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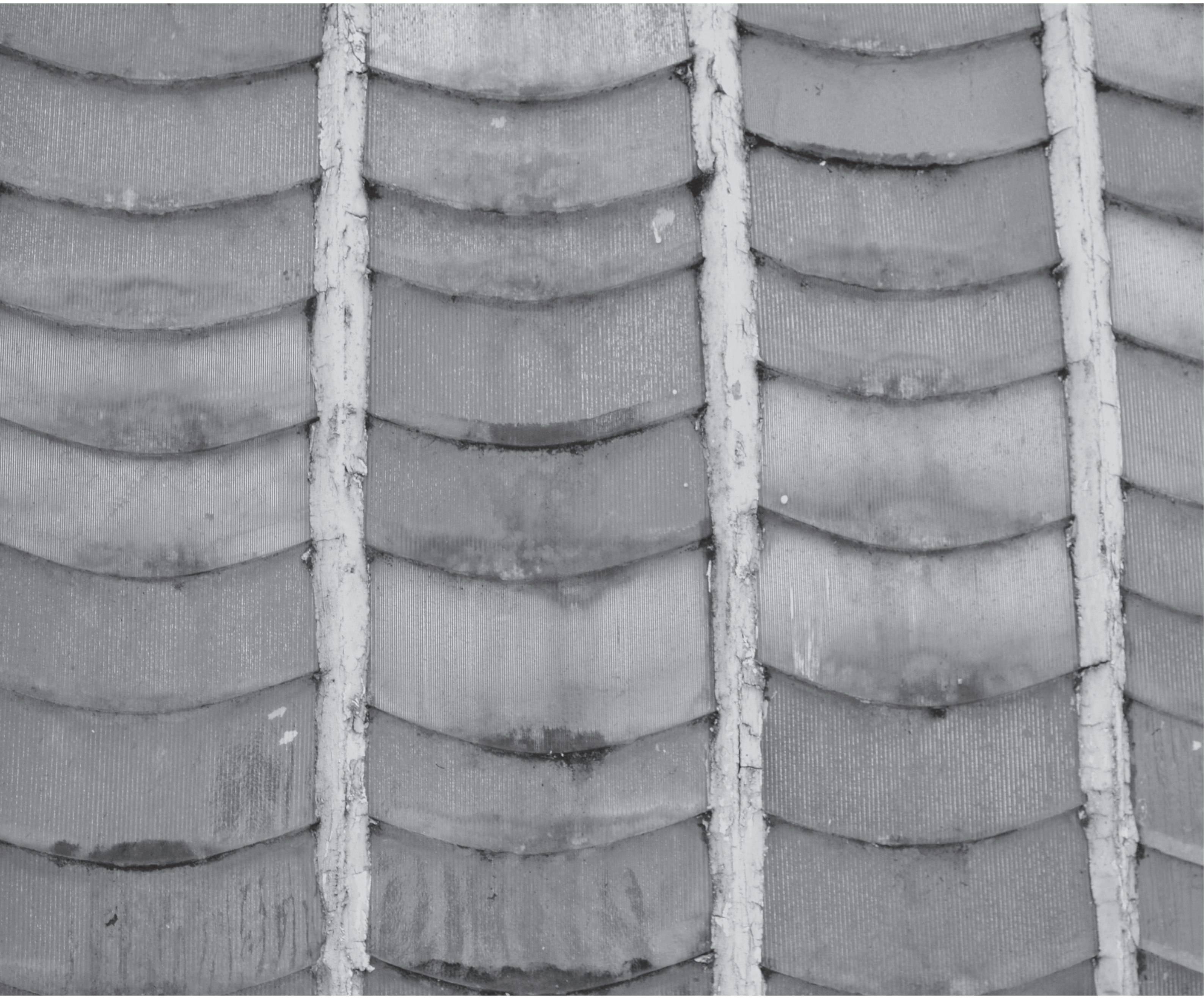
FELTON PARK HALL GREENHOUSE, FELTON, NORTHUMBERLAND
CHEMICAL ANALYSIS OF WINDOW GLASS

TECHNOLOGY REPORT

Vanessa Castagnino



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Chemical Analysis of Window Glass

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SUMMARY
In an attempt to confirm the date of construction, chemical analysis of window glass at the Grade II* greenhouse at Felton Park Hall, Northumberland was undertaken. The analysis provides information on the glass composition and subsequently gives a manufacturing date range. The resulting data shows several glazing phases, much related to the advancement in horticultural knowledge. Although to a great extent the glass analysed is chemically similar, it is the manufacturing techniques which in this case significantly changes the date of glass production, and consequently the construction date of the greenhouse.

ACKNOWLEDGEMENTS
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INTRODUCTION

Greenhouses were often a feature of estates in 19th–century England. They were large, imposing structures of iron and glass with which to impress; a perfect reflection of the Age and the technologies that accompanied it (Kohlmaier 1991, 1). Furthermore the experimentation with the greenhouse, otherwise known as ferrovitreous architecture, led to design innovations in load-bearing constructions (Kohlmaier 1991, 4). Up until this period, panes of glass were of a small size — the manufacture of larger panes was not successful using the crown glass method. The largest crown disc of glass being produced by the most skilled of glassworkers was approximately 1.5m in diameter, producing a maximum pane size of 0.6m square (Barker 1960, 51). These panes did not allow adequate sunlight through, whilst protecting the plants from heat damage (McGrath and Frost 1937, 115). Even with the introduction of the Leblanc process for soda glass in the mid-1830s and the return to the blown cylinder glass process, the fabrication of large window panes was still a difficulty (Douglas and Frank 1970, 150). The combination of the architectural feat of greenhouse construction and the need for a glass suitable for the purpose, together with the abandonment of glass duty in 1845, enabled and promoted experimentation with cast plate glass production headed by Hartley's in the 1840s (Douglas and Frank 1970, 150). Specific horticultural glass was manufacture and patented in 1847, it had a ribbed surface and the design diffused the light, reducing damage to the vegetation underneath it (McGrath and Frost 1937, 116–18).

Figure 1. Felton Park Hall Greenhouse.

To the east of Felton Park Hall stands a lean-to cast and wrought iron greenhouse (Fig 1) with a potting shed that incorporates an 18th-century garden wall. The greenhouse, considered to have been constructed *c*1830, displays a 'curved pent roof and fish scale glazing' (Pevsner and Richards 1972, 281). English Heritage, as part of the 'Building at Risk' remit (list no: 1154561), offered a grant for a series of investigative works and appropriate repairs. It was hoped that the chemical analysis of glass samples would give a fixed date for the glass composition if not the construction of the greenhouse. In addition, such analysis may provide additional information such as identifying repairs or replacement panes in the structure.

THE GLASS

Initially five different fragments of ribbed and textured window glass from the unoccupied glasshouse of *c*1830 at Felton Park Hall, Northumberland were submitted for analysis (batch 1). The fragments were removed from the greenhouse and a random selection was made by architectural investigators from Spence and Dower LLP. None of the five samples were complete panes and were either broken for the purpose or when recovered. Visually the samples looked different in terms of thickness, colour and surface appearance.

Figure 2. The west end of the greenhouse, comprising of an iron door complete with fish scale glazing. This can also been seen in the panel about the door. The glass in this end wall varies in thickness and chemical composition, and hence manufacturing dates.

The analysis of the first five samples submitted for analysis and subsequent discussion prompted a request for further glass analysis by the firm of Spence and Dower LLP. The author made a site visit to collect additional samples (with the agreement of both architects and the owner of Felton Park Hall, Mr Tim Maxwell). These fragments (batch 2) were sampled from all aspects of the building (10), in addition to the central glassed wall (2) and the internal floor of the greenhouse (9).

METHODS

In advance of sectioning, glass fragments were examined visually for thickness, tint and clarity. The samples were then examined using an optical microscope for corrosion and manufacturing defects, then the thickness was measured and the fragment photographed.

The glass was compared with examples illustrated in McGrath and Frost (1937); however, this was written over a century after the likely construction of the greenhouse and 90 years so after rolled glass was first patented. The nature of rolled glass may have changed through the 19th century but the subject has not yet been examined in sufficient detail. Hartley's of Sunderland were a major manufacturer between 1836 and 1894 (Barker 1960) and are a likely source of glass for Felton. Unfortunately, samples of Hartley's glass are not included in McGrath and Frost (1937) but only because they had by then ceased trading.

Small samples (1–2mm) from all five different pieces of window glass provided (batch 1) were taken from all the sections of glass and were mounted in epoxy resin before being ground and polished to a 1-micron finish. The samples were inspected for corrosion using an optical microscope and none was found. The samples were analysed using quantitative EDXRF to determine their chemical composition. EDXRF is a rapid technique that can be utilised to spot-check the identifications. The EDXRF is an Eagle II, which targets an area of approximately 4.5mm across, using a tube voltage of 40kV and 1mA. Data was gathered at a live time of 500 seconds to enable a full range of elements to be detected. The EDXRF can detect elements such as calcium, lead, silica and zinc, but cannot detect light elements, such as fluorine or carbon. It does provide improved sensitivity and accuracy for some of the minor elements, in particular iron, arsenic, manganese and strontium (Table 1).

The elements sought using EDXRF were Mn, Fe, As, Rb, Sr, Zr, Sn, Sb and Pb. Strontium (Sr) and arsenic (As) were especially sought after as both of these elements are important in establishing an accurate date range for the glass. Major consideration was given to those elements which give overlapping peaks. The data produced was compared to a range of certified standards of archaeological reference glass (Corning, NIST, DGG and others).

The batch 1 samples were also analysed using a scanning electron microscope with an EDS attachment. The SEM used was a FEI Inspect F which was operated at 25kV with a beam current of approximately 1nA. The x-ray spectra generated by the electron beam were detected using an Oxford Instruments X-act SDD detector. In advance of the analysis, the EDS spectra were calibrated using a cobalt standard. The data was quantified using the Oxford Instruments INCA software.

Table 1. Minimum Detection limits (MDL) and analytical errors for each oxide

	SEM-EDS			EDXRF	
	MDL	Error		MDL	Error
Na_2O	0.1	0.1	V_2O_5	0.02	0.03
MgO	0.1	0.1	Cr_2O_3	0.02	0.03
Al_2O_3	0.1	0.1	NiO	0.02	0.03
SiO_2	0.5	0.2	MnO	0.02	0.03
P_2O_5	0.2	0.1	Fe_2O_3	0.02	0.03
SO_3	0.2	0.1	CoO	0.02	0.02
Cl	0.1	0.1	CuO	0.02	0.01
K_2O	0.1	0.1	ZnO	0.02	0.01
CaO	0.1	0.1	As_2O_3	0.0`	0.01
TiO_2	0.1	0.1	SnO_2	0.1	0.05
BaO	0.2	0.1	Sb_2O_5	0.01	0.005
			Rb_2O	0.01	0.005
			SrO	0.01	0.005
			ZrO_2	0.01	0.002
			PbO	0.05	0.02

SEM-EDS is often more sensitive in detecting light elements (*eg* Na, Mg, Al and Si), whereas it is easier to detect heavier elements with the EDXRF. Nevertheless quantification of heavy elements is often better with SEM-EDS, if the element is readily abundant (pers comm D Dungworth). Three target areas were analysed and an overall compositional average taken for each sample using both methods of analysis.

The batch 2 samples were analysed using EDXRF alone to determine the presence and proportions of only selected oxides (*eg* MnO, Fe_2O_3, As_2O_3 and SrO).

RESULTS

Visual examination

The five samples in batch 1 were all rolled glass (Fig3).

Felton 1: 54 x 42 x 4.5mm. A rolled glass sample with a pale purple hue (Fig 3). Known as 'Plain Rolled', 'Ribbed Rolled' or 'Hartley's Rolled'. Manufactured in three thicknesses, this fragment is similar to the second category of thickness: 4.8–5.5mm. The pattern displays a fine fluted appearance: parallel ribs (19 to the inch), therefore ensuring considerable light diffusion of 80% plus. Manufactured by both Pilkington Brothers Limited of St Helen's and Chance Brothers and Co Ltd of Smethwick, Birmingham (McGrath and Frost 1937, 573)

Felton 2: 62 x 61 x 3.95mm. This fragment is of rolled glass is approximately 4mm thick and is similar to the first category of thickness: 3.4–3.8mm. The pattern is similar to No2 Fluted rolled glass produced by Pilkington Brothers Limited, St Helen's and Chance

Brothers and Co Ltd of Smethwick, Birmingham. This pattern displayed parallel flutes (11 to an inch), giving an 80% light diffusion. (McGrath and Frost 1937, 574) The fragment has a pale green tint, though colour is not noted in the production catalogue.

Felton 3: 100 x 72 x 4.3mm. This sample is similar in thickness to Felton 1, a rolled glass sample but of a different tint: pale green. This is a finer, but slightly thicker polished rolled glass, with rough under surface that differs dramatically from the other 4 fragments.

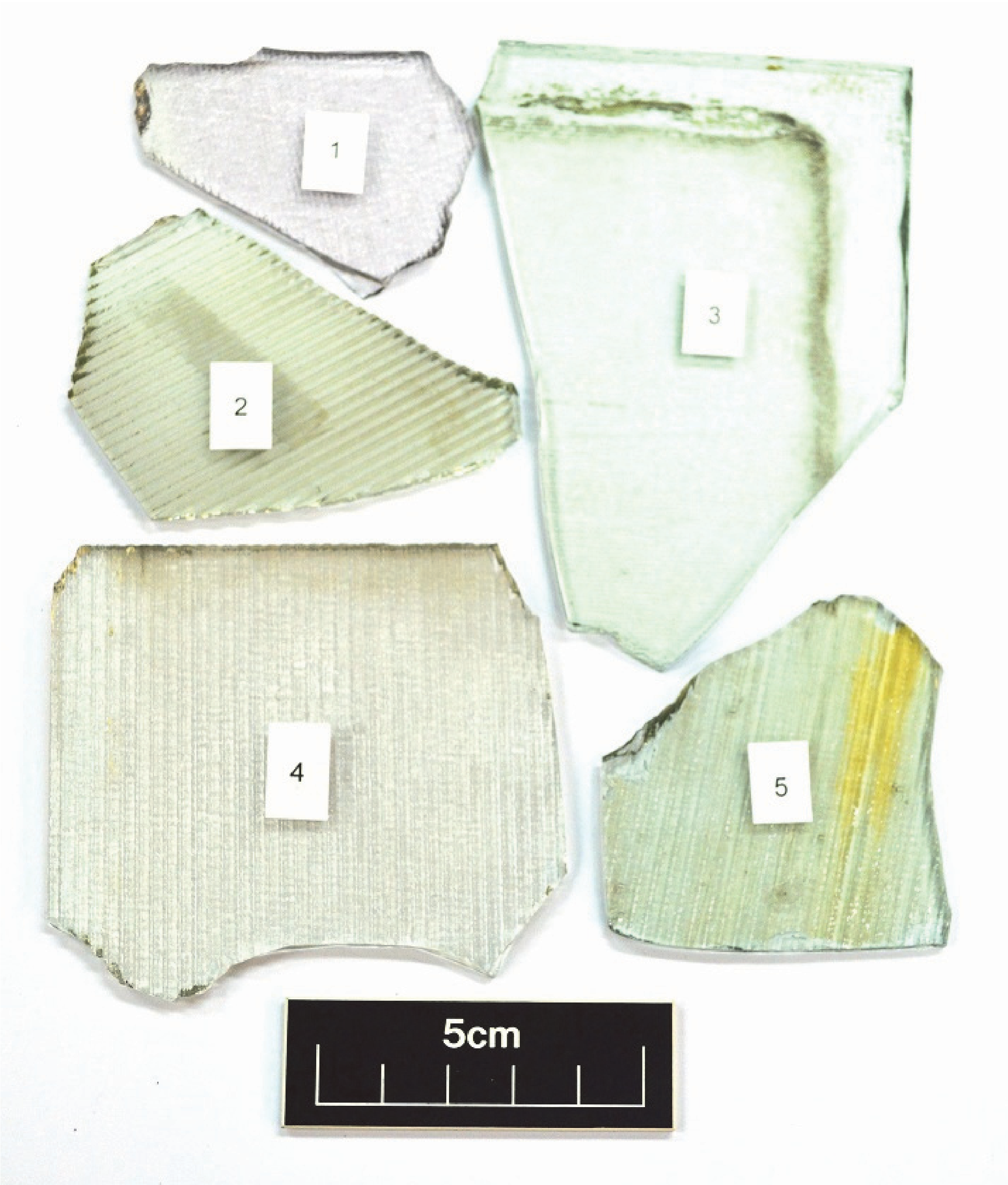

Figure 3. Selection of window glass from Felton Park Hall greenhouse (Batch 1).

Felton 4: 81 x 88 x 3.8mm. A clear rolled glass of approximately 4mm in thickness. The pattern is comparable to No2 Fluted rolled glass produced by Pilkington Brothers Limited, St Helen's and Chance Brothers and Co Ltd of Smethwick, Birmingham. This pattern displayed parallel flutes (11 to an inch), giving an 80% light diffusion. Though this sample is of clear white glass, it is otherwise almost identical in physical properties to sample 2 in every respect. This type of glass was manufactured in one thickness, 4.4–4.8mm, and this fragment's thickness does not conform. It was an all-purpose glass without particular usage (McGrath and Frost 1937, 574).

Felton 5: 81 x 88 x 3.5mm. The sample is almost identical to Felton 2 and also of comparable with Pilkington's No2 Fluted Rolled glass. However the discrepancy lies in its thickness and tint. The thickness of this sample is a little over 3mm compared to the standard 4.4–4.8mm produced by these manufacturers. The pattern is consistent with No2 Fluted rolled glass produced by Pilkington Brothers Limited, St Helen's and Chance Brothers and Co Ltd of Smethwick, Birmingham (McGrath and Frost 1937, 574). This sample has a pale green tint.

Table 2. Details of the batch 2 samples

		Distortion			Thickness (mm)	
#	Location	Reflected	Transmitted	Other defects	min	max
1	Central partition	Yes	Yes	Ream and dimples	1.8	2.5
2	Central partition	Yes	Yes	Ream and dimples	1.7	2.3
3	East End	No	Slight	None	2.0	2.0
4	East End	?	No	Iridescent surface	2.6	2.6
5	East End	Yes	Slight	Dimples	2.8	3.1
6	East End	Yes	Slight	Dimples	2.8	3.0
7	East End	Yes	Yes	Ream and dimples	2.7	3.0
8	West End	Yes	Slight	Dimples	2.0	2.2
9	West End	Yes	Slight	Dimples	1.8	2.1
10	West End	Yes	Slight	Dimples	3.3	3.6
11	South East	Slight	Slight	Ream?	1.8	2.0
12	South East	?	?	Iridescent surface	1.6	1.7
13	Unknown	Slight	Slight	None	1.9	2.1
14	Unknown	?	?	Iridescent surface	2.6	2.7
15	Unknown	Yes	Yes	Ream and dimples	2.0	2.2
16	Unknown	?	?	Iridescent surface	2.6	2.7
17	Unknown	Yes	No	Iridescent surface	2.6	2.7
18	Unknown	?	?	Iridescent surface	2.4	2.4
19	Unknown	?	?	Iridescent surface	2.5	2.6
20	Unknown	?	?	Iridescent surface	2.6	2.6
21	Unknown	No	No	None	2.0	2.0

Batch 2 consisted of 21 samples, containing only plain flat glass, without colour or texture, from each area of the greenhouse: both east and west end glass walls (Figure 2), the south-east and south-west windows (Figure 1) and the central dividing glass wall (Figure 8). The samples ranged in thickness from 1.6mm to 3.6mm with some variation in thickness discernible in most samples. Many of the samples provided distorted images when objects were viewed either through the glass or when reflected off the surface of the glass. Such distortions are common-place in most glass made before the development of the float process *c*1960. Several samples also displayed ream (heterogeneity to the glass) and/or cord (similar to ream but standing proud of the surface of the glass). In addition, some samples have small (<1mm) dimples on one surface which may possibly arise during the flattening cylinder glass. Many of the samples recovered from the floor of the greenhouse had iridescent surfaces (due to the chemical deterioration of the glass) and these obscured both transmitted and reflected images.

Chemical Analysis

The five samples of glass from batch 1 are all soda-lime-silica glasses (Table 3); these three oxides account for 95–98wt% of the glass. The batch 1 glass samples also contain a range of minor and trace oxides, some of which were probably present as impurities in the raw materials *eg* alumina (Al_2O_3) and iron oxide (Fe_2O_3) while others may have been deliberate additions to add refining or affect the colour of the glass, *eg* manganese oxide (MnO) and arsenic oxide (As_2O_3).

Table 3. Average chemical composition of the greenhouse window glass at Felton Park Hall (Batch 1, selected results, see Appendix for full results).

#	Na_2O	Al_2O_3	SiO_2	SO_3	K_2O	CaO	MnO	Fe_2O_3	As_2O_3	SrO
1	11.0	1.55	70.0	0.61	0.54	14.0	0.50	0.36	0.05	0.02
2	10.9	0.75	72.0	0.67	0.21	14.3	0.46	0.37	0.05	0.03
3	11.3	0.90	73.0	0.48	0.31	12.5	0.40	0.40	0.55	0.02
4	11.4	1.40	72.0	0.53	0.58	13.0	0.06	0.25	0.63	<0.01
5	12.1	1.13	71.5	0.49	0.29	13.0	0.47	0.33	0.09	0.02

The available data from the 21 samples of glass from batch 2 (see Appendix) suggests that these are all soda-lime-silica glasses — the levels of strontium and iron are lower than would be expected for plant ash glasses. Some of the batch 2 samples contain manganese (presumably used to decolourise the glass) and one contains arsenic (probably used to refine and/or decolourise the glass).

DISCUSSION

Glass from Felton has been examined and analysed to determine the likely period(s) of manufacture to provide information to assist with the conservation of the greenhouse. Dating glass can be achieved through both a consideration of its chemical composition and its form (and how the latter is affected by manufacturing techniques).

Prior to the introduction of synthetic sodium carbonate (Na_2CO_3) as a flux (*c*1830), plant ash was used in the form of the ashes of terrestrial and marine plants (Angus-Butterworth 1948, 26–7). There is little to no phosphorous (P_2O_5) or strontium (SrO) detected (see appendix) in any of the samples provided hence none of this glass had a plant ash component; all the glass was produced after the early 1830s (cf Dungworth 2009, 7). From the data it can be assumed that the glass fragments provided are contemporary with or later than the given construction date of the greenhouse (*c*1830).

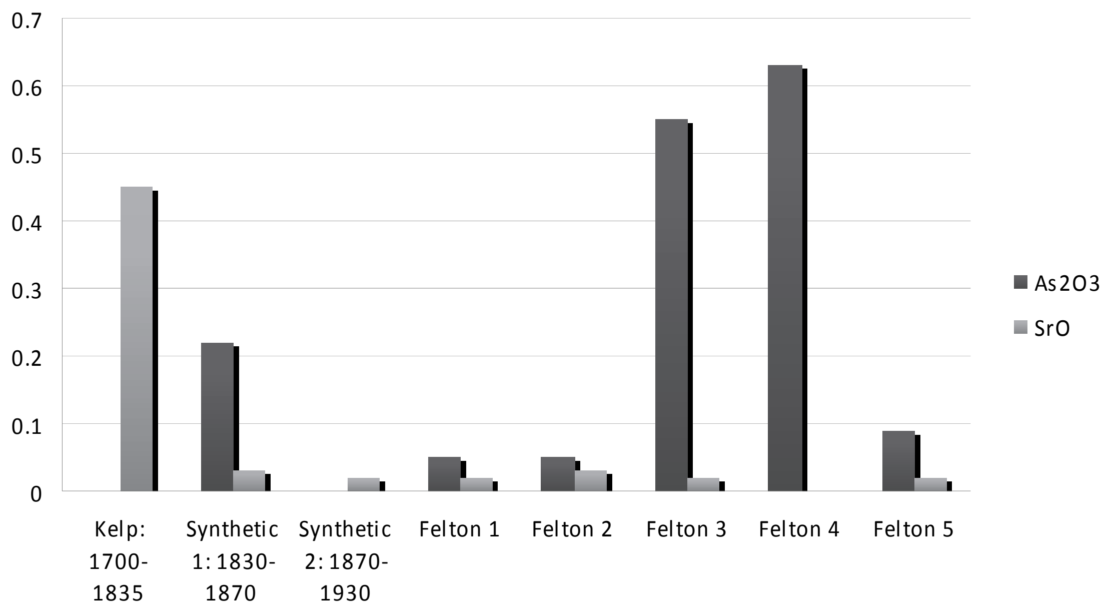

Figure 4. The strontium and arsenic composition of Felton Park Hall greenhouse window glass (batch 1). The low levels of strontium in the five samples analysed confirms that the window glass was not of 'kelp' composition of the early 1830s (and earlier).

Arsenic was present in relatively high concentrations in both Felton 3 and 4 (0.55wt% and 0.63% respectively — see Figure 4). Arsenic was used as a decolouriser and refining agent from the 1830s to the 1870s (Dungworth 2010, 6). From the 1870s arsenic ceased to be used, hence is not detected or detected as a trace element in window glass after this period. It has been noted that from the 1870s there is a small but significant increase in the potassium content, another refining agent (Dungworth 2011, 40). The glass composition of samples 3 and 4 suggests manufacture in the period *c*1830–*c*1870.

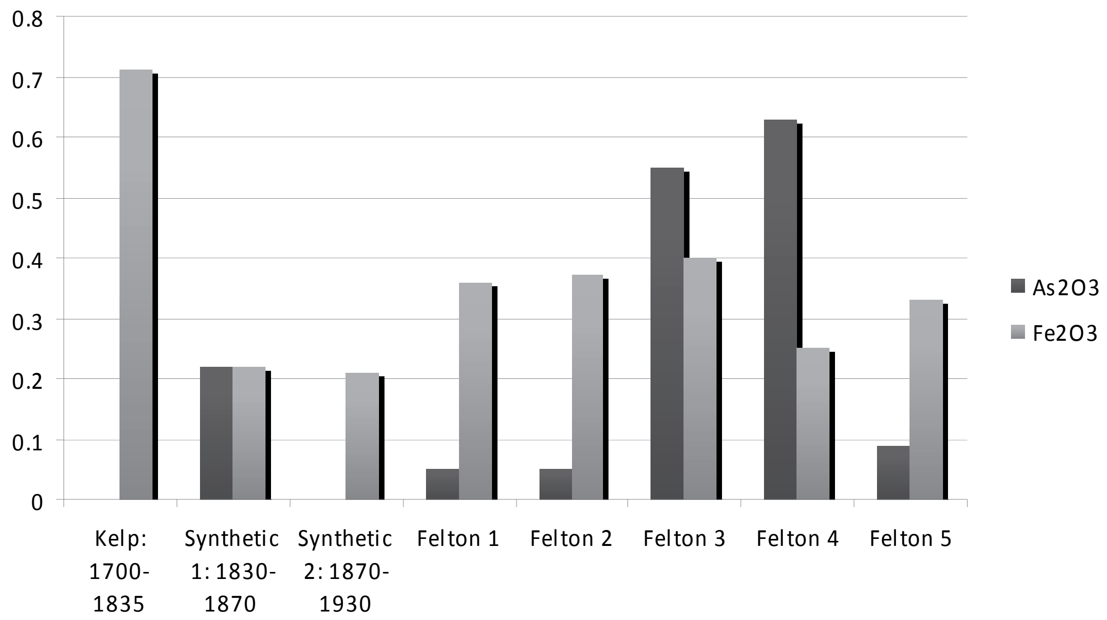

Figure 5. The iron and arsenic composition of Felton Park Hall greenhouse window glass. The elevated arsenic composition is consistent with production from 1830 to1870

The colour of Felton 1, a pale purple tint, which suggests a raised manganese (MnO) component. The sample had the highest level within group. It is noteworthy that the raised level of iron (Fe_2O_3) was also detected. Both of these elements colour glass.

Felton 1 and 2 contain very similar concentrations of both iron and manganese but they have quite different colours. The manganese acts on the colour of the glass in two ways: firstly to affect the oxidation of the iron (and the colour it produces) and secondly to contribute a pinkish colour to balance the blue-green of the iron. The manganese is usually added as MnO_2 and much of the manganese will be reduced to Mn^{2+} or Mn^{3+} in the glass. Although manganese decolourised glass may be colourless when made, prolonged exposure to sunlight can cause the glass to turn purple (solarisation). The phenomenon was noted as early as 1825 by Michael Faraday (Tyndall 1870) and was investigated empirically by Gaffield (1867) and Pelouze (1867). It is generally accepted that UV light causes the oxidation of the manganese, giving rise to the purple colour. It is likely that Felton 1 has been exposed to more sunlight than Felton 2; however, further speculation is unwarranted without knowing the exact context of these samples within the greenhouse.

In addition arsenic, a decolouriser, is detected in all samples. In comparison, Felton 4 has minimal levels of manganese (MnO) and low levels of iron (Fe_2O_3) but is colourless. This is probably due to the high concentration of arsenic (As_2O_3) and its presence as a decolouriser and refiner (Dungworth 2009, 14).

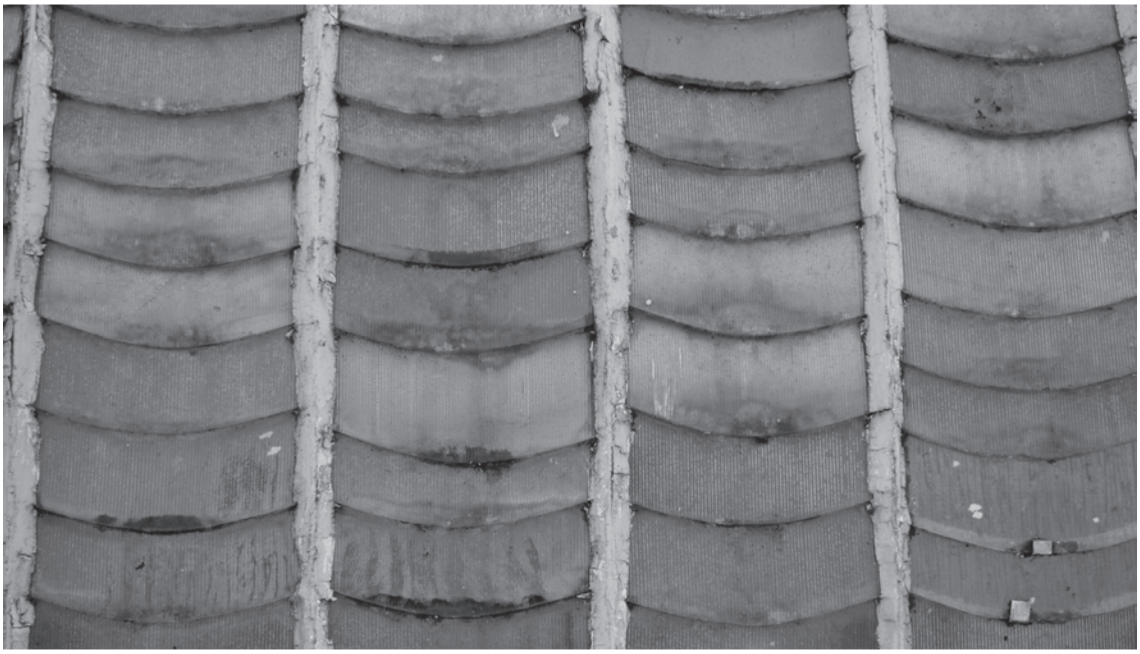

Figure 6. South aspect: view of small section of the pent fish scale glazing.

Figure 7. Internal view of the pent roof with fish scale glazing, showing the flexible wrought iron glazing bars, as designed by and described in Loudon's The Greenhouse Companion *of 1825.*

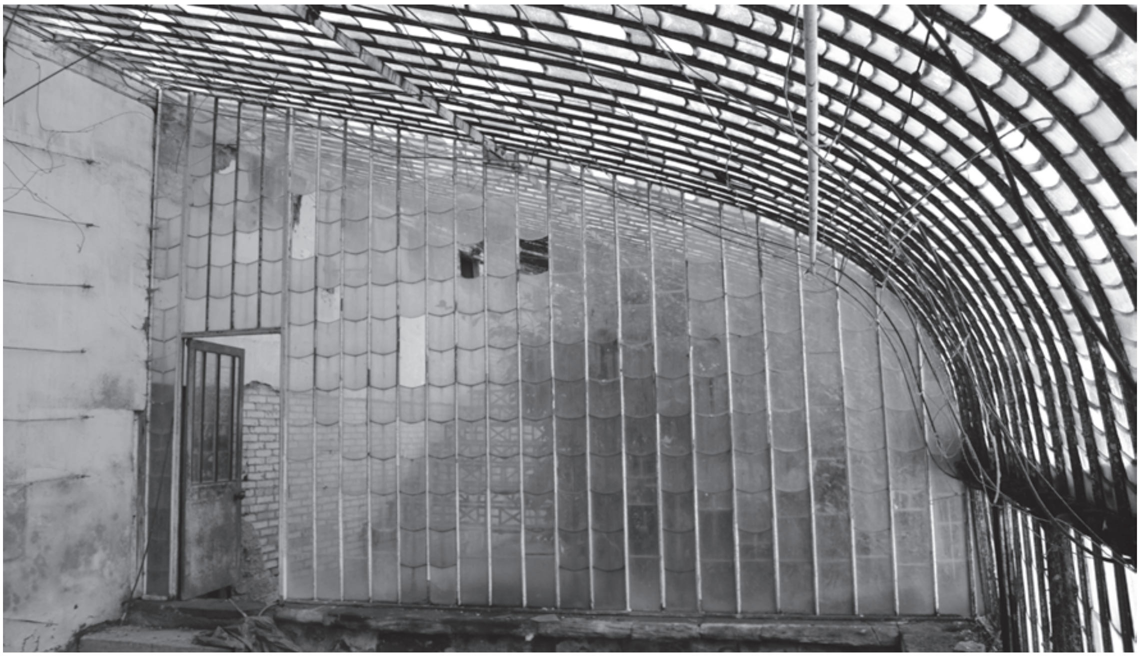

Figure 8. Central glazed partition, from which one sample was removed for analysis.

While the chemical composition of the glass can provide information on the likely period(s) of manufacture, additional information can also be gained from a consideration of the form. All five of the batch 1 window glass samples are of rolled glass with a fluted or ribbed effect (Douglas and Frank 1972, 151). As rolled glass of this type was patented by Hartley in 1847 none of batch 1 samples are likely to have been made before this date.

All the glass within this assemblage could have been produced by the t major manufacturers of the day, Pilkington Brothers of St Helens, Chance Brothers of Birmingham and Hartleys of Sunderland (Barker 1960; McGrath and Frost 1937). However, the greenhouse is a cast and wrought iron construction designed by the Scottish botanist and garden designer John Claudius Loudon (1783–1843). Loudon licensed his design to Messrs W and D Bailey of Holborn, London and it was produced in kit form. Due to the nature of its construction type, the greenhouse may have been erected by the company but glazed by local glass producers, of which there were numerable at the time.

Though the additional samples taken during the site visit (batch 2) were examined by EDXRF (see Appendix), they were inconsistent with earlier glass composition, *ie* kelp glass (1700–1835). The author was mindful of certain attributes of pre-1835 glass and applied the criteria accordingly,

a) inconsistency in thickness within one pane

b) slightly watery appearance when viewing through

c) overall thickness not more than 2.8mm, but better if 1–2mm

Only one fragment of window glass (batch 2 sample 13) contains detectable levels of arsenic and the variation in thickness. This sample has a chemical composition and form which is consistent with manufacture *c*1830. On the basis of their low levels of arsenic, the remaining samples of batch 2 glass are likely to have been made after *c*1870.

i ii

Figure 9. i) The central fish scale panel within the greenhouse: physical defects and inconsistency in thickness made it a necessity for sampling. ii) West end of the greenhouse: although weathered, imperfections and watery appearance made this central pane a further sample.

CONCLUSION

The data from both EDXRF and SEM-EDS analysis suggests that Felton 1 and 2 are of the later composition *c*1870–*c*1930, both displaying limited arsenic (<0.2wt %). Felton 5, due to its higher Na_2O composition (12.15wt %) may be of the same chemical composition as Felton 1 and 2 but possibly a later addition, hence a replacement to the greenhouse.

Felton 3 and 4 are the earliest window glass (*c*1830–*c*1870), from the samples provided, as they fit the chemical profile of early synthetic soda glass with a raised concentration of arsenic (Dungworth 2012, 17). However, the experimentation with rolled plate glass production did not take place until the early 1840s; the patent was not granted until 1847 (Barker 1960, 121–2). Therefore any rolled glass from Felton must have been manufactured after 1847.

The results suggest five different phases of glazing took place, two in 1847–1870 and three after 1870. If the construction of the greenhouse is secure at 1830, none of this collection of window glass can have been original. If the construction date is unsecure, the earliest date for original glass, and consequently the construction date of the greenhouse, is 1847.

The second batch of glass collected was more informative. A wide variety of samples were taken of glass which was not rolled but blown. These were compared to the English Heritage window glass reference collection. Although much of the window glass fitted aspects of the typology, only one fragment fitted the criteria: arsenic composition, watery or distorted when viewed though and a variation in thickness across the pane. This suggests a hand-blown cylinder glass, giving a date of *c*1830–*c*1870.

The information gained from the window glass from the greenhouse at Felton Park Hall suggests that there were a number of phases of glazing employed. One fragment of glass has a form and composition which matches the proposed construction date and the structure may have been originally glazed in that window glass; only to be later re-glazed in the rolled glass as horticultural glass manufacture developed and improved.

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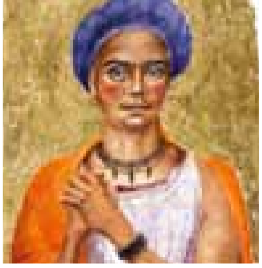
APPENDIX

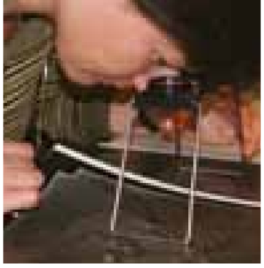
Table 4. Full data on chemical composition of Batch 1samples (clls= colourless; vpgn = very pale green; vpp= very pale purple)

#	1	2	3	4	5
colour	vpp	vpgn	vpgn	clls	vpgn
Thickness	4.5mm	3.9mm	4.3mm	3.8mm	3.5mm
Na_2O	10.98	10.93	11.31	11.42	12.15
MgO	0.14	0.20	<0.1	<0.1	0.19
Al_2O_3	1.55	0.75	0.9	1.4	1.13
SiO_2	70.42	71.55	72.66	71.78	71.52
P_2O_5	<0.2	<0.2	<0.2	<0.2	<0.2
SO_3	0.61	0.67	0.48	0.53	0.49
Cl	<0.1	<0.1	<0.1	<0.1	<0.1
K_2O	0.54	0.21	0.31	0.58	0.29
CaO	14.37	14.37	12.51	12.78	12.64
TiO_2	<0.1	<0.1	<0.1	<0.1	0.11
MnO	0.5	0.46	0.4	0.06	0.47
Fe_2O_3	0.36	0.37	0.4	0.25	0.33
As_2O_3	0.05	0.05	0.55	0.63	0.09
PbO	<0.05	<0.05	<0.05	<0.05	<0.05
SrO	0.02	0.03	0.02	0.005	0.02
ZrO_2	0.02	0.02	0.01	0.006	0.02

Table 5. EDXRF data on chemical composition of Batch 2 samples

#	MnO	Fe_2O_3	As_2O_3	SrO	ZrO2
1	0.59	0.27	<0.01	0.01	<0.01
2	0.66	0.30	<0.01	0.01	<0.01
3	0.05	0.26	<0.01	0.01	0.01
4	0.03	0.14	<0.01	0.04	<0.01
5	<0.02	0.29	<0.01	0.04	<0.01
6	<0.02	0.30	<0.01	0.04	<0.01
7	<0.02	0.29	<0.01	0.04	<0.01
8	0.54	0.36	<0.01	0.02	<0.01
9	0.62	0.43	<0.01	0.02	<0.01
10	<0.02	0.26	<0.01	0.02	0.01
11	<0.02	0.49	<0.01	0.02	<0.01
12	<0.02	0.33	<0.01	0.03	<0.01
13	0.02	0.31	0.13	0.05	0.01
14	0.03	0.30	<0.01	0.01	0.01
15	0.49	0.33	<0.01	<0.01	<0.01
16	0.03	0.16	<0.01	0.05	0.01
17	0.03	0.29	<0.01	<0.01	<0.01
18	0.04	0.24	<0.01	0.01	<0.01
19	0.04	0.28	<0.01	0.01	<0.01
20	0.03	0.22	<0.01	0.05	0.02
21	0.03	0.24	<0.01	0.01	0.01


ENGLISH HERITAGE RESEARCH AND THE HISTORIC ENVIRONMENT

English Heritage undertakes and commissions research into the historic environment, and the issues that affect its condition and survival, in order to provide the understanding necessary for informed policy and decision making, for the protection and sustainable management of the resource, and to promote the widest access, appreciation and enjoyment of our heritage. Much of this work is conceived and implemented in the context of the National Heritage Protection Plan. For more information on the NHPP please go to http://www.english-heritage.org.uk/professional/protection/national-heritage-protection-plan/.

The Heritage Protection Department provides English Heritage with this capacity in the fields of building history, archaeology, archaeological science, imaging and visualisation, landscape history, and remote sensing. It brings together four teams with complementary investigative, analytical and technical skills to provide integrated applied research expertise across the range of the historic environment. These are:

- Intervention and Analysis (including Archaeology Projects, Archives, Environmental Studies, Archaeological Conservation and Technology, and Scientific Dating)
- Assessment (including Archaeological and Architectural Investigation, the Blue Plaques Team and the Survey of London)
- Imaging and Visualisation (including Technical Survey, Graphics and Photography)
- Remote Sensing (including Mapping, Photogrammetry and Geophysics)

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