furnaces would have escaped us, were it not for Coathupe's notebook, again. It is important to remember that the dimensions are not 'cone specific', and he only gives us a snapshot about half-way through the life of the works, but the base of the last New House Cone furnace was clearly rectangular, and the Old House Cone remains gave no indication of anything other than a rectangular furnace. From the excavated evidence, the approximate final overall dimensions for the two principal furnaces were New House Cone, 7.5 x 5.0 m, and for the Old House Cone 10 x 5m. Mountain [see Appendix 8] states that both the New and Old House Cones had eight-pot furnaces, and this would have been round about 1860 onwards.

While it appears that there was no great difference in the overall dimensions of the two main cones, there are some observations to be made.

It is not entirely clear what the 'as-excavated' levels were at the New Hose Cone, but it would appear from a larger scale version of Figure 2.4 (1983) that there was in the order of 1.25 m of side wall surviving above the main airway floor. This had itself been raised slightly at some time. There appeared to be a maximum of a little over 1.4m of the side walls surviving above the airway floor of the Old House Cone. In neither case was there any observation that there had been bearing bars for the grate bars. Three feet equals 91 cms., so it is suggested that there should have been some evidence. Additionally, it does not leave very much headroom for a teazer to clear clinker or rake out ash. [The illustration in *The Red House Glass Cone* booklet, showing teazers working at the Walsh, Walsh factory in Birmingham shows them with clear headroom in the corbelled area beneath the furnace.] The width of the airway floor corresponds closely with the archaeology, but the diagram does not show, because no dimensions are given by Coathupe, how the walls of the airway under the furnace are actually corbelled in on each side. [They may not have been so in his time, of course.] This, plus the narrowing of the airway from cone circumference to furnace entry would have accentuated the force of the draught achieved, so what at first sight appears to be a rather deep-set grate probably needed to be that depth to generate the amount of heat required by burning a considerable volume of fuel. None of the interventions seem to record furnace bars being found.

---

[23] Chance, J F, p.8

[24] G Bontemps was a noted French glassmaker, who worked closely with the Chance Brothers.

The drawing used as the basis of Figure 3.10, below, has been amended on the left-hand side to show, notionally, the dimensions given by Coathupe, taking into account the corbelling of the airway. [However, bearing in mind that Coathupe, p.56, gives the length of the siege of a six-pot furnace as only 13 feet, and this has been checked against the original, there may be a problem with the above interpretation, because he gives the maximum pot diameter as 52¼ inches after annealing. Three times this dimension is just over thirteen feet.] Other illustrations of 19th century cone interiors may be used as analogies (e.g. that of the Richardson Glass Cone at Wordsley, Stourbridge, circa 1830, part of which is reproduced on the cover of the Shire publication *Glass and Glassmaking* by Roger Dodsworth). It is therefore suggested that there would have been arched areas of the furnace side-walls that would have been thinner than the rest in order to facilitate breaking them down to change pots.

These arches would have incorporated the working hole, which the original draughtsman has combined with the punty hole. The latter would in fact probably be separate. As originally drawn it would have been extremely difficult to get much more than halfway down the pot to make a gather. The punty hole has been shown as angled, because of "Inclination of Restings, 3 in." (Coathupe, p.57). It has been assumed that the function of the punty holes was to keep the ends of the punty rods hot, and the term "Restings" has been translated to mean where these rods rested. They are angled down and out so that the punty rods would not slide in to the furnace. It is possible, looking at the 'Richardson Cone' picture mentioned above, that the punty holes were in fact horizontal, placed lower than the working holes, and that there was an iron bar across the front of the arch on which the rods might rest, which might be three inches lower than the bottom of the punty hole. An alternative, suggested by an illustration in *The Window Glass Makers of St Helens*,[25] is that the 'restings' were where the pots sat on the sieges, because the drawing showed that there was a slope on them. In the illustration it showed this as outwards, but Mr Mike Tuffey considered that they should slope inwards, if at all, to make any flow of glass from a damaged pot run towards the eye of the furnace, rather than out the foot-holes towards the glassworkers. [This same illustration shows a double crown with the flue exit in the inner one directly over the pot, and the whole furnace heavily reinforced by an iron/steel frame and tie-rods.] No archaeological evidence remains at Nailsea for either case.

Also, by analogy with other illustrations, the flues might well have come up the outside of the furnace, rather than as shown speculatively. This would still have drawn the heat past the bottom of the pots, possibly thus reducing the particles in the furnace atmosphere, and the flues themselves would then have acted as buttresses to counter the outward thrust of the furnace roof arch. The latter would have reflected heat down on to the pots. Certainly, by 1847, Chance Bros. were building furnaces with "flues between every two pots as well as at the corners. James Chance took out a patent [English patent No. 11749, of June 15, 1847] on this principle: "the fire is placed below the pots, and the heat and flame rise up on either side of each."[26]

Having concluded that deeper grate rooms were desirable, only a year later it was, "the decided opinion of the board that shallow grate rooms are preferable to deep grate rooms for furnaces such as ours which are enclosed with doors; the former causing much less wear and tear both of the sieges and the pots."[27] Why this should be is not explained; presumably bitter practical experience was the driver?

---

25 Parkin, R A, Figure 15, p.20
26 Chance, J F, p.46
27 *Ibid.*, p.47

The function of the foot-holes is not clear. It is wondered if it might have been an aperture through which a crowbar might be inserted to rotate the pot on the siege, to even out wear on the pot. It might have also been necessary to allow a check to be made on the integrity of the pot and to give early warning of leaks from the pot, which would damage the sieges, apart from anything else. It has also been suggested that they might serve some function in local draught, and therefore possibly pot temperature, control.

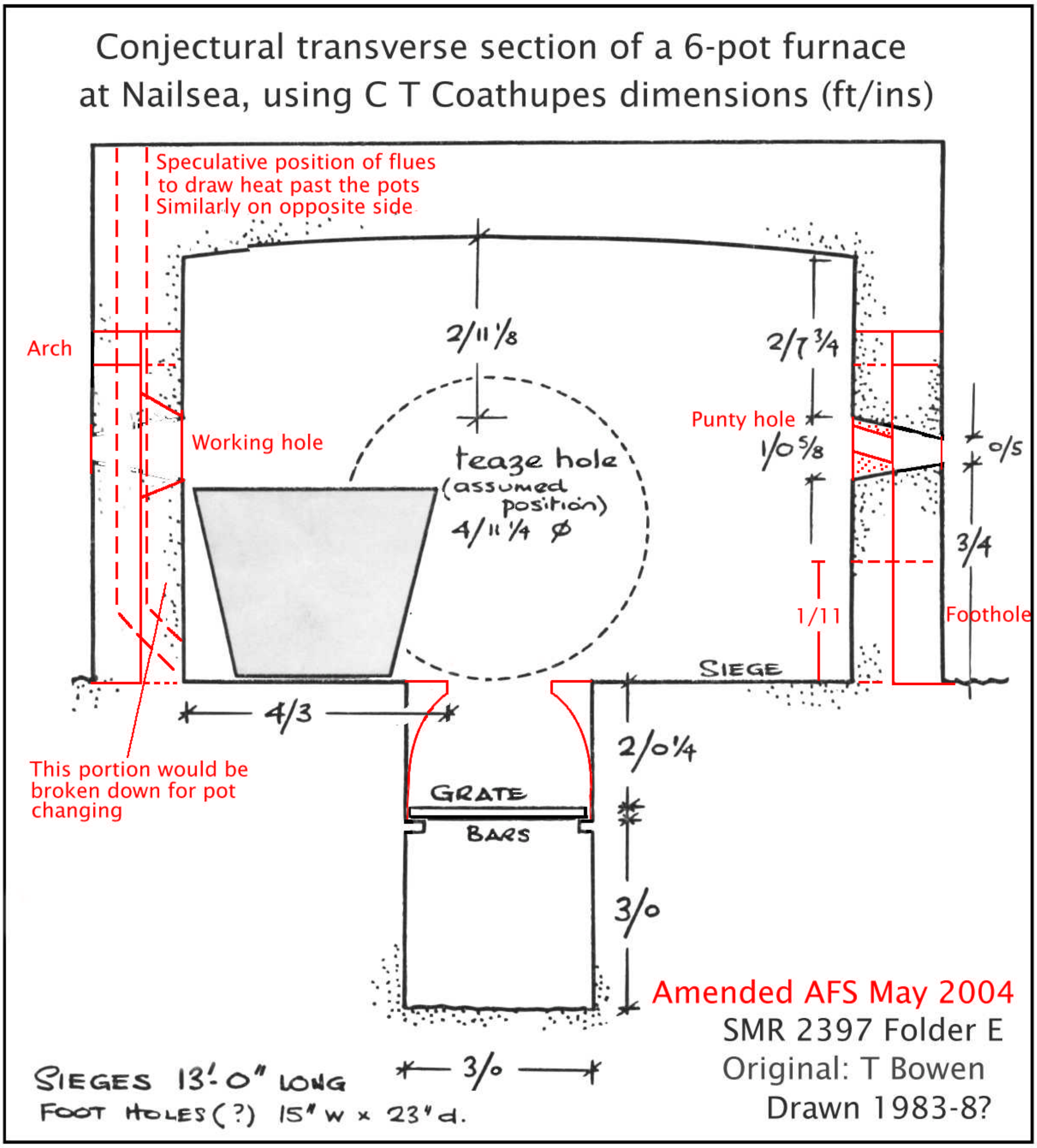


Figure 3.10: Furnace cross-section, derived from C T Coathupes dimensions

How the furnaces were fired, apart from the supposed position of the 'teaze holes' at each end, as shown in Figure 3.10, is not known, and the various illustrations seen have not made it any clearer. Likewise flues often seem to be omitted. Presumably the fuel was shovelled in at each end as required, and the openings closed between times. Clinker and ash were presumably raked out from below. Some clue may be gained as to later practice, as Mountain (Appendix 8) says, “The furnaces were worked underground.” This is where not knowing the actual working floor/siege finished levels is tantalising, especially as the floor of the main airway appears to have been raised slightly in the New House Cone at some time.

The presence of the two vertical chambers in the furnace base in the Old House Cone, already referred to in Part 2, 1995 and 2002, is also enigmatic. Some discussion has been included in Part 2, but for completeness an illustration and description of the Frisbie furnace feeder from the *Scientific American* of December 2nd 1876 is reproduced here, as Appendix 9. The feeder was patented in the UK by Frisbie in 1868; Patent No, 27. It is not certain that these chambers represent some sort of housing for the feeder, as neither the *Scientific American* article or the drawings accompanying the patent show clearly how it might be built in to a furnace, but they might represent a local attempt at something similar, as it was round about this period that there was a rebuild. Neither Chance nor Barker mentions this feeder in their histories, although Ashurst does twice, reporting its use on both occasions as unsuccessful.[28] It may be that the version shown might be more suited to a circular furnace

There may be two alternative explanations. One is that by drawing hot gas from the furnace the incoming air could be pre-heated and thus improve combustion. This might be an early attempt at a regenerative furnace, but on the available structural evidence and drawings of more advanced types this is discounted. The second is that they were chambers to produce ‘producer gas’, and/or ‘water gas’ to aid the combustion process and produce a cleaner flame. This would correspond with the schematic diagram, Fig. 20.9, on p.417 of Hicks’ *Comprehensive Chemistry*, but no scale is given. This will be discussed further under ‘Fuel’.

As well as the main furnaces, there would have been subsidiary furnaces. Mountain states that, “The number of kilns in use in the factory was about thirteen, with about five pot arches. There were about ten other furnaces used for heating before the metal was made in to Sheet or Crown glass.” This would probably have been around the 1860s. The dictionary definition of ‘metal’ in this instance is, “material used for making glass, in molten state”.

This leads on to the issue of furnace management, because the materials going in to the pot, even allowing for the cullet which has the effect of helping to lower the fusing temperature[29], require a higher temperature to fuse completely. At this temperature the (what is now) glass has a consistency, somewhere between a light machine oil and glycerine at room temperature[30], and the temperature has to be allowed to fall, even by something in the order of 10%, until the glass has a much more syrupy consistency for working. The actual temperatures involved obviously depend on the exact composition of the glass being made. It will be apparent that in a multi-pot furnace all the pots would require to be emptied and filled together, unless there was some way of regulating the individual pot temperatures, but no mention has been found of this being done.

On a visit to the English Antique Glass Company at Bordesley Hall the similarity between the shape of the flattening kiln there and the outlines (a tall ‘L’ shape with a bulky foot) shown on the alternative 1870 plan (Appendix 5) for the French Kilns in {10} was noted. In the present-day version the cylinders, having previously been cut and opened out slightly after annealing, travel down through the length of the flattening kiln. Each then comes in turn to a chamber at the end where they come on to a moveable table. Each cylinder in turn is completely opened out using a steel rod, and then flattened using a large block of wood. (Figure 3.11 below.) The

[28] Ashurst, pps. 79, 85
[29] Bell, J in Krupa and Heawood, p.5. also points out that cullet in larger sizes can “aid the entry of furnace radiation into the batch pile.”
[30] Frank, S, p.3

table is then moved sideways out of the terminal chamber and the flattened sheet is slid in to a further annealing chamber. Although they are not going through exactly the same process as that described for the ‘German sheet’ or ‘improved cylinder’ glass, none-the-less one gets a good idea of the process, and how much energy would be expended, both in the furnace and kilns and by the glass-blowers themselves.

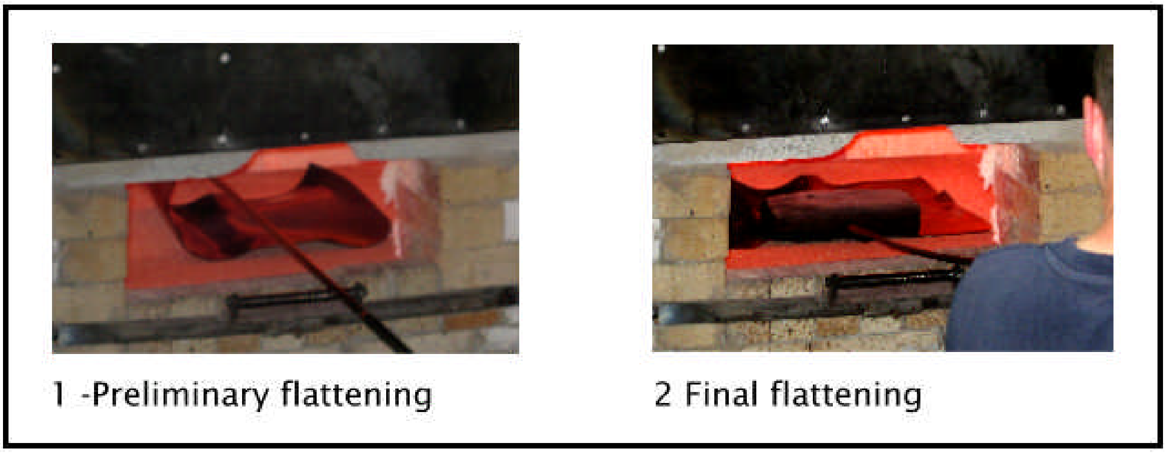


Figure 3.11: Flattening at English Antique Glass Co.

Once the glass has been manufactured and formed it has to go through a gradual cooling process to anneal it, otherwise there may well be stresses induced in the glass which lead it to fail prematurely. Kilns and lehrs [‘lears’ on the 1870 plan] are being dealt with under ‘Furnaces’ because the application of fuel and heat is required. It is just that the heat is now considerably less than that in the main furnace. It is clear that Lucas’ 1805 patent was to facilitate the transfer from the spreading/flattening kiln to the annealing kiln, in his terms. See Part 1.

Figure 3.12: 'Input ' end of an annealing lehr (Red House Cone)

When considering the archaeological interventions in Part 2, no firm conclusion had been reached about ‘French Kilns’ and ‘Belgian Lears’, although an unattributed note found in the SMR 2397 records states that a French Kiln was for flattening cylinder glass, and a Belgian

Lear, or lehr, was for annealing, the glass travelling through it on bogies from hot to cool. [Part 2, p.3] Some further evidence has now come to light in *A History of the Firm of CHANCE BROTHERS & CO. Glass and Alkali Manufacturers*, by J F Chance.

It seems that the early methods of flattening and annealing were wasteful, both in terms of energy and time. On p.14 it is stated that, "Manufacturers abroad were busy about methods of removing the flattened sheets continuously from the lear and annealing them separately, to the fore among them Hutter & Co. of Rive-de-Gier and Houtard of Mariemont ... ." Rive-de-Gier is about 30km SSW of Lyons, France, and Mariemont, now Morlanwelz-Mariemont, is about 25 km east of Mons, close to Charleroi, Belgium.

Figure 3.13: 'Delivery' end of an annealing lehr (Red House Cone)

Robert Lucas Chance, who seems to have been known in the family firm as Lucas Chance, had a representative, John Reynell, who apparently travelled widely on the Continent, and Chance himself visited Belgium in March 1837, and again in August 1841. Without going in to details, over the next dozen or so pages of J F Chance it is apparent that there was considerable development taking place, and it is clear that the terms refer to flattening and annealing devices. It does seem that the terms 'kiln' and 'lear' were used somewhat interchangeably. For example, "In November James Chance was authorised to erect, without Bontemps' aid, a lear on his second principle, "uniting a long annealing arch, containing railway carriages, with the present kind of flattening kiln" ... ." The remaining questions about the exact form of the structures are, for the time being, unanswered, although footnote 1, on p.32, states, "Particulars of all these kilns, Guide du Verrier, pp 285 fol." It will be seen by examination of the second 1870 plan that even the 'French Kilns' do not have the same ground plan throughout the works.

Later there is reference to a Belgian lear, "the invention of one Bievez. It was shown at the Paris exhibition of 1867, and was highly commended by Bontemps in his report for its simplicity and other merits. ... "However, the lear failed to give satisfaction, and after a short trial was pulled down."[31]

In the examples shown above, photographed at the Red House Cone at Stourbridge, the lehr ran from the inside of the cone and out through the cone wall, so that the glassware (not crown or

---

[31] Chance, J F, p.88

sheet in this case) could be passed straight from the blower in to the lehr as it was completed. (Figure 3.12, above) It was placed on wheeled trays that were linked together and thus went from the hot end inside the cone to the normal temperature at the delivery end as the trays were pulled through at a controlled rate. This is now a display feature. (Figure 3.13, above.)

Pot arches have already been mentioned; it seems that even if they were outside the cone, the pot would be so hot coming from the arches that for all the time it would take it would not loose a significant amount of heat. It would also be so hot that rain, unless torrential, would be vaporising at the surface and would therefore not affect them. (M Tuffey, pers. comm.)

Earlier there was speculation about 'blowing holes'. It now seems clear, from further reading, and having seen the process working, albeit on a more modest scale, that the gathers were made, and the initial forming done, at the main furnace. The partially formed cylinder was then transferred for re-heating and progressively further blowing to the blowing holes, which were in close proximity to the swinging pits, thus facilitating the expansion of the cylinder. 'Blowing furnaces' are first mentioned in Chance Bros.' Board minutes in 1840, but it is apparent that the use of a separate furnace for working had come into being in crown and shade manufacture well before that.[32] Angerstein shows this as a drawing and also mentions it in the text, with respect to crown glass manufacture in June, 1754, in Bristol.[33] Parkin, Figure 10, p.5, shows a blowing furnace and swing pits. It appears that this would date at Pilkingtons from 1841 to 1850.

The speculation about the introduction of cylinder glass at Nailsea has been referred to in Part 2, but it should be restated here that the archaeologists in 1983 wrote, "The similar stonework used in the construction of the cone wall and the adjoining swinging pit area enclosed between the cone wall and the outer wall 2, suggests that these structures are contemporary with one another. Historical records tell us that this could not be so as there was no actual cylinder (sheet) glass production at Nailsea until 1844 (Chance 1968:35)." As stated in Part 2, p14, et seq, "both the Old House and New House Cones have "flattening" and "annealing" kilns associated with them on the 1830s plan." It therefore seems, taking the archaeological evidence with that of Lucas' 1805 patent, that German sheet glass (the 'improved' cylinder method) could have been made at Nailsea considerably earlier than has been previously thought.

Fuel

This is maybe self-evident, after all that has been written about the placing of the glassworks on the Nailsea coalfield, but it should be mentioned for completeness, because in the end it appears that the difficulties encountered in winning sufficient suitable coal contributed to the closure of the works.

To many people, 'coal' is just coal, but depending on when and where it was laid down it can have very different characteristics. Some readers who are old enough may recall terms like 'steam coal', 'coking coal' and 'anthracite', for example, giving some indication of the different qualities. It is clear from J F Chance, that there was considerable debate at Chance Brothers about how much, what size, and what form (e.g., 'black coal', 'Round's bottoming coal', 'slack', 'large coal', and that, "no Brazils[34] are to be bought except to save large coal and

[32] Chance, J F, p.33
[33] Berg & Berg,2001, Fig. 132, p.130
[34] From "The Shorter Oxford English Dictionary on Historical Principles".: An old word for iron pyrites or coal containing much pyrites. The latter usage is probably the appropriate one. Dr Michael Baldwin, *pers. comm.*

for Badger's staining kilns."), and opinions varied with time[35] At present it is thought sufficient to note that the subject might be more complicated than would appear at first sight. We do not know enough about the furnaces to make further speculation about the coal worthwhile.

Parkin, writing about Pilkington, notes (pps. 17-18) that, "Up to 1830 coal was just burnt on a grate within a confined space to melt the frit. Somewhere between 1840 and 1855 it was found that by pouring a trickle of water on to the grate an even better flame was produced." Frank, p.113, writing about the Gawber site, notes, "the existence of drainage channels between and at the side of the sieges: any water on the site would thus drain away and not remain to form steam with the consequent risk of explosion." Without knowing the direction of fall, it is wondered if this might in fact be an early application of the procedure mentioned by Parkin. [In both cases it is thought that it might be very difficult to get water to trickle on to the grate, or to make significant inroads in to the siege area when one considers the ambient temperature under normal operating conditions.]

Similarly, the apparent ducted connection between the boiler on the southern boundary and the Old House Cone has not been explained, although it has been suggested that steam might have been used to keep grate bars cool [and clean of clinker, if the pressure was high enough], and that the steam, in limited quantities, might even aid combustion[36], through the creation of gases from the reaction between the steam and hot coals. The distance involved, and no trace of lagged pipes in the excavations does raise doubts about this theory.

However, the form of the vertical chambers in the Old House Cone furnace base, [revealed in 1995 and 2002, and as mentioned under 'Furnaces' above], which each seem to have a connection with the said duct, might indicate that experiments were tried to use some form of gas to augment the coal firing in some way. However, there is no further evidence at the time of writing.

To get producer gas, "a mixture of 35% carbon monoxide and 65% nitrogen", air is blown over white-hot coke. It turns first to carbon dioxide, and then with no more air and further coke this is reduced to carbon monoxide, which will then burn to form carbon dioxide again. The reaction will occur, provided the temperature is kept above 1000°C. Producer gas has a low heating value, but "it is a cheap fuel, normally used straight away, whilst still hot, for heating retorts or furnaces."[37]

Water gas "is made by passing steam over white-hot coke. It contains about 45% carbon monoxide, 50% hydrogen, with small amounts of carbon dioxide and nitrogen: ... Provided the temperature is kept above 1000°C the proportion of carbon dioxide is very small, ... For this reason water and producer gas are usually made intermittently from the same plant by alternating the input every few minutes between steam and air. ... Water gas has a high heating value. ... Another gaseous fuel [semi-water gas] is made by passing a mixture of steam and air simultaneously over white-hot coke in such proportion that the temperature is maintained above 1000°C." It "contains about 30% carbon monoxide and 15% hydrogen" ... and "has a lower heating value than water gas, of course, but has the advantage that it can be made continuously."[38]

---

[35] Chance, J F, pps. 39-41, and others.
[36] Attributed to Pilkingtons in an un attributed note in SMR 2397 papers - Item. 41, p2.
[37] Hicks, p416-7
[38] *Ibid.*, pps. 417-8

There is evidence, quoted in full in Part 4, Section 1, that in 1855 some coal was already coming from Wales and Coalpit Heath (South Gloucestershire).[39] It would seem that the majority of Nailsea coal was very suitable for firing the different furnaces in the works, as mentioned in Part 1, but some of the seams were very narrow, and there was at least one fault line causing discontinuities in the seams.

A gas retort is shown {10} on the 1870 plan, and a gas holder was excavated at the rear of 'The Royal Oak', immediately to the west, but the evidence is that the holder was in use from 1860, and was out of use by 1890 (see Part 2, 1983), and it appears that the coal was again a problem, not being entirely suitable, but see Part 1, para. 4.3. At that late stage the gas might possibly have been firing the French Kilns, {10}, but we have no direct evidence.

Equipment

Much of this can be best described by means of illustrations, but an interesting catalogue is available in an auction advertisement[40], following the bankruptcy of Samuel Bowen.

"The whole of the PLANT, FIXTURES, POTS, & C.

belonging to the bankrupt:

Comprising 2 excellent weighing machines (by Bartlett),
to weigh 4 cwt. each; 130 large clay pots, 3 large plate
glass roll tables, rollers and steels complete; bogees (*sic*),
drossers, [racks to support tables while annealing] 2 forge bellows, anvils, iron troughs, sundry
tools, 6 counting-house mahogany and deal desks, stools,
chairs, letter press and stand, iron safe, maps,
stationery, 9 forms, 5 reading tables, 72 cane seat
chairs, 2 dials, & c.; also 12 spring dillies [used to transport the crates of finished glass],
9 carts, 1 spring trolley, 4 spring wagons, timber carriage,
phaeton, brougham, bus gig, 2 chaff cutting machines,
2 hunting saddles, 2 side ditto, boys pad, martingale,
bridles, 11 sets cart harness, collars & c."

It is interesting that glassmakers' chairs are not mentioned, unless they come under the heading of 'sundry tools'. As seen at the English Antique Glass Co., the chair was used in both processes. It may well be that a glassmaker's chair and tools were his own property. [Whether the hunting saddles and side-saddles were relics of a more affluent age is not known for certain. Certainly B J Greenhill noted that "the late Squire Bean [later Rodbard] of Backwell Hill near Bristol, (who carried on for many years the then prosperous undertaking of the Nailsea glass works, and hunted his own pack of hounds in that district, ...)[41]". If not, it might be construed that although Samuel Bowen worked hard, he also enjoyed his recreation.]

In the same paper was an advertisement for the sale at Stourbridge of the stock, etc from Platt's Glassworks, also owned by Bowen. This is included below in order to give another view of the equipment etc. that might be found at a glassworks at that time.

"The stock consists of sheet and plate glass, of various
qualities and thickness, in about 200 crates, glass

[39] *The Bristol Mirror,* 26th May 1855 (p.5 col.6):

[40] Bristol Times and Mirror, 7th August 1869, p.1, col.6. From transcript in SMR 2397,Folder E

[41] Quoting Freeman, A B, 1907: *Bristol Worthies and notable residents*

shades of different sizes, glass tiles, about 100 tons
of best pot clay, 50 bags of nails, shovels, ladles,
iron bowls, five tons of salt cake, ground lime, cement
clay, arsenic & c.
The PLANT, FIXTURES and UTENSILS comprise two bogees [*sic*]
carts, 200 large drassers [*sic*], two stoves and pipes, three
flattening stone carriages, four good flattening stones,
two large plate and plain glass roll tables, 43 iron
moulding blocks, weighing machine (by Bartlett),
two pairs of patent forge bellows, two vices and tools,
rasps, files, shears, one large pot setting machine,
one pair of pot setting wheels, wheel barrows, office
furniture, iron safe. Also rick of new-made hay, three
horses, three carts, three sets cart harness, one trolley, & c."[42]

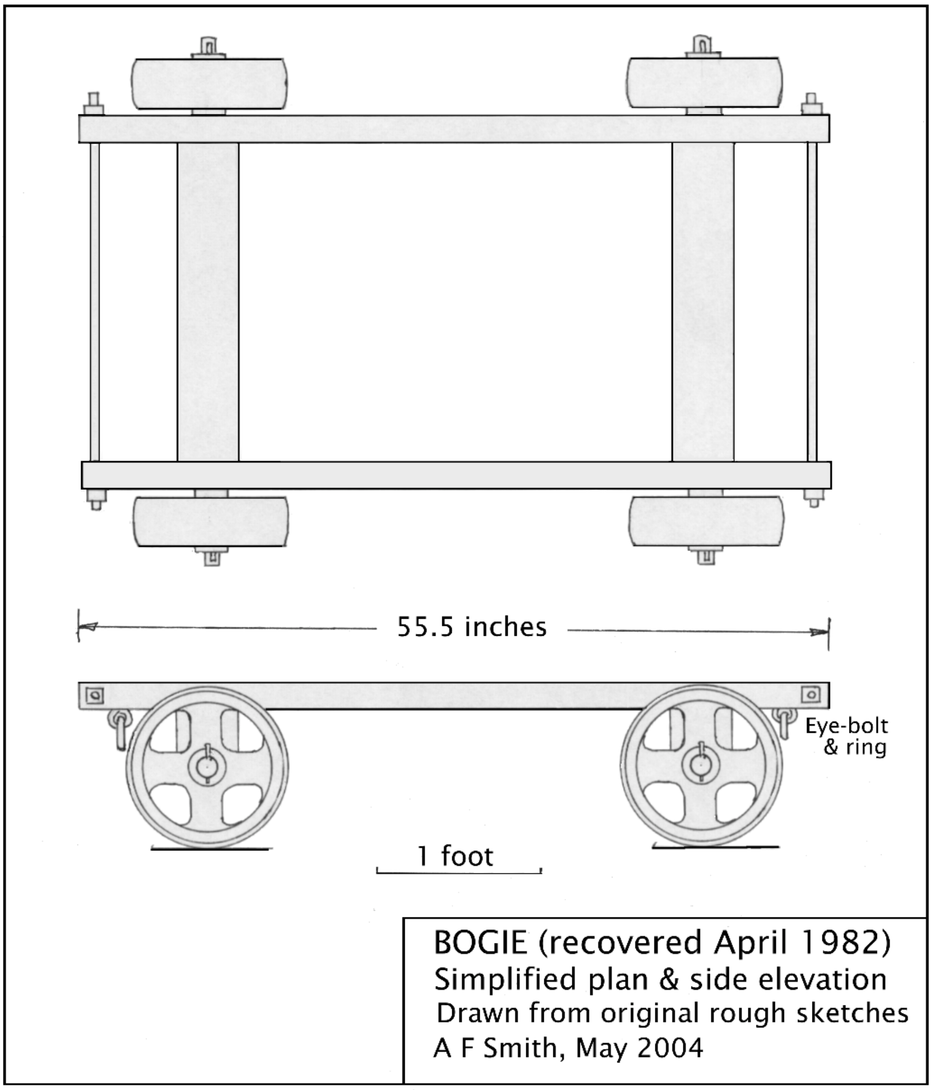


Figure 3.14: Glassworks bogie , possibly from annealing kiln, Nailsea

[42] Bristol Times and Mirror, 7th August 1869, p.1, col.7. From transcript in SMR 2397,Folder E

Reference to the bogie may be found in Part 2, 1982. The original sketches are difficult to interpret, so only a simple outline has been attempted in Figure 3.14. [There also appears to be iron braces to the axles and a shaped iron plate fixed to a transverse bar, of unknown purpose. The original bogie is in store at the North Somerset Museum at Weston-super-Mare, but has not been seen.]

Figure 3.15: Pot changing forks (Red House Cone)

Figure 3.16: Glass blowers' chairs (Red House Cone)

The above pictures, Figures 3.15 and 3.16, speak for themselves.

The following picture, Figure 3.17, below, is of a selection of tools from the Red House Cone, and it is judged that they were all used for handling hot glassware, on account of their length, and, in some cases, deformation.

Figure 3.17: A selection of glassworkers' tools (Red House Cone)

In addition the glassmakers would have had a selection of blowing irons, pontil rods, shears of various types and sizes, and various marvering blocks and moulds. In general these do not seem to have changed significantly over the centuries.

The equipment used for the rolled-plate making, obscuring, engraving, etc. will not be detailed here, as it seems fairly certain that the principal activities involved crown and cylinder window glass, although some large tenders to supply have been noted. Latterly, certain other items of glassware were made, some officially, and some probably unofficially. In both cases the equipment used was either fairly conventional, or has been described in other references

All the ancillary trades, such as the joiners, crate-makers, and so on would also have had their own specialised tools and equipment. It is clear that these would have changed over time with changing requirements in the manufacturing process.

Boilers and (steam) engines have been mentioned in passing. The form of the engine in use by 1870 is not known, and no attempt was made to find its foundation plan. By then it could have been a reciprocating engine with a flywheel using belting to drive a layshaft that ran through the building so that various individual drives could be taken off, again by belting, as required. This appears to be confirmed by the report of an accident in an undated newspaper cutting reproduced at the Scotch Horn Centre Nailsea.

The accident was reported as having occurred in the Glass House Saw Mills, when the, "Deceased got entangled in the shaft and drum ... The jury returned a verdict of *Accidental Death*, with a request that a pulley should be placed at the right hand of the sawyer, to communicate with the bell in the engine-room, to enable the engineer to stop the engine in case of accident."

The Products

It will be apparent that the early products of the glassworks were bottles and crown glass. In due course cylinder blown sheet glass became a significant product, eventually superseding crown glass. With the passage of time other forms of window glass were produced, such as rolled plate glass, and eventually, some non-window products emerged, but these were still made from window glass metal.

Figure 3.18: Sample of Rolled plate glass

[Given by Mr George Abraham who had joined the Nailsea factory in 1870.]

This sample is of interest, because it identifies the company as the "Nailsea & Stourbridge Glass Co."

Eyres, in his 1911 letter [see Appendix 10], comments that, "the 'Lily' ... was got ready for the purpose of making rolled Plate Glass, a large quantity of which I remember consigning to Crewe, and other large railway stations, for roofing purposes." There had been difficulties about the adoption of this method of production, as the patent was taken out by James Hartley in 1847, and was vigorously defended for its term by the other licensees, despite an apparent wish of Hartley to extend the scope.[43]

A note in the Scotch Horn Centre, Nailsea, display states, "In about 1865 the acquisition of a glassworks at Stourbridge allowed Nailsea to import their ruby, blue, orange and white ornamental glass and produce elaborate coloured window panes." Presumably somewhat like the illustration; right.

Figure 3.19: Display window in Bristol City Museum
© Bristol Museums & Art Gallery (Discontinuities in colour are due to reflections, or background.)

This illustration is included as an example of the sort of window that might have been constructed from the ornamental glass manufactured at Nailsea during the later years. As far as can be seen the patterns employed have not come from the extant pattern sheet – see Figure 3.20 below.

John M Eyres, a boy clerk in the glassworks in the 1860s, in a letter to H St George Gray dated July 1911, mentioned that after the end of 1862, " ... it was several years before the Old House was again at work. When it resumed work, sheet glass only was made, until a little side furnace was built for one or two men to make fancy goods, such as propagators, cucumber glasses, rolling pins and glass shades."

43 Chance, J F, 1919, pps. 77-79

Figure 3.20: Pattern Sheet, date uncertain, courtesy NDLHS

A bill from 1846 is reproduced in Appendix 11.

From a further sale notice relating to Bowen's bankruptcy comes the following:

"The whole of the very extensive STOCK-IN-TRADE

Comprising cathedral, ornamental, obscure, fluted, enamelled, and stained glass; several thousand feet of rolled plate and sheet window glass of various quantities and thickness; glass tiles, patent undulated glass, also about 1,000 deal planks and other timber, hoop and bar iron, 9½ ingots of block tin, copper sheet, nails, shovels, about 20 tons cullett [*sic*], white lead, sulphate of copper and iron, broomheads etc."[44]

Exactly what 'Cathedral glass' is has not been established, unless it was plain coloured sheet. Eyres, in his letter to St George Gray, referring to one James Kelley, ponders, "If that is the Kelley who was there in my time he was an Irishman who came to mix metal for the coloured glass which Mr Bowen tried his hand at making ..." In a much quoted passage, "He was a clever mixer ... and would be very proud of getting you to hold pieces of his handiwork up to the light, when he would shew you what a 'foine Catheadral tint' it was." It is interesting to note from the English Heritage Report (Appendix 7) that there was uncertainty, because of the thinness of the colour whether the red glass fragment found was 'flashed' or painted. For 'painted' we might read 'stained' from the above list. The term 'flashing ' has already been used to describe the opening out of the crown to form a table of Crown glass, but it is also used to describe the process of taking an initial gather of coloured glass, then surrounding it with a larger gather of plain glass. Then, when it was blown and spun in to a crown table, or blown out in to a cylinder, the colour would be very thinly spread over the surface of the clear glass. As some of the coloured glasses were very dense in colour, to the extent of almost seeming opaque when in bulk, in some cases, this technique had two advantages. The first was that the coloured glass need not necessarily be prepared in large quantities. The second was that patterns such as those shown in the pattern sheet above could be created quite simply by cutting, or etching, away the very thin layer of colour from the clear glass substrate.

Figure 3.21: 'Undulating-interlocking' glass window pane

© Bristol Museums & Art Gallery. 'Probably from Nailsea'. Presented by Mrs B A Challicom, 1939

[44] Bristol Times and Mirror, 7th August 1869, p.1, col.6. From transcript in SMR 2397,Folder E

The 'patent undulated glass' mentioned above is presumably the same as that mentioned by Eyres in his letter to St George Gray as having been introduced by Kelly on the 'undulating-interlocking' principle. This may best be described as slightly ridged rolled plate, like a fine corduroy material, that is then formed so that there are two sets of corrugations running at right angles. The overall impression is of a series of pyramids (that have each been truncated by rounding off their tops), separated on each side from its neighbour by a slight round-bottomed valley.

No illustration has been found of any Nailsea production bottles, but it is believed that they would generally have been dark green in colour. The form would have been very similar to say a modern sherry bottle, but because of the hand-made element, coupled with transport conditions less sympathetic to glass bottles than today, it probably would have been considerably heavier than a modern bottle. According to Chance, J F, p.18, bottle manufacturers were forbidden by the Excise to make any bottle of less than six ounces capacity. It has been suggested that bottle production at Nailsea probably ceased "by the 1830s."[45] Coathupe does not mention it in his notebook, and it is entirely possible that if Lucas had a good thing going with his window glass production, he would concentrate on that as he no longer had a direct need to produce bottles for his own business. Furthermore, one could pack a greater weight of window glass in to a given space than if the same weight of glass was in the form of bottles, so shipping costs would have been considerably greater for bottles.

This leaves us with the thorny question of 'Nailsea Glass'. A lot has been written about this material, some of which is very colourful and exuberant, and it is quite clear that it goes well beyond the utilitarian window and bottle materials that are fairly well recorded as the staples of the works for the majority of its lifetime.

Figure 3.22: Early 'Nailsea Glass'
© Bristol Museums & Art Gallery
From left to right: Front: A rather misshapen mug, c 1830; A hat, c 1830; A jar, c 1830; A sealed jug, c 1830
Rear: Large bottle with seal (bearing the initials JME & date 1833); Salt, c 1830; Decanter, c 1850; Flask (on its side), c 1840, from Mrs Challicom.

What is now on display at Bristol Museum and Art Gallery has been critically reviewed by the Museum staff, and while it will never now be possible to reverse the public perception and the collectors' desires it would appear that two illustrations sum up the style. Figure 3.22, above,

[45] Vincent, K, p.8

shows the earlier material, made from dark green bottle glass, with 'opal' white flecks marvered in to the gather at an early stage; Figure 3.23 shows later items in window glass.

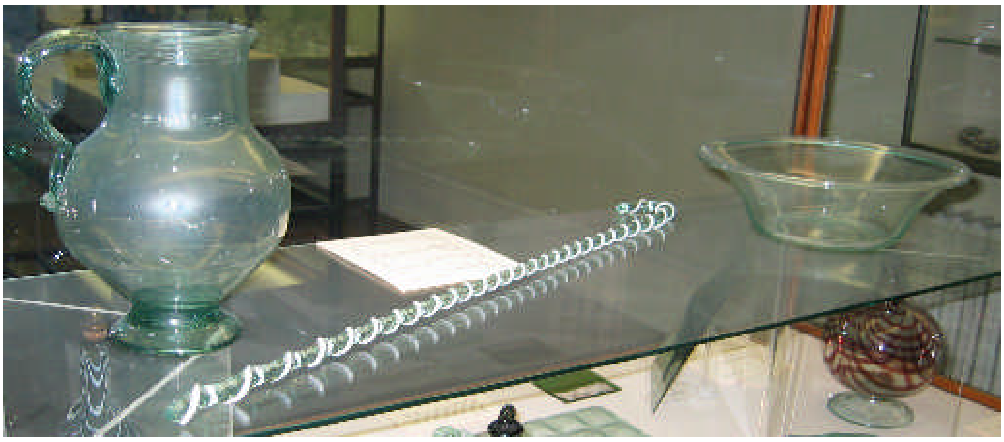


Figure 3.23: "Perhaps Nailsea" – 'Nailsea Glass': later styles
© Bristol Museums & Art Gallery From left to right: Jug, 1st half of 19th cent.,, from Mrs B Challicom, a noted collector; Walking stick, c 1860 (These were traditionally hung in the house, as it was believed that they attracted germs. By cleaning them down daily, disease would be prevented. It was apparently bad luck to break one.); Bowl, 1st half of 19th cent., used in dairies for separating cream.

The items in Figures 3.24, and 3.25 are basically all formed from window glass, with some additional decoration.

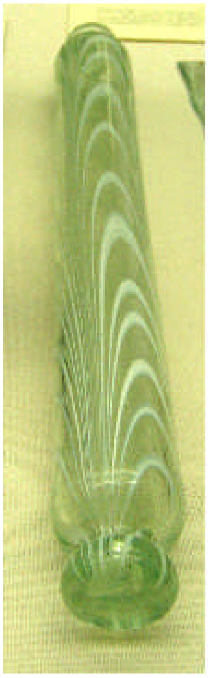


Figure 3.24: Left: Rolling pin; Right: Bottle
© Bristol Museums & Art Gallery

The rolling pin is much more decorative than that in Figure 3.25. It is "Perhaps Nailsea", c 1860, with the comment that 'the majority are purely decorative'.

The bottle is rather interesting. The accompanying description states that, "An old label records that this bottle was given by Mr Stonier, Manager of Chances' Nailsea Works, to George Masters who later gave it to Sir Edmund Elton. The ruby glass may be the same as that used for flashing window glass. The chemical composition indicates a Stourbridge origin."

[J F Chance mentions, "W Stonier, of the ledger department at Spon Lane, was deputed to take charge of the office" [at Nailsea in 1870].[46] We have seen above that coloured glass from Stourbridge was being employed at Nailsea under Bowen.]

Keith Vincent, who has written an extensive and well illustrated volume on *Nailsea Glass,* concludes that much of what has become 'Nailsea Glass' was never made at Nailsea. H St George Gray, whose articles in *The Connoisseur* may have originally helped fuel the idea, and Sir Hugh Chance, who was investigating his family's involvement at Nailsea, concur with this

[46] Chance, J F, p.106

view. Ashurst goes even further, pointing out that, "the Nailsea works, near Bristol, after which this style is named, did not come in to production until 1788 and originally only made common bottles. The Bolsterstone works was producing this form of decorative glass before it closed about 1758 ..."

Figure 3.25: 'Nailsea Glass' from the Scotch Horn Centre, Nailsea

Composite:

Top: Cucumber glass: makes the fruit grow straight

Bottom: Rolling pin in plain glass, Two knitting needles; two fragments of spiralled walking stick; Drumstick, with double blue spiral threads running down handle (R); Cullet

There is a further collection held in the Museum at Taunton Castle, that has not been seen by the writer. It derives from the collection of Mrs B A Challicom, a noted collector.

There is also a good collection at Clevedon Court, now in the care of the National Trust, and some examples are shown below, courtesy of the National Trust. In general, there does not appear to be any specific provenance displayed with any of the pieces, although this may be available. It was not deemed necessary to pursue this as part of this study.

Figure 3.26: Display of more formal clear and coloured 'Nailsea Glass' at Clevedon Court

Figure 3.26 shows a selection of the more decorative 'Nailsea Glass', both plain and coloured. It includes examples of the double (or gimmel) flasks, and other items with 'witch balls' at the top.

Figure 3.27: Vase and mug in dark green glass

The examples in Figure 3.27 are very primitive and roughly made. That on the left is described by Vincent as, "24 Jar or vase of dark green metal flecked with white enamel, some of the flecks having pale pink centres." (p.39.) On p.37 he describes the mug on the right-hand side as, "mug in dark blackish-green metal with large chips of white enamel marvered in (*height approx. 5 in.*) ... The metal ... has a distinct soft soapy appearance and feel, something like serpentine." If anything had the appearance of 'friggers' or 'end-of-day-glass' (or 'off-hand-glass' in the USA) (Newman, p.126), made by unskilled hands it is these two pieces. It seems that some works encouraged the blowers and/or apprentices to try their hands to improve their skills with the metal left in the pots, if it was not sufficient to make a production piece. Newman, p.125-126, defines them as, "A glass object, of various forms, made by a glassmaker in his own time and for his amusement and home decoration or for sale by him. They were usually made from the molten glass remaining in the POT at the end of the day, considered as the workman's perquisite. In some regions, they were made on Saturdays when the glasshouse was not working, and on Sunday each factory group paraded with its accomplishments (e.g. from Stourbridge to Wolverhampton), stopping at each public house en route to have the pieces voted on, and the most popular received a prize and the assurance of factory production ..."

Perquisite or not, Ashurst, p.113, reproduces a copy of a notice posted at Rotherham Glass Works 1st March 1871, which states, "

NOTICE.

Workmen are strictly prohibited using the Metal for any other purpose than making their Work.

Anyone found making, or carrying off the Premises, Glass Walking Sticks, or other Fancy Articles, Bottles, &c., without having first obtained permission, will be punished."

Incidentally, there appears to be two erroneous statements made by Sir Hugh Chance in the letter from him to H St George Gray, dated 21st October 1958, when he writes, "I still hold the view that the opal speckled bottles and the like were made at the Nicholas Street works or at Wick, in which Lucas and his partners had an interest." Also, in his January 1958 article he states that, "John Robert Lucas ... had a financial interest in bottle works in Bristol and Wick, some miles east of the City." Later in the same article he refers to the firm's warehouse in Nicholas Street. Matthews' plan of 1815 while showing a number of glassworks in and around the city does not place one in Nicholas Street. The question of Nicholas Street vs. St Nicholas Street has been addressed in the main Introduction to the study. H St George Gray, 1923, also suggests that Lucas had a glass house "probably at Wick," as well as at Stanton Drew. The writer is indebted to David Evans, SMR Officer for S. Gloucestershire Council, for the information that there is no known glassworks at Wick, S.Gloucestershire. From the Bath & North East Somerset SMR BN2247 it is clear that Stanton Wick is indeed the works in question, sitting within the parish of Stanton Drew, some miles south of Bristol. [It was difficult to know where to place this digression, but is was felt that the points should be clarified.]

Latterly, on the evidence of Eyres, some 'fancy goods' were made, but primarily in window glass it would seem. It has been stated that the works even exhibited glass window poles at the Great Exhibition, but window glass appears to have been developed as the primary business, once bottles had been given up.

This part of the study has not been intended as an in-depth study of 19th century glassmaking technology, so further reading is recommended. No particular recommendations can be made, because much depends on where the reader's particular interest lies.

BIBLIOGRAPHY

Adkins, L and R, 1998: *The Handbook of British Archaeology*, Constable, London

Allen, D, 1998: *Roman Glass in Britain*, Shire Archaeology, Shire Publications, Princes Risborough

Angus-Butterworth, L M, 1948: *The Manufacture of Glass*, Pitman, Bath

Ashurst, D, Undated: *The History of South Yorkshire Glass,* J R Collis Publications, Sheffield

Barker, T C, 1977: *The Glassmakers – Pilkington: 1826 – 1976*, Weidenfeld & Nicholson, London

Berg, T and P [eds.] 2001: *R.R.. Angerstein's Illustrated Travel Diary 1753-5*, London: Science Museum

Buchanan, A and Cossons, N, 1969: *The Industrial Archaeology of The Bristol Region*, David & Charles, Newton Abbot

Burgoyne, I and Scoble, R, 1989: *Two Thousand Years of Flat Glass Making,* Chalon Press Ltd, St Helens

Chance, Sir H, January 1958: The Nailsea Glass Works, *Pottery Gazette and Glass Trade Review*, pps 111 et seq.

Chance, Sir H, July 1968: *The Nailsea glassworks,* Paper read to the 8th International Congress on Glass – Studies in Glass History and Design, London, [By courtesy of the Society of Glass Technologists]

Chance, J F, 1919: *A History of the Firm of CHANCE BROTHERS & CO. Glass and Alkali Manufacturers*, Printed for private circulation, Spottiswood, Ballantyne & Co, London

Collinson, Rev. J, 1791: *The History and Antiquities of the County of Somerset*, Reduced facsimile edition, Sutton, Gloucester, 1983

Crossley, D W, 1967: 'Glassmaking in Bagot's Park, Staffordshire, in the Sixteenth Century', *Post Medieval Archaeology*, 1, pps. 44-83

Dodsworth, R, 1982:*Glass and Glassmaking*, Shire Publications Ltd., Princes Risborough

Dommett, H E, 1985: *Nailsea and the Glass-works*, Bristol Industrial Archaeological Society Journal 18

Dommett, H E, 1986: *Nailsea and the Glassworks Part 2*, Bristol Industrial Archaeological Society Journal 19

Dommett, H E, 1987: *Nailsea and the Glassworks Part 3*, Bristol Industrial Archaeological Society Journal 20

Frank, S, 1982: *Glass and Archaeology*, Academic Press, London

Frisbie, M J, 3rd January, 1868: *Letters Patent Nº 27..."Improvements in Mechanism or Apparatus for Feeding Fuel into Furnaces, Fire-boxes, and Fire-grates"*, Eyre and Spottiswood, London (Copy courtesy Science Museum Library)

Gilberton, D D, and Hawkins, A B, 1979: Nailsea Glass: Local sources of sand for the manufacture of. *Somerset & Dorset Notes & Queries*, Vol. 30, Ch. 47, pps. 101-104

Harden, D B, 'Ancient Glass': Reprint from *The Archaeological Journal*, Volumes 125 – 1968, 126 – 1969, and 128 – 1971: Royal Archaeological Institute, London

Hatton, G, 2004: *Scientific Examination of Glass and Glass Working Materials from Nailsea, Avon, Centre for Archaeology Report 16/2004*, English Heritage, Portsmouth

Hicks, J, 1982: *Comprehensive Chemistry*, Macmillan, London

Jones, B and Mattingly, D, 2002: *An Atlas of Roman Britain*, Oxbow Books, Oxford

Krupa, M and Heawood, R, 2002: *'The Hotties' – Excavation and building Survey at Pilkingtons' No 9 Tank House, St Helens, Merseyside*, Lancaster Imprints, Lancaster

Lafferty, P and Rowe, J (Eds.), 1994: *The Hutchinson Dictionary of Science,* Helicon, Oxford

Newman, H, 1977: *An Illustrated Dictionary of Glass*, Thames and Hudson, London

Ordnance Survey, 4th Edition (Revised) 1994, *Roman Britain, Historical Map and Guide*, Ordnance Survey, Southampton

Parkin, R A, 2000: *The Window Glass Makers of St Helens*, Society of Glass Technology, Sheffield

Rivet, A L F and Smith, C, 1981: *The place-names of Roman Britain*, Book Club Associates, London

St George Gray , H: "Notes on the Nailsea Glass Works", *The Connoisseur,* March 1923

Scientific American, December 2, 1876: Improved Furnace Feeder, (Frisbie), p358

Seddon, Col. H C, 1889, *Builders' Work and the Building Trades*, Rivingtons, London

Sykes, J B (Ed.), 1989: *The Concise Oxford Dictionary of Current English,* Oxford University Press

The Reader's Digest, (Ed. Davison, M W,) 1981: *Field guide to the Wild Flowers of Britain*, The Reader's Digest Association, London

Thomas, M, 1987: *The Nailsea Glassworks,* Thomas, H G and Thomas, M A, Bristol

Vose, R Hurst, 1980: *Glass*, Collins Archaeology 4, Eds. Lavell, C and Wood, E, Collins, London

Vincent, K, 1975: *Nailsea Glass*, David & Charles, Newton Abbot

Weeden, C, 1984: 'Bristol glassmakers: Their role in an emergent industry', *Bristol Industrial Archaeological Society Journal, 17, pps 15 -29*

Somerset Record Office

D/B/bW 2349: J Chubb papers – contains bill for glass bottles with glass-blowers vignette from Powells of Bristol, (27th October 1846) and another for window glass from Coathupes &Co. Manufacturers of Crown window glass & alcalis, [*sic*], (Bristol, 20th Feb. 1846) with vignette of Nailsea works, both to John Bowen of Bridgwater.

A/BHQ/1 (2 parts): Various relevant Chance papers, correspondence etc.

T/PH/isr 1-3: Hartley family history notes

Nailsea Local Studies Library

Copies of various items of correspondence from Box File: 'Nailsea Glassworks (photocopies of Chance collection)'

APPENDIX 1 - C T Coathupe's notes 1836-7

As an introduction, some of the units may need some explanation to modern readers, and to save confusion an attempt will be made to translate these simply.

Measures of length

12 inches (ins.)	= 1 foot (ft.)	One foot is equivalent to 30.48 cms.
3 ft.	= 1 yard (yd.)	
22 yds.	= 1 chain (ch.)	

N.B. When he refers to "feet" on pages 90 and 104 – 109 it is not certain what his unit really represents. It is thought that it may be square feet, but alternatively it could be linear feet of glass at a standard width, which has not been given or determined. As the thickness is a variable that is not given, attempts to check mathematically have been frustrated.

Measures of area

144 square inches (sq. ins.)	= 1 square foot (sq. ft. or ft^2.)	
9 sq. ft.	= 1 sq. yard	One square yard is equivalent to 0.84 sq. m.
4840 sq. yds.	= 1 acre	One acre is equivalent to 0.40 hectares.

Measures of volume

20 fluid ounces (fl. oz.)	= 1 pint (pt.)	One pint is equivalent to 0.568 litre
8 pints	= 1 (Imperial) gallon (gal.)	
8 gallons	= 1 bushel	
8 bushels	= 1 quarter	

Measures of weight

16 ounces (ozs.)	= 1 pound (lb.)	One pound is equivalent to 454 grams
28 lb.	= 1 quarter (qr.)	
4 qrs.	= 1 hundredweight (cwt.)	
20 cwt.	= 1 ton	One ton is equivalent to 1016.96 kilograms.

Currency

Coathupe expressed this in Pounds, shillings and pence (£..s..d)
The smallest denomination was a farthing, four to the penny, or $\frac{1}{4}$d.

2 farthings	= 1 halfpenny {'hape-nee'} or $\frac{1}{2}$d.
2 halfpennies	= 1 penny (d.)
12 pence (d.)	= 1 shilling (s.)
20 s(hillings)	= 1 pound (£)

Shillings and pence may also be shown separated by / (forward slash). For example five shillings would be 5/-, while two shillings and sixpence would be 2/6. He also occasionally uses this notation for weight. Look at the context, therefore. No attempt has been made to relate 1836/7 values to those of the present day, but the equivalent of 5/- post decimalization is 25p.

[Notes, etc., in the following transcript by the present writer are in red. Very few minor editorial liberties (not so highlighted) have been taken, only where it was thought that they would not alter the 'feel' of the document. However, most significant has been the change from the first transcription of the first 's' in 'ss' from 'f', representing the cursive 's' originally used. E.g. 'glass' had been originally written and transcribed as 'glafs' and 'potass' as 'potafs'. It was felt that to retain this was intrusive, as CTC thought and meant "glass" when he was writing. Inconsistencies by C.T.C. have not necessarily been corrected]

The Notebook

Nailsea Alkali Wks.

1836

£3,500

"Tophaceus" [Anagram for "Coathupe"]

1

Vitriol Chamber

Dimensions

Back:	74 feet.
Front	64 feet.
	2 ⁄ 138
Average	69 ft. x 24 ft. wide.

& 12 feet high.

Capacity, 19872 cubc. feet.

∴ The contents will be

69 x 24 x 144 = 238464

cubic inches, or $\frac{238464}{277.2738}$

= 860 Imperial gallons.

for each inch in depth.

2

The ordinary density of the Acid in the Chamber is 1.30.

		Impl. Gals.	ttr.*	
∴ $\frac{1}{16}$	inch =	53.75	= 280	Oil of Vit:
$\frac{1}{8}$	do.	107.5	$561\frac{5}{8}$	do
$\frac{1}{4}$	do.	215	$1121\frac{1}{4}$	do
$\frac{1}{2}$	do.	430	$2242\frac{1}{2}$	do
$\frac{3}{4}$	do.	645	$3363\frac{3}{4}$	do
1	do.	860	4485	do
2	do.	1720	8970	do
3	do.	2580	13455	do
4	do.	3440	17940	do
5	do.	4300	22425	do
6	do.	5160	26910	do
7	do.	6020	31395	do.

Ap. 1836.

[* What this is has not been determined.]

3

Vitriol Chamber

$\frac{1}{16}$	inch	=	$8\frac{5}{8}$	Cubc. feet
$\frac{1}{8}$	do	=	$17\frac{1}{4}$	do.
$\frac{1}{4}$	do	=	$34\frac{1}{2}$	do
$\frac{1}{2}$	do	=	69	do
$\frac{3}{4}$	do	=	$103\frac{1}{2}$	do
1	do	=	138	do
2	do	=	276	do
3	do	=	414	do
4	do	=	552	do
5	do	=	690	do
6	do	=	828	do

N.B. To the guage [*sic*] in the Guage Pan, add $83\frac{1}{2}$ cubc. ft. or to guage in whole, subtract $37\frac{1}{4}$ cubc. ft. [The function of the Gauge Pan has not been determined.]

4

Wages paid for Vit^{l}. Cham^{br}

Pemberton,	£0..18..9
Baldwell,	0..10..0
l/3rd Gainer,	0..10..0
Per. week.	£1..18..9
2692 lbs. Sulpr.	£8. 8..3
154 lbs. Nitre.	2.. 4..$4\frac{1}{2}$
Wear of Chambr.	1.. 5..0
Exps. fr. week	£13..16..4

Produce, @ £3..14..3 per ton.

{ 7882 lbs. Ol. Vit^{l}. - £13..1..4
{ 140 lbs. Sulpte. Potass. 15/-

5

No. 2 pan

Each inch of Acid @ 1.600 from No. 2 Pan is equivalent to 419 lbs. of Oil of Vit^{l}.

C.T.C. July 1837

6

Decanting Pan.

Each inch of Acid @ 1.600, from the decanting Pan, is equivalent to 48 lbs. of Ol. Vit^{l}. (July 1837).

7

Dft. Pipe.
Each inch of the Dft. Pipe
Contains $6\frac{1}{4}$ cubic feet.

8

Sulphur 16 - Sulp^{c}. Acid 49
Produce &c.

Average { $384\frac{1}{2}$ lbs. Sulph^{r}.
22 lbs. Nitre.

Per day, consumed.
<u>Produce</u>, 1126 lbs. Ol. Vit^{l}.
Per day: or very nearly
2 lbs. 15 oz. Ol. Vit^{l}. from
each lb. of Sulp^{r}. consumed.
C.T.C. July 1837
<u>Sulphate of Potass</u> about 20 lbs. per day.

9

Chloride Sodium 60
Salt Cake Furnace
Sulph^{te}. Soda. 72.
4 cwt. Fine Salt, decomposed
with $8\frac{1}{4}$ inches of
acid at 1.600, from the
decanting Pan (= 396 lbs.
Oil of Vit^{l}.), yields 4..2..14. [cwt..qr..lbs.] to
* <u>4..2..21 of</u> good Sulphate
of Soda. C.T.C. .July.37.
* Atomically, we should
cwt..qrs..lbs
get 4..3..5 of Sulpte. Soda.

10

3 Batches are produced
in 12 hours = 14 cwt.
<u>Wages</u> 1/- per Batch.
<u>Coal consumed,</u> 15 Quarters
per week, when working
by day only; and 21 Qrs.
per week, when working
night, and day.
Excess of Vit^{l}. made, when
working only by day, is
754 lbs. per week.

(Turn over)

11

Sulphate of Soda [S.S]
(Working by day)

	cwt. [qrs.] lbs.
18 Batches =	83.. 1.. 0.
72 cwt. Salt @ 30/6*	£ 5.. 9..$9\frac{1}{2}$
7128 lbs. Ol. Vit^{l}. @ 75/-*	11.18..8
Wages,	18..0
Coal, 15 Quart^{rs}.	1.. 0..0
Hauling do	1..8
	£19.. 8..1

Vide p.17
£4..13..$2\frac{1}{2}$ per Ton.
Difference 1/6 per ton.

[* cost per ton.]

12

Sulphate of Soda
(Working day and night)

	cwt.qrs.lbs.
36 Batches. =	168.. 3.. 0
144 cwt. Salt. @ 30/6	£10..19.. 7
14256 lbs. Ol. Vit^{l}. @ 75/-	23..17.. 4
Wages,	1..16.. 0
Coal, 21 Quarters, @ 1/4	1.. 8.. 0
Hauling do.	0.. 2.. 4
	£38.. 3.. 3

Vide p.17
£4..10..6. per ton
C.T.C. July, 1837
@ £4..10..0 per ton, Sept. 1837.

13

All the Excess of Vitriol
made, is only 754 lbs.
per week more than is used. when making
S.S. by day only, we could
not afford to work the
S.S. furnace by night
and by day for more than
one week in about 2 mo^{s}. [months]
without reducing the
proper stock of acid in
the Chamber.

14

Black Ash Mixt^{re}.

S.S.	192	} Jan^{y}. 1837
Hyd. Lime	140	
Coal.	100	

Wages paid. -

Pan men,	0..16..4 per week
Yardsmen,	0..14..0 (7 days)
Mixing men	0..10..0 per week
Blk. Ash. (57 balls)	18..0 .
Sulph^{te}. Soda. (18 Batches).	18..0
Finishing, 3d per cwt.	

15

Annual consumption of
Sulphur. (one Burner) 62 tons.
Nitre, --— do. 68 cwt.
Salt.... {One furnace working by day.} 187 tons.
Vitriol $165\frac{1}{2}$ tons.
S.S. {double work. 4800 tabs. per week} $204\frac{1}{2}$ tons.

Sulp[r]. Burnt : Vit[l]. made :: 19:56
Nitre used, : Vit[l]., made :: 1:56
Salt used, : S.S. made :: 32:37
Vit[l]. used, : S.S. made :: 1:1.31
Average of salt used : S.S. made, :: 32:37
Hence 187 tons Salt = 217 S.S.

16

Solution of S.S. saturate
boils @ 216° to 218° Fah[t].
Density, 1.255
Imp[l]. Gal. conts. 3.68 lbs. S.S.
C.T.C.

Solution of C.S. saturated
boils at 222°, to 226° F.
density 1.255 to 1.290
(varying according to its
purity) C.T.C
Imp[l]. Gal[n]. cont[s]. 4 lbs. C.S.

17 (Vide p.22)
Estimated.......
Cost of Vitriol and of.....

Sulphur @ 120/- per ton
Nitre @ 560/- per do.
Wear and tear of Chambr. @
10 per cent per an. on £1200
Produce, 2.928 lbs. Ol. Vit. per
1 lb. Sulph[r]. consumed.
Consumption, 2677 lbs. Sulp[r].
and 147 lbs. Nitre. per week.
Wages 38/9 per week
Coal, $4/4\frac{1}{2}$ per do
Total cost = 72/3 per Ton Vit[l].

18

from Six Months.
Sulphate of Soda (Oct. 1837)
Salt @ 28/- per ton = $24/2\frac{1}{4}$ per T. S.S.
Cwt qrs lbs
Produce 4.. 2..14 per cwt. Salt.
Consumption, 72 cwt. Salt.
per week, and 7128 lbs. Ol. Vit[l].
Wages 18/- per week } $4/3\frac{3}{4}$ per Ton
Coal. 17/6 per week } 4/3 per Ton.
"Wear and Tear" of Tools &c. 2/- per T.
Total cost <u>£4..10..</u> per ton.

Cost in Vit[l]. £2.15.3. per ton.

19

Atomic Equivalents.

Carbon	6	
Chlorine	36	Oxalic Acid
Sulphur	16	Silica
Lime	28	Iron
Carb[te]. Lime.	50	Acetic Acid
Soda	32	Sulp[ous]. Acid
Carb[te]. do.	54	Nit[c]. Acid
do Crystals.	153	
Sulph[te]. Soda	72	Nit[c]. Acid @ 1.50
do Crystals.	162	
Chloride of sodium	60.	

20

Potassa	48	
Sulp[c]. Acid.	40	Potassium
do. @ 1.845.	49	
Sulph[te]. Ba[*or* 'u']rita		118
Sulph[te]. Lead	152	
Oxalate of Lime.	64	
Silver	110	

[C.T.C. seems to be mixing 'Atomic Weights' and 'Atomic Numbers', and figures are not all in line with current usage, as defined in Hicks, 1982.]

21

Atomically.

1 Sulp[r]. = 2 Soda = $4\frac{1}{2}$ S. Soda
1 Soda = $1\frac{1}{2}$ Potassa. = $2\frac{1}{4}$ S. Soda
1 Carb[te]. Soda, = $1\frac{1}{3}$ S. Soda.
100 Sulp[r]. = 307 Sulp[c]. Ac[d]. @ 1.843
375 dry Chloride of Sodium,
450 dry Sulp[te]. of Soda.
200 pure Soda,
300 pure Potassa,
336 pure Carb[te]. of Soda ($337\frac{1}{2}$)
$956\frac{1}{4}$ crystals of do.
1013 crystals of S. Soda ($1012\frac{1}{2}$)

22

Practical Constants.
*760 lbs. Sulp[r]. } = 1 Ton Vitriol.
42 lbs. Nitre. }
Wages, 11/-; Coal, 1/3;
<u>Interest on Capital, &c. 13/1</u>
1 Ton S.S. =
581 lbs. Sulpr. } =1712 lbs. Vitriol
31 lbs. Nitre }
17.29 cwt. Salt.
Wages, $4/3\frac{3}{4}$; Coal, 4/3;
<u>Interest and Wear and Tear = 2/-.</u>
* Cr. By Sulph[te]. Potass. 37.8 lbs.
per Ton Vit[l]. made.

23

Specific Gravities.

Sp. Gr.	I. of W. Sand	2.644	(64°)
do	S. S. Glass,	2.532	
do	Rock crystal	2.6536	(60°)
do	do (perfect)	2.6577	(64°)

24

Glass House Mem[da].

S.S. Standard Mixture.

Sand.	16 [qrs =]	448 [lbs]
dry. S.S.	6	*168
Hyd. Lime.	5	140
Cullet	12	336
Charcoal lbs. to every 14 lbs. S.S.		12
Arsenic		2
Sp. gr. 2.53 .Mang[se].		1

* Or 46 gal[s]. S.S. Solution (Vide p.16)

25

Carb[te]. Glass mixture.

Sand,	I. of W.	448
Dry S.S.		42
Dry Chalk		126
Alkaline Liqr.		28 gals. = 11 lbs. Alkali

Cullet. 336
& Coloring, composed of
Sand, Manganese, &c.

26

The actual produce of Glass
from this mixt[re].
(deducting the wt. of cullet
used) was 48 cwt. 2 qrs. 24 lbs.
from Sand, 37.. 3.. 0 }
Chalk,. 10.. 1.. 12 } 48..0..12 of
sand and chalk used; or
about the amount of these two
ingredients, when employed
perfectly dry. (C.T.C.)

27

Sand.

Isle of Wight Sand at
Nailsea, 28/ per ton.
Dried and fit for use, 30/ per ton.
Loss in drying, barely 5 per cent.

Easton Sand, at Nailsea
16/6 per ton.
Dried, and fit for use, 18/ per ton
Sp. gr. @ 64° 2.644

Carb[te]. of Lime in I. of W.
Sand, not 0.5 per cent. C.T.C

28

Lime.

Price 3d. per Bushel (Quick)
or $4\frac{1}{4}$ d per cwt. when prep[d].
as Hydrate.
A Bushel of Good Quick
Lime, fresh from the Kiln
weighs 77 lbs. C.T.C.

Hydrate of Lime, as used
for Glass Making, contains
from 30 to 40 per cent of water
(Say 35 per cent).

(Turn over)

29

Lime, contd.

The extreme limit for the use
of Lime in Glass mixture,
is 36 lbs. of Hydrate (Ham's)
to 112 lbs. Sand. (C.T.C.)

In using dried Chalk
for Hydrate of Lime (Ham's)
we take 7 Chalk, for 8
Hydrate.
(C.T.C.)

30

Analysis of' Lime.

[No entries]

31

[No entry]

32

Charcoal

	cwt.	qr.	lbs.
6/6 per Bag, wt	1..	0..	14.

Value, when ground, 6/10 per cwt.
Limits for S.S. mixture
1 lb. to 14 lbs. S.S.; and
for Carbonate mixture,
there should not be any.

33

Coal

Price of Brush Coal, 2/8
per quarter, of 8 Bushels.
do of Small Coal. 1/4 per do.
Hauling from the Pit }
1/- for 9 Quarters. }

A Bushel of Brush Coal
weighs 82 lbs.
do. of Small Coal, 84 lbs.

34

Coal used for founding our
S.S. metal, 62 Quarters
Value, ~~£4.. 1..4~~ + 1/4
Hauling do. ~~6..9~~
~~£4.. 8..1~~ + 1/5 (£4..9..7)

Coal used for Working
12 Quarters of Brush.
Value, £1..12.. 0
Hauling do. 1..4
£1..13.. 4
Working double, for 6 hours
or, about 5/6 per hour. C.T.C.

35

Coal used for annealing
a New Furnace,
about 45 to 48 Quarters of Small
and 25 do of Brush.
Value £XXXXXXX
[Heavily deleted items follow.]

36

Coal used for annealing
6 Pots, Feb. 12th to 19th

24 Quarters Small	£1..12..0
6 do Brush	0..16..0
Hauling from pit.	0.. 3..6
	£2..11..6

Wages to Founders,	1..0..0
Drinking allowances to the workmen	1..1..0

37

Coal used at Alkali W[ks].
Pans and Calcars (double work)
26 Quarters of small per week

Salt Cake Furnace, and Boiler
15 Quarters small, per week
(working single)

*Crazling Cullet, per week,
$3\frac{2}{3}$ rds Quarter small
(for one Glass House)

Coal used for Chamb[r]. Boiler
alone, 3 Quarters per week.
Averaged from 6 weeks.
July. 1837 C.T.C.

[*Alternatively, 'Cr..' might possibly be 'Br..' or 'br..']

38

Coal allowances

8 loads of Brush coal per an.
to 3 Managers, 2 Flashers,
2 Pilers, 8 Blowers, 1 Spare
Blower, R[d]. & Tho[s]. Sims,
W[m]. & Sam[l]. Baldwell;
6 loads of Brush coal per an.
to 2 Carriers off, 3 assistants
2 Skimmers, 8 Gatherers;
5 Loads of Brush Coal per an.
to Edw[d]. Thomson, & 2 head
Founders. (Total 795 Quarters)

39

Coal &c.
The Glass Makers allowance
for Coal and House Rent.
amount to £4..15..4 per week.
or 11/11 per Journey.
This makes their Bare
Week's work amount to
£7..8..9 per Journey.
Overwork, is £5..10.. per do.

The Coal allowance to
the Founders is 50/ each,
per annum. (Perry & Culver)

40

Cullet &c.
Mixture allowance of
Cullet is 3/4ths of the
wt. of the sand used.

Cullet used for Topping
about 1 cwt. per pot.

Cullet used for Glazing
a New Pot, is about
$3\frac{3}{4}$ cwt. and for 12 inches
of Bottoms. $7\frac{1}{4}$ cwt.
(turn over)

[No entries : pages 41 to 49inclusive]

50

Cullet made in the shape
of Skimmings,
Moils & Pontys per found

	cwt. qrs. lbs.
Skimmings.	8.. 0.. 0
Moils	12.. 0..14
Pontys,	0.. 3..14
Breakage	1.. 1.. 6
	cwt 22 .. 1 .. 6

Wt. of moil, 1.845 lbs.
Wt. of a Ponty, 2.13 oz.
*Wt. Of Skim^{gs}. per pot 1.333 cwt.
(average of 736 Tab^{s}. made.)
*vide p.52.

51

Value of Cullet

Thin, picked and washed	5/- per cwt.
Ladlings & Skimmings	3/- per cwt.

Cullet produced from cutting up a good Crate of Glass into Export sizes, is 28 lbs. small sizes included.
Cullet produced from cutting up every description of Glass, i.e. "starved" Bad work &c. is 29 lbs. per crate (Small sizes not included).

52

Skimmings, since the adoption of Rings in the Pots, appear to coincide very generally with the average of 1 cwt. for every 100 Tab^{s}. of Glass made.

C.T.C.. Aug. 1837.

Total waste of Metal in the manufacturing = 3/6ths. of the Wt. of the Tables drawn --- Aug. 1837

C.T.C.

53

[No entry]

54

Founding

Patent S.S. mixture

Melt^{g}. Bottoms hours	2 to 3
Charging until the Pots are full	10 to 11 do
From Pots full 'til metal plain	7 to 8 do.
Melting Toppings.	2 to 3 do.
H.D. til Working.	7 to 9 do.
Total	28 to 33 hrs.

N.B. 30 hours is a very fair average. (Aug. 1837)

55

Patent Carbte. Mixture.

-------------2 hours

} $17\frac{1}{2}$ hours.

--------------3 hours
--------------$8\frac{3}{4}$ hours.
$31\frac{1}{4}$ hours.

(Novr. 1836)

(Coal used, 61, to $62\frac{1}{2}$ Quarters.)

C.T.C.

56

Furnaces.

Dimensions of a 6 Pot furnace.

Length of Sieges,	13 feet
Width of do.	4 ft. 3 in.
do. of Grate room.	3 ft.
Bearing Bars, to the top of the Sieges,	2 ft. $2\frac{3}{4}$ in.
Height of Square work from top of Siege,	3 ft 4 in.
Height of Pots from do.	3 ft. 1in.
Pitch of the Crown above the working holes	2 ft. $7\frac{3}{4}$ in.

57

Pitch of the Crown above the working holes, in the centre, or highest part, 2 ft. $11\frac{1}{8}$ in.
Diam. of the Teaze Holes 4 ft. $11\frac{1}{4}$ in.
Working Holes, 12 in. wide & $12\frac{5}{8}$ in. high (inside)
Foot holes, 15 in. wide and 23 in. high
Pnty. holes, 5 in. x 5 in.
Inclination of Restings, 3 in.
(Set Pots in 11 days, Furnace "turned" in 7 days).

58

Furnaces Contd.
From top of grate bars to top of sieges. 2 ft. $0\frac{1}{4}$ ins,
Dead Mug. 3 feet at bottom varying to 2 ft. 10 in.
N.B. The Height of the Crown of This Furnace above the working holes is 8 inches less than those we have used previously; and 4 inches less than the old standard height.

59

A Furnace may be very safely "turned" in 108 hours; and Pots may be set in 96 hours afterwards. (Total, $8\frac{1}{2}$ days). Feby. 1836.
The capacity of the grate room (allowing for the "dead mug") is 69 Cubc. Ft. or about $2\frac{1}{2}$ Cubc. yards.

60

Pots.

7 parts new clay }
1 do. old Potsherd }

Analysis of Pot Clay.

	100 grs.
Silex.	64.3
Alumina	27.6
Red Ox. Iron.	5.9
Lime.	3.3
	101.1

Wm. Herapath.

61

Dimensions when made

Inside top diameter		$52\frac{1}{2}$	inches
Outside do.	do.	56	do.
Inside bottom, do.		32	do.
Outside do.	do.	40	do.
Inside slant height		$37\frac{1}{4}$	do.
Outside do	do.	42	do.

If very carefully dried, they may be used in from 5, to 6 months.

C.T.C.

62

Pots contd.
Pots of the usual dimensions viz. 56 inches external diam. and 42 inches extl. slant height when new, become after they are annealed,
$52\frac{1}{4}$ in. extl. diam. at top, and 40 in. extl. slant height, and after one found,
$50\frac{1}{4}$ in. extl. diam. at top, and $38\frac{1}{4}$ in. extl. slant height,
$34\frac{1}{4}$ in. intl. -------- do.

C.T.C.

63

Pots, if carefully watched may be "turned" in the annealing Arch in 60 hours, and set in 36 hours afterwards.
They may be glazed from an adjacent pot, in $5\frac{1}{2}$ hours, and charged upon 12 inch Bottoms. C.T.C.

Six Pots may be set in a New Furnace in $1\frac{1}{2}$ hours and glazed in [*blank*] hours.

(turn over).

64

Pots continued.
A new Pot will require about $6\frac{3}{4}$ cwt. of thin Cullet for Glazing, &c.

Two Pots, No. 1 and No. 2. after $11\frac{1}{2}$ week's wear, measured when cold, as follows, viz.

No. 1.	$37\frac{1}{2}$ in.	extl.	slant.
	34 in.	intl.	do.
No. 2.	37 in.	extl.	slant.
	$33\frac{1}{2}$ in.	intl.	do.

65

A pot that has remained in the Furnace during 40 Founds, without having been once turned upon the Siege, measured at the Jowl, next to the fire $1\frac{3}{4}$ inches; but on the opposite side, $3\frac{1}{2}$ inches.

C.T.C.

66

Pots continued.
The average dimensions
of an average size Pot
after 4 or 5 Founds, may
be taken as follows.

Inside top diam[r].	$44\frac{3}{8}$ inches
do bottom Diam.	$30\frac{1}{4}$ in.
do 18 in. down do	$36\frac{1}{2}$ in.
do $20\frac{2}{3}$ in. down do.	35 in
Perpendicular depth	$33\frac{2}{3}$ in
From filling place to bottom.........	$32\frac{1}{2}$ in.

Oct. 1837

67

12 perpendicular inches of
Bottoms are found to contain
7 cwt. l. qrs. 0 lbs. Glass at
60° Fah.
$32\frac{1}{2}$ Inches (ring being in)
contains 23 cwt. 0 qrs. 0 lbs.
of Glass at 60° Faht., being
the usual quantity cont[d]
in a pot when about $1\frac{1}{4}$
inches out. (C.T.C.)
N.B. 13 slant inches
on Trial rod = 12 perpendicular.

68 **[Deleted entry]**

69 **[Deleted entry]**

70

Pots continued,

1st inch contd.		1.. 0.. 3. Glass.
3 following ins.		2.. 3..19
3	do.	2.. 3.. 1
3	do	2.. 2..11
3	do	2.. 1..21
3	do	2.. 1.. 3
3	do	2.. 0..13
3	do	1.. 3..23
3	do	1.. 3.. 5
3	do	1.. 2..15
3	do	1.. 1..25

71

3 bottom inches	1..1.. 7
+ $\frac{1}{2}$ inch. =	
Total	24..1..6

Oct[r]. 1837.
(Very nearly correct).

N.B. Pots of the usual
dimensions (without Clay
Rings in them) contain
25 cwt. of Glass.

Oct[r]. 1837.

72

Pots contd.
Total capacity of a
pot (as described p.66)
is 21.115 cub[c]. feet. (hot).
It will contain 25 cwt. of Glass
@ 60° Faht.

25 cwt. = 44800 oz.
and $\frac{44800}{21.115} = 2.1217$

N.B. 13 Cubic inches of
Hot Metal = 1 lb. Avoirdupoise. [*sic*]
C.T.C.

73

(Slant).			Cubc. Ins.
1st	3 inches from Top.		4475.7
2nd	do	do	4203.3
3rd	do	do	3941.8
4th	do	do	3687.8
5th	do	do	3442.
6th	do	do	3205.
1st	18th inches	do	22955.6
∴ the remainder =			13531.5
Total.			36487

being 1.2278 oz. per cubc. inch
∴ Sp. gr. at working
temperature must be 2.1217.
C.T.C.

[No entries pages 74 to 87 inclusive.]

88

Accurate results of careful investigations,
of the proportional products, &c. of the
patent S.S. mixture, described at p.24.

Total of Glass produced : Total of Mixture & Cullet used
as 1 : 1.18 = 0.847. r [r = reciprocal]
Total of Glass really made : Total of Mixture used.
as 1 : 1.31 = 0.763 r

89

Total of Glass really made : Total of Sand used,
as 1 : 0.78 = 1.28 r
Wt. of Metal wrought : Wt. of the Tables drawn.
as 1 : 0.648 = 1.54 r
Wt. of Cullet used : Wt. of Cullet ret^{d}. from Glass House.
as 1 : 0.854 (no Rings in the Pots)
$\therefore$ Wt. of Cullet used : Wt. of Cullet ret^{d}. from the Cutting Room,
as 1 : .0332, when we supply
not so much Cullet as we use. (turn over)

90

Total of Cullet used : Total of Mixture used
as 1 : 1.813
Total of Cullet used : Total of Glass extracted from the Pots,
as 1 : 2.38
Total of Cullet used : Total of Glass made from the mixture alone
as 1 : 1.38
Total of Cullet used : Total of Sand used,
as 1 : 1.08
Total of Cullet used : Wt. of Tables drawn,
as 1 : 1.528. Oct^{r}. 31. 1837

91

Total of Cullet used : Wt. of tables made exclusively from the Cullet itself
as 1 : 0.104.

N.B. These results were obtained in Oct^{r}. 1837, when the men were making double work.
i.e. 4800 tabls. per week, 1/11th. of which was cut up.

92

£2..12..0 per ton.
Patent S.S. Mixture.
Cost, Consumption & Produce
per week. 7 Founds, 4800 Tabs.
= $71\frac{1}{7}$ Batches.

Cwt. qr. lbs.		
284. .2..11	prepd. Sand @ 30/-	£21.. 6..11
106. .2..25	S.S.. @ 90/-------	24.. 0.. 4
88. .3..21	prepd. lime @ 7/1	1..11.. 6
7. .2..14	do Charc^{l}. @ 6/10	2..12..11
0. .2..17	do Mang^{se}. @ 9/11	0.. 5.. 7
1.. 2.. 0	do Arsen^{c}. @ 34/-	2..11.. 0
490.cwt.		£52.. 8.. 3
Interest on Buildgs.		.1.. 0...0
Mixers Wages and Coal -----		10.. 0.. 0

93

1 Ton mixture (exclusive
of Cullet) yields 15.810 cwt.
of Glass. = 15..3..7. (cwt. qrs. lbs.) =189 Tabs.
1 Ton of Glass thus Produced
costs (in materials mixed)
£3..5..10; or $3/3\frac{1}{2}$ per crate
(wheelers wages included)
N.B. The Cullet has been
omitted because it is reproduced.
The S.S. has been charged
at its cost price to us.
C.T.C. Oct^{r}. 26 1837

94

Patent S.S Mixture.

S.S. in Sol^{n}.	168
Dry I. of W. Sand	448
Hyd. lime.	140
Charcoal	12
	768 lbs.

When withdrawn from the
Calcar, this Batch
of Mixture weighs 775 lbs.
This is mixed, afterwards
with 336 lbs. Cullet, and
the Batch then weighs 1111 lbs.

95

Every 112 lbs. of Mixture
Prep^{d}. for the Found cont^{s}.

Cullet	33.87
Sand	45.16
S.S.	16.93
Hyd. lime.	14.11
Carb^{n}.	1.21
Extra moisture.	.72
	112.

C.T.C.
Oct. 1837.

96

Patent S.S. Mixture.
7 Founds required
$71\frac{1}{7}$ Batches, being
$10\frac{1}{6}$ Batches of Found.
The quantity of Sand
in these $71\frac{1}{7}$ Batches
was 284 cwt. 2 qrs. 11. lbs.
= 31875 lbs. and the
Quantity of Glass really made
(exclusive of the Cullet and
Toppings) was 341 cwt. 3 qrs. 17 lbs.
= 38265 lbs. ? (+)
∴ Glass : Sand used :: $1\frac{1}{5}$: 1 ?
C.T.C. Oct. 25 1837

97

Hence, as 7 founds are
just a week's work for
two furnaces (making from
4700 to 4800 Tabs.) we have
for a week's consumption

of Materials.	cwt. qrs. lbs.
Sand...........	284.. 2.. 11
S.S...............	106.. 2.. 25
Hyd. Lime..........	88.. 3.. 21
Cullet in Mixtre.	213.. 1.. 22 }
do for Topping....	64.. 2.. 6 }
Charcoal............	7.. 2..14
Mangse.............	0.. 2..17
Arsenic..............	1.. 2.. 0

98

Crates &c.
10 Doz. Poles will make
2 Doz. pair of Crates,
making every allowance for defective
poles. (I. Gwyn.

Cost of Crates, per Pair.	£
Wages per Pair	0..1..0
Poles, 10 @ 2/ per doz,	0..1..8
Strips, 4 ft. @ $1\frac{1}{2}$ d.	0..0..6
Nails 80 @	0..0..$3\frac{1}{2}$
	£0..3..$5\frac{1}{2}$

Aug.1837.

99

Boxes &c.
Newton's charge for boxes
is 1/- per 50 ft. box. below 12 x 10
1/5 per do above do
1/10 per 100 ft. do below do
2/6 per do above do

A Dilly takes 50 boxes
of 50 ft.; or 30 of 100 ft.

[No entries pages 100 to 101 inclusive.]

102

Sp. gr. of our S.S. Glass. 2.532. @ 60°
Sp. gr. of do workg. temp. 2.120
Sp. gr. of Clay rings, annle[d]. 2.100.
Sp. gr. of Isle of Wight Sand. 2.644.

The accurate produce of the S.S.
mixture (p.24) is just so much
Glass as amounts to the Wt. of
the dry sand used. and $+\frac{28}{100}$ ths.
N.B. the Cullet used has been deducted
from Wt. of Glass produced.

103

Glass.
Wt. of Glass per Crate.
Ap. 1836 to Ap. 1837.
Average of 20 crates per week
(making 1000 crates) as

follows, viz.		cwt.qrs.lbs.
200	Crates.	196..2..23
200	do	197..0.. 1
200	do	198..0..23
200	do	199..3..22
200	do	198..1..14
1000	crates	990..9..27
or		0..3..27 per crate.

104

Average wt. of 12 tables
of Glass is 112 lbs.
100 ft. of Glass weigh $61\frac{1}{2}$ lbs.
1 ft. of do = 0.615 lbs. or 9.84 ozs,
∴1 ft. conts. 6.715 cubc. inches.
112 lbs. of Glass (cut into
squares) = 182.113 ft.
112 lbs. of Glass = 1223 cubc. in.
∴1 Tab. = 101.96 Cubc. in.

105

Average produce of every cwt. of Glass
cut up, from Breakage, Small & Bad
Work, Starved & melted, & Glass of
Good size but bad quality; (taken from
the year 1836) is $135\frac{1}{2}$ feet;
& this number of feet, includes Quarries,
& sizes less than 6 x 4; and there
will remain, about 29 lbs.
of Cullet C.T.C.

106

The average number of feet of Export Glass only, produced from each cwt. of Glass cut up during the year 1836, was 130.9; of smaller panes, $4\frac{1}{2}$ feet and of cullet 29 lbs. (C.T.C.)

107

A crate of Glass (112 lbs.) of good work, and averaging 50 inch tables, will without any extraordinary care, produce $136\frac{1}{2}$ feet of the usual export sizes; and 28 lbs. of Glass in smaller panes, & Cullet will remain. (C.T.C.)

108

Experimental crates cut up with great care.
No. l. 50 in. tab. wt. 0..3..25.
Produce (cut 6 in. from Bullion)
141..4 feet Export squares
12 small squares. wt. $\frac{1}{2}$ lb.
& 21 lbs. of Cullet.

No. 2. 50. in. tab. wt. 0..3..$20\frac{1}{4}$
Produce, (cut as usual)
136..11..4. feet Export squares.
4..0..6. feet smaller do
Cullet, 20 lbs.

109

No. 3. $50\frac{1}{4}$ in. Tabs.

Produce. Quarries, 10s.	135..7	feet
Squares...... ..	3..6.	do
	139..1	feet.

No. 4. $50\frac{1}{2}$ in. Tabs. Produce.

Quarries, 10s.	135.. 1	feet
Squares, ...	...6..10	ft.
	141..11	ft.

110

Waste in the Glass house whilst manufacturing, is = 2/6ths of the wt. of the total amount taken from the pots.
Calculated Aug. 30th 1837.
Wt. of a Moil = 1.845 lbs.
Wt. of a Ponty = 2.13 oz.
Wt. of Skimmings, 1 cwt. per 100 tabs. made (Rings)
do.....do..... 144 lbs. per 100 tabs, when we did not use rings.

111

Tables of Glass.

48 inch. Tab. conts.	1809.5	sq. in.
49 in. do	1887.4	do
*50 in. do.	1963.5	do
51 in. do	2042.8	do
52 in. do	2123.7	do

1 foot conts. 6.715 cubc. inches
17 Tables contain about 1 cubc. ft.
*a well made table of glass should be 50 inches in diamr. and weigh $9\frac{1}{3}$ lbs. it then contains 101.915 cubc. ins.

112 **113**

	Duties &c	Debentures,
112 lbs.	£3..13..6	£4..18..0
136 feet	£2.7443	£3.6591
$136\frac{1}{2}$ ft.	2.7544	3.6725
$135\frac{1}{2}$ ft.	-	3.6456
100 ft.	2.0179	2.6905
28 lbs. Cullet.	0.9188	
29 lbs. Cullet.	0.9516	

114

Epitome of Wages.

Glass Makers per Journey £7.. 8..9 (vide P.39)
do do per Over journey. 5..10..0
Founders Crew per week £10.. 0..0
including allowance and Coal Wheeling. &c.
Cutters, Packers, &c. £12..10..0 to 13..10..
Halliers & Dilly men. £5. to 6.
Crate makers, £3. to 4.
Pot making & Clay department £5. to 5..5..0.
House and Coal allowances £5.9.9 per week.

115

Alkali workers per week.	£3..6..8
Metal mixing, &c.	9..7..0
Glass Pickers	2..8..0
Smiths	£3..8..0
Carpenters	2..0..0
Masons	4..0..0
Pensioners	£1..7..6. variable
Yardsmen	7..0..0 variable

Standing exp[s]. in Wages and allowances £138 to £158 per wk.

116

The Rent and Coal allowances
to those who receive 8 loads of
Brush Coal per an., & £5 rent,
amount to £0..3..$2\frac{1}{2}$ per week.
Total allowance in Coal and House
rent, to all who receive them
is * ~~£285..8..4 per annum or 5..9..9 per week~~
*It is now £286..5..0 per an.
or £5.10..0. per week in
consequence of the Founders.
Aug. 1837

117

Wages @ Nailsea

Managers,	£200 ea. per an.
Clerk. £100 + (C. + H.) = £120.	
Pot Maker	35/-. H. & Coal.
Furnace Mason	28/- H. & C.
Other do	21/-
Carpenter	20/-
Smith's, Headman	28/-
2nd. do	21/-
Assistant	12/-
Lad	7/-
Crate makers	1/- per pair.

118

Glass Makers Wages.

Edw^{d}. Phillips	£3..17..0
John Brooks.	2.. 5..0
Tho^{s} Smart	2.. 5..0
2 Flashers @ 30/-	3.. 0..0
2 Pilers @ 30/-	3.. 0..0
2 Assistants @ 20/-	2.. 0..0
2 Carriers Off @ 21/-	2.. 2..0
8 Blowers @ 30/-	12.. 0..0
1 do. practising 25/-	1.. 5..0
8 Gatherers @ 25/-10.. 0..0	
1 spare Gatherer @ 25/-	1.. 5..0
2 Skimmers @ 25/-	2..10..0

119

for "4 double journeys"

2. 1st time Gatherers @9/-	£0..18..0
1 Ponty sticker @ 12/-	0..12..0
1 do do @ 9/-	0.. 9..0
2 do do @ 7/-	0..14..0
2 spare boys @7/-	0..14..0
2 Marver cleaners @ 5/-	0..10..0
7 other boys @ 4/-	1.. 8..0
1 Spare man (N.S.) @ 10/-	0..10..0
2 Blowers behind @ 20/-	2.. 0..0
2 Flashing F^{ce}. Keep^{rs}. @ 18/-	1..16..0
1 Crambo Keep^{r}. (N.S.) @ 15/-	0..15..0
Total. ...	£55..15..0

Besides Coal allowances &c.
(in Feb^{y}. 1836.)

120

Founders Crew

Founder	£1..10..0
2 Teazers @ 23/-	2.. 6..0
2, 2nd do @ 18/-	1..16..0
2 Spare men @ 15/-	1..10..0
Cave man	0..16..0
Coal wheeler	0..15..0
Average Pot money	0..12..0
Sweeping Furnace	0.. 1..0
Wheeling Ashes off	0.. 7..0
Usual drink allowance	0.. 5..4
Extra allowance-	0.. 1..4
Total-	£9.. 19..8

121

Metal Mixers.

Edw^{d}. Gainer. 2/3rds.	£1.. 0..0
Jas. Connelly	1..10..0
Assistant mixer	0..12..0
2 Pan men @ 14/-	1.. 8..0
2 Caulker men @ 18/-	1..16..0
2 Mill men @ 12/- 1.. 4..0	
2 Horses @ 18/-	1..16..0
24 Quarters of Coal @ 1/4	1..12..0
Hauling do.	0.. 2..8
Total Wages.	£11.. 0..8

for 72 Batches of Mixture.
= about 4800 Tables; or
8 double journeys.

122 **[No entry]**

[Not numbered, = 123]

Index.

[Not numbered, = 124]

[Not numbered, = 125]

Glass.	103
Duties & Debentures.	112
Wages &c.	114
Waste in manufacg.	110
Wt. of Moils, Pontys, & Skimmings.	110
Sp. gr. of Glass.	102
Accurate produce from S.S. mixture.	102, & 96
Consumption of Materials.	97

[Not numbered, = 127, 126 blank]

Consumption of Material per An.
(omitting 6 weeks for furnace
building) for

2 Furnaces. 7 founds per week.
Making 4700 to 4800 Tabs.

Sand..........	654 tons.	11cwt.	2qrs.
S.S.	204	11	0
Lime (Hyd[te].)	184	2	0
Cullet	640	0	0
Charcoal	17	10	3
Manganese	1	9	1
Arsenic	3	9	0

(C.T.C. Oct 1837)

[Not numbered, = 128]

Wages &c. (no overwork)

Glass makers only	£59..10..$4\frac{1}{2}$
Other departments	81.. 6..$8\frac{1}{2}$
do in Bristol	30.. 1..6
Per week	170..18..7

or £21..7..4 per Journey, if
the Weeks work be made.

Wages &c. (5 Journeys overwork)

Glass makers only	£86.15..3
Other departments	90.19..6
do. in Bristol	30.. 1..6
Per week	207..16..3 or

£207.16.3 - £170.18.7
£36.17.8 for the 5 over journeys.

[Not numbered, = 129]

Wages per Journey (no overwork)

Glass makers only	£7..8..$9\frac{1}{2}$
Other departments	10..3..4
do. in Bristol.	3.15..$2\frac{1}{4}$
	£21.. 7.. $3\frac{3}{4}$

∴ 416 Journeys, or 10400 Crates
cost us in Wages and allowances
£8886..16..0 = 52 weeks work.

Wages &c. per Journey (overwork)

Glass makers only	£5..10..0
Extra packers &c	1..17..$6\frac{1}{2}$
	£7..7.. $6\frac{1}{2}$

Difference in wages and allowances
only, about £14 per Journey
C.T.C. Aug. 1837

[Not numbered, = 130]

Constants for Calculations
Per Journey of 300 Tabs. (No overwork) } or 10400 Crates per an.

Wages and allowances to Glass makers only	£7.. 8..$9\frac{1}{2}$
do do to other departments, at Nailsea	10.. 3..4
do do do at Bristol	3..15..2
Constant Charge per Journey	£21.. 7..$3\frac{1}{2}$

or rather more than £170 per week (£8886..16..0 per 52 weeks.)

And for every Journey exceeding 8 per week to Glass makers only (double set)	£5..10..0
Extra packers and laborers	1..18..7
Constant charge per Journey "Overwork"	.£7.. 8..7

or £29..14..3 per 100 Crates.

Aug. 1837.

End note: It had been established by comparison with the photograph of pages 118 and 119 on p.21 of Thomas, M, 1987, that the earlier transcription, copies of which are in the SMR, at Nailsea Library, and presumably elsewhere, was not necessarily accurate. There are three mistakes on p.118 alone. Additionally it seemed improbable that Coathupe would not have had his furnace big enough to take his pots, if his furnace details were interpreted correctly. In the event it seems that he didn't.

I am very grateful to Mrs B Knutson, at Nailsea Library, and to Mr T Bowen of NDLHS for facilitating the re-examination of the original in order to achieve a more reliable transcription. The foregoing is the result. It is understood that in the near future the notebook will be transferred to the Somerset Record Office for conservation and safe-keeping. (Aug. 2004)

APPENDIX 2 - Extract from *Builders' Work and the building Trades*, Seddon, 1889

"*304*.

Materials.

Glass used for glazing purposes is distinguished according to the method of its manufacture, as *crown glass, sheet glass,* and *plate glass,* and is described either by its weight per foot super or, in the thicker descriptions, such as plate glass, by its thickness; and may be either flat or bent to any required curve. The sizes of the sheets are limited by the process of manufacture.

Crown Glass. —*Crown* glass, also called Newcastle glass, from the chief seat of its manufacture, is blown in circular tables from 3 feet 6 inches to 5 feet diameter, leaving the boss, from which it was blown, in the centre. The method of blowing it, and bringing it to the required thickness—by making the tube, through which it is blown, revolve rapidly on its axis, causing the glass to run out by centrifugal force from the centre to the circumference of the disc—tends to an inequality of thickness, decreasing from the centre boss to the circumference, as well as to its being more or less striated in concentric rings; thus limiting the size of the good glazing panes which can be cut out of a table.

The qualities [1] of crown glass are known as *selected glazing* or

[1] The quality, weights, and sizes here given are those furnished by the "Glass Tariff" of Messrs. Hartley and Co. of Sunderland.

305 PAINTER'S, GLAZIER'S, AND PAPER HANGER'S WORK.

picture qualities and *usual glazing qualities.* There are two picture qualities, called A for best and B for second best. The usual glazing qualities are divided into *best, seconds, thirds,* and *fourths* or *coarse.* The second quality is used for officers' quarters, etc., thirds for all ordinary barrack purposes, and fourths only for very inferior glazing, such as outhouses, stables, etc.

The weight of crown glass per foot super varies considerably, even in the same table, owing to its decreasing in thickness from the central boss, towards the edges; for windows it should run about 16 oz. per foot super. For every $\frac{1}{16}$ of an inch in thickness it weighs about 13 oz. per foot super.

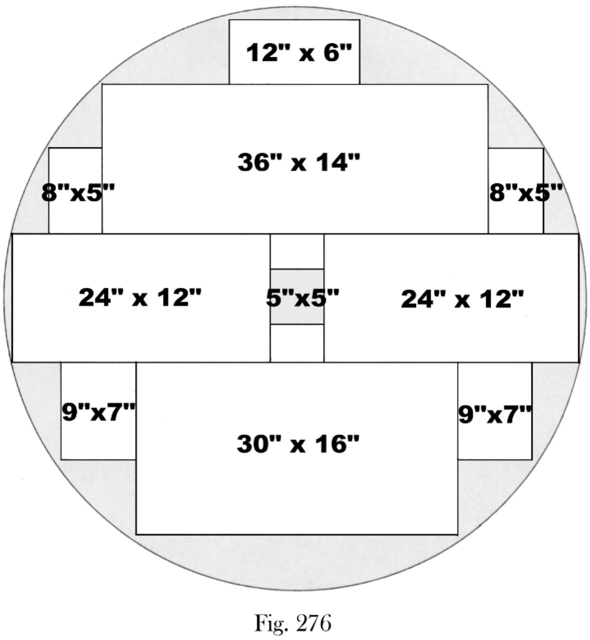


Fig. 276

On an average about 10 or 11 feet super can be cut out of each table, but if cut to the best advantage about 13 feet super can be got from a table, such as is shown in Fig. 276."

Figure 3.28: 54.34 inch table cutting diagram (Redrawn from Fig.276 from Seddon.)

The sheets are usually cut to about $2\frac{1}{2}$ inches from the centre, leaving a *quarry,* generally 5 by 5 inches, which, having the central boss in it, is chiefly used for stable or similar work. The term *quarries* is also applied to glass cut up into small pieces for lead glazing. There is a difficulty in cutting sheets containing more than 6 feet super.

Crown glass is sold by the foot super in *crates* of 12 circular *tables* averaging 52 inches in diameter, if of *extra* thickness; or of 18 tables averaging 53 inches, if of the *usual* thickness for glazing. It may also be obtained in flattened slabs, or in squares cut to order, and bent to any curve required. Large squares run more expensive than smaller ones, on account of the greater waste to which the tables cut.

Unflattened is superior in quality to flattened crown glass, but unless specially selected, is so much curved as to necessitate cutting the sash bars, **or** using a large amount of putty.

On account of the improvement in the manufacture of *sheet glass,* in which the defects inherent to the manufacture of *crown, glass* are avoided, the latter is no longer made at many of the large glass works, and is therefore going rapidly out of use; at the same time it is more colourless and less brittle than sheet glass.

Sheet Glass. —*Sheet, flattened sheet, crystal or British sheet,* all signifying the same glass, is used for all ordinary glazing purposes, and is blown in a hollow cylindrical form with closed ends, which when removed leave a glass tube 3 to 4 feet long, and from 10 to 12 inches diameter: these, when cut down one side, are opened up into sheets and flattened out in a reverberatory furnace, and tempered by being cooled gradually in a succession of ovens, each of a lower temperature than the last. It can be polished on face, bent to any curve, or ground on face or edges, as may be ordered.

Sheet glass is either of the ordinary clear description known as crystal, or a light, tinted glass is supplied at an increase in cost of about 10 per cent. Crystal sheet glass is generally used for photographic studios, but an extra white quality can be supplied, though at a higher rate.

The *qualities* sold are A and B *picture qualities,* and the usual glazing qualities—viz. *best, second, third,* and *fourth* or *coarse.* The seconds are used for officers' quarters, offices, etc., and thirds for ordinary barrack purposes.

The *weights* per foot super are generally 15 oz., 21 oz., 32 oz., 36 oz., 42 oz., the latter being nearly $\frac{1}{4}$ inch thick. As a rule every $\frac{1}{16}$ inch may be taken as 13 oz. to the foot super.

In *dimensions* the ordinary stock sheets do not exceed in area 17 feet super, in length 75 inches, or in breadth 45 inches; nor are they less than 10 feet super, 44 inches in length, or 34 inches in breadth.

Sheet glass is sold by the foot super of the required quality and weight, in *crates* or in *squares* cut to order.

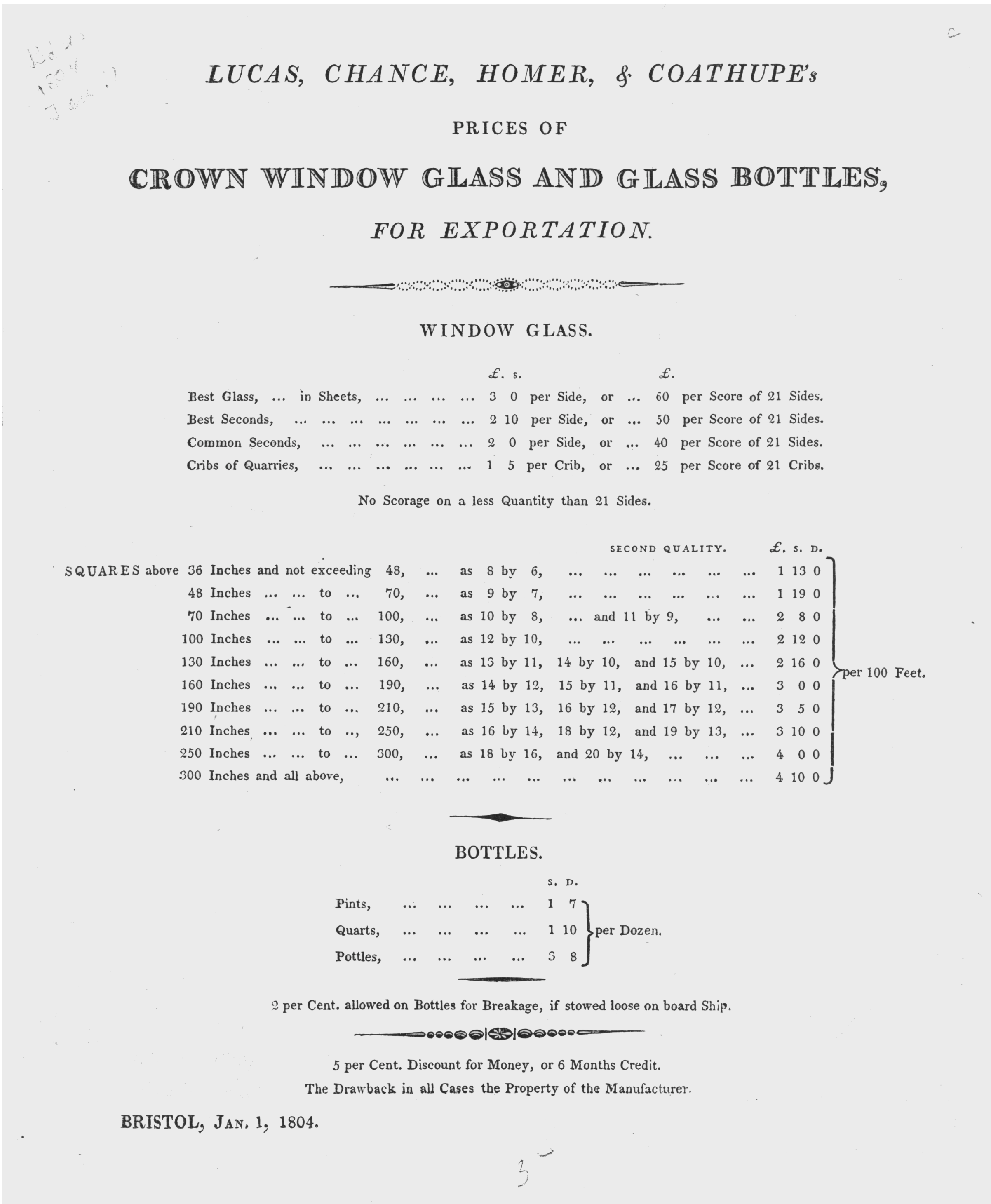
Obscured Sheet. —Sheet glass, obscured or frosted, so as to appear like ground glass, is made from any description of the third quality glass; it is cheaper than ground glass, and may be obtained either plain or in patterns of endless variety.

Fluted Sheet. —Sheet glass of third quality from 15 oz. to 32 oz. per foot super, is rolled, so as to form flutes or corrugations on both sides, which while it secures privacy without obstructing light, makes it much stronger than either ground or obscured sheet glass.

Patent Plate. —*Patent plate* glass is merely a superior class of polished sheet glass, and can be distinguished from *plate glass* by a more wavy appearance of the surface, as well as by the air bubbles, which in sheet glass and patent plate are oval, whilst those in crown and plate glass are circular."

APPENDIX 3 - 1804 Price List

"Lucas, Chance, Homer & Coathupe's Prices of Crown Window Glass and Glass Bottles, for Exportation." Broadside. Bristol: 1804. Courtesy of the Massachusetts Historical Society



LUCAS, CHANCE, HOMER, & COATHUPE's

PRICES OF

CROWN WINDOW GLASS AND GLASS BOTTLES,

FOR EXPORTATION.

WINDOW GLASS.

	£.	s.		£.	
Best Glass, ... in Sheets, ...	3	0	per Side, or ...	60	per Score of 21 Sides.
Best Seconds, ...	2	10	per Side, or ...	50	per Score of 21 Sides.
Common Seconds, ...	2	0	per Side, or ...	40	per Score of 21 Sides.
Cribs of Quarries, ...	1	5	per Crib, or ...	25	per Score of 21 Cribs.

No Scorage on a less Quantity than 21 Sides.

			SECOND QUALITY.	£.	s.	D.	
SQUARES above 36 Inches and not exceeding	48, ...	as 8 by 6,	... ...	1	13	0	per 100 Feet.
48 Inches ... ... to ...	70, ...	as 9 by 7,	... ...	1	19	0	
70 Inches ... ... to ...	100, ...	as 10 by 8,	... and 11 by 9, ...	2	8	0	
100 Inches ... ... to ...	130, ...	as 12 by 10,	... ...	2	12	0	
130 Inches ... ... to ...	160, ...	as 13 by 11,	14 by 10, and 15 by 10, ...	2	16	0	
160 Inches ... ... to ...	190, ...	as 14 by 12,	15 by 11, and 16 by 11, ...	3	0	0	
190 Inches ... ... to ...	210, ...	as 15 by 13,	16 by 12, and 17 by 12, ...	3	5	0	
210 Inches ... ... to ...	250, ...	as 16 by 14,	18 by 12, and 19 by 13, ...	3	10	0	
250 Inches ... ... to ...	300, ...	as 18 by 16,	and 20 by 14, ...	4	0	0	
300 Inches and all above,	... ...	... ...	... ...	4	10	0	

BOTTLES.

	S.	D.	
Pints, ...	1	7	per Dozen.
Quarts, ...	1	10	
Pottles, ...	3	8	

2 per Cent. allowed on Bottles for Breakage, if stowed loose on board Ship.

5 per Cent. Discount for Money, or 6 Months Credit.

The Drawback in all Cases the Property of the Manufacturer.

BRISTOL, JAN. 1, 1804.

Figure 3.29: 1804 Price list with available sizes

To aid with interpretation, a transcription from the above broadside (Ref.: Broadsides – small 1 January 1804, held by the Massachusetts Historical Society), is given below.

LUCAS, CHANCE, HOMER, & COATHUPE's

PRICES OF

CROWN WINDOW GLASS AND GLASS BOTTLES

FOR EXPORTATION.

WINDOW GLASS

		£.	s.			£	
Best Glass,	in Sheets	3	0	per Side,	or	60	per Score of 21 Sides
Best Seconds,		2	10	per Side,	or	50	per Score of 21 Sides
Common Seconds		2	0	per Side,	or	40	per Score of 21 Sides
Cribs of Quarries		1	5	per Crib,	or	25	per Score of 21 Cribs

No Scorage on a less Quantity than 21 Sides.

				SECOND QUALITY	£.	s.	d.	
Squares above	36 Inches and not exceeding		48,	as 8 by 6	1	13	0	per 100 Feet
	48 Inches	to	70,	as 9 by 7	1	19	0	
	70 Inches	to	100,	as 10 by 8, and 11 by 9	2	8	0	
	100 Inches	to	130,	as 12 by 10	2	12	0	
	130 Inches	to	160,	as 13 by 11, 14 by 10, and 15 by 10	2	16	0	
	160 Inches	to	190,	as 14 by 12, 15 by 11, and 16 by 11	3	0	0	
	190 Inches	to	210,	as 15 by 13, 16 by 12, and 17 by 12	3	5	0	
	210 Inches	to	250,	as 16 by 14, 18 by 12, and 19 by 13	3	10	0	
	250 Inches	to	300,	as 18 by 16, and 20 by 14	4	0	0	
	300 Inches	and all above			4	10	0	

BOTTLES

	S.	D.	
Pints	1	7	per dozen
Quarts	1	10	
Pottles[47]	3	8	

2 per Cent. allowed on Bottles for Breakage, if stowed loose on board Ship

5 per Cent. Discount for Money, or 6 Months Credit.

The Drawback in all Cases the Property of the Manufacturer.

BRISTOL, JAN, 1; 1804.

The above was found through a web search. A further search revealed that there is an 1809 price list with the Koerner Library at the University of British Columbia. There is also a reference at the same source to a "*Crown glass cutter and glazier's manual*" by William Cooper, 1835. Both are held as microforms, but have not been requested, as these and the above were only located very late in the study.

[47] From the Concise Oxford Dictionary: pottle: (archaic) measure for liquids, half gallon pot etc. containing this.

APPENDIX 4 - 1830s plan

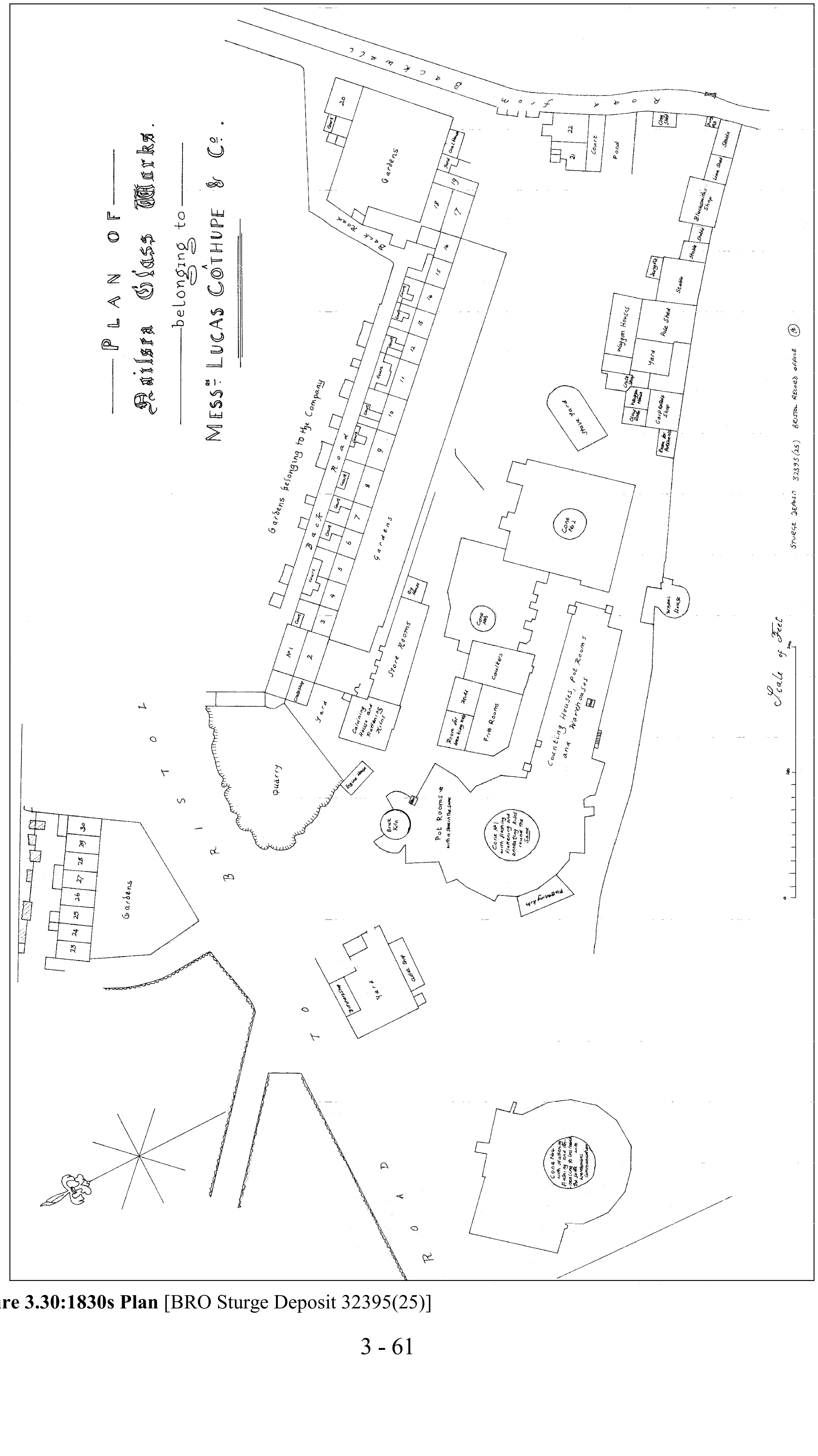


Figure 3.30:1830s Plan [BRO Sturge Deposit 32395(25)]

APPENDIX 5 - 1870 plan and schedule

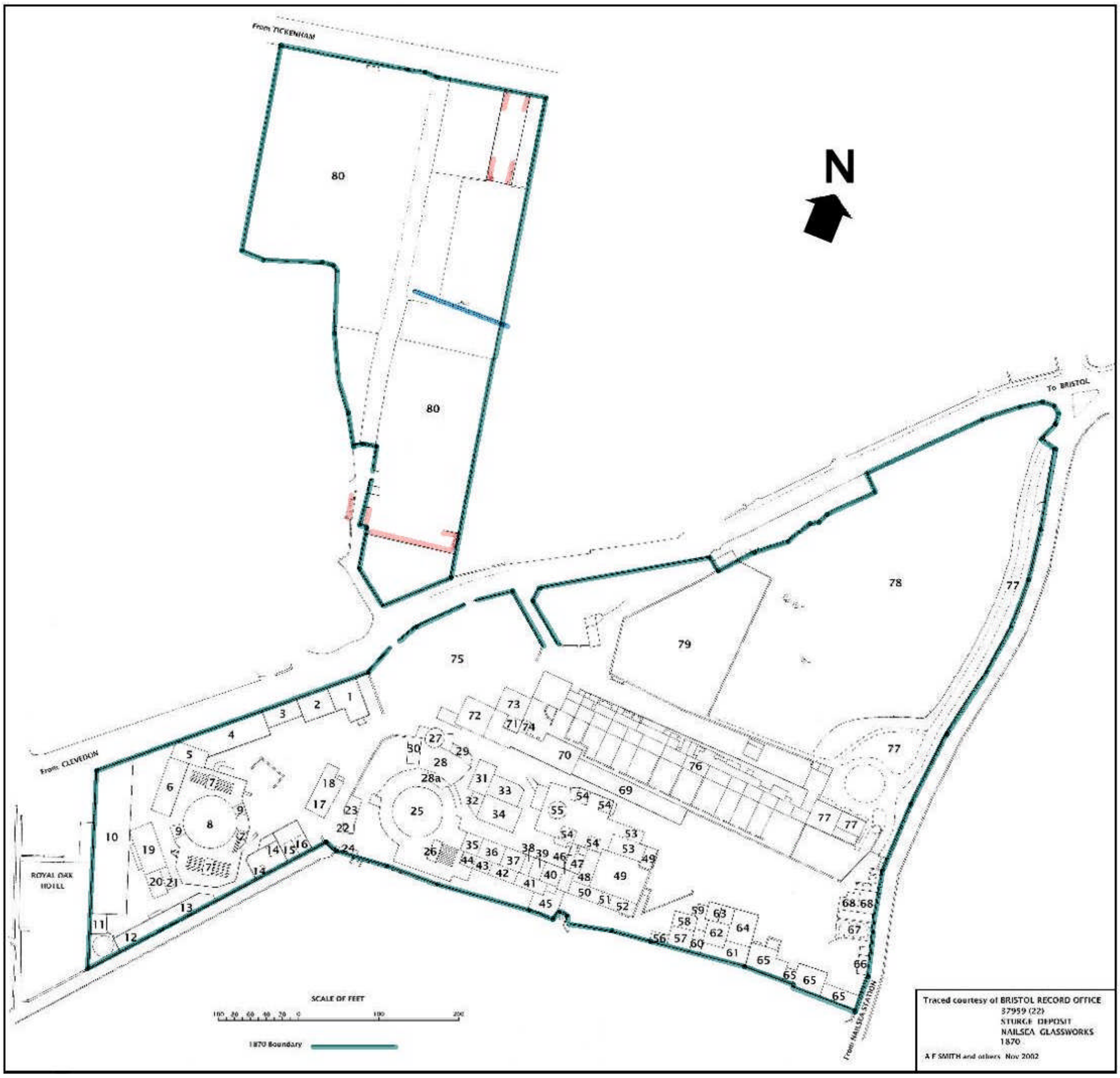


Figure 3.31: 1870 Plan of the Nailsea Glassworks Holding [BRO Sturge Deposit 57959 (22)]

It is not known for certain, but the writer suspects that the photograph in the Scotch Horn Centre at Nailsea of an 1870 plan (Figure 3.32, below) in fact represents an original. The BRO version has either been taken from that or is an earlier working copy.

Table 3.3 - Schedule referring to the 1870 plan

Schedule referring to Plan of the Nailsea Glass Works 6.6.70 [6th June 1870]

No.	*Description*		
1	Offices		
2. 2.	Two French Kilns		
3	Smith's Shop		
4	Belgian Lear		
5	Cutting Room		
6	Six storey building 2 packing & cutting Rooms 3 Pot rooms and loft for lift machinery		
7,7,7	Blowing holes		
8	Cone N° 1 Furnace		
9	N° 1 Furnace cylinder room		
10	Two French Kilns		
11	Gas Retort		
12	Sand caulker		
13	Mixing Room		
14	Two French Kilns		
15 & 16	Pot arches		
17	Old office		
18	Crucible furnace		
19	Cutting & packing room		
20 & 21	Store Rooms		
22 & 23	Old Watch House		
24	Boiler		
25	Cone of N° 2 Furnace		
26	Blowing Holes (12)		
27	Brick Kiln		
28	Brick Room & Pot room over		
28a	Crown Kilns (2)		
29	Brick Room		
30	Stone dressing room		
31	Pot arch		
32	Cylinder room		
33	Room for making small bricks with straw loft over		
33, 34	Two French Kilns		
	Ground Floor	**1st Floor**	**2nd Floor**
35	Coloured cullet room	Cylinder rooms	Pot rooms
36	Mixing Room		
37	Sand store room	Packing room	
38	Store for Limestone		
39	Limestone & Salt Cake Mill	Enamel grinding room	
40	Clay Mill	Obscuring Room	40 & part of 46: Ring Room
41 & 42	Clay Room		
43 & 44	Coloured Cullet room. Brilliant cutting room		
45	Saw Mill		
46	Engine Room		
47	Open space for coal for feeding boilers		
48	Old arches of bottle house - useless		

49, 49	Open spaces where old bottle house stood	
50	Clay Mill	Chaff & corn loft
51	Arch	
52	Empty shed	
53	Covered unoccupied space	
54, 54, 54, 54	Four rolled plate kilns	
55	Lilly cone	
56	Shed for chipping potsherds	
57	Empty Room	
58	Old chapel (used for Carpenters Room)	
59	Boy Shop	
60	Store room for centres	
61	Joiners Shop	
62	Open space	
63	Empty shed	
64	Dilly shed	
65	Stabling &c	
66	Fowl pen	
67	Pond	
68, 68	Cottages	
69	Rolled plate room with pot & tile room over	
70	Lear	
71	Ornamental burning kiln	
72	3 Storey Building - Cutting packing & assorting Rooms	
73	Drill Room empty	
74	W.C. &c for cottages	
75	Waste ground for rubbish	

Schedule of Quantities

Numbers		a	r	p
1 to 76	Works and cottages	6	1	29
77	House, Lawn, Drive, etc	0	3	10
78	Paddock	2	1	4
79	Garden	0	2	0
80	Colliery, etc	3	1	34
	Total	13	1	37

[Initialled] *H H*[48]

[In pencil] *Messrs Chance Brothers & Co*
Glass Works
near Birmingham

[BRO (Sturges) 37959/22]

[Transcribed from original manuscript by the writer, 25th September 2002.]

Note: **a** =acres, **r** = roods (4 to an acre), **p** = perches (40 to a rood). 1 acre = 4840 sq. yards
1 hectare = 10,000 sq. m. = 2.47 acres approximately.

[48] This may be H H Ham mentioned by J Eyres (See Part 3 Appendix 8)

Figure 3.32: Photograph of a photograph of an another version of the 1870 plan

(Courtesy Scotch Horn Centre, Nailsea and North Somerset Museum, Weston-super-Mare)

APPENDIX 6 - Chemistry

It was felt that some recognition should be given to the chemistry of glass, as part of the technology, as glass is in fact initially formed by a chemical reaction. Furthermore some of the terms popularly used are only infrequently defined, and some misconceptions have been found as to the derivation of some compounds.

Initially it is very likely that the process was fairly empirical – if a 'recipe' was found that worked it would probably not be altered, unless circumstances changed. As the chemistry behind the processes became better understood, then controlled experimentation could result, leading to a much more consistent product.

Following this, it is evident that at some stage the works at Nailsea included the means of producing the chemicals required on an industrial scale on site. An extant billhead implies that there was indeed a surplus to the needs of the glassworks that could be sold on the open market.[49]

The following is an attempt to address these points in simple terms, but for more detailed, but still comprehensible, expositions see Frank 1982 or Vose, 1980, for example.

Definitions

In the Hutchinson *Dictionary of Science*, 1994, ***glass*** is described as a "transparent or translucent substance that is physically neither a solid or a liquid. ... It is made by fusing certain types of sand (silica): this fusion occurs naturally in volcanic glass [obsidian]." It is well attested that glass comes into a class known as a "super-cooled" liquid, and that this accounts for many of its physical characteristics – for further details see Vose, 1980, pps 21-25, for example.

Hicks, 1983, p.425 writes, "**Glass.** Whilst glass varies widely in its composition, essentially it consists of a mixture of silicates which have not crystallized out on cooling from the molten state. ... Common glass, such as that used in windows, has the approximate composition: $Na_2SiO_3.CaSiO_3.4SiO_2$. The physical properties of glass depend on the proportions of the various silicates present."[50]

We are only concerned with simple glasses here, as lead crystal and other more sophisticated glasses were not, as far as can be determined, made at Nailsea, certainly not in commercial quantities.

N.B. It should be noted that the definition of 'Alkali' in the Hutchinson *Dictionary of Science* is "in chemistry, a compound classed as a base that is soluble in water. ... The hydroxides of metals are alkalis; those of sodium and potassium being chemically powerful; both were historically derived from the ashes of plants. The four main alkalis are sodium hydroxide (caustic soda, NaOH); potassium hydroxide (caustic potash, KOH); calcium hydroxide (slaked lime or limewater, $Ca(OH)_2$); and aqueous ammonia ($NH_{3(aq)}$). ... Alkalis react with acids to form a salt and water (neutralization)."

However, in the Corning Museum of Glass *Glossary*[51] it is defined as, "Alkali : In glassmaking, a soluble salt consisting mainly of potassium carbonate or sodium carbonate. It is one of the essential ingredients of glass, generally accounting for about 15-20 percent of the

[49] SRO D/B/bW 2349: Coathupes &Co., Manufacturers of Crown Window Glass & Alcalis, [*sic*], (Bristol, 20th Feb. 1846) – See Appendix 11

[50] Hicks, J, 1982, pps. 424-5

[51] From the Corning Museum of Glass website

batch. The alkali is a flux, which reduces the melting point of the major constituent of glass, silica."

Compounds

Substance – common name	Chemical name	Chemical formula	Derived from
Alkali (see **N.B.** above) Potash Soda ash	See below under individual entries	See below	See below
Black Ash	Sodium carbonate	Na_2CO_3	Na_2 SO_4 heated with coal and limestone. Soda extracted by leaching
Caustic potash	Potassium hydroxide	KOH	Similar to caustic soda
Caustic soda	Sodium hydroxide	NaOH	Slaked lime + dilute sodium carbonate solution +heat
Ferric Oxide	Ferric Oxide	Fe_2O_3	Haematite
Lime	Calcium oxide	CaO	Burning limestone in a kiln
Lime(stone)	Calcium carbonate	$CaCO_3$	Limestone, but also chalk
Nitre, Saltpetre	Potassium nitrate	KNO_3	
Oil of Vitriol, Vitriol	Sulphuric Acid	H_2SO_4	
Potash	Potassium carbonate	K_2CO_3	Land plants (ash)*
Salt	Sodium chloride	NaCl	
Salt cake	Sodium sulphate	Na_2SO_4	Salt treated with sulphuric acid
Silica	Silicon dioxide	SiO_2	Quartz as Common sand
Slaked lime	Calcium hydroxide	$Ca(OH)_2$	Lime plus water
Soda ash	Sodium carbonate	Na_2CO_3	Marine plants (ash) esp. kelp†

*Wood-ash from beech was favoured[52], and ash from bracken was also used.[53]

† Also, the Concise Oxford Dictionary gives "**glass-wort**, plant of genus *Salicornia* or *Salosa* formerly burnt for use in glass-making." [It is also known as 'marsh samphire'[54]]

[As chemical engineering developed, less reliance was placed on plant derived compounds and synthetic compounds produced by reactions on an industrial scale were employed. These will not be detailed here. However, the increased purity of the constituents meant that certain

[52] Adkins, L and Adkins R, 1998: p.268
[53] Burgoyne, I and Scoble, R, 1989: p.3
[54] Reader's Digest *Wild Flowers of Britain,* 1997, p.95

elements that had naturally been in the earlier product, and were in fact beneficial, had to be re-introduced, examples being lime, alumina and magnesia.[55]]

Hicks, 1983, p.420, under **Silicon Dioxide, Silica, SiO_2** says, "This compound occurs naturally as quartz and sand and also as flint, opal and agate." He points out that "pure silica is colourless, but sand is usually coloured yellow or brown by ferric oxide impurity."

Reactions

Hicks, *Ibid.*, gives typical reactions, [of silica] "important in glassmaking", as, when heated strongly:

"$SiO_2 + Na_2CO_3 = Na_2SiO_3 + CO_2\uparrow$"

[Silica + sodium carbonate gives sodium silicate with carbon dioxide given off.]

"$SiO_2 + Na_2SO_4 = Na_2SiO_3 + SO_3\uparrow$"

[Silica + sodium sulphate gives sodium silicate with sulphur trioxide given off.]

On p.424, Hicks, *Ibid.*, writes, "It [glass] is made by melting together silica (i.e. sand) with calcium carbonate or oxide and sodium or potassium salts, usually the sulphate and the carbonate:

e.g. $SiO_2 + CaCO_3 = CaSiO_3 + CO_2\uparrow$

$SiO_2 + K_2SO_4 = K_2SiO_3 + SO_3\uparrow$ "

The alkali acts as a flux, bringing the melting point temperature down, while the lime(stone) acts as a hardener. If the sodium compound predominates the melting point will be lower, relatively, which means less fuel would be consumed in the heating and working processes; it will not be lowered to the same extent if the potassium compound is present. The addition of scrap glass, commonly called 'cullet', also assists considerably in lowering the melting point of the raw materials if it is included in the mix.

Pilkington give the following, under 'Chemistry of Glass'[56], "Important glassmaking chemistry: the basic reactions:

$$Na_2CO_3 + SiO_2 \xrightarrow{1{,}500^{o}\,C} Na_2SiO_3 + CO_2\uparrow$$

$$Na_2SiO_3 + xSiO_2 \xrightarrow[\text{Digestion}]{Na_2SO_4} (Na_2O)(SiO_2)_{(x+1)}$$

For practical and economic reasons, the high melting point and viscosity of silica is reduced by adding sodium oxide (a flux) in the form of a carbonate."

Traces of other elements either added accidentally as impurities in, say, ash, or later deliberately, such as manganese, could affect the chemical stability of the glass, for example. They might also decolourise it or colour it depending on the appropriate element or compound being added. It is not considered necessary to explore the chemistry of these reactions any further here.

It can be seen that the processes were not good either for greenhouse gasses (CO_2) or acid rain (SO_3 combines with water to form sulphuric acid.) In addition the "stack" at Nailsea gave off gaseous hydrochloric acid, which, understandably, gave offence under certain weather conditions.

[55] Vose, p86

[56] From Pilkington Glass website

APPENDIX 7 - English Heritage Report

Centre for Archaeology Report 16/2004

Scientific Examination of Glass and Glass Working Materials from Nailsea, Avon

Gareth Hatton

ISSN 1473-9224

The Centre for Archaeology Report Series incorporates the former Ancient Monuments Laboratory Report Series. Copies of Ancient Monuments Laboratory Reports will continue to be available from the Centre for Archaeology (see below for details).

Centre for Archaeology Report 16/2004

Scientific Examination of Glass and Glass Working Materials from Nailsea, Avon

Gareth Hatton

Summary

Historical documents show that the glassworks at Nailsea were established in 1788 and continued until 1874. An assemblage of glass and glass working waste (2.8kg) was submitted for examination and subsequent analysis. Samples to represent the range of colours, forms and sizes present were selected for chemical analysis. It was determined from these analyses that colourless glass was produced on site. The glass is a soda lime silicate glass.

Keywords

Glass
Post Medieval

Author's address
Gareth Hatton: Centre for Archaeology, Fort Cumberland, Fort Cumberland Road, Eastney, Portsmouth P04 9LD. Telephone: 023 9285 6784. Email: gareth.hatton@english-heritage.org.uk

World Wide Web: hhttp://www.english-heritage.org.uk
E-mail: cfa@ english-heritage.org.uk
Centre for Archaeology enquiries: telephone +44 (0) 23 9285 6700
Centre for Archaeology, Fort Cumberland, Fort Cumberland Road, Eastney, Portsmouth PO4 9LD

Introduction

Nailsea (ST 465 695) is some 12km south west of Bristol. The Nailsea glass works were established in 1788 and began producing glass bottles, moving on to produce crown and sheet glass until its demise in 1874. It was ideal for the production of glass for two reasons; it had access to a local source of coal, also worked during the medieval period, and was near enough Bristol to feed from its success. The site was excavated during the 1980s and 1990s when a number of environmental samples were taken. Thirty-one of these samples were submitted for examination and subsequent analysis (see Table 9, Table 10, Table 11 and Table 12). A number of samples contained significant amounts of various glass fragments and debris from the glassworks.

History

The historical evidence for the production of glass at Nailsea is extensive and a small book has been published on the subject (Thomas 1987). The site was chosen in 1788 and two cones (cover buildings for furnaces) stood on the site from 1790. A further cone 'Lily', was constructed by the early 1840s. During the life of the Nailsea glassworks the production of glass at the works went through phases with the primary product shifting from bottle glass through crown glass and, later, cylinder window glass. The presence of swing pits provide evidence that cylinder glass was produced, most likely using the improved cylinder method described briefly below. This development dates from the late 1830s.

By the 1860s sheet glass was the main product, the Old House making cylinder and crown glass and the New House making cylinder glass. The 'Lily' cone was producing plate glass. Crown glass was produced from 1788 to 1862 when the melting furnace in the Old House collapsed. In the 1860s coloured sheet glass of 'Cathedral type' glass was also made (see Painted and blue glass).

Due to bankruptcy and the faltering local coal supply production of glass on the site the works were finished in 1874 when the site was put up for sale. It was never sold and went from decay to dereliction.

Glass production

Charles Coathupe, a manager at Nailsea –1836/37, kept a notebook, which, along with wages and so forth provides us with several recipes for the production of glass (Thomas 1987), one of which is shown in (Table 1). These weights can be converted into percentages and compared with the results from the analysis (see Table 6).

Table 1: Recipe for sulphate of soda mixture (quantities used in one week)

	Cwt	Qr	Lbs
Prepared sand	284	2	11
Sulphate of soda	106	2	25
Prepared lime	88	3	21
Prepared charcoal	7	2	14
Prepared manganese	0	2	17
Prepared arsenic	1	2	0

Cullet was also added to this mixture to aid the initial melting and also to cut on costs to produce the glass charge. This was common practice. Arsenic was added to glass batches to decolourise the glass that had a variable iron content (from the sand) and therefore variable colour (Parkin 2000); manganese is also known to decolourise glass. The materials, whether the ones above or not were melted in pots measuring 5 feet high and 70 inches across (Thomas 1987).

Excavation

The New Cone was excavated in 1983/87 and bags of samples collected. These are listed in tables 9-11. In the excavation records there is a description of a pit that had a clinker fill (A10) followed by an ashy layer (A14), providing a possible chronology. The site diary records that the layer may have built up during the use of this pit as a swing pit. This is to the east of the furnace in the New House cone.

The samples detailed in Table 10 were all taken from the New House cone to the west of the Nailsea complex. All samples except SA06 and SA03 were taken from an area close to the cone (NGR ST47692 70841) labelled as clinker and ash on a sketch plan of the excavations.

To the east of New House cone, Old House cone was partly excavated in the 1990s and further samples were collected (see Table 12).

Terms used

Crown glass was produced in England between 1696 and 1872 but by 1832 it was in decline as a technique for the manufacture of glass panes (Burgoyne and Scoble 1983). This is the method where glass is blown into a small bulb and then spun to produce a circle of glass four or five feet in diameter, which is called a table. The main disadvantage is that the cutting of the table result in relatively small panes of glass due to the bullion or bull's eye in the centre that was considered waste. The replacement for this technique was the **improved cylinder method** (cylinder glass). This involves blowing a cylinder of glass which is then split whilst still malleable. Swinging the cylinders in a swing pit made them longer. Both methods were certainly in use at Nailsea (see below). Colourless glass was found which had a distinctive ridged surface; this is described as **ridged glass**.

Aims

- To determine the chemical composition of the glass being made at Nailsea, and whether this changes over time
- To see if the composition of the vessel and ridge glass show that they could have been made on site
- To compare Coathupe's recipe (see Table 1) with analyses of waste glass from the site
- To see if coloured glass has the same composition as the colourless glass, but with added colorant(s)

Processing of samples

Wet and dry sieving was undertaken on one of the larger bags of material [cone area (301) sample number 801] to determine the most efficient way of extracting glass production waste. The sieves used had 1.4, 2, 4 and 5 mm mesh. The <1.4 mm portion of material recovered during dry sieving was too small to be useful, consisting of very small fragments that cannot be identified as production waste (Dungworth 2002); this portion of the sample was discarded. The other material can be placed into categories according to the sieve size (5mm, 4mm, 2mm, 1.4mm).

It was found easier to sort the wet-sieved than dry sieved residues so all further processing was by wet sieving. All the available samples were examined, and sub-samples of those that contained glass or glassworking debris were processed (see tables 9-12). From this it was clear that burnt waste, glass waste and colourless glass were the dominant materials to be found (see Table 2). This material was in most contexts along with debris from buildings, which, for convenience has been labelled **ceramic building material** (CBM).

Several contexts contained only one type of material. These were only visually processed, examined both in hand specimen and under low-powered binocular microscope, their characteristics noted and a classification applied. These were ashy material, clay, stones, soil and mortar. The mortar was tested with dilute hydrochloric acid. A positive result (fizzing) indicated that it contained calcium carbonate and was mortar.

A single fragment of blue glass was recovered.

No crucible fragments were found in the material sieved. However one small fragment of ceramic material was found and has a vitreous surface or a drip of glass.

Table 2 :Material recovered from all contexts

	Weight (g)	%
Waste from burning (clinker, coal, coal ash)	741	26.5
CBM (mortar, brick fragments, unidentifiable stones)	345	12.3
Patterned window glass (red)	2	0.1
Colourless curved or flat glass	806	28.8
Colourless ridged glass	25	0.9
Glass waste (moils, lumps, chips)	664	23.7
Runs drips and threads	104	3.7
Brown bottle glass	48	1.7
Blue glass	<1	0.0
Green bottle glass	64	2.3
Other (wood, shell)	1	0.0
	2800	

Non-glass waste makes up 38.8% of the total material recovered. The most rare material recovered was coloured glass which, including the painted glass, only accounts for around four percent of the total.

The categories ‘other’ and blue glass were less than 0.1% of the total. A more detailed breakdown of material type by context can be found in Table 14.

Selection of samples for analysis

Samples for analysis were selected to represent the range of colours, forms and sizes of glass and glass waste. A number of larger pieces found during the excavation (see Table 13) were also sampled and analysed, these came from various key areas of the site. Each sample was mounted in acrylic resin, polished and examined with a scanning electron microscope (SEM) and analysed using an energy dispersive X-ray detector (EDS). Preliminary analysis was done on cleaned surfaces using an X-ray fluorescence spectrometer (XRF). These both give quantified percentage compositions.

Table 3: Samples taken for SEM-EDS analysis

Number	Context	Description
1	802 Nr building 260	Brown bottle glass
2	802 Nr building 260	Colourless drip
3	802 Nr building 260	Colourless lump
4	802 Nr building 260	Colourless ridge glass
5	802 Nr building 260	Green bottle glass
6	802 Nr building 260	Painted glass
7	Bag 301 cone area	Cylinder glass
8	Bag 304 [cone area]	Misshape glass fragment
9	NG 83 A (10) 8	Colourless glass, flat
10	NG 83 A (10) 8	Colourless glass, part of moil
11	NG 83 A (10) 164	Colourless glass, lump
12	NG 83 A (10) 184	Colourless glass, lump
13	NG 83 A (14) 9	Colourless glass, flat
14	NG 83 A (14) 9	Colourless glass drip
15	NG 83 A (14) 177	Colourless glass, lump
16	NG 83 A (14) 200	Colourless, lump
17	NG 83 A (14) 206	Colourless glass, lump

Glass and glassworking waste

Large lumps of frothy waste (Figure 1) were only found in context (301) [801]. Smaller fragments of this material were also found throughout this context.

Figure 1: Frothy glass waste

Colourless glass was found in most contexts. Some of these fragments were unidentifiable while others were remains of cylinder glass or moils, fragments cracked off from the blowing iron leaving a dark iron-rich layer on the curved surface (see the left of Figure 2) Bottle and coloured glass was most commonly found in context (260) [802].

Figure.2: Colourless glass

Figure 3: Coloured glass fragments (green on the left, brown on the right and blue in the middle)

In addition to the material above there were many larger fragments which had been picked out during the excavation. Selections of these from the same contexts as the sieved material (see Table 13) were also analysed. These included what is described as ‘clay ring fragment’. This was probably part of a gathering ring, which floated on the surface of the molten glass allowing the gatherer to rest the blowing iron while he collects enough glass to produce the beginnings of a crown. The rings were placed in the bottom of a pot, the batch was then added and the ring was allowed to float to the surface. These rings were made of the same material as the pots and made in the same way (Parkin, 2000). The composition of the glass on the ring should have a similar chemistry to that of the glass produced at Nailsea, though with contamination from the ceramic material. Therefore a sample of this ring and the adhering glass was taken and a profile produced of the glass layer-ceramic interaction.

Analytical results

Qualitative XRF was undertaken on rough cleaned surfaces to aid sampling the large amount of glass recovered, the elements where reported are the ones that were most significant for each sample. From these results it was determined that most of the colourless glass and glass waste was of the same composition. Below is a summary table of the EDS results for each sample. These are the results illustrated by the graphs (see Figure 4, Figure 5 and Figure 6*Figure 6: EDS results for soda and potash*).

Table 4 : Average composition of material determined by EDS

Sample No	Na_2O	MgO	Al_2O_3	SiO_2	K_2O	CaO	TiO_2	MnO	Fe_2O_3	As_2O_3	Total
2	10.3	0.2	1.1	68.8	0.2	15.2	0.1	0.0	0.3	0.3	97.3
3	8.0	0.3	1.5	66.7	0.6	19.1	0.1	0.0	0.4	0.4	98.3
4	12.4	0.0	0.9	70.1	0.1	13.5	0.0	0.0	0.3	0.5	98.9
7	15.3	0.2	0.6	68.1	0.0	12.6	0.1	0.0	0.3	0.3	98.5
8	11.3	0.1	0.8	69.7	0.1	12.3	0.1	0.2	0.2	0.3	95.9
9	14.3	0.3	0.7	69.4	0.1	13.1	0.0	0.1	0.2	0.2	99.0
10	12.9	0.2	0.6	67.8	0.1	13.0	0.0	0.1	0.1	0.1	95.7
11	14.6	0.4	0.8	70.1	0.2	13.3	0.1	0.0	0.2	0.3	100.6
12	14.8	0.4	0.7	70.1	0.1	12.8	0.1	0.0	0.3	0.2	100.0
13	12.4	0.1	0.6	66.1	0.1	12.4	0.2	0.0	0.2	0.2	92.9
14	12.6	0.2	0.8	68.0	0.0	12.9	0.2	0.0	0.2	0.2	96.1
15	14.5	0.3	0.7	70.7	0.1	13.3	0.1	0.1	0.2	0.2	100.7
16	13.4	0.2	0.7	68.4	0.1	12.8	0.2	0.1	0.2	0.2	96.9
17	16.2	0.4	0.7	71.2	0.1	13.4	0.0	0.1	0.2	0.1	103.2
1 (brown)	7.1	6.1	3.7	56.0	1.0	16.5	0.2	3.9	2.1	0.1	97.6
5 (green)	4.5	2.6	4.4	59.5	1.4	19.9	0.2	0.2	2.9	0.1	96.8
6 (painted)	2.0	0.0	0.3	76.8	9.7	7.0	0.0	0.0	0.1	0.3	96.8
All colourless (average)	13.1	0.3	0.8	69.0	0.1	13.5	0.1	0.1	0.2	0.2	98.2

Frothy glass waste

The surface appearance (Figure 1) suggests the glass is heavily weathered, which is born out by the high silica and low soda values in (Table 5). The material was not selected for further analysis for this reason. The other values are consistent with and indistinguishable from the other colourless glass analysed. Therefore this waste is likely to have been a primary product or waste material from producing the finished glass fragments found. The results shown are from four different pieces of this waste. There is no significant difference in composition between discoloured and colourless glass.

Table 5: XRF surface analyses of frothy waste glass from context 301

Na_2O	3.4	2.8	3.3	4.3
Al_2O_3	1.9	2.0	2.0	1.7
SiO_2	81.3	80.9	82.4	80.2
SO_3	0.7	0.7	0.7	0.7
K_2O	0.1	0.2	0.1	0.1
CaO	12.1	12.8	11.0	12.4
TiO_2	0.1	0.1	0.1	0.1
MnO	<0.1	<0.1	<0.1	<0.1
Fe_2O_3	0.2	0.3	0.2	0.2
As_2O_3	0.2	0.2	0.2	0.2
SrO	<0.1	<0.1	<0.1	<0.1

Colourless glass

Rough surface analysis was undertaken with no sample preparation to select a suitable sub-set for EDS analysis. The results of the XRF analysis showed a very tight clustering suggesting that the glass may have been produced using the same recipe with tight control of the quality and source of the raw materials. The EDS results also showed a tight clustering with some variability introduced from weathering of the alkalis. There is no evidence for chronological variation within the colourless group. The colourless lump has a different composition but not significantly so. It contains higher amounts of calcium and slightly higher alumina (see Table 4). The spread of alumina, iron, manganese and magnesium values is less than 1% in the colourless glass studied (see Figure 4). The colourless glasses are from both cone areas and various contexts, suggesting that there is no variation in the type of flux used over time for the colourless glasses, though the samples analysed may all come from relatively late phases of use of the site.

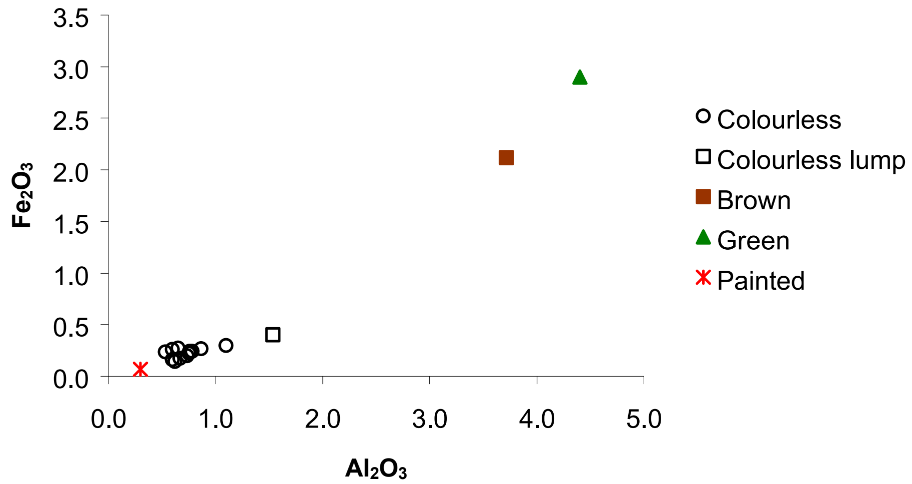


Figure 4: EDS results for Al_2O_3 and Fe_2O_3

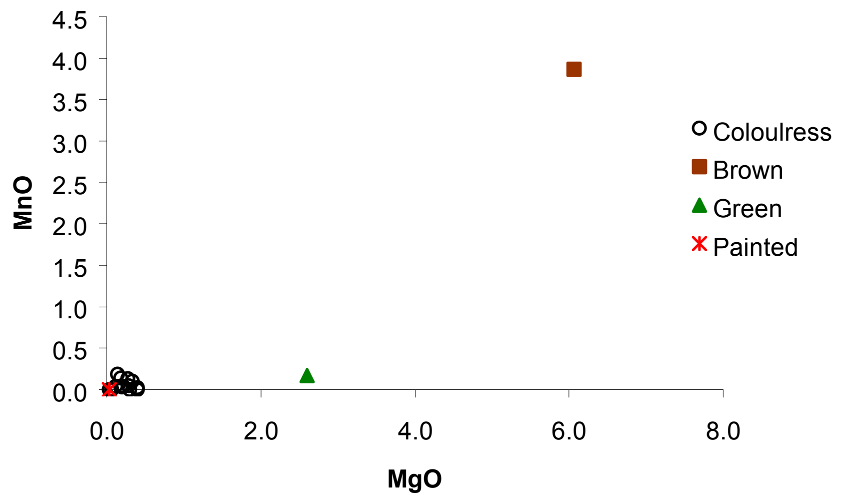


Figure 5: EDS results for MnO and MgO

The recipe given in Table 1 has been converted into the weights in kilograms of the oxides assumed in modern analysis of glass, and then into percentages (see Table 6). This composition can then be compared to the chemical data obtained by SEM-EDX (the last two columns in Table 6) which shows a good match, though with slightly more lime and less decolourisers than in the recipe.

Table 6: Nailsea glass recipe in kilograms and percent

	Kg	%	Average colourless glass	Normalised
SiO_2	14458.4	72.2	68.8	72.1
Na_2O	2667.9	13.3	13.0	13.6
CaO	2530.2	12.6	13.3	13.9
C	387.4	1.9		0.0
MnO	33.1	0.2	0.1	0.1
As_2O_3	76.2	0.4	0.2	0.2

Coloured glass

XRF analyses of the brown and green bottle glass fragments showed significantly higher magnesia, alumina and iron than in the colourless glass, with the brown glass also being high in manganese. The glass is also lower in arsenic. XRF suggested all the glass of the same colour had similar composition so only one sample of each colour was subjected to EDS analysis to determine if the colourless glass was used as a base glass or if they were of a separate composition (see data Table 4 and Table 15).

The EDS results show that the most significant shift in elemental composition, compared to the colourless glass, is both brown and green being higher in potash magnesia and iron. The brown glass also contains significantly more manganese and magnesia than the green (see Table 4 and Figure 5), confirming the results suggested by the XRF analysis.

Figure 6 shows the relationship between soda and potash in the glasses studied. As can be clearly seen there is a separation between the high soda/low potash colourless glass samples and the coloured glasses, which are slightly higher in potash and lower in soda. This suggests different sources of flux were used for the colourless and coloured glasses.

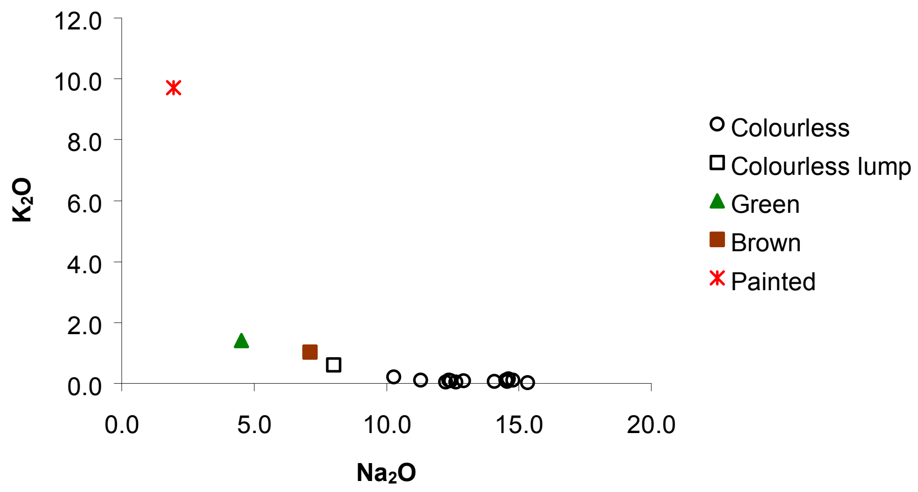


Figure 6: EDS results for soda and potash

Painted and blue glass

A single piece of colourless glass with a very thin layer of what appears to be red paint was examined. With the XRF and the EDS it was not possible to resolve a small enough area to determine the composition of the paint layer in cross-section, nor was it possible to determine its composition when surface analysis was undertaken due to its thinness. However the composition of the bulk glass was determined using EDS. As can be seen the painted glass is distinctly different from both the colourless and coloured glasses (*Figure 6: EDS results for soda and potash* Figure 6) as it is high in potash, suggesting another source for the flux. Examining the entire contents of the bag from 260 near building 802 only three further small pieces of this red-covered glass were found.

Three small pieces of blue glass were recovered but were not considered a significant product on site so only XRF was undertaken on one of them. As can be seen from the results of XRF on the surface of the blue glass (three areas on the sample piece of glass) the glass is heavily weathered resulting in low values for alkalis (soda and potash).

Table 7: Blue glass XRF values

Na_2O	3.7	3.8	3.4
Al_2O_3	2.8	2.8	2.9
SiO_2	81.6	81.1	81.0
SO_3	0.7	0.6	0.7
K_2O	0.5	0.5	0.6
CaO	10.1	10.5	10.7
MnO	<0.1	<0.1	<0.1
Fe_2O_3	0.2	0.2	0.2
CoO	0.2	0.2	0.2
Ni_2O_3	0.1	0.1	0.1
CuO	<0.1	<0.1	<0.1
ZnO	<0.1	<0.1	<0.1
As_2O_3	0.2	0.2	0.2
SrO	<0.1	<0.1	<0.1

Clay ring fragment

EDS was carried out on a polished section of the clay ring fragment (NG83e (3)-69) to determine the chemistry of the clay as well as the adhering glass. The ceramic was found, as expected, to be high in silica and alumina. The glass was found to be higher in alumina where it had interacted with the ceramic (Table 8).

Table 8 :EDS values of clay ring fragment and adhering glass

	Na_2O	MgO	Al_2O_3	SiO_2	K_2O	CaO	TiO_2	MnO	Fe_2O_3	As_2O_3	SrO	Total
Glass	10.3	0.1	4.1	69.7	0.3	11.9	0.1	0.1	0.5	0.1	0.4	97.4
Interaction	11.1	0.0	14.9	68.4	0.5	3.3	0.7	0.0	1.0	0.0	0.4	100.3
Ceramic	0.0	0.3	20.2	74.8	0.8	0.1	1.2	0.0	1.5	0.0	0.2	99.1

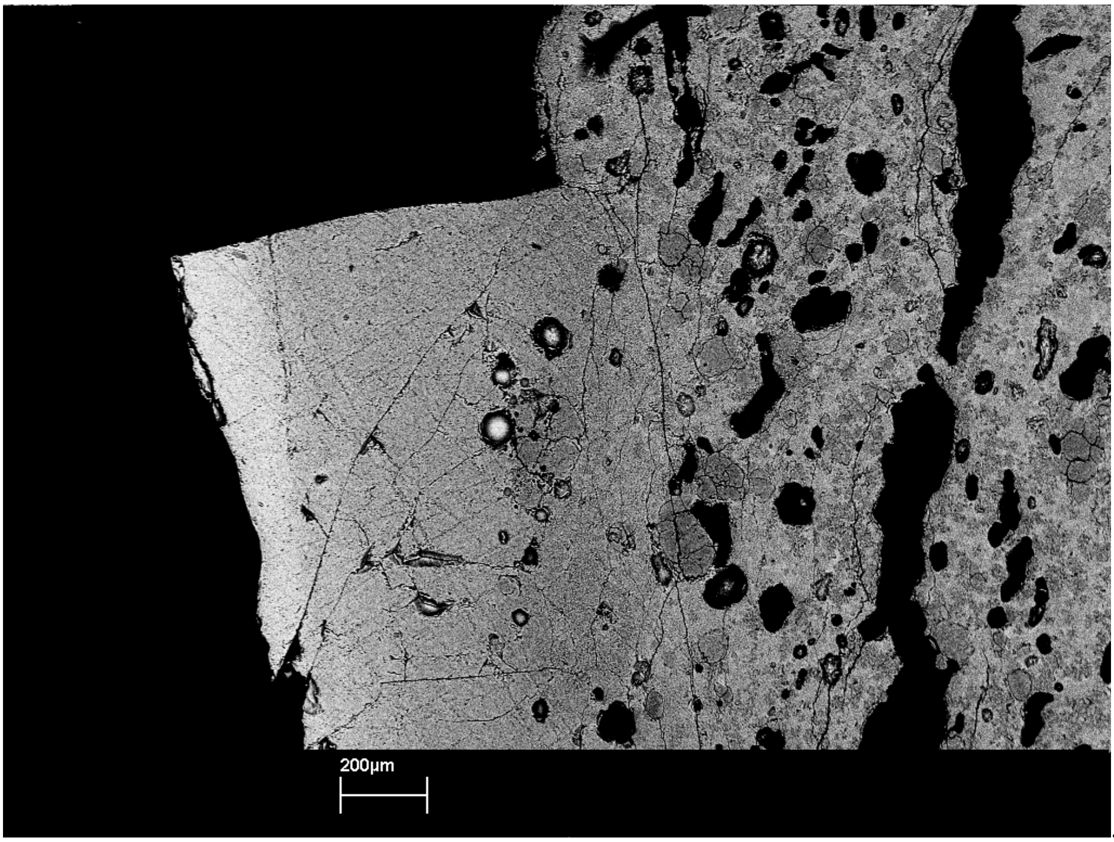


Figure 7: Backscatter electron image of a cross-section of the clay ring fragment. The black areas are voids.

Figure 7 shows the glass (paler on the left) adhering to the clay body (right, containing slightly darker grey quartz particles) with an interaction between the glass and the clay (areas with lower average atomic number look darker in backscatter electron images). The interaction causes a change in composition and therefore in backscatter contrast. The glass gets darker from left to right as lighter elements such as alumina are introduced into the glass from the ceramic by diffusion. It is likely that the composition of the glass is contaminated even at the edge by the clay-glass interaction due to the long time for which the gathering ring will have been subjected to high temperatures.

In light of these results, the possible drip adhering to a ceramic material found in when sieving sample [801] cone area (301) was re-examined. Under a binocular microscope the drip appears to be adhering to a mortar-like matrix that does not appear to have enough quartz grains to be of the same material that forms the clay ring. This was confirmed using XRF and dilute hydrochloric acid (the mortar fizzed). This drip was probably adhering to the furnace structure.

Conclusions

The analytical results show a tight clustering of compositions for the colourless glass. Because the samples were taken from two different cones and some taken from two different levels within the swing pit (on the west side of the New House Cone), it is likely that this lack of variation can be explained by the careful control of the raw materials used to produce the colourless glass. Though the majority of the glass working debris may only be from one main phase of operation of the site, the stratigraphic relation ships of samples A10 and A14 does show that there was little variation over the period of use of the swing pit. Unfortunately at the current time we do not know how long a period these layers represent. However, these layers have to be after the introduction of cylinder glass to Nailsea (late 1830s) as finds were from a swing pit, essential for the manufacture of cylinder glass. We can also suggest that the recipe shown in Table 1 could have been the one used to produce the glass at Nailsea which has been analysed (although it dates to 30 years earlier than the last use of the site) as we find only low potash levels and traces of arsenic in the colourless glasses.

There is not a lot of coloured glass recovered from the material studied but it does suggest a bias towards brown bottle glass. This is unlikely to be colourless glass (of the type analysed) with the addition of a colorant but the colorant does introduce high levels of manganese, magnesium and iron. There is no coloured glass waste in the assemblage, suggesting that these pieces of bottle glass were not made at Nailsea. Further, a bottle base, brown in colour, was found that has BRI… imprinted in the glass. This clearly came from Bristol and is of a similar composition to the brown glass analysed, which may therefore also have been made in Bristol.

The compositions found for the colourless glass are that of the glass produced at Nailsea as we have primary glass waste. These may be isolated to one period of production, but are more like to have been from at least two. The glass is characteristic in that it contains a significant amount of arsenic, suggesting that it was, indeed produced using the materials suggested in the recipe (see Table 1).

There is no evidence in this assemblage for the manufacture of ‘Nailsea type’ glass at Nailsea.

It is also clear from the waste that coal was used as the source of fuel, as was suggested by the documentary evidence and siting of the glass works.

Further work

If there are identifiable pieces of cylinder glass and crown glass from secure contexts it may be possible to determine the composition of the glass and say for certain whether there was a compositional change over time.

Bibliography

Burgoyne, I and Scoble, R 1983 *Two thousand years of flat glass making*. St Helens: Chalon Press limited.

Dungworth, D 2003 *Scientific examination of glass and glass working materials from Silkstone, Yorkshire*. Centre for Archaeology report 90/2003.

Parkin, R A 2000 *The window glass makers of St. Helens*. Sheffield: Society of Glass Technology

Thomas, M 1987 *The Nailsea glassworks*. Bristol: H G and M A Thomas.

Appendix

Table 9: Samples from box 5 NG83.

Box 5	NG86	Sample	Weight (g)	Comments
Bag				
5G	Ashy layer above brick floor area A above pit	2	270	Sieved and sorted (wet 270g)
5H	Soil and mortar from above brick floor area A	1	473	Fizz with HCl
5I	Ash or soot from hole 'drain' area C	3	286	Ash/coal ash
5P	A(10) area A sample of material from fill of pit	5	324	Stones/ash
5Q	A(10)	8	1662	Sieved and sorted (wet 500g)
5R	A(14)	9	1011	Sieved and sorted (wet 500g)
5T	Mortar from wall W9	4	430	Fizz with HCl

Table 10: Samples from NG86

Sample	Context	Plan No	Grid ref	Date		Level	Weight (g)	Comments
(SA04?) A	31	13	280(-)010	02/12/1986	DC		882	Nothing of interest
(SA03?) B	31	13	330(-)005	02/12/1986	DC		1168	Nothing of interest
SA11	45	19	290-010	22/01/1987	PB		299	Soil
SW Airway below context 18+26	27	4+8	004-008	18/10/1986	DMC		682	Compacted soil
SA23				29/05/1987	PB		153	Burnt coal
SA22				29/05/1987	PB		189	Coal/burnt coal
SA010	44	19	297-004	26/01/1987	PB		105	Soil
SW Airway bottom of fill cont. 18	26	4+8	004-008	18/06/1986	DMC		1172	Sieved and sorted (wet 500g)
SA06	31	13	330(-)005	08/12/1986	PB		652	Soil
	24	?		18/11/1986	PB		128	Soil
SA09	43	?	290-010	26/01/1987	PB		386	Soil
SA01	29	8	290-010	27/11/1986	PB	31-882	383	Sieved and sorted (wet 383g)
SA07	33	15	270-010	09/12/1986	PB		179	Soil
SA02	30	8	290-010	27/11/1986	PB		435	Sieved and sorted (wet 215g)
SA08	42	?	279-002	06/01/1987	PB		28	Soil/ash

Table 11: Samples from NG 88

Sample	Context	Date	Weight (g)	Comments
SA27	Channel beneath extant floor (south/west)	23/02/1988	2276	Sieved and sorted (wet 500g)
SA(25)	338 water channel mortar	10/02/1988	95	Fizz with HCl
SA26	Clay from within covered water channel	15/02/1988	233	Clay
SA24	Sample from mortar (wall by lifted floor)	12/01/1988	417	Fizz with HCl

Table 12: Samples collected from 1990's excavation

Sample No	Context	Weight (g)	Comments
801	Cone area (301)	2465	
801	Cone area (301)	2607	Sieved and sorted (big lumps removed dry 455g; wet 465g)
801	Cone area (301)	1980	
802	Near building 2	2824	Sieved and sorted (wet 500g)
	Building 2	3151	
	Cone area (304)	2708	Sieved and sorted (wet 500g)
	Sample (278)	173	
	Sample (348)	256	Sieved and sorted (wet 256g)

Table 13: Material analysed that was removed from the general bags of finds

Description	Context
Ceramic ring	NG 83c (3)-69
Curved glass	Bag 301 cone area
Glass lump	Bag 304 cone area
Curved glass	NG 83 A (14)-178
Crazed glass	NG 83 A (14)-200
Thick curved	NG 83 (10) 158
Curved thin	NG 83 (10) 184
Thick colourless with bubbles	NG 83 (10) 160
Thin colourless	NG 83 (10) 206
Thick curved	NG 83 (10) 164

Table 14: Breakdown of materials found by context (weight g)

	Waste from burning	CBM	Patterned window glass (red)	Colourless curved or flat glass	Colourless ridged glass	Glass waste	Runs drips and threads	Brown glass	Blue glass	Green glass	Other	Total
Cone area 301 #801 wet	101	17				61				<1		**179**
Cone area 301 #801 dry	152	10				72	8				1	**243**
Cone area 304	54	23		152		43	72				<1	**344**
260 Nr building 802	42	25	2	53	25	14	9	48	<1	61		**279**
NG 82 A (10) 8	78	3		344								**425**
NG 83 A (14) 9	22	18		205		211	7			1		**464**
278	53	19		5		54						**131**
348	125	10				6						**141**
SA 27	16	97		47		102	7				<1	**269**
SW Airway bottom of fill		83				8						**91**
SA02	61	4										**65**
SA01	18	1				72	1					**92**
Bag 5G	19	35				21				2		**77**
Total	**741**	**345**	**2**	**806**	**25**	**664**	**104**	**48**	**0**	**64**	**1**	**2800**

Table 15: EDS results

	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	K_2O	CaO	TiO_2	MnO	Fe_2O_3	NiO	ZnO	As_2O_3	SrO	
A (14) 200	12.0	0.1	0.5	67.1	0.3	0.6	0.0	12.7	0.1	0.0	0.2	0.0	0.0	0.0	0.2	94.0
A (14) 200	12.1	0.0	0.5	67.8	0.0	0.5	0.0	12.7	0.2	0.0	0.2	0.0	0.0	0.2	0.0	94.4
A (14) 200	12.6	0.1	0.6	68.2	0.2	0.6	0.1	12.9	0.1	0.0	0.3	0.0	0.1	0.3	0.1	96.0
Bag 301 cone area cylinder	17.6	0.4	0.7	70.0	0.0	0.7	0.0	12.6	0.1	0.0	0.3		0.0	0.2		102.6
Bag 301 cone area cylinder	17.6	0.3	0.6	70.0	0.1	0.6	0.1	12.5	0.1	0.0	0.3		0.0	0.0		102.1
Bag 301 cone area cylinder	14.1	0.2	0.6	66.9	0.2	0.6	0.0	12.7	0.1	0.1	0.2	0.0	0.0	0.5	0.3	96.4
Bag 301 cone area cylinder	13.8	0.1	0.5	66.8	0.3	0.7	0.0	12.6	0.0	0.0	0.2	0.1	0.0	0.2	0.2	95.6
Bag 301 cone area cylinder	13.6	0.1	0.6	66.8	0.2	0.7	0.0	12.6	0.0	0.1	0.3	0.0	0.1	0.4	0.2	95.7
Colourless drip 802 Nr building 260	10.5	0.3	1.0	68.3	0.1	0.6	0.2	15.0	0.2	0.1	0.3	0.0	0.0	0.2	0.0	96.9
Colourless drip 802 Nr building 260	10.1	0.1	1.1	69.3	0.2	0.5	0.2	15.3	0.1	0.0	0.3	0.0	0.0	0.4	0.0	97.7
Colourless drip 802 Nr building 260	10.2	0.2	1.2	68.7	0.1	0.6	0.2	15.2	0.1	0.0	0.3	0.0	0.1	0.2	0.1	97.2
Colourless lump 802 Nr building 260	8.1	0.3	1.6	67.3	0.1	0.9	0.6	19.2	0.1	0.0	0.4	0.0	0.0	0.4	0.1	99.3
Colourless lump 802 Nr building 260	7.7	0.3	1.5	66.4	0.1	0.8	0.6	19.0	0.0	0.0	0.4	0.0	0.1	0.3	0.3	97.4
Colourless lump 802 Nr building 260	8.2	0.3	1.5	66.5	0.1	0.8	0.6	19.0	0.1	0.0	0.4	0.0	0.0	0.4	0.3	98.3
Colourless ridge 802 Nr building 260	12.6	0.0	0.9	70.2	0.2	0.6	0.1	13.6	0.1	0.0	0.3	0.0	0.0	0.5	0.4	99.4
Colourless ridge 802 Nr building 260	12.5	0.1	0.8	71.2	0.1	0.6	0.1	13.7	0.0	0.0	0.3	0.0	0.1	0.5	0.3	100.2
Colourless ridge 802 Nr building 260	12.0	0.0	0.9	69.0	0.2	0.6	0.1	13.3	0.0	0.0	0.2	0.1	0.0	0.5	0.2	97.1
Mis shape bag 304 [cone area]	11.5	0.1	0.7	69.4	0.0	0.5	0.1	12.4	0.1	0.2	0.2	0.0	0.1	0.3	0.1	95.7
Mis shape bag 304 [cone area]	10.9	0.0	0.7	69.1	0.2	0.5	0.1	12.2	0.1	0.2	0.2	0.0	0.0	0.3	0.3	94.7
Mis shape bag 304 [cone area]	11.4	0.1	0.8	69.8	0.1	0.4	0.1	12.2	0.0	0.2	0.3	0.0	0.0	0.3	0.0	96.0
Mis shape bag 304 [cone area]	11.0	0.2	0.6	67.1	0.2	0.3	0.1	12.1	0.1	0.2	0.3	0.0	0.0	0.4	0.2	92.9
Mis shape bag 304 [cone area]	11.0	0.2	0.7	68.6	0.2	0.6	0.1	12.2	0.1	0.1	0.3	0.0	0.1	0.2	0.1	94.4
Mis shape bag 304 [cone area]	11.6	0.2	0.9	71.9	0.2	0.3	0.1	12.3	0.1	0.2	0.2	0.1	0.0	0.4	0.1	98.7
Mis shape bag 304 [cone area]	11.6	0.2	0.9	71.9	0.1	0.5	0.1	12.5	0.1	0.2	0.2	0.0	0.1	0.5	0.1	99.0
NG 83 A (10) 164	15.4	0.3	0.7	69.9	0.0	0.6	0.2	13.4	0.1	0.0	0.2		0.1	0.3		101.1

	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	K_2O	CaO	TiO_2	MnO	Fe_2O_3	NiO	ZnO	As_2O_3	SrO	
NG 83 A (10) 164	14.8	0.5	0.8	70.4	0.0	0.6	0.1	13.2	0.1	0.0	0.2		0.0	0.4		101.3
NG 83 A (10) 164	14.6	0.3	0.8	70.1	0.0	0.6	0.2	13.3	0.1	0.1	0.2		0.0	0.4		100.5
NG 83 A (10) 164	13.6	0.5	0.7	69.9	0.0	0.6	0.1	13.4	0.1	0.0	0.3		0.1	0.1		99.3
NG 83 A (10) 184	15.6	0.5	0.7	70.6	0.1	0.5	0.1	12.7	0.1	0.0	0.3		0.1	0.2		101.4
NG 83 A (10) 184	15.3	0.4	0.7	69.7	0.1	0.5	0.1	12.8	0.1	0.0	0.3		0.1	0.1		100.1
NG 83 A (10) 184	14.3	0.4	0.6	70.2	0.1	0.4	0.1	13.0	0.2	0.0	0.3		0.1	0.2		99.7
NG 83 A (10) 184	13.9	0.3	0.6	70.0	0.1	0.5	0.1	12.8	0.1	0.0	0.2		0.0	0.2		98.8
NG 83 A (10) 206	16.3	0.4	0.7	71.5	0.0	0.5	0.1	13.5	0.0	0.1	0.2		0.0	0.1		103.3
NG 83 A (10) 206	16.3	0.4	0.7	70.9	0.1	0.6	0.0	13.4	0.1	0.2	0.2		0.0	0.0		102.9
NG 83 A (10) 206	16.0	0.5	0.8	71.2	0.1	0.6	0.1	13.4	0.0	0.0	0.2		0.1	0.3		103.3
NG 83 A (10) 8 colourless glass	11.7	0.0	0.6	66.5	0.1	0.4	0.1	12.5	0.0	0.2	0.1	0.0	0.0	0.4	0.0	92.6
NG 83 A (10) 8 colourless glass	12.0	0.2	0.6	67.5	0.1	0.5	0.0	12.6	0.1	0.2	0.2	0.0	0.1	0.4	0.0	94.4
NG 83 A (10) 8 colourless glass	13.3	0.3	0.5	67.3	0.0	0.7	0.1	12.7	0.1	0.1	0.1	0.1	0.0	0.2	0.0	95.4
NG 83 A (10) 8 colourless glass	12.9	0.1	0.8	69.0	0.3	0.6	0.0	12.9	0.0	0.1	0.2	0.0	0.2	0.0	0.1	97.1
NG 83 A (10) 8 part of moil	12.8	0.1	0.6	67.7	0.0	0.5	0.0	13.0	0.0	0.1	0.2	0.0	0.1	0.0	0.0	95.1
NG 83 A (10) 8 part of moil	13.4	0.0	0.6	69.2	0.0	0.6	0.1	13.2	0.0	0.1	0.1	0.1	0.0	0.0	0.0	97.3
NG 83 A (10) 8 part of moil	12.4	0.2	0.7	67.9	0.2	0.5	0.1	13.1	0.0	0.1	0.1	0.2	0.1	0.0	0.0	95.6
NG 83 A (10) 8 part of moil	12.2	0.2	0.6	65.4	0.0	0.4	0.1	12.8	0.1	0.2	0.1	0.0	0.0	0.2	0.0	92.4
NG 83 A (10) 8 part of moil	13.8	0.4	0.6	69.0	0.1	0.5	0.1	13.0	0.1	0.2	0.2	0.0	0.0	0.1	0.0	98.2
NG 83 A (14) 177	15.6	0.4	0.7	70.5	0.0	0.5	0.1	13.3	0.1	0.0	0.2		0.1	0.3		101.8
NG 83 A (14) 177	15.8	0.4	0.9	70.2	0.0	0.6	0.1	13.4	0.0	0.1	0.2		0.0	0.2		101.9
NG 83 A (14) 177	14.8	0.3	0.7	70.1	0.1	0.5	0.1	13.3	0.1	0.1	0.2		0.0	0.1		100.3
NG 83 A (14) 177	14.7	0.5	0.7	70.1	0.0	0.5	0.1	13.3	0.1	0.1	0.2		0.0	0.0		100.4
NG 83 A (14) 177	12.7	0.1	0.7	70.3	0.2	0.4	0.1	12.9	0.1	0.0	0.2	0.0	0.0	0.2	0.2	98.2
NG 83 A (14) 177	13.4	0.0	0.7	72.8	0.0	0.4	0.1	13.3	0.1	0.0	0.2	0.0	0.0	0.3	0.0	101.3
NG 83 A (14) 200	12.0	0.2	0.6	64.9	0.1	0.4	0.1	12.1	0.1	0.1	0.2	0.0	0.0	0.1	0.1	90.9

	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	K_2O	CaO	TiO_2	MnO	Fe_2O_3	NiO	ZnO	As_2O_3	SrO	
NG 83 A (14) 200	16.0	0.4	0.9	71.4	0.0	0.6	0.0	13.3	0.2	0.1	0.3		0.0	0.1		103.4
NG 83 A (14) 200	15.7	0.4	0.8	71.1	0.1	0.6	0.1	13.2	0.2	0.1	0.2		0.0	0.3		102.7
NG 83 A (14) 9 colourless glass	12.5	0.0	0.7	65.5	0.0	0.6	0.0	12.3	0.2	0.1	0.1	0.0	0.1	0.1	0.0	92.1
NG 83 A (14) 9 colourless glass	12.7	0.3	0.5	65.6	0.1	0.6	0.1	12.5	0.1	0.0	0.1	0.0	0.1	0.0	0.0	92.6
NG 83 A (14) 9 colourless glass	12.0	0.0	0.5	65.9	0.1	0.6	0.1	12.5	0.1	0.0	0.3	0.0	0.1	0.2	0.0	92.6
NG 83 A (14) 9 colourless glass	11.9	0.2	0.6	66.5	0.0	0.4	0.1	12.5	0.2	0.0	0.1	0.0	0.0	0.4	0.0	93.0
NG 83 A (14) 9 colourless glass	13.0	0.1	0.7	67.0	0.0	0.4	0.1	12.3	0.2	0.1	0.2	0.1	0.1	0.1	0.0	94.3
NG 83 A (14) 9 glass drip	13.0	0.1	0.8	67.8	0.1	0.7	0.1	12.7	0.2	0.0	0.3	0.1	0.0	0.1	0.0	95.8
NG 83 A (14) 9 glass drip	12.6	0.4	0.7	67.9	0.1	0.7	0.0	13.0	0.1	0.2	0.2	0.0	0.1	0.4	0.1	96.4
NG 83 A (14) 9 glass drip	12.5	0.0	0.7	67.2	0.1	0.6	0.0	12.9	0.1	0.0	0.3	0.0	0.0	0.0	0.5	94.8
NG 83 A (14) 9 glass drip	12.4	0.3	0.7	68.3	0.0	0.5	0.0	12.8	0.2	0.0	0.1	0.1	0.2	0.1	0.0	95.5
NG 83 A (14) 9 glass drip	12.6	0.1	1.0	69.0	0.2	0.8	0.1	12.9	0.2	0.0	0.3	0.1	0.0	0.5	0.0	97.8
Painted	1.8	0.1	0.3	76.5	0.2	0.1	9.7	7.0	0.0	0.0	0.1	0.0	0.1	0.2	0.1	96.2
Painted	2.1	0.0	0.3	76.7	0.4	0.2	9.7	7.0	0.0	0.0	0.0	0.0	0.0	0.4	0.3	97.3
Painted	2.0	0.0	0.3	77.1	0.2	0.2	9.7	7.0	0.0	0.0	0.1	0.0	0.0	0.3	0.1	97.0
Green 802 Nr building 260	4.9	2.5	4.5	59.7	0.1	0.7	1.4	19.9	0.2	0.1	2.9	0.0	0.0	0.1	0.1	97.2
Green 802 Nr building 260	4.3	2.6	4.3	59.2	0.3	0.7	1.4	19.8	0.2	0.2	2.9	0.0	0.0	0.1	0.3	96.5
Green 802 Nr building 260	4.4	2.7	4.4	59.5	0.1	0.7	1.4	20.0	0.2	0.2	2.9	0.1	0.0	0.0	0.1	96.8
Brown 802 Nr building 260	7.1	6.2	3.7	56.1	0.2	0.6	1.0	16.5	0.1	3.9	2.1	0.0	0.0	0.1	0.3	98.1
Brown 802 Nr building 260	7.4	6.0	3.7	56.1	0.2	0.6	1.0	16.6	0.2	3.8	2.2	0.0	0.2	0.1	0.2	98.3
Brown 802 Nr building 260	6.6	5.9	3.6	56.0	0.1	0.6	1.1	16.4	0.2	3.9	2.1	0.0	0.1	0.3	0.1	96.8
Brown 802 Nr building 260	7.2	6.1	3.8	56.0	0.2	0.6	1.1	16.5	0.2	3.9	2.1	0.0	0.0	0.0	0.1	97.8
Brown 802 Nr building 260	7.2	6.1	3.8	56.0	0.1	0.6	1.0	16.5	0.2	3.9	2.1	0.0	0.0	0.1	0.2	98.0
Brown 802 Nr building 260	7.1	6.1	3.7	55.5	0.0	0.5	1.0	16.3	0.2	3.8	2.1	0.0	0.0	0.1	0.1	96.7

All values in this table represent an individual analysis. Blank portions of the table indicate that this element was not sought. A summary of these values can be found on page 77 (*Table 4*).

APPENDIX 8 - Francis Mountain's memoir

This is reproduced from a copy held in the SMR 2397 documentation, and also several copies exist in the archives. The name of the person who made the transcription is not known. Their statement that the original is in the Bristol Museum was checked, but could not be confirmed by the Museum staff.

"In 1915, at the age of 72, Francis Mountain wrote an account of his time at the Nailsea Glassworks. This paper is now in the Bristol Museum and I quote it below, in its entirety, as a first hand record of an industry and way of life which existed a century ago.

"HISTORY OF NAILSEA GLASSWORKS"
Written by Francis Mountain, one of the glassworkers, when seventy-two years -of age.

Nailsea Glass Works are about eight miles from Bristol, and one mile from Nailsea station. Three large cones were erected and furnaces built inside for melting the metal. The first house was on a smaller scale than the others and was named the Lily; it was the Plate house and only plate was made in it; the furnace held four pots only.

After the metal was melted it was taken by two men in ladles to a long table, some 30 or 40 feet in length; the metal was placed in front of the roller and drawn over by two men, the wheels working in cogs in the table. After the roller had passed over it, it was drawn on to a pair of wheels faced up with plaster of Paris and conveyed to the annealing kiln. When the kiln was full it was closed up for a little while until the metal was cool enough to handle and be taken to the warehouse. About four kilns were used in the Plate house.

The pots were made upon the premises with the best fire-clay from Stourbridge, and made by hand. When made and dried for a few months, they were taken to a pot arch and gradually heated until burnt very hard; they were then ready to be put into the furnace.

The bricks used for the crown of the furnace were obtained somewhere in Wales - these would not run but would glaze over so that not much could drip into the pots of metal.

The pots were about 5 feet in height, 3-4 inches in thickness and about 70 inches across from brim to brim. When empty in the furnace they are filled full up, then melted down, then after about six or eight hours filled again and melted down again.

The next house is called the Old House. Between fifty and sixty years ago, on account of the foundations being insecure, it was found necessary to take part of this cone down about half-way and re-build it again. This furnace would hold eight pots, and both Sheet and Crown glass were made in it.

The Crown glass is made on a different scale altogether from the Sheet glass. Sheet glass is swung and blown at the same time until it is the required length - it is made in cylinders; when cold it is split with a glazier's diamond and taken to the flattening kiln to be made flat by a man called the Flattener, it is then piled up in the kiln.

Crown glass is made in the shape of a plate with the bullion in the centre. About fifty years ago a patent to do away with the bullion was tried, but this proved a failure.

Fluted glass was also made at Nailsea, oval and round shades, jugs, decanters, fish-bowls, bottles and all kinds of fancy work. Cut glass was also made, then cut with sand and water and wheels worked with machinery.

Next we come to the New House - this had a large cone, capable of holding eight pots in the furnace. This furnace was from 30 to 40 feet in length and was fed with coal at each end when melting the metal was in process. It would take from 18 to 24 hours to melt the metal fit to be blown into glass. This was a sheet glass cone only, no other kind was made.

When the pots were broken they were taken out of the furnace by a large machine on two wheels, which would raise them up and draw them out of the furnace; new ones were put in their place by the same machine. Pots last from one to three months; sometimes a pot could be mended, that is to say, turned round, and black bottles melted and placed upon an angle of iron would repair it.

The furnaces were worked underground - caves leading from one end to the other. Bars of iron, from four to twelve in number, were also used to keep up the fire in the furnace.

Surrounding the cones there were in the yard sheds for crate-making, stables, saw-mill, roller crushers, warehouses, weigh-bridge, offices, etc. All goods were taken to Bristol by the well-known vehicle commonly called the Dilley. Salt-cake was also brought from Netham Chemical Works to Nailsea, likewise coke from Bristol Gasworks; sea-sand was brought from Portishead to Bristol, then by rail to Nailsea, then dried in kilns for use.

The number of kilns in use in the factory was about thirteen, with about five pot arches. There were about ten other furnaces used for heating before the metal was made into Sheet or Crown glass.

Some sixty or seventy years ago Alkali Works were carried on in Nailsea Glass Works for the manufacture of chemicals such as salt-cake, brimstone[57], acid and other things. About fifty years ago the high chemical stack at the Glass Works was thrown down by a man named Yendole, who undermined it with a pick, propped it up with wood, then set fire to it and down came the structure.

Some little distance from Nailsea Glass Works two large ponds were dug for the storage of water for the works. While digging operations were going on, a large spring of water was met with, also a large bed of valuable clay. This clay was taken to the Works, a Pottery was formed and built, and a gentleman named Paget was appointed to manage it. All kinds of articles were made, such as bricks, pipes, bends, plates, cups and saucers, and other things too numerous to mention. The work went on as long as the clay, of which there must have been several thousand tons, lasted.

About the year 1859 a fire broke out in the warehouses of the Works and did considerable damage; as they had to send to Bristol for fire-engines, the fire got a strong hold but no one was injured and no lives were lost; this was in the time of S. Bowen, Master.

About 1858 Sheet glass blowers came from France and Belgium to England, and came to Nailsea. This made no small stir but after coming to an understanding, they were allowed to start work with the English men of Nailsea as Sheet glass blowers. As regards their workmanship, it was not up to the standard of our Nailsea men. They went to live in some cottages near the Works, then called the French Row, and it is so called to the present day. When the war broke out in France they all left to fight for their country.

The ingredients for making Sheet, Crown and Plate glass were as follows:

> Burnt limestone from Clevedon, slaked and sifted fine for melting purposes.
> Salt-cake, once made at Nailsea, in later years from Netham Chemical Works.
> Charcoal
> Arsenic
> Sand from Portishead
> Cullet, or broken glass, all well mixed together.

Before the Frenchmen came most of the blowers were Nailsea men. Some of the best crown blowers were:- I. Knight, I. Barnet, H. Lester, T. Raybould

Sheet glass blowers:-	T. Gerrard	R. Pearless	C. Briant	I. Malcolm
Fluted Glass:-	F. Mountain	G. Mountain."		

[57] [Sulphur. AFS]

APPENDIX 9 - Frisbie's Furnace Feeder

Transcribed from the *Scientific American*, Vol. XXXV – No. 23 [New Series] December 2, 1876.

"IMPROVED FURNACE FEEDER

Years ago Dr Arnott taught us that the proper method was to light a fire from the top and let it burn downwards, consuming the gasses as they were evolved; and, in accordance with this view, he invented a domestic grate for charging at the bottom. Mr. Frisbie's patent feeder, represented in the annexed engraving, which we select from the pages of *Iron,* is designed to accomplish the same object in furnaces and the fire grates of steam boilers.

The accompanying engravings are longitudinal vertical sections, Fig. 1 showing the charging cylinder in a vertical position and with the piston raised; while Fig. 2 shows the cylinder brought back to an inclined position and filled, with the piston at the bottom. In place of the usual fire bars is a central aperture, surrounded by segmental gratings, which are easily removable, while the whole annular arrangement of grate bars runs on friction rollers, like a turntable, and may be rotated by means of a crowbar inserted in the holes for that purpose. Underneath the central aperture is hung the cylinder or hopper, swinging on pivots, and provided with a movable bottom or piston. This cylinder is supported by side plates working in bearings on the floor of the furnace, and, after being filled in the inclined position, is brought up to the vertical by one set of arms and crank pins on the crank shaft, taking into notches in links jointed to the supporting plates. The crank shaft is driven by means of the hand winch and bevel gearing, and when the cylinder has reached the full extent of its swing, which brings it directly underneath the central circular aperture, the crank pins leave the notches, and the links then rest upon the shaft, thus locking the hopper in a vertical position. By a continued turning of the winch handle, the crank of the shaft, which is provided with a friction roller, now comes into contact with another set of arms on the shaft, which raise the piston with its charge of fuel to the top of the cylinder, thus causing the fresh charge to displace the previous one (shown at Fig. 2 [Figure 3.33, below]), and propel it into the incandescent mass above. Turning the handle in the contrary direction has the effect of bringing the cylinder back to the inclined position, the crank pin of the first set of arms taking into the notches, and disengaging the links by raising them. A cast iron apron follows the cylinder up, so as to retain in its place the coal just charged into the furnace. The piston remains at the top of the cylinder until it has passed the opening in the center, when it is released by a catch coming in contact with a cross bar, and falls to the bottom of the cylinder, ready for a fresh charge of fuel.

It is claimed that, by this arrangement, the gases evolved from the coal cannot escape without being consumed; and so perfect is the combustion that nearly all the residuum forms a fine ash, which falls between the bars on their being moved round. Any clinker or incombustible substance contained in the fuel is continually lifted and loosened, and gradually carried to the circumference of the grate by the successive charges of fresh fuel forced up in the center, and may be removed from all portions of the grate by its being brought, in its revolution, opposite the fire hole door. Raking of the bars is entirely superseded, and the fire door need be opened only [on] rare occasions. Again, the stoker is completely protected from the violent heat, and has a much less laborious task than in hand stoking. There is no fear, as might at first be supposed, of the cylinder being melted by the heat; the fact is that it does not come in contact with the fire itself, but only with fresh coals. The draft through the grating also tends to keep the gear cool. We learn that there are already over thirty of the feeders now in use in Birmingham, England."

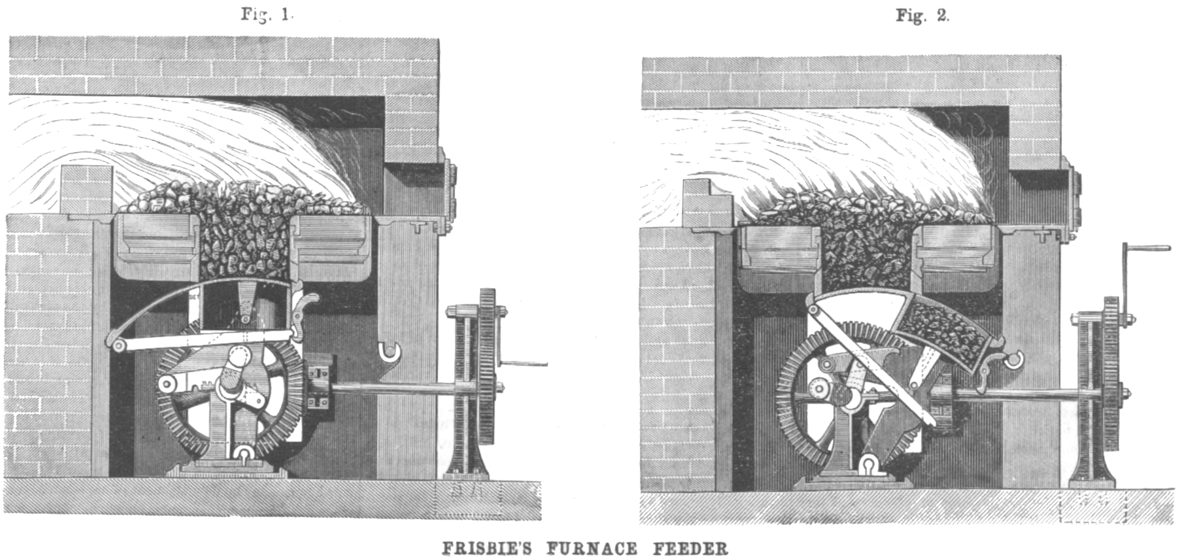


Figure 3.33: Frisbie's Furnace Feeder

APPENDIX 10 - John M Eyres' 1911 letter to H St George Gray

Subject: - Personal experiences in. Nailsea Glassworks

Source: - July 1911 letter from John M. Eyres to H. St. George Gray

"Having spent seven years of my youth[58] at the Nailsea Glass Works, in the packing rooms and office, I have naturally read your article in the June number of the 'Connoisseur' with great interest. Pray permit me to make a few remarks thereon. The large Cone, plate I, represents what we used to call the 'New' House, and to the right of it is the tall Warehouse in which the glass was cut, packed and stored. Further to the right again, in my early days, stood a very tall Chimney Stack, which became so dangerous that Mr Bowen had it thrown down. Then there were large Acid Chambers running parallel with the square in front of the Royal Oak Inn.

Nothing but sheet glass was ever made in the 'New' House whilst I was there, but, in the 'Old' House, which had a rather fuller-bodied cone and lay to the east of the New House, I saw, in the summer of 1862, many a red hot bulb whirled out into a Crown table before the 'flashing' furnace and placed with infinite care by skilful hands into an annealing kiln. I have never seen a more beautiful process anywhere than the manufacture of Crown Glass. The 'bull's eye', which I now see is being revived in modern glazing, is just the central spot of a Crown table from which the 'punty stick' was severed. I believe I am right in saying that after the Melting furnace of the Old House fell in, in September '62, no more Crown Glass was made at Nailsea during Mr Bowen's time. By October of that year the 'New' house had been got ready for making sheet glass only, and it was several years before the 'Old' house was again at work. When it resumed work, sheet glass only was made, until a little side furnace was built for one or two men to make fancy goods, such as propagators, cucumber glasses, rolling pins and glass shades.

Before work was resumed in the 'Old' house, the 'Lily' (the small Cone of which was still standing in 1907 when I paid the ruins a visit) was got ready for the purpose of making Rolled Plate Glass, a large quantity of which I remember consigning to Crewe, and other large railway

[58] 1862-1869 (Vincent, p.19)

stations, for roofing purposes. The ruins of another small house lay alongside the Lily, where, in former days glass was made, but what kind I could not say. I remember seeing specimens of plaited glass, similar to plate III, but never saw any made. Pipes, similar to those in plate 17, I have also seen but never witnessed the making of them. A Wagoner, from over Backwell Hill, must have heard something about them, for he came into the Works one day and asked one of the Teazers (stokers) if he thought he could find any 'Curiosity bacca pipes' among the cinders.

I never knew sand come from anywhere but Phippard's, at Wareham in Dorset, during my time there. A very decent old fellow used to bring limestone daily from Walton or Weston-in-Gordano, via Clevedon, and take 'breeze' (small coke) as back carriage, for burning in his kilns. I think his name was Shepstone.

Stonier's account of wages earned by the blowers does not tally with my experience. Of course he was there in the early '70s (seventies) with Chance Bros., so I cannot contradict him; but in '68 or '69, I had the making up of the men's wages book every Friday, and on Saturdays, to call out the amounts to the Cashier, as he paid the men; and my recollection is pretty clear that £4 to £4-10/- per week was about the highest wages the ([something omitted here]).

Saltcake was an important ingredient in the mixture of glass metal and that had to be fetched by the Dilly-men from the Netham Chemical Works, the further side of Bristol, after the men had delivered their loads of glass at the Quay or Railway Stations. The clay of which the huge melting pots were made came, invariably, from Stourbridge, but the making of them was done on the premises at Nailsea.

Working in such a fierce heat as the Blowers and Gatherers were obliged to, it is not to be wondered at that some of them developed an unquenchable thirst. They tried different modes of slaking it. 'The majority drank beer, when they could get it, but there were teetotallers, even in those days, who drank barley (or oat meal) water, and found it sustaining as well as refreshing. I can safely endorse what you say about snail eating on page 93, by English, as well as Frenchmen. As long as you get the right kind of snails, in dry condition, they are very palatable. I have eaten and enjoyed them myself, baked upon a shovel held for a few minutes at the mouth of a furnace, and taken from their shells with a two inch nail. If oysters, mussels and winkles, why not snails? On page 96 you mention James Kelly. If that is the Kelly who was there in my time he was an Irishman who came to mix metal for the coloured glass which Mr Bowen tried his hand at making - Kelly was the man who introduced the undulating-interlocking principle but, unfortunately, very few orders ever came in for those goods. He was a clever mixer, however, and would be very proud of getting you to hold pieces of his handiwork up to the light, when he would shew you what a 'foine Cathedral tint ' it was. I should have taken much more pains to educate myself in the mysteries of coloured glass, at the time, had I known then that I should, in later years, have the privilege of gazing up at the glorious windows of Exeter Cathedral, York Minster and other magnificent (?) up and down England and Scotland.

No. II plate, shewing the latticino glass, is very beautiful but none of that ever came within my ken during the time I was at Nailsea.

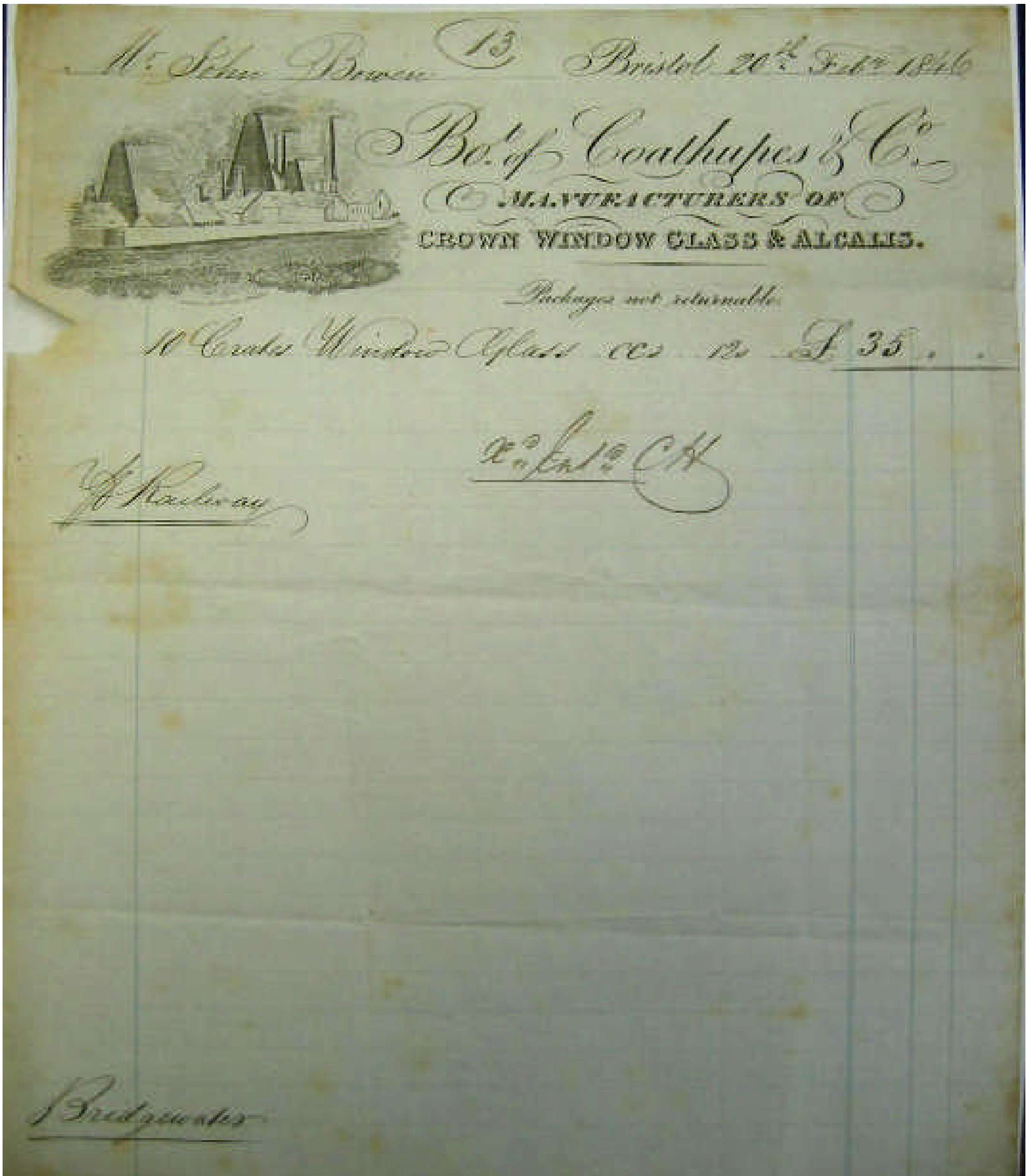
You do not describe those two little worm like objects in plate XII, but in my day, if you wanted to be initiated into the mysteries of glass making, either of the gatherers would be ready to oblige you. He would just gather a few ounces of melted glass at the end of a 'puntystick' and drop a portion of it into a kettle of water. When cold enough he would fish it up with his fingers and offer you the thick end of it, bidding you hold tight. As soon as he found you had a grasp of it, he would give the thin end a twist, when hey, presto; you would find yourself with a handful of glass dust after a loud explosion, with a sensation in your fingers and thumb which would last you for some time. [These were known as 'Prince Rupert's drops' after a cousin of King Charles II. He was a member of the Royal Society, where in 1661 there was a 'glass drop' experiment[59] as described by Eyres. The ones shown in Figure 3.34 are on display at Clevedon Court, and were photographed by courtesy of the National Trust.]

Figure 3.34: Prince Rupert's drops (approx 2 x actual size)

One French glass blower, only, Louis Amede, was at Nailsea during my time; tall-and ungainly but a good plain workman on sheet cylinders. He never attempted any 'fancy' blowing. There were three French flatteners, two brothers and a cousin, called Desguin. Emile and Jules were the brothers, but Jules went away, and the cousin Oliveur came to take his place. Emile, who was short of stature, spoke English capitally, and he and I struck up a close friendship - he had been in a Hussar Regiment and had fought against the Austrians at Montabello, where he received a sabre scar upon one of his wrists. Space forbids me to gossip any further about a subject which is very interesting to me but I hope to make your acquaintance some Saturday afternoon at Taunton, when I should like to pursue the matter still further should it suit your convenience to hold a conversation with me."

[59] Information from National Trust information sheet, Clevedon Court

APPENDIX 11 - Bill from Coathupes and Co. 20th February, 1846.



Mr John Brown (13) Bristol 20th Feb 1846

Bot. of Coathupes & Co.

MANUFACTURERS OF

CROWN WINDOW GLASS & ALCALIS.

Packages not returnable

10 Crates Window Glass CC 12 £ 35 . .

Bridgewater

Figure 3.35: Bill from Coathupes & Co., 20th February, 1846

APPENDIX 12 – Cones compared

Left:

Figure 3.36:Alloa, United Glass Limited

Built 1824, operated until 1973

Approximateley 15m internal diameter

Height about 27.4m*

Brick on Sandstone

8 openings, one of which is rectangular

Scheduled

Right:

Figure 3.37: Amblecote, Dial Glass Cone, Plowden & Thompson

Date stone says "1788", but probably established in 1704*

Brick construction

Left:

Figure 3.38: Bristol, Prewett Street

Dated to about 1780, but converted to hotel restaurant 1971*

Brick construction

*From Vose, pps.189 – 194

Left:

Figure 3.39: Catcliffe, nr Sheffield

"Dating from about 1740, is claimed to be the oldest surviving example of this type of structure in Europe" *

Archaeology showed it was in use to at least 1900*

Approximately 12m internal diameter

Height: 18.2m*

Brick on sandstone

Approx 6 major openings plus 'windows'

Believed to be 'listed'

Right:

Figure 3.40: Wordsley, Red House Cone

Viewed from the canal

Late 1700s to 1939*

Height:30.5m*

Visitor attraction with interpretative displays, etc, and reconstructed circular central 'furnace'

Brick construction

Now Grade II* listed

[Probably the nearest in size to the two major cones at Nailsea.]

*From Vose, pps.189 – 194