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ELMBRIDGE FURNACE, OXENHALL

The Economics of a Gloucestershire Blast Furnace in the Seventeenth Century

Stretching across the gap between the steep eastern edge of the Forest of Dean plateau and the southern extremity of the Malvern ridge is an area of high undulating ground that separates the Hereford Plain from the Vale of Gloucester. This area is nowadays renowned for quiet woodlands and wild daffodils, but to former generations it had more a commercial aspect.

Contrary to the usual impression, ironworking in the Forest of Dean area was not restricted to the confines of the royal forest boundaries, but extended well out into the adjoining wooded countryside of Herefordshire and Gloucestershire. Here advantage could be taken of available water power, together with freedom from the legal restrictions so frequently imposed for the protection of Admiralty timber on iron works within the royal forest. One such favoured location in the 17th and 18th Centuries was the upper valley of the Ell Brook, at Oxenhall, above the small country market town of Newent, in the area just described.

The Ell Brook, a tributary of the tiny River Leadon, had sufficient power available to drive at least two mediaeval corn mills above Newent, and both the ancient manors of Oxenhall and Newent possessed, as their waste, extensive coppice and woodlands for the production of charcoal ("Coles"). In addition, there were local outcrops of iron ore ("Myne"), and also great tracts of reworkable slag ("Cinder"), still very rich in iron, left by mediaeval (and earlier,) small hand-worked bloom furnaces.

The use of "cinder" in the smelting charge of the water-powered, charcoal-fuelled, blast furnaces of the 17th century was particularly beneficial to good quality pig iron, and the importance of this raw material to local iron production at this period is illustrated by Andrew Yarrington in his book The Improvement of England by Sea and Land, * printed in 1677:-

> "In the Forest of Dean and thereabouts, the iron is made at this day of cinders, being the rough and offal thrown by in the Romans' time; they then having only foot blasts to melt the iron stone; but now, by the force of a great wheel that drives a pair of bellows twenty feet long, all that iron is extracted out of the cinders, which could not be forced from it by the Roman foot blast. And in the Forest of Dean and thereabouts, and as high as Worcester, there are great and infinite quantities of these cinders, some in vast mounts above ground, some underground, which will supply the iron works some hundreds of years, and these cinders are they which make the prime and best iron, and with much less charcoal than doth the ironstone".

* Quoted in H.G. Nicholls, Iron Making in the Forest of Dean (1858)

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Only very limited information has so far been traced as to the earliest days of Ell-bridge, (later Elmbridge) Furnace, and this is to be found in various Oxenhall and Newent title deeds in the Foley of Stoke Edith archives held at Herefordshire Records Office. These indicate the existence at the beginning of the 17th century of a water powered corn mill owned by Thomas Hooke of Oxenhall. In 1624, for example, a mortgage redemption describes the premises as a "Mill or Water Corn Mill called Elbridge Mill in Oxenhall with garden and hemp close."

The first intimations to be found in these deeds of the conversion of the corn mill to iron working are two deeds of 1639. Both these documents refer to transactions by Francis Finch who was lord of the manor of Oxenhall. It should of course be noted that amongst the normal privileges due to a lord of a manor were the sole rights to mines, minerals and all timber trees. By the first document, dated 20 April, 1639 Finch acquired a grant of "synders" from Thomas Dobbins of Newent in a parcel of arable called the "sinderpitts" in Newent. In the second document, dated 3 August, Finch leased from Sir John Wintour of Lydney, (who owned iron-works in the Forest) for a period of 21 years, a watercourse running to a mill called "Hill howse Mill" in Pauntley. The identification and precise location of Hill House Mill, at that time (and since at least 1609) occupied in conjunction with Hill House by Thomas Hill of Newent, yeoman, are by no means certain. However, in the absence of any evidence to the contrary, it is reasonable to assume that this is the same as Crooke's Mill, a corn mill on the Ell brook some half a mile immediately upstream of Elmbridge.

The first conclusive evidence of the Furnace in being is given in another of these deeds dated 1 October, 1645. Again Francis Finch leased a watercourse, this time from Edward Hooke of "Crooks in Pauntley" running through a "close called Loveridge". The lease contains a most significant clause to the effect that when Finch "shall not have occasion to use the water at the Furnace or Ironwork near Elbridge, Edward Hooke may divert it to a water corn mill called Crooks Mill."

As to Elmbridge Mill itself, this had been acquired from the Hooke family by Edward Clarke the elder of Newent, and by a deed dated 29 October, 1642 leased for 200 years to Guy Hall of Martin Hussingtree, Worcs., together with a house called Marshalls. Francis Finch was evidently sub-tenant of the mill building and confirmation of its new use is given in a marriage settlement by Edward Clarke dated 8 November, 1647 which refers to the "messuage called Marshall, Ellbridge Mill part of which is now converted into a furnace for making iron, and meadow ground called Mill-plot."

By 1655 Francis Finch was apparently in financial difficulties, for on 12 December of that year he mortgaged the furnace to Thomas Lowbridge of Wilden, Worcs., and Thomas Foley of London, repayment being in iron delivered to Wilden. The Foleys were the leading ironmasters of the period, having amassed a great fortune by being the first to exploit the use of slitting mills for the production of wrought iron in bar form. The great Foley empire, based on a series of mills along the River Stour, was no doubt only too pleased to secure regular supplies of Forest pig iron at advantageous rates with relatively simple transport along the best industrial highway available at that time - the River Severn.

Francis Finch's difficulties continued, and with the debt of £4,000 remaining unpaid he had to transfer the Furnace to Thomas Foley on 2 October, 1658. Within a year Thomas Foley had acquired the manor of Newent, and shortly thereafter Finch sold him the manor of Oxenhall. The site of the Furnace itself was not part of the manorial land so the Foleys only had a leasehold interest until Paul Foley, Thomas's eldest son, bought out the freehold reversion from the Clarke family in 1671.

It was with Paul Foley, of Stoke Edith Park in Hereford, that the Foley interests in the Forest of Dean area really developed. These included furnaces at Elmbridge, Linton Bishopswood and Blakeney; furnaces, forges and wire-works on the Wye at Tintern; and a complex of forges around Monmouth based on a furnace at St. Weonards. In 1692 Paul Foley, in conjunction with his brother Philip, set up a partnership with John Wheeler and Richard Avenant to run a group of Stour valley forges linked with the Forest of Dean furnaces at Linton, Elmbridge, Bishopswood, and Blakeney. The annual account books of this partnership survive in a complete form for quite long periods of continuity, and it is from the accounts in respect of the years between 1692 and 1700 that the following details of the working and economics of Elmbridge Furnace have been extracted.

The accounts are, as can be expected, quite complicated, being principally concerned with the allocation of profits and assets between the partners and the apportioning of charges and sales between the various enterprises. However annual stock accounts are given in some detail for each of the furnaces and forges, and individual personal accounts do provide information as to trading costs and methods.

As can be seen from the attached summary of annual production figures for Elmbridge, Blakeney, and Bishopswood Furnaces (Appendix A) the amoung of pig iron produced varied considerably from year to year but principally lay in the range 600-700 tons per annum. These variations can be traced mainly to the length of time the furnace was continuously in blast, i.e. the "campaign". At this period it was rare for a furnace to be able to be run for periods in blast of more than 12 months, although there are indications that Blakeney Furnace was achieving at least two year campaigns at that time. Unfortunately the partnership accounts do not always give the campaign dates, but for Elmbridge the general pattern was a start in late autumn, usually the beginning of November, a campaign of 250-300 days, to finish about July but often extending into September.

The choice of final date does not appear to have been governed by any shortage of fuel or ore, the closing stock accounts showing plenty in hand. Lack of water in the Ell Brook may well have been the real reason, bearing in mind the care and expense taken in later years to provide reservoirs at its head-waters.

What is remarkably consistent at all three furnaces is the rate of iron production per day in blast of 2.2 - 2.9 tons, with an overall average of $2\frac{1}{2}$ tons per day. Linton Furnace was not in blast in 1692 having apparently ceased production a year or so before. Thereafter its stocks of pig iron, myne, and cinder were distributed to the other furnaces, and the site used only as a reception depot for cinder destined for Elmbridge.

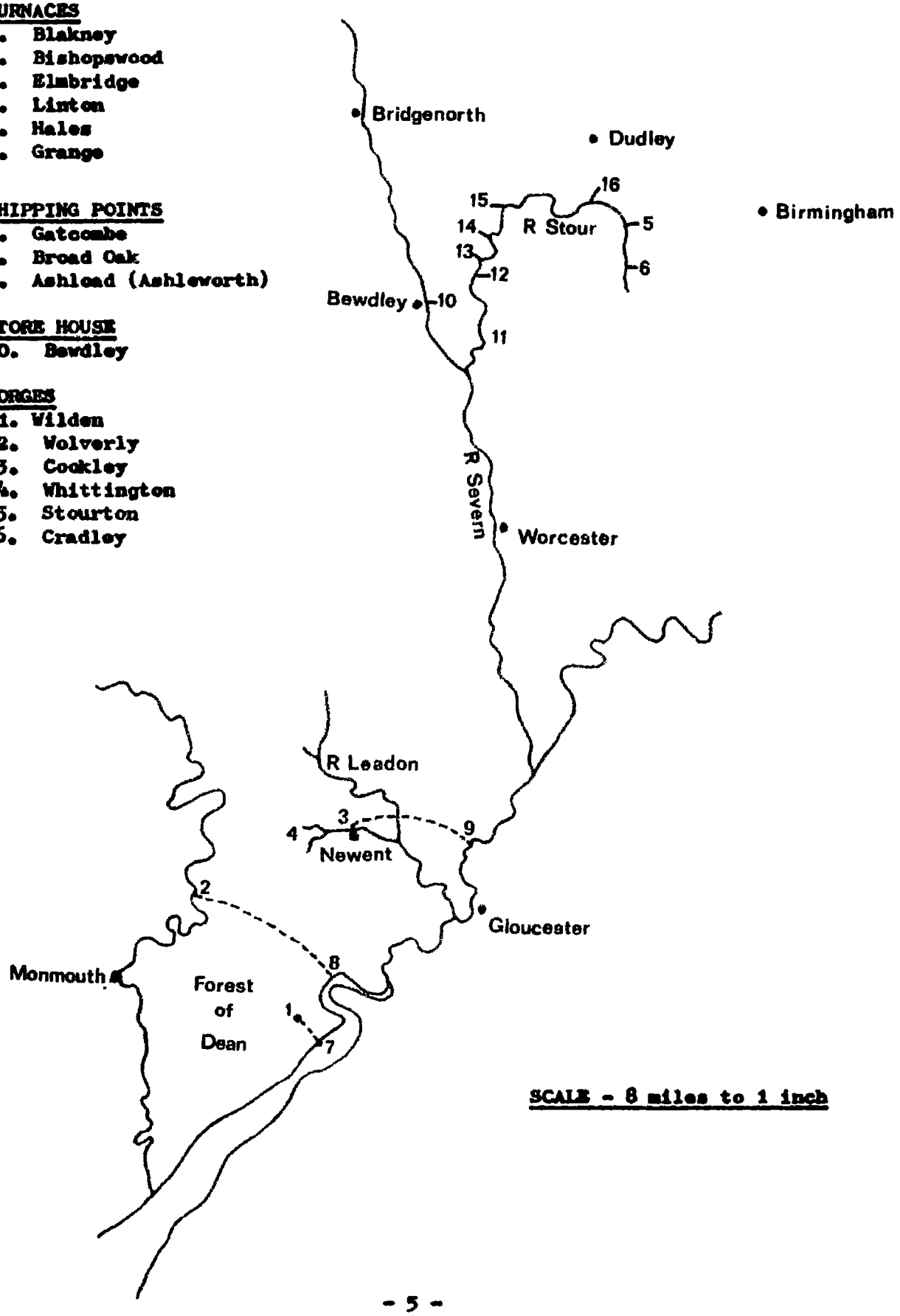
IRON WORKS OF THE FOLEY, AVENANT & WHEELER PARTNERSHIP AT THE END OF THE 17th CENTURY

FURNACES
1. Blakney
2. Bishopswood
3. Elmbridge
4. Linton
5. Hales
6. Grange

SHIPPING POINTS
7. Gatcombe
8. Broad Oak
9. Ashlead (Ashleworth)

STORE HOUSE
10. Bewdley

FORGES
11. Wilden
12. Wolverly
13. Cookley
14. Whittington
15. Stourton
16. Cradley



SCALE - 8 miles to 1 inch

The total costs in fuel and ore for all three furnaces in production were about 80s. to 90s. per ton of pig iron. By far the greatest proportion of these costs were for the charcoal, which for the 2 loads required to produce one ton of pig iron cost in the region of 70s. Elmbridge was using a much lower proportion of myne to cinder in its furnace charge:- 1 : 5 as compared with the 1 : 3 used by the other two furnaces, and by the turn of the century Elmbridge was using only 1 : 6. In actual amounts Elmbridge was using about 5 bushels of myne which cost approx. 1s. 7d., and about 25 bushels of cinder which cost approx. 15s., per ton of pig iron produced. The other two furnaces were using about 10 bushels of relatively more expensive myne which cost approx. 5s., but any economic advantage to Elmbridge was completely lost by variations in the overwhelming costs of charcoal.

To obtain a full understanding of a furnace in operation it is necessary to find out the quality of the ores being used. Whilst excavation of the site and analysis of residues would provide the best answer, a reasonable estimate can be worked out from the quantities quoted in accounts. One basic problem is that all quantities of cinder and myne are given not by weight but by capacity, i.e. in bushels and dozen bushels. Although we know that it was the custom in the Forest of Dean to use the national standard Winchester bushel rather than any local variant, too much reliance should not be put on the standards of accuracy of the period. An example of such lack of accuracy is shown in the accounts themselves, where, in the Linton stock account of October 1696, it was found that the amount of cinder (held in store for Elmbridge Furnace) was 358 dozen bushels short "in Mr. Merecks bad measure of Cinders brought there & chiefly in the measure at Elmbridge being much larger than at Linton Furnace."

There is also the problem of how densly packed were the ores in the measuring containers, dependant on lump size and grading, and how efficient the ore preparation works were in removing rock waste. It is reasonable to assume, although there is no confirmatory evidence in the accounts, that a certain amount of calcining (ore roasting) took place in concentrating the furnace charge.

Bearing in mind the likely inaccuracies inherent in such a calculation, the following figures give at least a reasonable estimate for ore conversion rates at Elmbridge Furnace in a typical year (1693/4):-

pig iron produced — 542 tons

cinder used — 1,103 doz. 4 bushels

= 13,240 bushels @ 1.285 cu.ft. per bushel = 17,013 cu.ft.
17,013 cu.ft. @ (say) 18 cu.ft. per ton = 990 tons

myne used — 244 dozen bushels

= 2,928 bushels @ 1.285 cu.ft. per bushel = 3,763 cu.ft.
3,763 cu.ft. @ (say) 10 cu.ft. per ton = 376 tons

Conclusions

Total weight of ores used = 990 + 376 = 1,366 tons, to produce 542 tons.
Therefore recoverable iron = 39% of ore charge
And if myne is assumed to contain 50% recoverable iron
Then iron from myne = 188 tons
And iron from cinder = 352 tons which from 990 tons = 36% recoverable iron

The Foley partnership accounts are, unfortunately, most reticent on details of Elmbridge Furnace in its construction, layout, and physical working. A few scraps of information can be gleaned from items of maintenance such as:-

"By getting & carrying the Hearth & Bosh Stone £11. 0. 0."

or again

"By getting & carrying In wall Stone, building In walls & several odd charges about new In walls."

(Inwalls are the tapering upper shaft of a furnace, as opposed to the lower reverse taper or Bosh.)

The Furnace repairs and maintenance seem to have been generally carried out by local craftsmen hired only as and when required. Time payments are recorded for carpenters, sawyers, masons, and smiths, with corresponding payments for timber, stone, nails, hides, grease and tallow (for dressing the bellows) and even, on occasion, liquor for the workmen. General labouring for such works as washing and riddling cinders, or clearing the mill water leats were also dealt with on a time and materials basis.

The only permanent staff, paid an annual salary, were the Manager, the Clerk, and his assistant. Additionally a Founder was employed on a piecework basis, being paid at the rate of 3s. 4d. per ton of pig iron produced, plus 50% extra for casting in plate form, or 75% extra for casting "boules". Although this generally worked out to a sum double that of the Manager's salary a considerable portion must have been paid out by the Founder in turn employing at least two complete shifts of skilled furnace assistants to tend the Furnace continuously day and night whilst in blast.

As could be anticipated, the high costs of transporting the pig iron away from the Furnace figure prominently in the accounts, although again there are disappointing blanks on some aspects, such as the mode of transport from Furnace to shipping point on the River Severn which presumably was by pack horse. What is certain is that it cost 5s. per ton to carry pig iron the 5 miles overland to Ashload (Ashleworth) as compared with 2s. 6d. per ton for shipping it 30 miles up the River to Bewdley. One load carried by road to Hereford, about 14 miles, was charged at the rate of 11s. per ton.

The majority of the pig iron from Elmbridge went up-river by Severn trow, having been assembled into boat-loads at Ashload on a riverside wharf specially rented for the purpose of £3 per annum. The main landing places were at Bewdley, Redstone (just south of what is now Stourport), and at 'Clothouse' (so far unidentified). The shipping rates from Ashload to all these three points were identical at 2s. 6d. per ton of pig iron, half the equivalent charges to the same points from Gatcombe. At first the partnership utilised the established river trading trows, particularly those belonging to Beale & Perks. In 1695, however, they bought their own trow from George Clarke, at a cost of £95, and a barge two years later. Both these vessels were attached to the establishment records of the Bewdley storehouse but are not listed after 1698 when stocks in general at the storehouse were being drastically reduced in quantity.

Although at times a somewhat tedious exercise, the sifting of basic information from financial records can be very illuminating as to the realities of a situation. One aspect in particular that has been most clearly revealed in this investigation is the excessive proportion of the total costs of manufacturing pig iron in the late 17th century attributable to the very high cost of producing charcoal. I believe it is to this simple fact, rather than any rampant destruction of forest timber, that we may look for the principal spur to the widespread and determined experimentation by ironmasters in the following century to find ways of using coal as an alternative smelting fuel.

R.A. Stiles

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APPENDIX A

Pig Iron Production, 1692-1700

(a) Elmbridge Furnace

1692/3	==========*	597 tons
1693/4	==========*	542 tons
1694/5	============*	689 tons
1695/6	==============*	786 tons
1696/7	============*	694 tons
1697/8	==============*	790 tons
1698/9	=======*	346 tons
1699/0	============*	737 tons

(b) Blakney Furnace

1692/3	=====*	273 tons
1693/4	================*	925 tons
1694/5	==============*	810 tons
1695/6	==================*	1047 tons
1696/7	==============*	794 tons
1697/8	============*	697 tons
1698/9	==============*	995 tons
1699/0	============*	725 tons

(c) Bishopswood Furnace

1692/3	==============*	739 tons
1693/4	=========*	488 tons
1694/5	==============*	753 tons
1695/6	==========*	537 tons
1696/7	==============*	777 tons
1697/8	============*	684 tons
1698/9	==========*	656 tons
1699/0	================*	825 tons

Scale of graph ==* 100 tons

APPENDIX B

BASIC SUMMARY OF ANNUAL FINANCES OF ELMBRIDGE FURNACE IN OPERATION

(Synthesised from the Foley Partnership Accounts H.R.O. F/VI/Def/1-8 in two typical years)

(1) FINANCIAL YEAR Michaelmas 1693 - Michaelmas 1694

Pig Iron Production, 8 Nov. 1693 - 27 June 1694 (237 days)
542 tons - valued at £5. 10s. 0d. per ton "cost price" * £2981. 0. 0.

Less

	£	s.	d.	£	s.	d.
(a) Fuel & Ore Costs						
Charcoal used	1965	16	8			
Myne used	42	18	8			
Cinders used	413	15	6			
Cost of washing cinders	10	5	7			
				£2432	16.	5
(b) Wages & Salaries						
Founder	110	17	3			
Sam. Whitmore (Manager)	50	0	0			
Wm. Painter (Clerk)	30	0	0			
Mr. Hawkins	10	0	0			
				£200	17	3
(c) Furnace & Bellows Maintenance						
Materials	113	16	9			
Labour	17	6	3			
				£131	2.	0.
(d) General						
Watercourse rents	17	13	0			
Taxes on stock	3	6	0			
Rent to Paul Foley	100	0	0			
Sundry charges	74	10	1			
				£195	9.	1.
Total				£2960	4	9
"Profit" on year =				£20	15	3

Stock & Inventory Value, Oct. 1694 £1,111 9s. 5½d.

* Note The Pig Iron is valued at a basic "cost price" applicable only to internal transactions within the Partnership where the majority of the iron produced was destined. When sold direct to the public prices varied but were in the region of £6 per ton for pig iron in bulk, and £10 per ton for castings.

(2) FINANCIAL YEAR Michaelmas 1697 - Michaelmas 1698

Pig Iron Production, 4 Nov. 1697 - 19 Aug. 1698 (289 days)

790¾ tons - valued at £5 15s. 0d. per ton "cost price" £4542 10. 0d.

Less:-

		£	s.	d.			
(a)	Fuel & Ore Costs						
	Charcoal used	3082	0	0			
	Myne used	59	19	10			
	Cinders used	614	0	7			
	Cost of washing cinders	16	9	6			
	Casting sand	4	3	0			
	Scrap iron	8	4	4			
					£3784	17	3
(b)	Wages & Salaries						
	Founder	152	0	4			
	Sam. Whitmore (Manager)	50	0	0			
	expenses -	3	0	0			
	Wm. Painter (Clerk)	30	0	0			
	Mr. Cordey	10	0	0			
					£245	0	4
(c)	Furnace & Bellows Maintenance						
	Materials	45	1	0			
	Labour	26	6	2			
	Iron for tools & smith's work	11	19	2			
					£ 83	6	4
(d)	General						
	Watercourse rents	22	0	0			
	Taxes on stock	2	6	0			
	Rent to Paul Foley	100	0	0			
	Sundry charges	9	18	7			
					£134	4	7
		Total			£4247	8	6
	"Profit" on year	=			£295	1	6

Stock & Inventory Value, Oct. 1698 - £3,033 13. 6.