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.

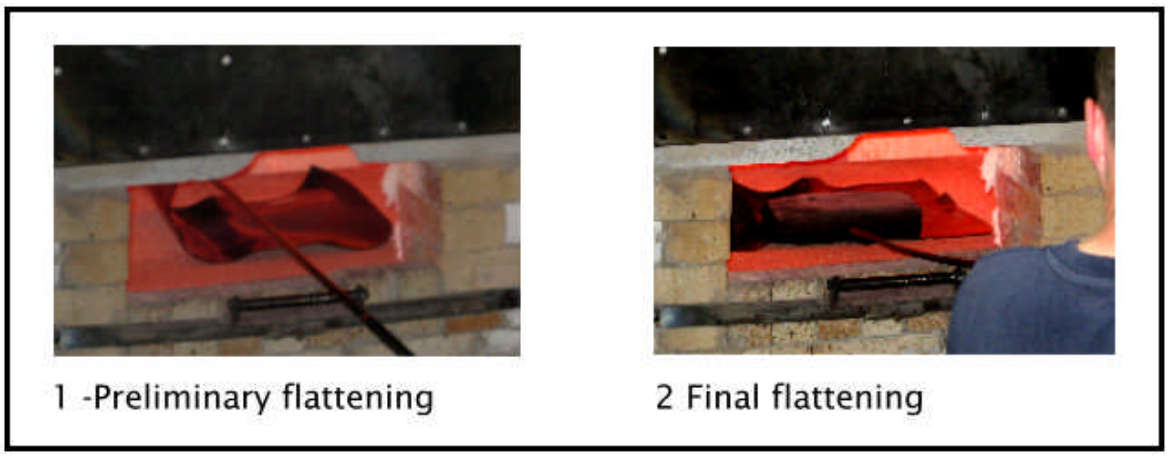

Figure 3.11: Flattening at English Antique Glass Co.

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*