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].