CURRENT RESEARCH ON ENGLISH GLASS FURNACES

Introduction

Between 1500 and 1750 three technical developments took place in the English glass industry: firstly, in the second half of the 16th century medieval methods were replaced by those of immigrant glass-makers from France, who used more efficient furnaces and made glass of better quality. Secondly, early in the 17th century wood was replaced by mineral fuels and, finally, in the decades around 1700, lead-crystal glass was introduced, made in furnaces which became more complex, particularly in their flue systems. Within this last development came the building of the great conical superstructures depicted by Diderot in the Encyclopédie. Over the last 20 years archaeological research has helped to clarify these changes, but much remains to be done, notably to provide more material for scientific examination, to explain changes in quality and durablility achieved by post-medieval glassmakers.

1. *Early-sixteenth-century furnaces and their products*

At the end of the middle ages a significant proportion of the window and green vessel glass sold in Britain was imported from France and Germany, while crystal glass came from Italy. English producers appear to have made poorer-quality glass, and little remained of the fourtoenth-century tradition of production in the forests of the Weald (Sussex and Surrey) or Staffordshire. Kenyon (1967, pp. 117-120) found that few glass-makers were still working in the Weald in the middle of the 16th century, but one Surrey glass works has been excavated from this period. This was at Knightons, Alfold (WOOD 1982), and was dated to about 1550. In Staffordshire, a furnace dated archaeo-magnetically to approximately 1535 has been excavated in Bagots Park in Needwood Forest (CROSSLEY 1967).

At Bagots Park the main furnace held six crucibles, and the crown win~ dow glass which was made was annealed in a separate furnace. The excavated glass was susceptible to surface weathering, to an extent which contrasts markedly with late 16th-century material. The earlier glasses have beeni shown to owe their poor weathering performance to relatively low percentages of silica (less then 66.7 molar per cent: NEwToN-DAv~soN 1989, p.~ 149). The furnace at Bagots Park appeared to have had a short life, for scum;` ("gall") had overflowed from the crucibles and choked the flue between the two sieges. Bagots Park represents the medieval English tradition, for although the final use of Knightons has becn dated to about 1550, before the major influx of French immigrants, methods there show signs of change.. The excavation recorded three phases, each marked by the base of a rectangular melting furnace of medieval type, containing six crucibles and producing window glass. The distinctive feature was an annealing furnace, structurally linked to the last melting furnace. As only outlines had survived, it was not possible to be certain of the relationship between the superstructures, but there is a possibility that fuel was saved by drawing heat from the main~ fire for annealing. Documentary evidence suggests that a French glass-maker made a brief attempt to work in this part of the Weald in

about 1550, and it is tempting to associate him with this furnace, for reasons which are explained below.

2. *The English glass industry alter the arrival of the French immigrants*

THE ORIGINS OF THE NEW METHODS

Many of the immigrant glass makers who were attracted to England after Jean Carré secured his patent to make glass in 1567 came from Lorraine, wEere it is known that complex furnace designs were used. Field exploration in Lorraine, without, so far as is known, any excavation, has shown that a furnace would comprise a central rectangular unit in which melting took place, and wings built at each corner for other stages of manufacture. It should be noted in passing that the 15th-century illustration of Bohemian practice, (KENYON 1967, pl.x) also shows annealing in the same structure as the melting furnace. Unfortunately, little information is yet available about the methods used in glass-houses in Normandy: many of the immigrant glassmakers reaching England late in the 16th century came from this region, and an important objective for current fieldwork in Normandy is to determine the form of furnaces and the quality of the glass.

IMMIGRANT-TYPE FURNACES IN ENGLAND

The early fieldworkers in the Weald, Winbolt and Kenyon, located furnaces with complex plans, and identified them with late-16th-century French glass-makers. The surface-finds of glass at these sites included vesselfragments in the forms and quality associated with the immigrants, and contrasting with medieval English glass by their unweathered surfaces.

An over-view of late-16th-century furnaces throughout England sLows that the four-winged plan should not be taken as a stereotype. Those at Buckholt, Hampshire (KENYON 1967, pp. 214-217), Woodchester, Gloucestershire (revision of DANIELS 1950), and Rosedale, Yorkshire (CRoss~EYAberg 1972) possessed this layout, but those at St Weonards, Herefordshire (BRIDGEWATER 1963) or Bishops Wood, Staffordshire (PAPE 1933-1934) appear to have been of simple rectangular plan. The furnace at Hutton, Yorkshire (CRoss~EY-AsERG 1972) developed from a plain rectangular plan to one with two wings.

The excavation at Rosedale (Fig. 1) has provided the most complete example of a winged furnace. The central melting furnace was conventional, with two sieges, each for one crucible, and a fire-trench between; a cover of clay was supported by stone arches, fragments of which remained. There had originally been four wings, but one had becn removed during the life of the furnace. On none of the three survivors were there indications of burning sufficient to suggest the setting of a fire, so it is assumed that heat was derived from the main furnace. In addition there were two separate annealing furnaces, but it was uncertain whether these had been built at the same time as the main furnace or afterwards: the removal of one of the wings might suggest tEat the annealing furnaces were secondary, to give more working space round the main furnace or more control over annealing. The quality of the vessel-glass found at Rosedale was excellent, and was the product of a welltried technology using suitable materials. Examination of the glass has

shown proportions of silica above what is regarded as the level significant for durability, and amounts of lime and magnesia were in a range also seen as significant in this respect (NEwToN-DAvIsoN 1989, pp. 141-148).

By contrast, at Hutton, only 10 km from Rosedale, another late-16thcentury furnace has becn excavated, where differences in methods and standards suggest that much is still to be learned about English regional glass makers at this time. At Hutton the melting furnace had been rebuilt twice. The first phase was of plain rectangular plan, but the two successors each had two wings placed diagonally opposite each other. One of the wings, in its final phase (Fig. 2), had been used with its own fire, shown by a thick layer of burnt clay. The glass found at Hutton was more affected by weathering than that from Rosedale, samples being relatively high in lime and magnesia but low in potash. There is no explanation for the difference in composition and quality between the glass from contemporary furnaces in the same locality.

There have been too few excavations of English forest-glass furnaces to give more than an impression of change and development over the half century from 1570. The lack of reliable archaeological evidence from the Weald, the documented centre of production nearest to London, poses a particular priority for future work. Overall, the industry changed, not just in scale, but in the quality of its products and the ability to sell glass at attractive prices, which rose less in the inflation of the 16th century than those of most industrial products. This was partly because of a reduction in the cost of transport, due to the use of glass-houses in dispersed parts of England, but also to efficiency in the use of fuel at a time when the price of wood was rising. These changes were probably cumulative, with steady prices ad good quality creating a market for window and vessel glass which in turn led glass-makers to move to new areas.

3. *The change to the use of mineral fael*

The use of coal as fuel for glass furnaces took place rapidly, in the decade after 1610. Furnaces had to be adapted to burn a fuel with a short flame, care had to be taken that sulphur in the coal did not affect the quality of the glass, and additional supplies of alkali had to be found to replace the wood-ash which the forest glass makers had collected from theTr fires.

The earliest coal-using furnaces were built on the south bank of the Thames, opposite the city of London, in or about 1611. A "wind-furnace" was in operation at Winchester House, Southwark, in that year and a furnace at Lambeth, making window glass, followed in 1613; neither have been located on the ground. In 1615 Robert Mansell, owner of the patent of monopoly to manufacture glass, attempted to reduce costs of production by setting up furnaces adjacent to coal deposits. He began in Nottinghmshire, at Wollaton (SMITH 1962), but transport costs to London were too great. The site of the glass-house is unknown, but there is a plan which shows a rectangular building which contained the furnace, but not the furnace itself. The second of Mansell's attempts took place at Kimmeridge, Dorset (CROSSEEY 1987). In 1615 he built a furnace to produce window glass, using the local oil-shale as a fuel. The shale proved troublesome, so Mansell made a third brief attempt, in west Wales, near Milford Haven, about which nothing is known. He eventually succceded on Tyneside, where his Newcastle glasshouse became a major producer, supplied with local coal and sending glass to London by cheap coastal shipping.

Newcastle remained a centre of glass production throngh the subsequent centuries, but it has not been possible to excavate a furnace site.

A second and more successful attempt to produce glass was made at Kimmeridge, by licencces under the Mansell patent. Vessel-glass manufacture was permitted in 1617, to supply south-west England, at first using the furnace abandoned by Mansell. A replacement was built in 1618, which lasted until 1623, when it was demolished after a legal dispute over the sale of Kimmeridge glass in London, This furnace has been excavated, and shows how the problems of the use of coal were overcome; the close dating is also helpful in illustrating types of vessel glass in production around 1620.

Superficially, the Kimmeridge plan (Fig. 3) was that of a winged forestglass furnace, with all stages of manufacture taking place in a single unit. It differed from tradition in having a fire at the centre of the furnace rather than one at each end. Air was drawn through a low-level passage which ran from beyond each pair of wings, each end being accessible by stone steps. The flues supplied air to the fire and provided a route for the removal of ash. They had been roofed over with vaulted stonework, and the floor formed at groundlevel had allowed the fire to be stoked. The central fire was necessary with mineral fuel, due to the short flame. The furnace lay within a rectangular building, whose proportions correspond with the plan of the Wollaton glasshouse.

The Kimmeridge excavation suggests that the "wind furnace" at Winchester House, Southwark, would have used a similar system for draught (Fig. 3). It clarifies features at three other early-17th-century furnaces. At Denton, Lancashire, excavations showed a furnace with a deep air passage, suggested by documents to date between c.1615 and 1653 (HURST VOSE, forthcoming). A brief excavation at Wolstanton, Staffordshire (Birmingham University Excavation Unit, unpublished), showed a similar design, dating from the middle of the 17th century. Most recently, in 1989, a 17th-century furnace has been excavated at Vauxhall, London, the results of which are awaited.

In the first half of the 17th century, glass made in England owed much to the traditions of the wood-fuel period. The Kimmeridge glass was essentially "waldglas" in appearance and in form. The colouring was still affected by the iron in the sand, and there seem to have been no attempts to use manganese as a decoloriser. One change was towards the production of small bottles, which were plentiful at Kimmeridge and appear in increasing quantities in contemporary contexts, a sign tUat falling costs of production were allowing more glass to be used for containers. Over the middle years of the 17th century, this change developed, and glass wine bottles became more common: by the 1660s the furnaces of Tyneside were producing bottles in large quantities.

4. *Seventeenth and eighteenth-century developments*

A significant problem is how and when there evolved the great conical superstructures which became common in the 18th-century glass industry. The first reference is to a cone built by Philip Roche in Dublin in 1694 (WESTROPP 1920, pp. 37-38); cones are shown on a view of Bristol dated 1710 (WITT-WEEDEN-SCHW1ND 1984, p. 19). The first excavated example, at Gawber, Yorkshire, dated from 1739-40 (ASHURST 1970). The earliest surviving cone stands not far distant, at Catcliffe, east of Sheffield, and was also built in 1740. It is not yet known whether the Dublin cone was a pioneer, or whether there were early examples elsewhere in Britain. Continental origins are

unlikely, for Diderot in his Encyclopédie names the cone “ la Verrerie Anglalse ”.

We are still short of archaeological evidence for the development of late17th-century furnaces, and the two sites so far excavated show no sign of the use of the cone. The first was an early furnace at Gawber; this was only a fragment, whose final use was archaco-magnetically dated to before the end of the 17th century. A more substantial survival is the recently-excavated furnace at Bolsterstone, Yorkshire (AsHuRsT 1987): the existing building is the earliest glass-house in Britain to remain essentially complete, although the wide arched entries on either side have subsequently been blocked. The above-ground parts of the furnace itself had becn destroyed, but excavation has shown the plan of the underground flues, and the relationship between the furnace and the standing building (Fig. 3). These were possibly in use in the second half of the 17th century, and definitely between about 1700 and 1740, when the glass-makers departed to Catcliffe, to build the cone which still survives.

Although the Bolsterstone glass-house was operated without a cone, it incorporated features which show a development of the layout recorded at Kimmeridge. As at Kimmeridge, a central fire was used, as were long belowground flues, bringing air from either side of the building. However, three further passages entered the centre of the furnace, from beneath the sieges. Two had provided extra air, and one of these also drained water from the flues. A third, entering the fire area above one of the side passages, showed signs of intense heating, and it has been argued that this was part of a regenerative system in which air in the furnace was recirculated through the fire. If this was indeed so, at Bolsterstone is the earliest known example of a technique common in several 19th-century industrial processes. Despite the survival of the glass-house building, work at Bolsterstone does notLing to solve the problem of the design of chimneys for melting furnaces of the pre-cone era: the building had becn re-roofed after the furnace went out of use. However, within this glass-house there were two annealing furnaces: although theTr bases had been removed, the chimney-flues remain in the wall o f the building, and are the first of the kind to be recorded.

Bolsterstone provides the earliest physical evidence for the use of domedtop crucibles with angled apertures, which could be sealed to the gathering holes in the sides of the furnace, hence isolating the contents of the pots from the atmosphere of the furnace interior. These were named "English pots" by the mid-18th-century French writer Bosc d'Antic (NEWTON 1987). The development comes after a period of uncertainty over whether or how crucibles were sealed. Until the Kimmeridge excavation it had been assumed that lidded pots would be used in the early coal-fired furnaces, to prevent contamination of glass by sulphur. In fact, no evidence for tLis practice was found there, but although analysis of Kimmeridge glass showed that sulphur was present, it was not at a level which would make grecn glasses difficult to produce. Problems were more likely to occur when producing clear "crystal" glasses, and Merret (1662, pp. 241, 246) notes a practice of "piling" pots, where a crucible was sealed by placing another on top of it. It is not known what form of sealing was used by Ravenscroft in the 1670s in his development of lead crystal, in which contamination with sulphur would be a serious matter. At Bolsterstone the sealed pots certainly appear to have been used for lead crystal, whereas traditional open crucibles were employed for bottle-glass.

Conical glasshouse superstructures bocame common in the 18th century. The reasons for the development appear to be twofold. The draught induced by the height of the cone

helped to remove smoke and fume from the gathering and worLing holes in the sides of furnaces. In addition, the draught in the melting furnace could be more easily regulated: contemporary illustrations, and the surviving cone at Catcliffe, show that most cones were provided with several base arches: although some of these led into surrounding buildings, others possessed doors opening to the exterior; these could be opened or closed to vary the proportion of draugEt passing through these openings or through the furnace air tunnels.

All the standing cones in Britain have had their interior features cleared and the floors concreted over. Therefore, information about underground air passages used in cones has come from excavation, notably the work carried out on the site of the Gawber cone, built in 1740. This furnace originally had two air passages, later supplemented with a third (Fig. 4). A brief excavation at Catcliffe (unpublished) located four air-passages.

Conclusion

This brief outline has shown that further work is required on two distinct topics; on the furnaces of the French immigrants in the latter part of the 16th century, and on the period of remarkable innovation at the end of the 17th century. On the first, it is important to relate the results of excavation and field-survey in England to the work now in progress in France, so that comparisons may be made between furnaces and glass in the areas where migrant glass makers originated and in those where they settled. Much larger samples of glass and of furnace-waste sbould be collected and examined than was possible at the time of the excavations of English 16th-century sites referred to above. On the second topic, there is more to be learned about the problems and achievements of the glass makers who developed the production of lead-crystal glass, to provide material for comparison with the glass from Bolsterstone. It must be emphasised that in the examination of glass-furnace sites of all periods, more resources should be devoted not just to the structures and to fragments of finished glass, but to material from all stages of manufacture. At present there is little archacological information about the initial preparation of material to be chargecI into the crucibles, namely the making of frit. Also, there are still many questions to be asked about the range of qualities of glass produced at a furnace and, in particular, how discarded glass compares in quality with the finished and saleable product.

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Bibliography

D. ASHURST, 1970, *Excavations at Gawber glassbouse near Barnsley Yorkshire*, " Post" Medieval Archaeol ", 4, pp. 92-140.

D. ASHURST, 1987, *Excavations at the 17th-18th-century glassbouse at Bolsterstone, Yorkshire*, " Post-Medieval Archaeol ", 21, pp. 147-226.

N. P. BRIDGEWATER, 1963, *Glasshouse Farm, St Weonards: a smallglass working*

site, " Transactions Woolhope Naturalists Field Club ", 37, pp. 300-315.

D. W. CROSSLEY, 1967, *Glass making at Bagots Park, Stuffordshire in the 1 6th century*, " Post-Medieval Archaeol ", 1, pp. 44-83.

D. W. CROSSEY, 1987, *Sir William Clavell's glassbouse at Kimmeridge, Dorset*, " Archaeol Journal ", 144, pp. 340-382.

D. W. CROSSEY and F. A. ABERG, 1972, *16th-century glass making in Yorkshire: excavations atfurnaces at Hutton and Rosedale*, " Post-Medieval Archacol ", 6, pp. 107-159.

J. S. DANIELS, 1950, *The Woodchester Glasshouse*, Gloucester.

E. S. GODFREY, 1975, *The Development of English glass making*, Oxford.

R. HURST VOSE, *Excavations at Denton glass furnace (forthcoming in Post-Medieval Archacol)*.

G. H. KENYON, 1967, *The Glass industry of the Weald*, (Leicester).

C. MERRET, 1662 (transl and ed), A. NERI, *The Art of Glass*.

R.G. NEWTON, 1987, *Who invented covered pois?,* "Glass Technology", 29.1, pp. 49-50. R.G. NEWTON and S.DAIDSON, 1989, *Conservation of Glass*, London.

S. PAPE, 1933-34, *Medieval glass-workers in North Staffordshire*, " Trans North Staffs Field Club ", 68, pp. 3-50.

R. S. SMITH, 1962, *Glass making at Wollaton in the early 17th century*, " Trans Thro~ ton Society ", 66, pp. 24-34.

M. S. D. WESTROPP, 1920, *Irish Glass*.

C. WITT, C. WEEDEN and A. P. SCHWEND, 1984, *Bristol Glass*, Bristol.

E. S. WOOD, 1982, *A 16th-century glasshouse at Knightons, Alfold, Surrey*, " Surrey Archaeol Collections ", 73, pp. 1-46.