



Minepits in St Leonard's Forest
(Jeremy Hodgkinson)

Field Notes
Further Investigations in the Dudwell Valley
Report on Whitepost Wood, Hartfield
Wealden Iron Waterwheels, Bellows and Tuyeres
St Leonard's Forest Minepits
A Pope Family Fireback
Hothfield Forge, Kent
Estimating 18th Century Cannon Boring Times
Issues, Emotions and Achievements in the 18th Century

compiled by J. S. Hodgkinson
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CONTENTS

Page No.

Field Notes	compiled by J. S. Hodgkinson	3
Further investigations in the Dudwell Valley	David Brown & Tim Smith	5
Archaeological investigations on a pre-Roman Iron Age site at Whitepost Wood, nr. Holtye, Hartfield, East Sussex	Simon Stevens	8
Some operating characteristics of Wealden iron industry waterwheels, bellows and tuyeres: addendum	J. Prus	20
St Leonard's Forest minepits	Vivienne Blandford	23
A Pope family fireback	J. S. Hodgkinson	27
Hothfield Forge, Kent - a new water-powered site	Tony Singleton	32
Estimating 18th-century cannon boring times, costs and throughputs	Alan F. Davies	38
Issues, emotions and achievements - managers and agents of a mid 18th-century cannon manufacturer	Alan F. Davies	48
Index		66

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FIELD NOTES

COMPILED BY J. S. HODGKINSON

A bloomery site in Danehill, East Sussex

A small bloomery site has been discovered in Pollardsland Wood, east of Danehill, at TQ 4199 2730. An area of slag, some pieces with marks indicating that they may have flowed over lengths of wood while hot, and some in excess of 10cm across, lies on gently sloping ground on the west side of a small ghyll, a tributary of the Annwood Brook. The site measures a mere 10m along the ghyll by 5m, but slag has been noted in the stream up to 70m below the site. A few pieces of furnace lining have also been noted.

A scattering of slag has also been noted along the stream in the next valley to the west, between TQ 4206 2864 and 4191 2859, the source for which may lie further up the valley where there are two ponds. The scatter may have resulted from slag laid on trackways. The geology of the area is Ashdown Beds.

We are grateful to Mrs G. Crawshaw for drawing attention to these sites.

A probable late second-century bloomery in Stone-cum-Ebony, Kent

Subsequent to surface finds of iron slag and furnace lining following ploughing, a small excavation in a field, part of Huggit's Farm, to the south of the Old Rectory in Stone-in-Oxney has yielded the base of a bloomery furnace (TQ 9396 2724). Further tap slag and furnace lining were recovered, together with six sherds of pottery and a fragment of

Roman cast window glass. The sherds include three fragments of East Sussex ware, together with single pieces of Colchester ware, West Kent ware and Gaulish black colour-coated ware. Also found was a *sestertius* of Marcus Aurelius (161-80AD). The dating of the coin, together with the date range of the Colchester (130-250AD) and Gaulish (150-200AD) wares, suggest a probable date in the late-second century, given the modest size, and therefore short working life, of the site. The geology of the area is Wadhurst Clay.

We are grateful to Alan Charman of Hastings Area Archaeological Research Group for information about this site, which he and his colleague, Sarah Burgess, investigated.

FURTHER INVESTIGATIONS IN THE DUDWELL VALLEY

DAVID BROWN AND TIM SMITH

Continuing the search of the Dudwell valley for signs of ironworking, this foray covered the upper reaches of the river, concentrating on the southern side of the valley, the northern side having revealed no evidence of ironworking at all. Since the bloomery site previously found in this valley¹ had been some distance from the Dudwell close to the upper (southern) limit of the limestone, an effort was made to cover the area between the river and the interface between the limestone and the Ashdown Beds. On the ground this was revealed as a series of depressions accompanied by spoil heaps, presumably the result of mineral extraction.

Significant quantities of slag (some lumps 1 kg or more in weight) were found in the River Dudwell approx 150m upstream of a wooden footbridge, extending from TQ 6228 2179 to TQ 6224 2178.

Probing on both sides of the river to the south from the level of the upper track and on the north for about 20m into the field (including a drainage ditch running perpendicular to the stream failed to find the source of the slag.

On a return visit in May 2012 a scatter of small and large pieces of furnace slag were found on the slope leading up to a field at TQ 6112 2141 (previously located by Dave Bonsall). On the bank, probing only located a scatter under the surface, but on probing in the field a triangular area of slag was found some 30cm below the surface the apex of which was a point about 20m into the field (TQ 6110 2141). The exact area of the heap could not be determined accurately as the field had been ploughed at some point scattering the slag and raising some into the top 30cm. At the fence line the extent of the heap was about 30-35m. Seen

from the western edge of the field the fence line could be seen to rise to a peak at the centre of the heap with the ground falling away on both sides. The fence at this point is some 20m away from a small tributary of the Dudwell in the wood, but it seems unlikely that the finds in the river mentioned above emanated from this site. However, this site lies upstream of the other finds so the possibility cannot be completely discounted.

The owner, Chris Davis of Streatfield Farm, mentioned his father had told him the field had once been the site of a group of buildings (thought to be called Sharness), evidence for which was discovered by a group from the French embassy in the 1980s using metal detectors. Unfortunately no record of the find is known to exist. Nothing is shown on OS maps, or the Gardner, Gream and Yeakel map of 1795. A record in the Historic Environment Record refers to the medieval village of Tottingworth in the vicinity (MES4343), location unknown.² A link between the ‘settlement’ and the bloomery cannot be ruled out. If the farmer assents, there is an initiative to geophysically survey the field to locate anomalies.

It was noted that a tributary of the Dudwell had cut through sandstone, limestone and Purbeck (shelly) beds with narrow layer of blue clay between Purbeck Beds. The geological memoir for Tunbridge Wells states,

“... in Tottingworth Park (6170 2217) ... two clay beds each up to 10 ft (3.0 m) thick were traced above the Upper Purbeck clays and a clay pit in one of these (6210 2234) may possibly have been dug for iron stone.”³

Unfortunately the group were denied permission to look in the land to the north of the Dudwell, now owned by Tottingworth Farm.

Charcoal platforms were located at TQ 6204 2115, 6218 2116, 6224 2116 (large oak growing within platform est. 150 years), 6223 2109, 6226 2141, 6069 2137, 6082 2139, 6137 2157, 6176 2179, 6214 2175, 6173 2158 and 6113 2141.

Platforms with no evidence of charcoal staining were found at TQ 6068 2140 (circular, 5m diameter) and TQ 6098 2127 (rectangular, 19m x 8m).

A possible pond bay was found at TQ 6244 2175 with a well-cut,

approximately 1.75m-high arch for a track to the east but no evidence of a sluice. Another pond bay was located at TQ 6074 2142, the upstream bank level being about 0.5m higher than that downstream. A culvert constructed of dressed sandstone (possibly ornamental) at TQ 6178 2180 provided access from one side of the Dudwell to the other, but with scant evidence of a track leading away from it.

Two similar-sized depressions of unknown application, symmetrical in profile and cone-shaped about 2m deep and 5m in diameter were found at TQ 6209 2180 and 6209 2175 near the river.

All the woods visited had been coppiced at some time in the past.

An old ornamental pond was found at TQ 6226 2130.

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ARCHAEOLOGICAL INVESTIGATIONS ON A PRE-ROMAN IRON AGE SITE AT WHITEPOST WOOD, NR. HOLTYE, HARTFIELD, EAST SUSSEX

SIMON STEVENS

*with contributions by Anna Doherty and Jeremy Hodgkinson and
illustrations by Fiona Griffin*

INTRODUCTION

Whitepost Wood lies between the settlements of Holtye and Blackham, at the junction of the A264 and the B2026, close to the border between East Sussex and Kent (TQ 5471 1391). Today the area is occupied by relatively dense mixed woodland, bisected by streams, which have cut deep channels into the underlying clay and sandstone geology, which lies close to the junction of the Ashdown Beds and Wadhurst Clay formations (BGS 2012) both of which are known to contain deposits of iron ore (Hodgkinson 2008a, 10).

Ironworking debris was positively identified at a location in the woods during a foray by the Wealden Iron Research Group (hereafter WIRG) in 2008 (Hodgkinson 2008b). Analysis of a sample of charcoal retrieved from the site returned a radiocarbon measurement of 1180 ± 100 BP (660 – 1020 cal. AD at 95.4% probability; Gd-19298), suggesting the possibility of an all-too-rare late Anglo-Saxon ironworking site (Hodgkinson 2010). Given the paucity of ironworking sites of this date in the Weald, and in keeping with WIRG's continuing campaign of targeted

excavations on a variety of sites, (e.g. Herbert 2010) it was decided to evaluate the potential of the site by the excavation of archaeological trial trenches.

THE EVALUATION

The use of mechanically or manually excavated trial trenches is an accepted methodology for investigating the level of preservation of previously detected archaeological remains, in this case with a mind to further work at the site. Given the woodland environment (and the availability of a group of enthusiastic WIRG volunteers) it was decided that a number of test trenches would be dug with hand tools at the location identified during the foray (see above). Five trenches of varying size were excavated at the site by eleven such volunteers on 13th December 2009. A straightforward stratigraphic sequence was revealed, which consisted of a surface deposit of forest leaves and mulch, context [001], which was a maximum of 30mm in thickness. This overlay poor quality topsoil, consisting of a c.200mm thick layer of mid-greyish brown silty clay, context [002], which contained numerous sandstone pieces and was heavily disturbed/mixed by roots. This in turn overlay the 'natural' geological deposit which consisted of a mixture of yellow silty clay and sandstone outcrops, context [003].

Results were universally encouraging, as all of the five excavated trial trenches produced smelting slag in varying quantities from context [002]. Given the identified surface spread, this was perhaps not entirely surprising, but the retrieval of a small assemblage of pottery from one of the trenches was highly significant. Initial examination in the field suggested the material might be Anglo-Saxon, although subsequent examination by a ceramics specialist showed that the pottery was actually Mid to Late Iron Age in date; a period more common in the archaeological record of ironworking in the Weald, but still rare compared to the number of identified later Romano-British, medieval and post-medieval sites, forming only 13% of currently dated sites (Hodgkinson 2008a, fig. 15).

Unfortunately, it appeared that the specific location of a possible

furnace, as indicated by a concentration of slag and furnace lining lay under a substantial tree. However, given the disparity between the radiocarbon measurement and the date of the pottery, and the potential for the investigation of an ironworking site of either date, it was decided that further work should be undertaken at the site, to involve more detailed excavation, culminating in publication of the results.

THE EXCAVATION

The full excavation of the identified area was undertaken during the summer of 2011. Following the fortuitous felling of the tree occupying the potential location of the possible furnace/hearth during a campaign of tree management at the site, it was possible to target that area and its surroundings.

The area around the felled tree was investigated to assess the level of root damage and the surviving tree stump was then removed and the underlying deposits investigated. This allowed an area measuring *c.*2.5m by *c.*2.5m to be fully excavated and recorded over three day-long sessions in May, June and July 2011.

Excavation showed that a furnace did not appear to have been sited within the boundaries of the excavated area, but that a dump of material, perhaps from the maintenance of a nearby furnace had been deposited there. Removal of the forest mulch, context [001] revealed the root-disturbed topsoil, context [002] which contained further pottery, ironworking slag, pieces of roasted ore and large chunks of furnace lining, with slag still adhering to them. This deposit was again a maximum of 250mm in thickness. No kiln or furnace structure was encountered *in situ*, although the area directly below the felled tree showed a marked concentration of ironworking debris, ironically protected from disturbance by a position in the ‘epicentre’ of the spreading roots. This concentration of material sat directly on top of the surface of the ‘natural’, context [003], with no evidence of a tell-tale ‘halo’ in the surrounding deposits – the usual indication of intense heating – suggesting that the material had been dumped.

Although it was perhaps disappointing that no structure associated

with ironworking had been encountered during the excavation, the range of finds recovered was clearly indicative of the process, with firm associated dating evidence.

THE FINDS

The Pottery by Anna Doherty

A small assemblage, totalling 43 sherds, weighing 444g, was collected from the site. Most of the sherds derive from two vessels, from which fairly substantial parts of the upper profiles survive.

The pottery was examined using a x20 binocular microscope. Fabrics were defined using a site specific fabric type-series according to the guidelines of the Prehistoric Ceramics Research Group (PCRG 1997). The pottery was quantified by sherd count, weight and estimated vessel number (ENV).

Fabric type-series

GLAUC1 Common well-sorted glauconite most c.0.2mm with rare quartz up to .5mm

QUARTZ1 Common angular moderately-sorted quartz c.0.1-0.3 in a highly micaceous matrix

GROG1 Common angular grog c.1-3mm, mostly dark in colours and rare iron stone up to 3mm

Overview of fabrics and forms

The most diagnostic vessel is a well-burnished S-profile jar in a glauconitic fabric, GLAUC1, featuring opposing diagonal bands of shoulder decoration bounded by similar horizontal bands (Fig. 1 Pot 1). Each individual band of decoration is formed by doubled tooled lines filled by a double line of rectangular toothed impressions, probably made with a roulette. Interestingly, the vessel has been well burnished on the interior surface, which would not have been readily visible. This perhaps

suggests that the purpose of the burnishing was to make the vessel more watertight rather than as a decorative effect.

The other diagnostic vessel is a plain rim ovoid jar, with an internal bead or thickening at the rim, in a grog-tempered fabric, GROG1 (Fig. 1 Pot 2). A few other bodysherds derive from a maximum of three vessels, two in fabric GROG1 and one in a sandy micaceous fabric, QUARTZ1.

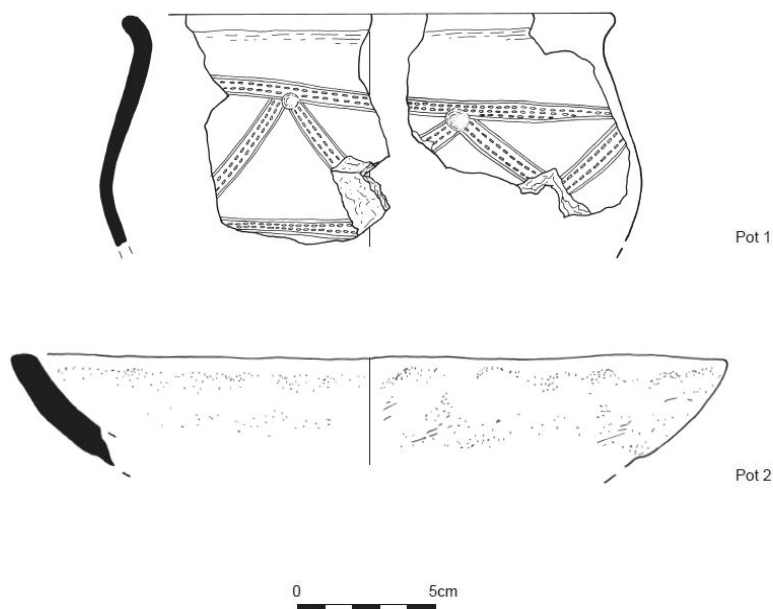


Figure 1 - Pottery from Whitepost Wood: Pot 1, S-profile jar with zone of rouletted and tooled decoration on the shoulder; Fabric GLAUC1. Pot 2, Ovoid plain rim jar with internal bead or thickening; Fabric GROG1.

Discussion

Most of the pottery sherds are fairly large and many are cross-fitting pieces derived from two different vessels, both of which are about a fifth

to a quarter complete. This suggests that, although the pottery was unstratified, it had not travelled far from its original context of deposition. Whilst the pottery is not necessarily all directly contemporary, it would all be consistent with what we would expect in a transitional Middle to Late Iron Age assemblage from East Sussex or southern Kent.

The rouletted vessel incorporates elements of the decorative style of the Middle Iron Age 'saucepan' continuum but the fact that it has a well-defined, shouldered S-profile probably places it in the later Middle Iron Age; furthermore, rouletted decoration does not seem to appear in entirely Middle Iron Age assemblages in Sussex but is commonly found in assemblages of a transitional Middle/Late Iron Age character such as those from Horsted Keynes (Curwen 1937, Figs. 11 & 12) and St Anne's Road, Eastbourne (Barber in prep).

The date of the first appearance of grog-tempering in East Sussex and southern Kent remains uncertain. Unlike in areas like Essex, Hertfordshire and north Kent, early examples of this tempering tradition in the region do not necessarily seem to be associated with Late Iron Age Aylesford-Swarling style pottery forms. At the south-eastern end of the Channel Tunnel Rail Link route, assemblages of Middle Iron Age character including saucepan forms, sometimes contained a significant proportion of grog-tempered wares. This was assumed to a development the Middle/Late Iron Age, although a few unusual grog-tempered vessels were associated with earlier Middle Iron Age radiocarbon dates (Morris 2006, 67-73). Unfortunately, there is very little independent evidence to date the more common appearance of grog-tempered wares, although if the two most diagnostic vessels are contemporary, a date in the 1st century BC is probably a reasonable estimate. Having said this, the grog-tempering tradition was particularly long-lived in this region and, in terms of form, the grog-tempered vessel could be placed anywhere from the Middle/Late Iron Age to earliest Roman period (c. 100BC-AD60).

Catalogue

- P1 S-profile jar with zone of rouletted and tooled decoration on the shoulder; Fabric GLAUC1
- P2 Ovoid plain rim jar with internal bead or thickening; Fabric GROG1

The Iron-Making Waste *by Jeremy Hodgkinson*

The waste materials submitted for visual examination comprised three main types: lumps of bloomery slag likely to have been formed within a furnace; flat masses of slag, with vermiform flow patterns on the upper surface, formed when slag was allowed to run from the furnace during smelting; and masses of fired clay with either a slagged or vitrified surface, which are detached pieces of the inner lining of the bloomery furnace. The slagged surface will have derived from areas lower down within the furnace where prolonged interaction between the refractory lining of the furnace and the slag descending during the smelting process has caused slag to become attached to the furnace wall. Vitrification has occurred higher up in the furnace, where the intense heat has melted the silica in the materials from which the furnace was constructed producing a glassy surface. In one sample submitted, both lining surfaces have been noted, indicating the interface that would have been evident on the inner furnace wall between the two areas in which the surface of the lining has been differently affected. Samples of slagged furnace wall exhibit a curved surface from which it is possible to estimate the diameter of the internal plan of the furnace. An average of two samples with consistent curved surfaces indicates an internal furnace diameter of 450mm.

The samples submitted do not constitute all the waste material from the site, but are representative of the types of material found there. Some of the material is likely to have been from primary depositional locations, but some may simply have been a convenient material to hand for backfilling unwanted pits. It is reasonable to suppose that they all derived from the same process and were broadly contemporary. Slag debris at the site was estimated to cover about 60m².

The most significant material is the slag formed when flowing, which indicates that slag tapping took place during the smelting process. This places the furnace within a large group of bloomeries identified in the Weald which operated in this way (Hodgkinson 2008a, 26). However, at least one sample of slag submitted showed signs that it had flowed over a length of wood, evidence that has been taken in the past to suggest non-tapping furnace technology (Hodgkinson 2008a, 26-7).

DISCUSSION

It has been argued that the output of the Wealden iron industry was actually a factor in the Roman invasion of Britain (Drewett, Rudling & Gardiner 1988, 171). Arguably given the fact that less than 30% of known Wealden sites have been dated, it is likely that a significant number of ironworking sites were in operation in the Weald in the centuries before the conquest, perhaps based on technology imported from the continent (Cleere and Crossley 1994, 53). Evidence from the classical writers is useful here. Although Caesar, writing in the mid first century BC is dismissive of the volume of iron produced in the 'Maritime Region' (i.e. the south-east of England), half a century later Strabo lists iron as one of Britain's exports, suggesting significant expansion of the industry (*ibid.*), and perhaps giving weight to the argument that the Romans coveted this valuable resource.

Excavated evidence of pre-Roman ironworking has been found at some of the region's Iron Age hillforts, such as Saxonbury, Rotherfield, from where "British (Celtic) iron slag" was recovered (Winbolt 1930, 228), and at Garden Hill, Hartfield, where there was evidence of smelting and forging of iron (Money and Streeten 1979, 23), dated to the Iron Age on the evidence of furnace type (see below; Cleere and Crossley 1995, 54). This has led to speculation that the hillforts may have acted as centres for processing of ores prior to redistribution during the Iron Age (Drewett, Rudling & Gardiner 1988, 160; Hamilton & Manley 1999). However, a number of Iron Age ironworking sites with no obvious local centre nearby have been identified by limited pottery finds at locations such as Footland Farm, Sedlescombe and at Crowhurst Park (Hodgkinson 2008a, 29). However evidence from excavations is limited, with notable exceptions at Goffs Park, Crawley (Cartwright 1992, 47-50), and Horsted Keynes where datable Middle/Late Iron Age pottery was found in association with "iron slag" and "burnt sandstone" (?roasted ore), suggesting ironworking at another 'isolated' site (Hardy 1937).

Unfortunately further study is hampered by the paucity of comparable assemblages from across the Weald (Hamilton 1992, 50), and by problems with close dating the so-called 'domed furnace' thought to be pre-Roman in origin but predictably continuing in use into the early

Romano-British period (Cleere and Crossley 1994, 41). The well-preserved example at Minepit Wood, Rotherfield, was dated to the “first half of the first century AD” on the evidence of associated pottery (*ibid.*).

Having acknowledged these issues, perhaps some tentative conclusions can be drawn relating to the distribution of Mid to Late Iron Age ironworking sites in the Weald. The later post-conquest Romano-British pattern of the organisation of ironworking appears to rely on larger central sites, such as Bardown acting as administrative centres to numerous ‘satellite’ bloomeries (Cleere 1970). It has also been suggested that much of the Weald was administered as an ‘Imperial Estate’ linked to security of the supply of iron for the Roman military machine. (Cleere & Crossley 1995, 68).

Although the Romano-British ironworking industry was clearly on a much larger scale than its Iron Age antecedent, arguably the evidence from hillforts such as Garden Hill or Saxonbury hints at a central control of iron production, in much the same manner that the distribution of other commodities such as timber and quernstones were apparently controlled (Drewett, Rudling & Gardiner 1988, 159-60). Miles Russell (2002, 131) goes so far as to suggest that there may have been a hillfort-based system of ‘protection’ of all those involved in iron production.

The Minepit Wood site lies close to Saxonbury, and Garden Hill also appears to have had its own ‘satellite’ ironworking sites, identified at Pippingford Park and Cow Park (Cleere and Crossley 1995, 54), and is thought to have “performed managerial rather than industrial functions, which could have included the supervision of nearby iron-working sites” (Money and Streeten 1979, 24) at a later date. Could Whitepost Wood have been another such Iron Age ‘satellite’ site, linked to Garden Hill (which is less than 10 miles away) or to another unidentified centre?

Perhaps then the post-conquest implementation of central control was not entirely new in the Weald, but simply expanded and intensified an Iron Age tradition? Jeremy Hodgkinson (2008, 30) has argued that variations in technology might have been influenced by the complex tribal allegiances of the Late Iron Age Weald. Hence does it seem likely that such technologies were controlled by tribal elites based in the Weald’s hillforts, administering satellite bloomeries and managing distribution of the product? Waste from the Whitepost Wood bloomery

shows evidence of tapping of the furnace during smelting, a tradition thought to have been introduced from the Rhineland in the century before the Roman invasion (Cleere & Crossley 1995, 53), but perhaps also influenced by Roman innovation via trade with the near continent (Cunliffe 2005, 176).

Perhaps just as imported luxury Roman goods were used “to maintain and enhance the status of the aristocracy” (*ibid.*) in the Late Iron Age, perhaps control of this method of production (or more specifically control of the specialist ironworkers) was seen as significant in Late Iron Age elite society, not only as a clear marker of high status but perhaps also on a more practical level as a secure source of aggrandizing artefacts such as fine iron weaponry and currency bars. Such currency bars or ingots were accepted as items for trade and exchange among Late Iron Age elites, and are often found deposited as hoards in hillforts (*op. cit.*, 496-7), providing further credence to the theory that ironworking was centrally controlled at this time.

Clearly much fieldwork will be needed before this undoubtedly over-simplistic model can be tested, but sites such as Whitepost Wood do offer the opportunity to add to the as yet limited raw data. If nothing else, perhaps the site offers a clear warning against the reliance on a single radiocarbon measurement to date the remains of a bloomery, or indeed any other archaeological site (cf. Hodgkinson 2010, where the site is carefully described as a “*possible* Saxon bloomery”).

However, in conclusion the recovery of Iron Age pottery from any Wealden site is of great significance in its own right, as to quote Sue Hamilton (1992, 52),

“the lack of pre-Roman Iron Age material from the Sussex Weald makes any material of this date from the Weald a valuable contribution to our limited understanding of Wealden Iron Age ceramic traditions.”

Clearly excavations targeted on spreads of slag can be invaluable for dating the associated ironworking, but also have the potential to offer far more to the still-limited understanding of past human activity in the Weald.

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SOME OPERATING CHARACTERISTICS OF WEALDEN IRON-INDUSTRY WATERWHEELS, BELLOWS AND TUYERES. ADDENDUM.

J. PRUS

It was argued in a previous paper (Prus 2010) that the power output of Wealden ironworks waterwheels may not have exceeded 300 Watts. The argument was based on indirect evidence from the archaeology, the available historical descriptions, minimum power requirement of the bellows and from the likely power output of two men when foot-power was used in the absence of sufficient water.

There is an additional line of evidence that establishes beyond reasonable doubt the small power outputs of some blast furnace waterwheels. This evidence comes from calculating water throughput in the relevant catchment area. A small proportion of the known blast furnace sites are sited quite close to stream sources. One of these sites (Warbleton Priory) has been studied in detail.

The centre of the Weald has an average annual rainfall of about 600 mm. Interpolating between the heads of the stream system of Warbleton Priory Furnace and adjacent stream systems outlines an area of slightly less than 1.5 km². Thus precipitation would have an average value of about 29 litres per second.¹ However, a number of factors inform us that this volume would not have been available for continuous use:

- Evaporation and transpiration reduce run-off. The area is dominated by broadleaf woodland (mainly oak) and the Forestry commission website

suggests that areas with such trees can use *at least* 350 mm. of water each year. (URL: [www.forestry.gov.uk/pdf/fcin065.pdf/\\$FILE/fcin065.pdf](http://www.forestry.gov.uk/pdf/fcin065.pdf/$FILE/fcin065.pdf))

- Rainfall varies chaotically between years.

The distribution of rainfall within each year is chaotic, so that massive surface run-off can occur. It seems an invariable rule that Wealden pond bays have spillways to deal with such spates. This water is lost and cannot help generate power.

These adverse phenomena are, to some extent, mitigated by other factors:

- The working systems are buffered by pond bays, and in many cases by pen ponds upstream. Warbleton Priory Furnace has three bays. Although precise calculation is impossible, these could have held several weeks' reserve.
- On the Hastings Beds, Wealden streams are fed by groundwater as well as surface run-off. Although small, the Warbleton Priory stream (Christian's River) seldom, if ever, dries up.

The campaign season spanned the wetter months and we may guess that nobody started a campaign until the ponds were full.

Nonetheless, the ratio between stream flow and precipitation is unlikely to have been more favourable than 250:600. Thus average throughput is about 12 litres per second. The difference in level between the spillways and the ground below the furnace-remains is consistent with a wheel three metres in diameter, so this system would have struggled to develop a steady 300 Watts. The crucial fact to note is that the furnace seems to have operated (with interruptions) for about forty years between about 1540 and about 1640. Its layout poses some problems of interpretation, but in most respects it seems typical of its time and place.

It is not the purpose of this note to suggest that water-flow problems contributed to the final demise of the works (c. 1640). By 1640 Wealden blast furnaces were in steep decline (King 2005, 7) and other ironworks, many on bigger streams, went out of production at around this time.

Neither this particular example nor the arguments previously presented 'prove' that more powerful systems did not exist in the Weald. But they show that smaller blast furnaces definitely were run on miniscule

power outputs.

Notes

1. Area = 1.5 sq. km = 1.5×10^6 sq. metres. If rainfall is 600 mm. then volume of precipitation = 9×10^5 cu. metres in the given area. There are $24 \times 3600 \times 365 = 3.1536 \times 10^7$ seconds per year. Thus about 0.029 cu. metres or 29 litres fall, on average each second. But if the characteristic vegetation and soil of the area cause 350 mm. total precipitation to be transpired and evaporated, then only 250/600ths. can run off. Thus an average of about 12 litres per second may be expected to flow in the streams.

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ST LEONARD'S FOREST MINEPITS

VIVENNE BLANDFORD

An archaeological survey of St Leonard's Forest was undertaken during 2010/2011 for Forest Enterprise to review its historic environment resource and provide conservation and management recommendations to Forest Enterprise for the heritage of this area of woodland.

St Leonard's Forest is owned and managed by Forest Enterprise on behalf of the Forestry Commission. The area of land owned by the Forestry Commission was once part of a much larger area of ancient forest and heathland known as St Leonard's Forest. It lies within the High Weald Area of Outstanding Natural Beauty, and forms the most westerly extension of the Weald Forest Ridge. It lies to the east of Horsham and to the south-west of Crawley, between two prominent ridges of prehistoric east-west routeways. The northern route, Ashdown Forest to Horsham, passes through Colgate, a forest entrance or gate, and the southern road, Slaugham to Horsham, crosses over the causeways to the dams of the Hawkins Pond and Hammer Pond.¹ The northern entrance of the Forest today is called Colgate, the first element of the place name Colgate (coal=charcoal) may indicate the practice of charcoal burning in the forest.²

Cleere and Crossley recorded that, within St Leonard's Forest, was an area known as The Minepits which had been photographed by Straker in 1931 when this area was an open oak wood.³ It is now under cover of beech. The geology is of Upper Tunbridge Wells Sand.

In the Weald the principal method of obtaining ore was a method of mining which left minepits in the landscape. These were generally vertical shafts of about 1.8 to 2.4 metres in diameter, although the ones in St Leonard's Forest are considerably larger. They were sunk to the seams, or layers of ore. The pits would be filled in with material dug from a new pit a short distance away.⁴ Today this results in a pock-marked landscape

with pits which are often filled with water, but the minepits in St Leonard's Forest are nearly all free draining and do not hold water.

The St Leonard's Forest minepits are an unusual example of their kind, being much bigger than the average minepit found in the western Weald, and were the source of ore for the nearby 16th-century ironworks. Later land improvements and 20th-century forestry planting have removed most of the evidence for charcoal burning platforms which could have been associated with the iron industry.

Between circa 1550 and circa 1660 the chief non-agricultural economic activity of the area was ironworking. The ironworks existed by 1562 when they were described as "the iron mills in St. Leonard's Forest". The twin St. Leonard's ironworks at Hawkins and Hammer ponds on the Horsham-Slaugham road were the largest in western Sussex; the eastern pond, called Hammer pond, had a forge, known as the Upper Forge, and the western pond, called Hawkins pond by 1585, fed both a forge, known as the Lower Forge, and, between about 1584 and 1615, a furnace.

In the 1580s, the owner of the nearby ironworks was a Roger Gratwicke whose sole right to mine ore in the forest was challenged by Walter Covert of Slaugham whose workmen began digging ore in the forest, their workmen clashing several times with those of Gratwicke. In reply to Gratwicke's suit against them, the two men alleged that his minepits were wastefully operated and were producing more ore than he could use, while they themselves were merely taking the lower deposits which his men left behind.

In 1588 they claimed to process 1,000 loads of ore annually, the ore being obtained south-west of Colgate, where many deep minepit craters can still be seen. These are large craters up to 9m across at the ground surface and up to 2.5 m deep. The pitted ground is on the flat top of a ridge between two deep valleys, where, since the beds are nearly horizontal, the iron seam could have been followed underground by workings that maintained a near-constant level.

The deepest and largest spread of minepits is found in the northern section of the survey area (near to Colgate) around TQ 2205 3205. These are quite spectacularly depicted on the lidar image (Fig. 1) and it is the first time such a set of minepits are so well depicted as they are difficult to photograph from ground level and aerial photographs



Figure 1 - LIDaR (Light Detection and Ranging) survey of part of St Leonard's Forest, centred on TQ 220323; courtesy of Chris Butler Archaeological Services Ltd.

cannot penetrate the woodland canopy. This group of numerous minepits are deep holes with large rounded piles of spoil spread around circumference, not of even size. Classically the spoil spreads round circumference of pits in a horseshoe shape, leaving a clear exit point, the spoil banks are a couple of metres high. The pits are slightly conical in shape, up 8-10 metres deep, but of varying sizes. Some pits are shallower than others, all closely spaced together with a 1-3 metres baulk between pits. This set of minepits continues on other side of the Forest track and have been cut and filled in by the track at this location. The minepits on

the eastern side of the track are generally smaller. The majority of minepits found during the survey were not water filled as the soil here is free draining. In the south-east of the survey area at TQ 2129 3000 there was a scatter of minepits, one of which was water filled, and they varied in size from 2-3m across and deep to 7m across and 7m deep. Some of the minepits were very shallow and more like surface quarrying. Many of the minepits had an obvious exit and access route out from the minepit which was reflected in the horseshoe shaped spoil around the edges of the crater.

The depth and size of the minepits are directly related to both the geology and the topography; it was noted that some of the minepits were deeper on the higher ground or plateau and shallower further down slope and to the southern part of the survey area. However some variation in size could be due to inconsistent mining practices in the 16th century.

It is fairly unusual to be able to positively date something like a minepit but there can be little doubt that the minepits that survive today, under beech woodland, in the northern part of St Leonard's Forest, can be dated to the late-16th and early-17th century and were worked by miners employed by Roger Gratwicke and Walter Covert.

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A POPE FAMILY FIREBACK

J. S. HODGKINSON

A cast-iron fireback has been identified as bearing the arms of the Pope family of Hendall, in Buxted (Fig. 1).¹ It has the date 1625 and the initials SP. The fireback appears to have been cast from a one-piece wooden pattern with arms carved in low relief within a shield embellished with strapwork motifs, which were typical of the early 17th century. The styling of the initials, on each side of the shield, suggests that they were carved as part of the original pattern. However, the date, which may well have been carved as a small stamp, appears to have been added to the mould before casting as it obliterates one of the fleur-de-lys embellishments above the shield.



Figure 1 - Fireback of 1625 showing quartered arms of Pope and initials, SP; W 525 x H 585mm; photo courtesy of N. Gifford-Mead.

The condition of the fireback is poor and the details of the heraldry are not clear. However, another example of the same back is known and on this the detail is better, although a mistake in pouring the iron during casting has caused an excrescence on the upper right side (Fig. 2). The shield is quartered into six: from the top left, 1st. Pope (or, two chevrons gules, on a canton of the last a mullet of the first); 2nd. Walshe (argent, three bars gules, on a canton ermine a bend of lozenges of the second); 3rd. Waller (sable, three laurel leaves in bend or between two bendlets argent); 4th. Lansdale (azure, a chevron between three crosses moline argent); 5th Weston (ermine, on a bend gules three lions' heads erased or); 6th. Pichingham (azure, a lion rampant or supporting a cross patée fitchée of the second). The quarterings represent marriages with heiresses in the Pope and Waller descent.²

***Figure 2 - Fireback as
Fig. 1; from a glass
negative in the
Bridgewater Collection;
courtesy of Sussex
Archaeological Society.***



Hendall furnace, in Buxted, was owned and operated by Nicholas Pope in 1574, and is almost certainly the “Pope’s furnace” noted as working about four years earlier.³ Ralph Hogge made iron there between 1576 and 1581.⁴ Nicholas Pope referred to his “fordge or hammer” in his will of 1598 but did not mention the furnace, which may have been let at

the time, and the works were, presumably, still in the ownership of the Pope family in 1620 when Rafe Pope, who had taken over on the death of his father in 1599, was in possession of two sows belonging to Richard Maynard of Rotherfield.⁵ There are no further references, suggesting that the furnace and/or forge went out of production soon after, probably with the death of Rafe Pope in 1621. Rafe Pope's eldest son and heir was Sackville Pope, and the inevitable conclusion is that the initials on the fireback are his.

It is tempting to consider that this fireback was cast at the ironworks that Sackville Pope may have inherited from his father. Nicholas Pope had referred to his forge but not the furnace that had been operated during his lifetime, but did Rafe Pope revive it or take it back into possession after the end of a lease, it then being un-named in Rafe's less-detailed will of 1616?⁶ Is the existence of the fireback of 1625 evidence that the furnace was still in operation at that date? Sackville Pope sold most of his Sussex property in 1626 and moved to Yorkshire.⁷ His will of 1644 makes no mention of the Hendall property.⁸

The Pope fireback also bears similarities with another back, which may have been cast from a pattern made by the same woodcarver at around the same time (Fig. 3). Also armorial, it shows the shield, helm, mantling and crest of the Pelham family. The shield has strapwork embellishments as does the Pope shield, and the carving is in the same distinctive low relief that is rather uncommon on firebacks. Having a closed helm and no supporters, it shows the arms of a gentleman, and the absence of a baronet's badge may indicate that it was made for Thomas Pelham (d. 1624) prior to the creation of the Pelham baronetcy in 1611.⁹

The possibility that the pattern for this back may have been the work of the same craftsman as the Pope fireback does not, of course, imply that both firebacks would have been cast at the same furnace.

Notes and References

1. I am grateful to Nicholas Gifford-Mead, of Pimlico, for making details of this fireback available to me.



Figure 3 - Fireback showing quartered arms of Pelham; W 845 x H 730mm; Anne of Cleves House, Lewes; courtesy of Sussex Archaeological Society.

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HOTHFIELD FORGE, KENT - A NEW WATER-POWERED SITE

TONY SINGLETON

The earliest suggestion that the construction of some ironworking facility was being contemplated in the Ashford area was in a letter of 1570 from Archbishop Parker to Queen Elizabeth, stating that Sir Richard Sackville had intended, “as I am credibly informed, in that wood (Longbeach, Westwell) ...to erect up certain iron-mills, which plague, if it come into the country, I fear it will breed much grudge and desolation”.¹

Possibly local opposition prevented any further action being taken in the area although Nicholas Tufton, of Hothfield Place (1578–1631), purchased Ewhurst Furnace in 1623 and, on his death, it passed to his son, John (1608-1664).² John married Sir Richard’s great-great-granddaughter, Margaret, and it is most likely that it was he who made the decision to construct a forge at Hothfield because it is not until the 1650s that there is any documentary evidence of forging there.

In 1654 Elias Standen married in Hothfield parish church and a daughter was baptised there the following July. Elias was the third son of James Standen, who had been leasing the forge and furnace at Hawkhurst in the 1640s.³ Elias and his younger brother, Edward, were born in Hawkhurst and it was father, James, and Edward who are mentioned in the Cranbrook parish registers shortly after:

“23 Sep 1656 Edward Standen of Hothfield, hammerman, son of James of same, hammerman, married Elizabeth Ferrall.”

Edward stayed in Cranbrook but Elias and his father, James, subsequently moved to Biddenden, where another brother, Thomas, was employed as the “fineryman” at Hammer Mill. It therefore seems likely that James, with his experience at Hawkhurst, was recruited by John Tufton of

Hothfield Place to commission the hammer forge there, and that James brought his sons, Elias and Edward, to assist him in about 1650. This date is further supported by the fact that the Tufton estate documents include a survey of Longbeach Wood (owned by Canterbury Cathedral) made in 1647 which they later leased.⁴ The Tuftons owned much woodland in the area but those at Longbeach, in the neighbouring parish of Westwell, were extensive; the survey cites an earlier lease in which the estate extended to 808 acres, of which 300 acres were to be maintained as timber trees. Further entries in Hothfield parish registers confirm that a forge was in operation in the 1650s and 1660s as they include the name of “Russell the hammerman” in 1653 and several burials of forgermen or members of their families in the early 1660s. In May 1661, the registers record the marriage of the hammerman, Edward Luxford, and when he lost his wife, Anne, three years later, the requisite marriage licence confirmed his occupation in April 1665.⁵

When Sir John Tufton died in 1664, there must have been problems with his will, because, although a copy survives in the Tufton papers, it was not registered.⁶ As part of probate, an inventory of his moveable goods and chattels was drawn up, much of which is a detailed list of furnishings in Hothfield Place. However, equipment and iron at the forge in Hothfield are also valued, together with a list of bonds for the sale of iron.⁷

Page 34 of the inventory has:

At the Hammer Forge	
3 pr of Bellows	005 - 00 - 00
22C of Iron Castware	004 - 08 - 00
A Forge Anvill	000 - 10 - 00
10 pr of working Iron Tongs	001 - 00 - 00
6 Iron Ringers)	
2 Irone Turne Sowes)	
3 Iron Twaires)	001 - 10 - 00
and other working tooles)	
1 Hamer beam lying in the Pond	003 - 00 - 00

180 Tons of Barr Iron was valued at £2160 (£12 per ton) at “Hammer

At the Hammer Forge.

3. p ^{cs} of Hollows	-	605	-	00	-	00
22. p ^{cs} of Iron Bastards	-	604	-	00	-	00
At forge Anvil	-	000	-	10	-	00
10. p ^{cs} of working Iron Tongs	-	001	-	00	-	00
6. Iron Limbors	-	-	-	-	-	-
2. Iron Turners Sawes	-	-	-	-	-	-
3. Iron Twains	-	001	-	10	-	00
and other working tools	-	-	-	-	-	-
1. Hammer beams, lying in y ^e p ^{cs}	-	003	-	00	-	00
7. waynes, & 2 Hambroes	-	002	-	00	-	00

Figure 1 - Extract from the draft copy of John Tufton's inventory (Kent History and Library Centre, U455 E1).

Cluttery & Westwell". The cluttery appears to be a local(?) name for a finery. In December 1663, a local man was accused of "knocking down the chimney ... from a house in the Earl of Thanet's ground, called the Cluttery alias the Finery".⁸ Presumably iron was at Westwell en route to customers. The inventory also includes several merchants' bonds for iron totalling £4229, of which one bond for £3050 was described as "desparate". The remaining 18 years of a lease (expiring in 1682) of Longbeach Wood in Westwell was valued at £1200. On a preceding page, goods at Ewhurst Furnace are listed; 245 tons of sows there were valued at £4 10s per ton and some or all were possibly destined for the forge at Hothfield - a long haul of about 23 miles on current roads.

John's eldest son, Nicholas, inherited the freehold estate and a retrospective marriage settlement was drawn up for Nicholas' wife, Elizabeth, in February 1664/5.⁹ This contains a detailed list of the properties which Nicholas had inherited, including "a messuage or tenement and forge in the tenure or occupation of John Missing." John

was the eldest son of William Missing, blacksmith, of Hothfield, who, on his death in 1661, bequeathed to John “all my working toles belonging to my trade”. There is no evidence that William worked at the hammer forge but John had clearly become the forgemaster in the 1660s, because the above inventory also includes, under the hammer forge heading, iron valued at £8 in his possession.

Site Location

A preliminary visit to all former water-powered mill sites in Hothfield parish was made in March 2013 but no evidence of slag, early pond bays or tailrace channels was found. There is only a small fall on the River Stour as it passes through the parish so it appears that the mills on this river were probably only breast-shot. However, a tributary, rising to the northeast in Westwell on the North Downs, has a better gradient and powered an overshot wheel at Denne’s Mill at TQ 988450 near Potters Corner, close to the modern A20. The 19th century building is still standing (used as offices) but much modern development has destroyed most of the evidence of that mill site. This stream meets another from the north and fills a large fishing lake with a modern(?) pond bay, at least two metres in height, at TQ 986445; the site is known today as Waterfall. The lake was ‘created’ in 1851 by the Tufton family for fishing and boating but early OS maps of the area show a smaller pond on the site and what may have been the remains of a tailrace running parallel to the main stream for 200-300 metres before rejoining it. There are clear signs of disturbance in the field where this second channel has been filled in. No slag was found in the stream, which leaves the lake today, but further exploration of this area looks promising and needs to be undertaken.

The End

Nicholas Tufton died in 1679 and bequeathed all his freehold property to his three brothers, Richard, Sackville and Thomas.¹⁰ In view of the considerable contraction in the number of Wealden forges operating



Figure 2 - First Edition Ordnance Survey Map (Sheet 3 covers Kent), first surveyed 1789, showing the vestigial pond and twin water channels south-east of Hothfield village.

during this period, it is likely that the forge at Hothfield ceased operation about or before his death. If not, it had definitely closed by 1684. A surviving book of accounts of the Tufton estate, starting at Lady Day 1684, includes alphabetical lists of tenants with their rents and brief descriptions of the lands they occupied.¹¹ There are several fields described as in or near the “Old Ham(m)er Pond”. The use of the pronoun ‘in’ indicates that the pond had been wholly or partly drained so that the land could be used for farming again. This is confirmed on a map of Kent published by Andrews, Drury, and Herbert in 1769 (and copied by Hasted) which shows a vestigial pond (the OS map, Fig.2, is less clear). Interestingly, in 1684, Edward Sheppard was paying a rent of £1 5s “for the Fineryman’s house”.

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11. KHLC, U455 A1.

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ESTIMATING 18TH-CENTURY CANNON BORING TIMES, COSTS AND THROUGHPUTS

ALAN F. DAVIES

INTRODUCTION

A previous article (Davies 2012) describes how a computer model, using information from *The Fuller Letters 1728-1755*, explored business performance of a mid 18th-century Wealden gun manufacturer. A linked subsidiary model provided estimated cannon boring times and costs as part of direct manufacturing costs in the main model. This showed boring process represented around 1% of direct campaign costs compared with, for example, cast metal costs of about 80%. Good technical control of boring and effective throughput helped ensure timely deliveries for proofing and debenture incomes.

This article describes development and use of this subsidiary model. It explores interactions between key variables to estimate operating limits for cannon boring times, direct labour costs and mill throughput performance. Model results are validated against several of the Fullers' *Letters* commenting on cannon delivery times.

Also it is suggested that Fuller's policy change from 1740 to manufacture larger guns had the effect of reducing gun value throughputs of his single boring mill. Whilst Fuller's second mill, from 1742 (*Letter* 429), provided additional boring capacity this article shows how work flow might be adjusted also to benefit most from this extra capacity.

TIME AND COST OF BORING A CANNON

Boring methods

Written records describe a number of tooling methods for boring cannon. Choices include three or four cutters mounted equidistant in a dog-head of a boring bar or fewer cutters but with additional side pads to maintain a cylindrical bore or even using two-pass boring with a fine finishing cut. Optionally a single end cutter may be attached to smooth the breach section (Partington, 1838, 58).

The *Letters* indicate that the Fullers used only basic boring machines with horizontally-mounted hollow cast cannon being pulled on a trolley using a capstan, rope and later chains, (*Letter* 439), against a fixed cutting tool head rotated by a directly coupled waterwheel. Moreover Trent and Smart's examination (1984) of a Wealden 17th-century hardened steel/wrought iron laminated and tapered side cutter, head and bar arrangement (in use some 90 years prior to Fullers' time) suggest the boring head originally contained four side cutters for metal removal.

Boring time and cost calculation

The model calculates a total boring time in minutes for a cylindrical metal volume removed from a gun bore in one revolution multiplied by the number of revolutions for a calibre average bore length, all divided by the r.p.m. of a directly-coupled waterwheel. Cylinder external diameter combines shot diameter and windage of either earlier 21/20 or later 25/24 ratios. To this time are added estimates of set-up time (and unloading) as a function of gun calibre, time to replace worn cutter(s) and continue boring until either next the tool change or completion, to give an estimated total gun boring time. This time is expressed as boring hours per gun calibre and so gives the number of each gun size bored in a ten hour day (variable). Boring time multiplied by craft labour rate (variable) gives the estimated direct absorbed cost of boring one cannon.

Hardened high carbon steel tool cutting speed

Guidelines for early 20th-century machining, using properly hardened and sharpened carbon steel cutters on hard grey cast iron, establish a likely best 18th-century cutting speed of 10-15 surface feet/min (around 3-4.5m/min). For a 32-pounder gun a cutting rate of much above about 9 r.p.m. would exceed the suggested surface cutting speed range. By comparison, a six pounder gun could be cut at up to about 15 r.p.m. Actual speeds used in the Weald in the 18th century would most likely be lower owing to low-rigidity wooden machines, variability of hand capstan tool feed and cutter quality, bore surface defects and most importantly water supply rate for the wheel.

Waterwheel rotation rate

Trent and Smart (1984, 8) suggest that a boring mill waterwheel could operate at “10 r.p.m. giving a cutter speed of 2m/min” (about 7 feet/min); historical Wealden data indicates furnace waterwheels probably rotated at about 2 r.p.m. for an optimum bellows blowing rate. However smaller-diameter forge and boring wheels would rotate faster than a furnace wheel for the same water flow rate. Prus (2010) identifies water supplies as a key factor limiting Wealden waterwheels to probably around 2 r.p.m. So for the basic model a rate of 2 r.p.m. was adopted for Fuller’s Boring Mill. Effects of different rotation rates are shown later.

Tool Life

As much as surface cutting speeds, tool life depends on cutter hardness and wear from the volume of metal removed. Temperature rises above about 200°C for hardened high carbon steel, progressively reducing cutter hardness giving faster wear. Also life is reduced markedly by damage from any bore surface irregularities or white iron zones. To contain these operating uncertainties the model uses outcomes of early 20th century machining experiments and adopts a conservative total chip removed volume of 130 cubic inches (variable) as a working criterion for changing cutter(s) .

Basic boring model variables and throughput

Variable	Value	Metric
For hardened Carbon Steel Cutter on hard cast iron	10 ft/min	c.3.0 m/min.
Depth of Cut (DOC) (Fixed from tool geometry)	0.14 inches	c.3.5 mm
Feed Rate low owing to 'low rigidity' of machine and tooling	0.13 inches/rev.	c.3.25 mm/rev
Tool change after volume of metal cut:	130 cubic inches	c.2032 cm ³
Time to do Tool Change - withdraw cutter bar, change & set cutter(s), reinsert and continue boring	15 min.	-
Labour Rate - skilled gun borer	24 d./day (10 hrs.)	0.01 £ /hour
Waterwheel Rotation Speed - direct drive	2 r.p.m.	-
Working day	10 hours	-
Initial set up time (Loading gun onto boring machine, alignment checking, fastening, cutter tool setting, cutting trial check)	Gun Pounder+20 'minutes'	-

Table 1 – Variables Used in Basic ‘Single Pass’ Boring Model Calculations

Pdr.	Shot Diam ins.	Bore 21/20	Large Rad ins.	Small Rad ins.	Depth ins.	Face Area cu ins.	Vol. Fe cu ins.	Wheel RPM	1 Rev. cu ins.	Nos. Revs
18	5.0	5.25	2.63	2.49	102	2.25	229.25	2.00	0.29	785

continued...

Pdr.	Boring Time Min.	Tool/ Set Up Mins.	Revs. To Tool Change	Nos. of Changes	Change Time-Mins.	Boring Total Mins.	Boring Total hrs.	Labour Cost £/ Gun	Throughput Guns/day
18	392	38	445	1.00	15	445	7.42	£0.074	1.35

Table 2 – Example Basic Model Calculations for 18-Pdr. Cannon

Table 1 shows variable values used for basic ‘single pass’ model calculations and Table 2 an example of model calculations for an 18-Pdr. cannon.

Figure 1 shows model results of basic calculations for range of cannon pounder sizes.

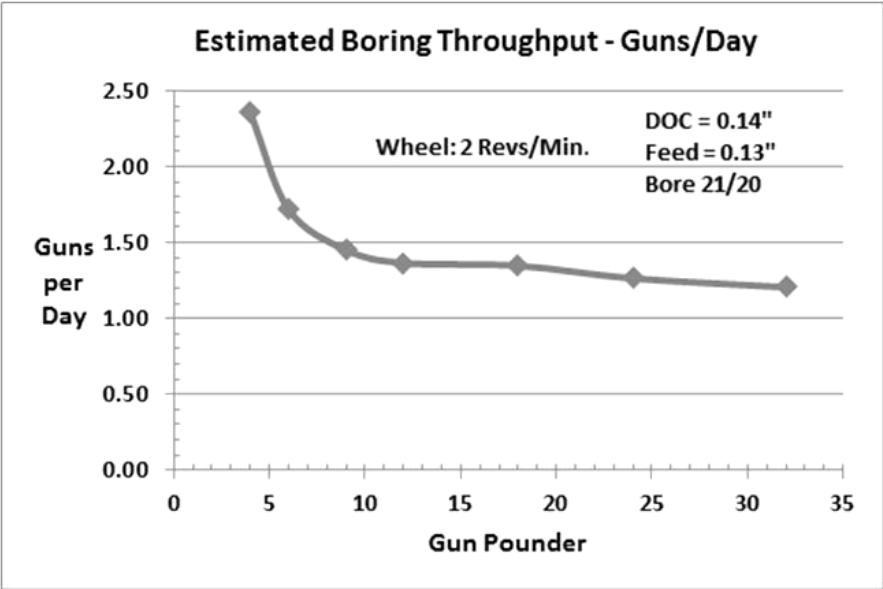


Figure 1 – Basic Model Calculations for Gun Throughput per Day by Calibre

Estimated direct labour cost to bore a cannon

Figure 2 shows for the basic model, absorbed direct labour cost in UK pence for each cannon pounder size bored on site. ‘Labouring’ at a lower indirect overhead hourly rate is assumed for hoisting and securing cannon on to and off a boring machine and selecting and mounting a cutter bar. Similarly indirect skilled labour would probably be used for setting and maintaining sets of sharpened tool cutters.

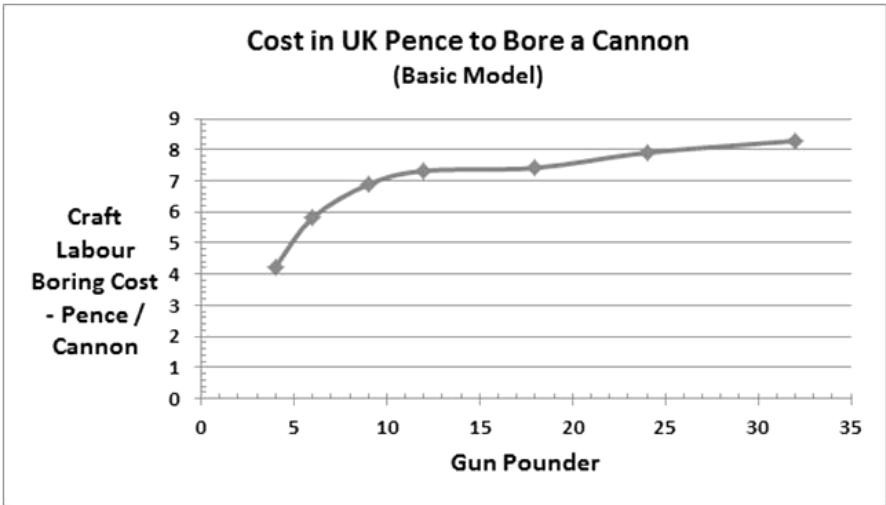


Figure 2 – Cost in UK Pence to Bore a Cannon of given Calibre

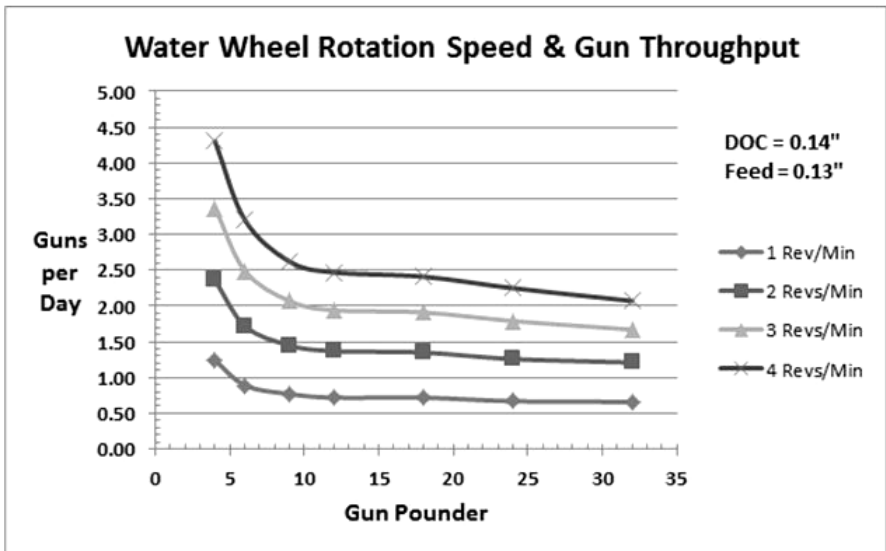


Figure 3 – Effect of Waterwheel Rotation Rate on Gun Throughputs

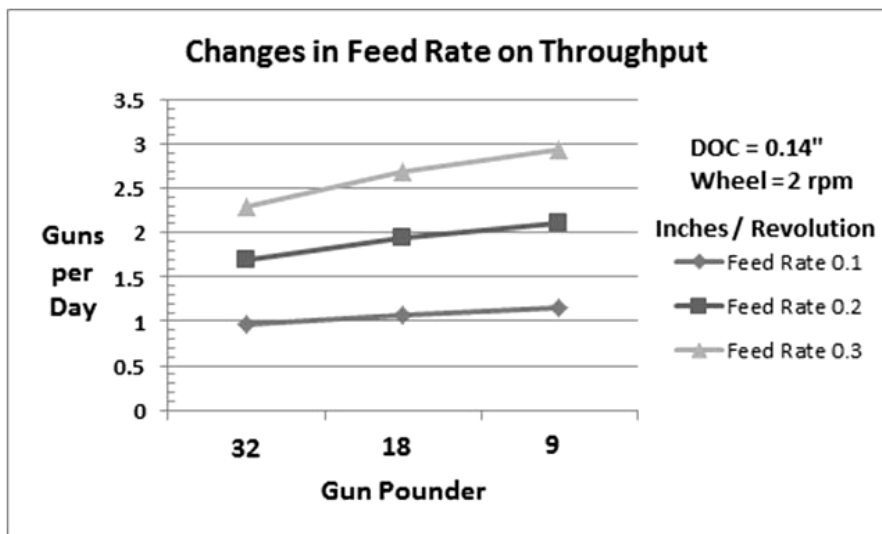


Figure 4 - Effect of Boring Tool Feed Rate on Gun Throughputs

Effects of changes in variables on production throughput

Figures 3 and 4 show respectively how small changes in waterwheel rotation rate and tool feed rates independently change gun throughputs.

These model results show how a boring machine operator could use experience to vary or optimise output of bored guns by adjusting operational parameters – but within limits. For example doubling feed rate alone would almost halve cutting time per cannon and increase throughput. However any excessive tool overheating or damage may have required additional tool change(s), so negating the effects of any feed rate increase.

MILL UTILISATION AND THROUGHPUT

The Fullers' output of cast metal from the furnace was around ten tons per week. Dedication to cannon production would enable 16 four-pounder cannon to be cast followed by seven days (= 100%) of single shift boring capacity (using basic model calculations). This would give about £124 of

potential weekly debenture income. For this gun size, weekly casting output and boring throughputs were more or less 'in balance'. Instead this furnace weekly metal output would cast a great gun every 2-2½ days followed by eight hours or so to bore. So this output of about 2½ guns, produced in a week towards the end of a campaign and bored, would take only around 30% of boring mill weekly capacity and provide a lower potential debenture income of about £110 for 32-pdr cannon.

Figure 5 shows this overall effect for gun sizes produced and especially lower mill utilisation for larger cannon sizes produced and bored towards end of the campaigns.

Fortunately any gun backlogs from early campaign production can be used to fill this spare end campaign capacity. Table 3 shows an example of how scheduling a mix of cannon sizes improves single mill weekly total value throughput and utilisation.

Similarly, using two mills would effectively double these throughputs and benefits, with the opportunity for additional productivity benefits from second shift working.

Overall Fuller's policy of wanting and achieving, from 1740, higher proportions of great guns in his warrants probably imbalanced his single boring mill throughputs. Whilst his *Letters* are silent on this problem he did set up a second boring mill, available during 1742, effectively doubling capability. Also making use of any gun backlogs would give his workpeople more flexibility for allocating guns, scheduling and balancing mill throughputs and so maintain overall high output debenture values. Importantly, a second mill would maintain some output capability against interruptions in one of the mills.

MODEL VALIDITY

The reasonableness of the basic model as an indicator of throughputs is tested against the following comments made in the Fullers' *Letters*. Two output rates are given. A lower value for the basic model and higher value for increased waterwheel rotation rate of 3 r.p.m. with constant Feed Rate so giving estimated longer and shorter completion times respectively. An assumption is the uninterrupted boring of a batch of

guns.

Letter 384 mentions a batch of 11 x 18-pounder guns still to be bored and available in a very short time. At about 1.35 or 1.91 guns per day respectively these would take about six to eight days to complete.

In Letter 427 Fuller identifies 70 x 9-pdr guns to bore and that they should be ready in two or three weeks when his new boring mill is running. For a 9-pounder gun the basic model output is about 1.45 or 2.07 guns per day. So for 70 guns around 34-48 days' work is needed or around 17-24 days if both boring mills were used. This backlog could be cleared within three weeks.

Letter 429 mentions 80 x 9-pounder guns that are expected to be ready in a short time. At about 1.45 or 2.07 guns per day average requires either around 39-55 days' work or about 20-28 elapsed days using two boring machines together as Fuller indicated. Delivery time would be halved again if both boring machines were worked for double shifts.

Fuller identifies 70 large guns to be bored and that they will be done within about a month. The model estimates these 70 guns would take around 42-58 days to bore or around 21-29 days for again either two shift working or two boring machines dedicated to single shift working. Again the intended time can be met.

With no specific mention in the *Letters* about shift-working, it is likely this option would be needed to process backlogs or bulk numbers of guns for the basic model parameters selected. Using this capacity, the model is estimating throughputs broadly in line with stated expectations. However analyses show that making even small adjustments to boring operating parameters or mix of guns can give marked changes in gun throughput rates. However avoiding tool overheating or breakage probably gave a practical upper limit to gun throughputs for a mill.

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ISSUES, EMOTIONS AND ACHIEVEMENTS - MANAGERS AND AGENTS OF A MID-18TH-CENTURY CANNON MANUFACTURER

ALAN F. DAVIES

INTRODUCTION

A previous article¹ describes modelling of information in *The Fuller Letters 1728 – 1755*² to show how differing combinations of factors about gun demand, manufacturing and management decisions affected the performance of the Fullers' cannon business.

This study extends analysis of the *Letters* data, using a different modelling approach, to seek some initial insights of what it was like practically and emotionally for father and son Fuller to run their businesses under varying economic, operational and financial conditions.

Comparisons are made of how each Fuller reacted to conditions as well as the role effectiveness of their agent in influencing performance.

METHOD OF ANALYSIS

Of the 300 letters related to cannon manufacturing 159 were selected covering 25 years' relationship between the two John Fullers and their agents. Themic Analysis³ methods, supported by Microsoft EXCEL 2010 software, recorded and organised dispersed, coded, qualitative *Letters* Data Items. Table 1 shows the two code sets. Grouping common characteristics enabled analysis of reactions and associations with events.

Code Set	Describes	Use
Business Processes	Functional part of manufacturing business	Selected stage of manufacturing where key reaction is either associated or reported
Emotive	Emotion expressed in a Data Item	Selectively coded from a set when a Fullers' reaction for a Data Item is expressed or inferred

Table 1 – Code Sets Used

Number of Data Items forming a group also gave a useful proxy measure of relative importance when compared with other grouped Data Items.

Comparative analysis Periods were created by grouping *Letter* data spanning several years. Fortuitously life spans of Fullers and their Agent times provided a natural grouping, Table 2.

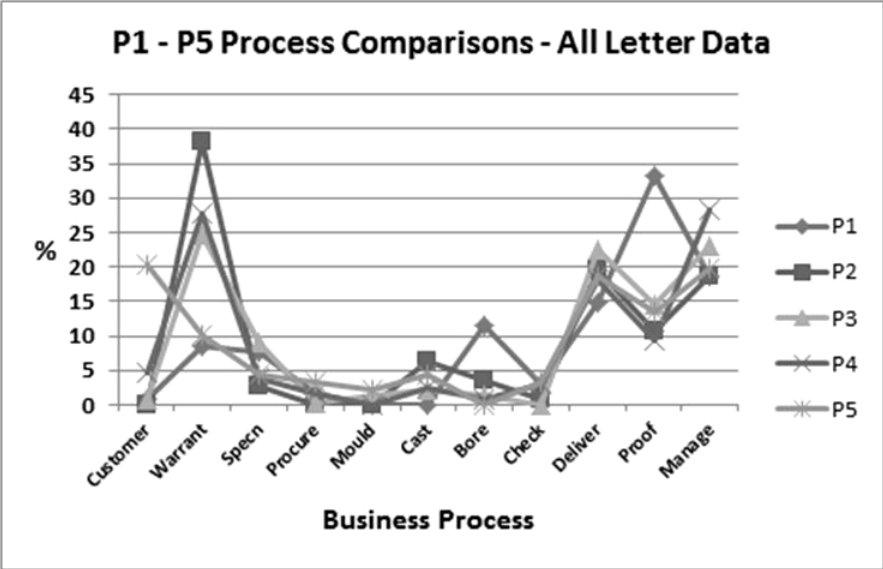
Historical campaign records of furnace gun and iron outputs were modelled to show how Fullers' expected business incomes and cash creation varied over a number of consecutive years.

Principal	Date Span of Letters	Agent	Analysis Years	Period No.
John Fuller (JF1)	1728-1745 (died)	Samuel Remnant	1729-1734	1
			1735-1739	2
			1740-1745	3
John Fuller (JF2)	174-1750	Samuel Remnant	1746-1750	4
John Fuller (JF2)	1750-1755 (died)	Jefferson Miles	1751-1755	5

Table 2 – Principals, Agents and Analysis Periods

FINDINGS

Manufacturing Stages



*Figure 1 – Detail Comparison of Manufacturing Processes
Periods 1 to 5*

Figure 1 shows a common Period pattern of results from grouping Data Items by manufacturing business processes referred to in *Letters*. Not surprisingly these processes comprise agent-related matters about ‘Warrant’ especially in Periods 2, 3 and 4, ‘Deliver’, ‘Proof’ – especially in Period 1 and ‘Manage’. ‘Customer’ process in Period 5 is prominent from JF2’s focus on getting foreign gun business.

Apart from these peaks there is generally much lower incidences of comments about internal manufacturing processes, except for ‘Bore’ process in Period 1, unless they affect either delivery or give quality problems such as casting defects.

Displaying Period *average* values and excluding emotive data content gives an easier chart to view, Figure 2, showing long term strategic content for ‘Warrant’, ‘Deliver’, ‘Proof’ and ‘Manage’ processes. Altogether about 82% of *Letters* content involves these four processes.

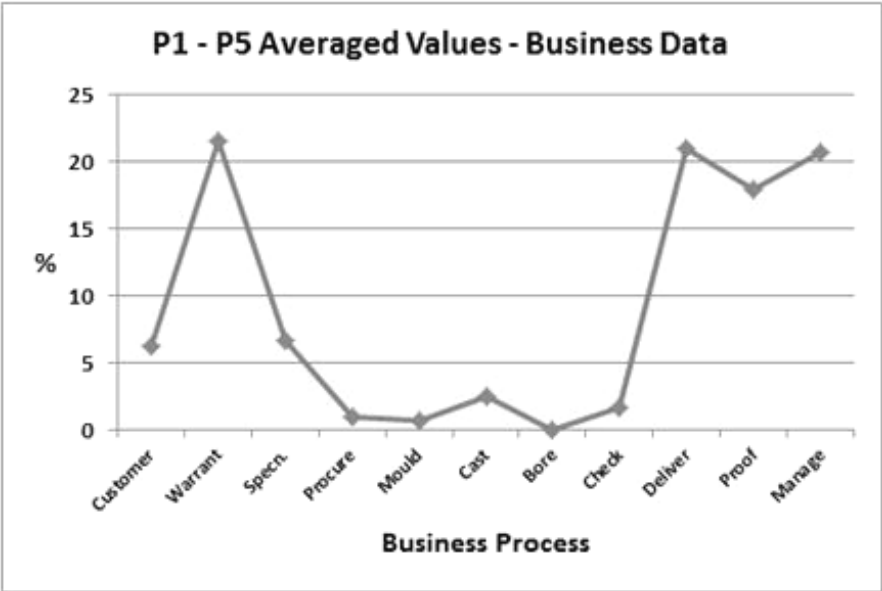


Figure 2 – Averaged Comparison of Business Processes Periods 1 to 5

Management Reactions

Second stage of analysis shows how John Fuller I (JF1) and John Fuller II (JF2), using mainly their own words, actions or inferred coded responses in *Letters* exchanges, reacted to situations and events. Table 3 shows how percentage of Fullers’ emotive responses varied within Period Data Items.

Fuller	JF1			JF2	
Agent	SR				JM
Period	P1	P2	P3	P4	P5
%	36	23	24	22	19

Table 3 – Percentage of Data Items with Emotive Reaction

General Reactions

Detailed analysis reveals a broadly common Period pattern of emotions expressed over the five Periods. However using *average* values for each Emotion gives combined reactions for JF1 and JF2 shown in Figure 3. This chart shows the variability with several significant peaks aligned against ‘Concern’ especially, ‘Confidence’, ‘Disappointment’, ‘Frustration’ and ‘Pleasure’. Table 4 shows working definitions for these key reactions.

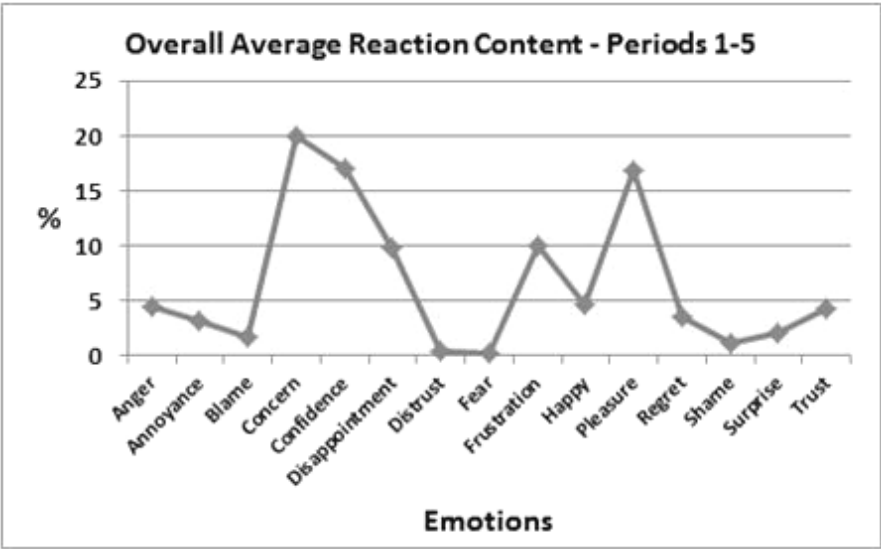


Figure 3 – Combined Reactions Averaged for the Five Periods

Emotion Code	Definition
Annoyance	Irritation and distraction from own conscious thinking
Concern	Anxious, worried, troubled
Confidence	Being certain that chosen course of action is best
Disappointment	Feeling of dissatisfaction following failure of expectations or hopes
Frustration	Anger and disappointment from perceived resistance to achieving own wishes
Pleasure	Enjoyment, satisfaction, glad or contented

Table 4 – Summary Key Emotion Codes and Working Definitions

Comparison of JF1 and JF2 Reactions

However important differences are revealed when these combined reactions for JF1 and JF2 are separated out as shown in Figure 4. JF1 expressed to his agent at times significant ‘Concern’, ‘Frustration’ and ‘Annoyance’ with events as well as ‘Confidence’ when accepting warrants for delivering guns.

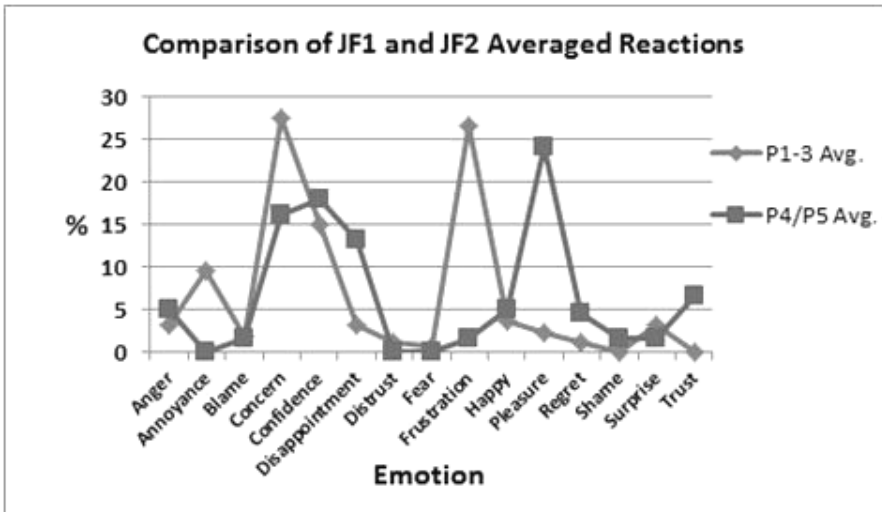


Figure 4 – Comparison of JF1 & JF2 Averaged Reactions

In contrast JF2 expressed lower ‘Concern’ than JF1 but with more instances of ‘Disappointment’ especially from sub-contractors not delivering his guns, faults in guns and delivery delays. Expression of ‘Confidence’ was comparable to JF1. However and interestingly expressions of ‘Frustration’ and ‘Annoyance’ were hardly made. Notable was JF2’s much higher likelihood in expressing ‘Pleasure’ to Jefferson Miles than Samuel Remnant in some outcomes or dealings with others.

Whilst JF2, compared with JF1, may express fewer instances of his feelings in *Letters* as shown in Table 3, these findings suggest important differences in how father and son responded to tribulations of manufacturing and frequency of expression of these to their agents. Notably the analyses give a glimpse of how agent working styles and handling of business situations can prompt different reactions from each Fuller.

ASSOCIATION OF REACTIONS

The third stage of analysis combines these two sets of findings to show how stages of manufacturing are associated with greater or lesser emphasis in emotive responses.

JF1’s Profile

Figure 5 shows a general spread of reactions across most external facing processes and with differing emphases in emotions. The generally high ‘Concern’ is primarily driven by ensuring warrants had the right mix of guns, getting clarity of manufacturing specifications as well as good delivery and proofing results. High ‘Confidence’ for ‘Warrant’ process came from expected higher proportions of great guns in warrants, and high ‘Confidence’ for ‘Manage’ in that the Board will let refused over-bored guns lie until proofed.

In parallel much relative ‘Frustration’ was again associated with ‘Deliver’ conditions, ‘Warrants’ mix, ‘Proof’ outcomes and especially a ‘Bore’ problem. Fairly high ‘Manage’ ‘Annoyance’ reactions occurred from a combination of need to produce extra guns to offset failures, lack of agent feedback and especially for outstanding gun numbers to make,

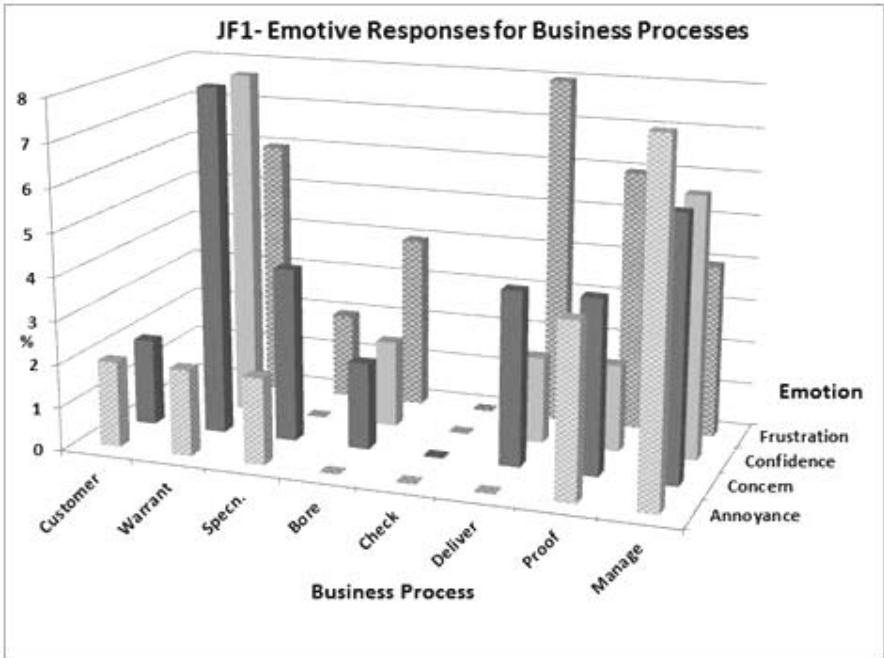


Figure 5 – JF1 - Emotive Responses for Manufacturing

payments and possible loss of management ‘Confidence’ by the Board in JF1 for his representations about over-bored guns.

Scenario – Causal Events

Data shows these reactions varied in emphasis at different times over a sixteen year span. To explore this effect analysis was extended to create a scenario of possible causal influences and how their interactions and timing may have affected responses. Further information was gathered from Saville’s article⁴ about times of variable gun/pig iron demand and quantities, poor workforce relationships and low furnace productivity. Also variable gun demands and loss of income from over-bored guns were modelled⁵ to give some insight into the likely financial effects and so the possible influence on emotive responses.

Figure 6 shows the results for the major reactions of ‘Concern’ and ‘Frustration’ and how these episodes are associated with Issues and fluctuate over the three Periods. Low furnace productivity (possibly timed by furnace operators to exploit a situation) coincided with second upturn in government cannon demand in 1735-1737 causing ‘Frustration’. A later upturn in demand from 1740 onwards enabled Fuller to get his warrants for great guns, reducing a major ‘Concern’, but with lower manufacturing efficiencies, extra proofing problems and delayed payments all causing major ‘Frustration’ and possibly some on-going ‘Concern’.

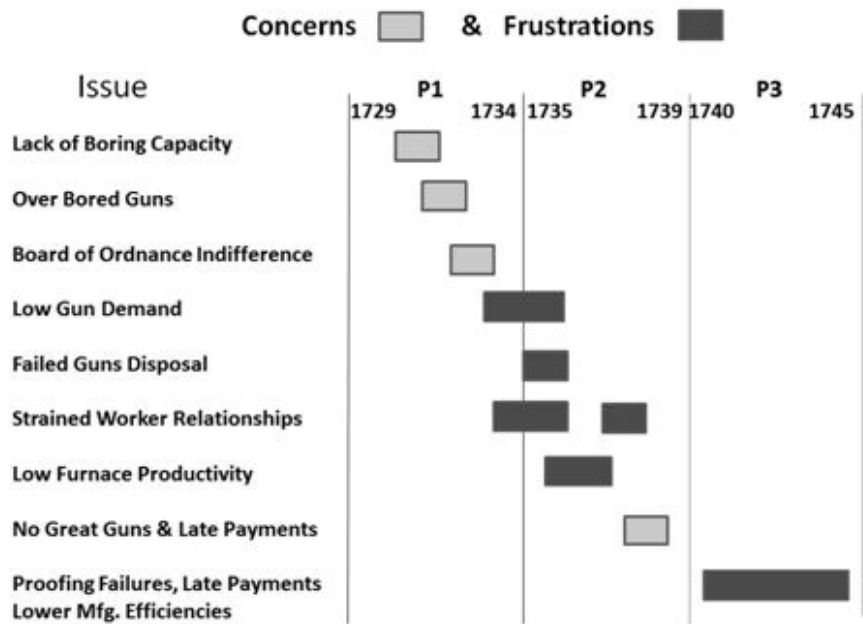


Figure 6 – Episodes of Concern & Frustration during P1-P3

Fluctuating gun demand with balance of pig iron production for Periods 1 and 2 was modelled to show indicative *expected* financial outcomes, see Figure 7. Notable is the higher than expected debenture incomes due in

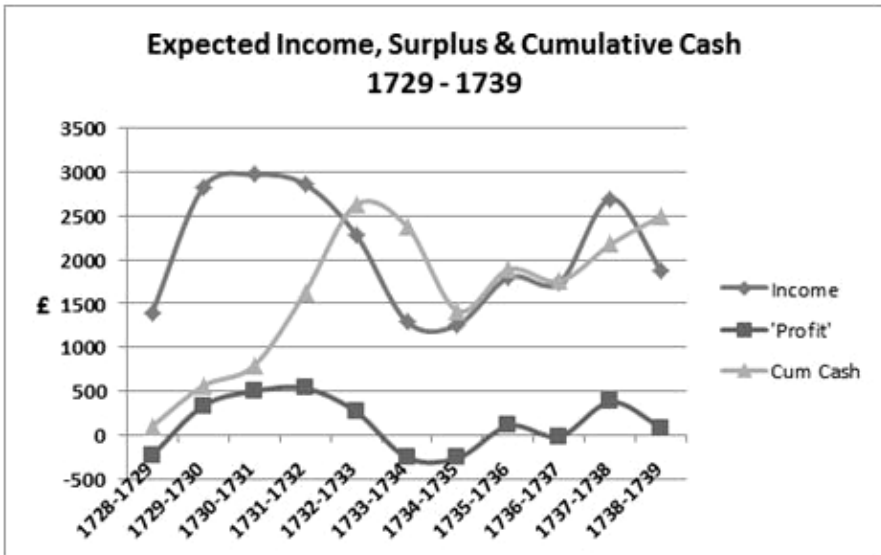


Figure 7 – Modelled Expected Financial Performance

early programmes but with Fuller’s ‘Concern’ at lack of boring capacity from low water to achieve timely outputs. Additionally on-going problems of late debenture payments shows as significant delays in cash received.

However during campaign year 1731-32 these modelled expected financial profiles were changed into those more likely as shown in Figure 8. The cause was an operator carelessly boring 99 guns slightly oversize and their refusal by the Office of Ordnance. This reduced significantly the campaign income due, causing trading loss. Whilst incomes recovered somewhat during the next campaign, cash retention was reduced significantly. Only by JF1 disposing of these refused guns to third parties or reluctantly as scrap would help recover some of this cash loss to the business. This was a period of significant ‘Concern’ for JF1.

Overall this scenario shows how a combination of:

- Consequences of fluctuating cannon demand
- Delayed debenture payments

- Adverse financial and management effects from over bored gun sizes
- Internal operational manufacturing, management and quality issues
- Strategic issues of attempting to get larger gun sizes in warrants

Durations to resolve these situations made gun manufacturing such a challenging and emotive business for JF1.

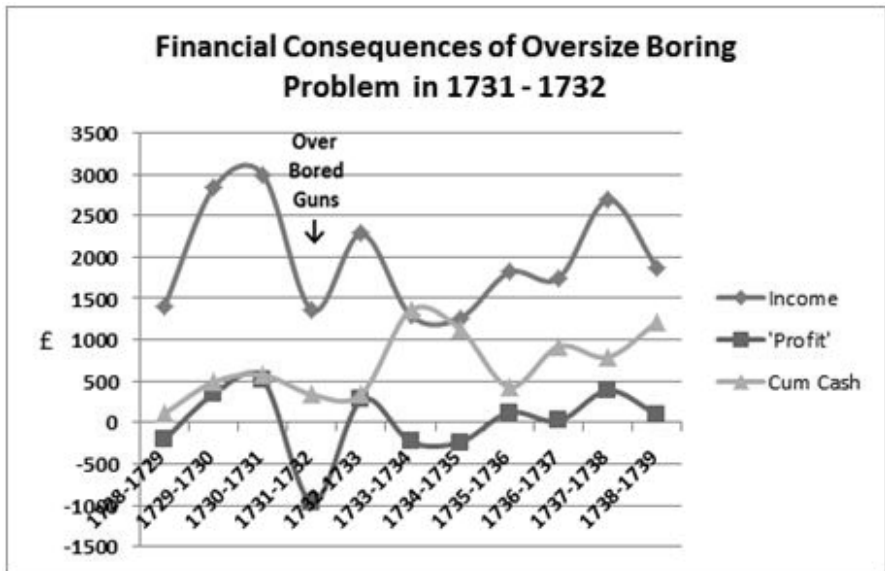


Figure 8 – Modelled Financial Consequences of Over-bored Cannon

JF2's Profile

In comparison JF2 reveals a significantly different profile, shown in Figure 9, albeit covering a later and shorter time span than for JF1.

Apart for some reactions reported for 'Warrant' associated activities most of JF2's reactions relate more to delivery and acceptance processes within the chain. Of these 'Concern' about 'Proof', as ever, remained paramount. In contrast there was relatively high 'Confidence' in delivering products

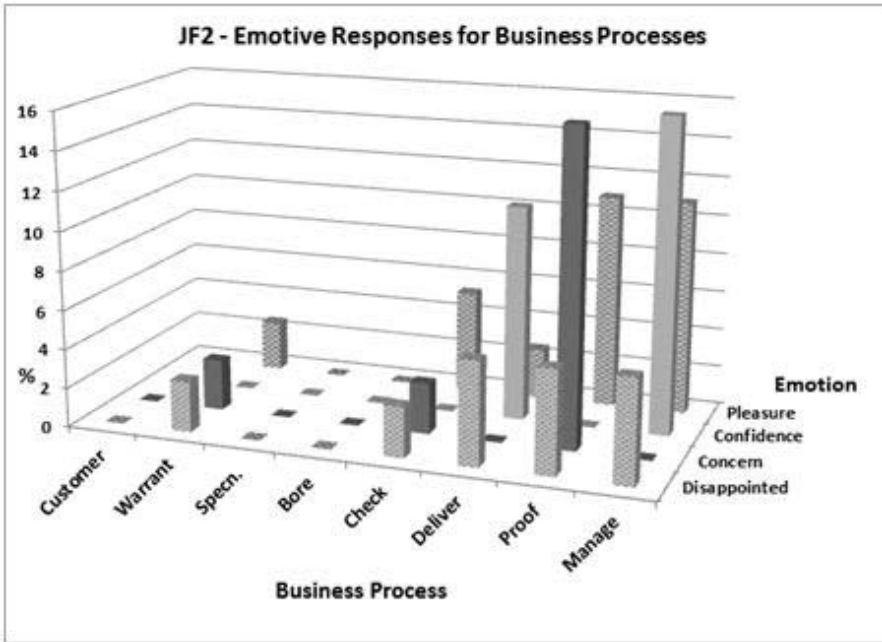


Figure 9 – JF2 - Emotive Responses for Manufacturing

and especially in ‘Manage’ process content from seeking improved relationships with Samuel Remnant, as well as producing better quality work.

Office of Ordnance delayed payment issues may have been mitigated by JF2 taking some orders directly to supply furnace output as guns to overseas customers. Seemingly his contracting arrangements helped offset any poor proofing results to maximise income along with holding customer cash in escrow to avoid late payments once guns were proofed successfully.

‘Pleasure’ is especially expressed at times about successful proofing outcomes and sometimes about warrant contents. ‘Disappointment’ generally comes from poor proofing results or being let down by others not keeping to commitments such as timely gun delivery on his behalf to meet contracts.

Figure 10, covering modelled Period 4 & Period 5 outputs, shows the effects of varying metal tons produced giving a varying income stream, especially in mid Period 5. Whilst notional ‘profit’ is likewise variable, cash creation increases. Overall it shows a much improving performance.

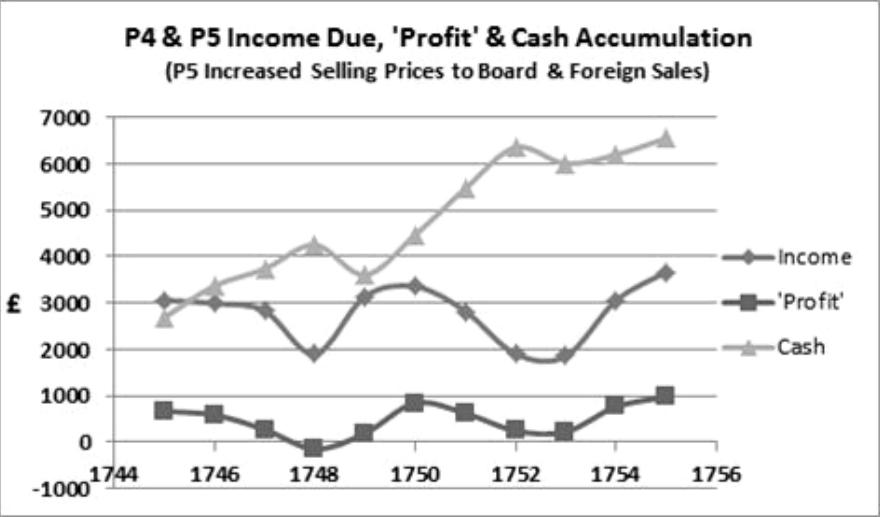


Figure 10 – Modelled P4 & P5 - Financial Performance

Comparison Summary

In summary Figure 11 compares significant differences in reactions between JF1 and JF2 for a variety of key issues. ‘Concern’ for proof testing and outcomes were common for both Fullers.

AGENT’S ROLE ACHIEVEMENT

The final analysis looks at the agent’s role, achievements and effectiveness and how this could influence business performance.

Hodgkinson⁷ described an agent’s role as including “negotiating with the Board of Ordnance for orders and payment,

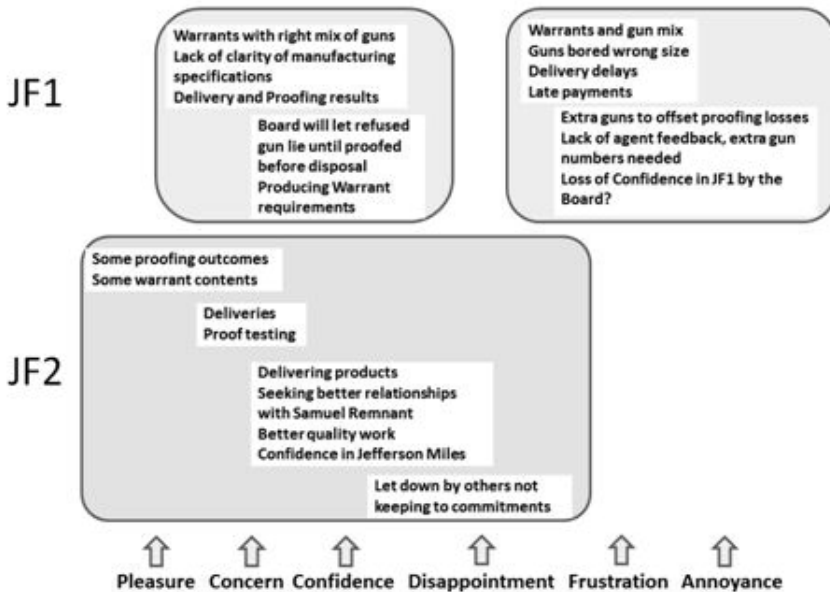


Figure 11 – Summary Comparison of Key Reactions to Issues

keeping his clients updated on the movement of guns and shot at Woolwich, and disposing of refused products. An important role... [taken on by Samuel Remnant from his business and agency relationships with other iron masters]was that of coordinator..... able to assist in arranging the sub-contracting of parts of orders to enable founders to complete their warrants and secure payment more quickly.....it is clear that he lacked some awareness of the difficulties that managing a furnace campaign entailed.”

Agent - Behavioural Examples		
Role	Samuel Remnant	Jefferson Miles
Organised	<ul style="list-style-type: none"> ● Not advising JF1 of imminent Warrant contents to enable better manufacturing planning - others get this information ● Not advising JF1 of Board Imprest account facilities for quicker payments so causing JF1 payment delays ● Not always giving reasons for proofing failures so JF1 can review and improve methods ● Not always giving full details to JF1 about Warrant completion dates ● Not progressing large gun warrants from Bowen for JF2 thereby affecting manufacture and payments ● Believed missing Proof Advice letters from Remnant to JF2 	<ul style="list-style-type: none"> ● Better method developed for managing guns for JF2 compared with Remnant's method ● JF2 accepts that as JM has not informed him of a gun delivery then it has not arrived ● JF2 and JM accounts for gun totals and status tally
Focus	<ul style="list-style-type: none"> ● Keeping received guns in abeyance to offset any future proofing failures so delaying payments ● Ordering reproofing for previously failed guns when same people will be involved giving high probability of failure again ● JF2 objecting to having proofing commission but not attending proofs ● Guns made two years earlier for JF2 not proofed so delaying income payments 	<ul style="list-style-type: none"> ● JF2 comments on Care and diligence in JM's work ● JM found more guns waiting for payment and JF2 blames it on Remnant's negligence or ignorance
Board Rep.	<ul style="list-style-type: none"> ● Not advising Board that JF1 can produce large guns and excluded from his warrants so affecting earlier receipt of higher incomes ● Not advising Board of hardships caused by payment delays to JF1 business ● Causing JF1 to think he can get a better price for guns if he meets directly with Board member(s) 	<ul style="list-style-type: none"> ● JM able to make agreements with Board on behalf of JF2 ● Postponement of Crown orders so can make other orders (for overseas customers) ● Wants warrant for a number of guns as agreed with Board
Responsible	<ul style="list-style-type: none"> ● Involved in dubious business dealing with others at Board of Ordnance and eventual departure in 1750 and as JF1 agent 	<ul style="list-style-type: none"> ● Awarded power of attorney by JF2 and can contract in JF2's name ● Requires sample copy of JM signature to be held at bank ● Authorises JM to sell guns on JF2's behalf ● Requested to arrange contract on behalf of JF2

Table 5 – Agents Behavioural Examples

Table 5 compares examples of agent behaviours.

Important differences are shown in the 20-year relationships between Samuel Remnant with JF1 and latterly JF2 and the subsequent five years relationship between JF2 and Jefferson Miles. Evidence suggests that whilst relationships with Samuel Remnant broadly worked over a long time there were, nevertheless, instances of inattentiveness, inconsistency or even negligence. This was commented in Letter 732 by JF2 to Jefferson Miles, shortly after his appointment as agent, which might be taken as somewhat unfavourable towards running their businesses.

In contrast and noting different time spans, evidence for period 5 illustrates how Jefferson Miles’ working style and achievements were on the whole more cooperative and less contentious for causing adverse reactions with JF2.

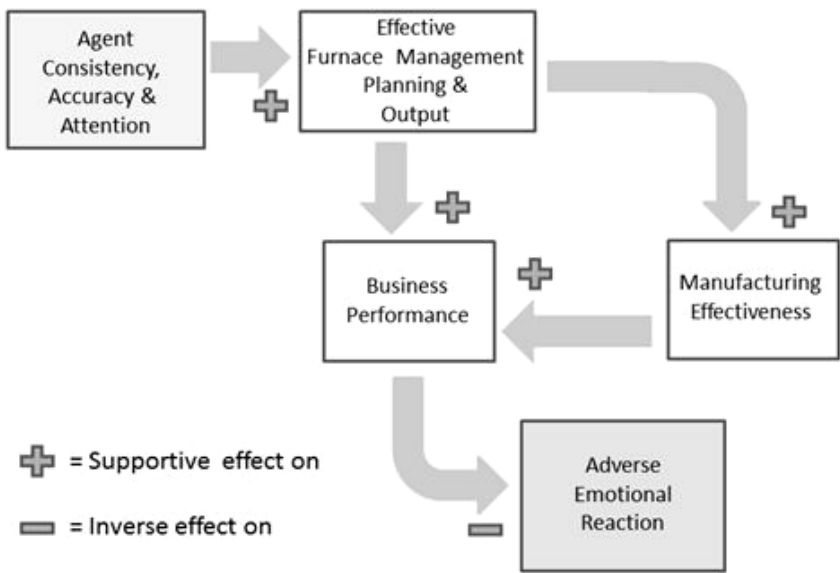


Figure 12 – Agent Influences on Planning, Performance & Emotive Responses

The significance of these finding is shown in the summary Influence Diagram, Figure 12. This shows how the flow of either supportive or adverse agent behaviours can ripple through to influences business performance and either reduce or increase adverse emotive reactions.

Whilst other factors (not shown) can either support or detract from manufacturing effectiveness the role taken on by an agent is, by default, an integral and contributory part of a successful management and manufacturing system.

CONCLUSIONS

Themic Analysis applied to *Letters* information has enabled characterisation of issues and graphical comparisons of how Fuller father and son responded to business challenges. Importantly insights are achieved for both shared and important differences in how they expressed their reactions in running their businesses. Overall JF1's letters contained a higher proportion of emotive content than those from JF2 and which may indicate how their personalities compared. However this must be set in the context of separate time spans, different focus of issues, production demands, opportunities as well as capabilities of and relationships with their agents.

Data shows JF1, even with investing in and expanding his manufacturing business, had to contend with many problems. These included times of variable staff relationships, uncertain production demands, inadequate agent feedback, delivering guns on time with worries of proofing besides receiving late payments from the Office of Ordnance. The incident of over-boring a large number of guns was especially damaging to performance, cash flow and possible standing of JF1 with the Board. Aspects of these caused episodes of expressed personal 'Concern', 'Frustration' and sometimes 'Annoyance'. Evidence suggests that whilst his agent relationship with Samuel Remnant broadly worked over a long time there were, nevertheless, instances of agent inattentiveness, inconsistency and possibly even negligence likely to hinder timely management of his business.

By JF2's time most manufacturing problems seem to cause fewer reactions and were focused more on acceptance processes as discussed with his agents. However this may just be that JF2 was less expressive in *Letters* at times than JF1. Nevertheless proofing guns especially and getting paid on time, as for JF1, was still a source of major uncertainty. Whilst expressing instances of being let down in commitments made to him by others, JF2 expressed also more instances of 'Pleasure' with others or achievements. Overall his business approach and somewhat less dependence on the Office of Ordnance helped ensure outwardly improved income and wealth creation. He continued to produce larger guns with higher prices paid and at times was helped especially by ensuring earlier payments from several overseas customers. Especially important over the latter five years was his much better working relationship with and confidence in his agent Jefferson Miles compared with his earlier years with Samuel Remnant.

Taking the broad view and over the longer term the Fullers' businesses were successful. Even so evidence shows that managing and operating a mid 18th-century furnace business over the 25 years examined, irrespective of ownership, was an evolving, challenging and at times an emotionally demanding occupation.

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Index to *Wealden Iron*, 2nd Series, 33 (2013)

compiled by J. S. Hodgkinson

- Annwood Brook, 3
- anvil, 33
- Ashdown Beds, 3, 5, 8

- bellows, 20, 33
- Biddenden (Kent)
 - Biddenden Hammer Mill, 33
- Blandford, V., 23
- bloomeries, 3, 5, 8, 16
 - furnace lining, 3, 14
 - Iron Age, 8, 15-17
 - satellite, 16
- boring – *see* guns
- Brown, D. M., 5
- Buxted (East Sussex)
 - Hendall, 27, 29
 - Hendall Furnace & Forge, 28, 29

- charcoal, platforms, 6
- Christian's River, 21
- clutter – *see* finery
- coin, 4
- Colgate (West Sussex), 23, 24
 - Hammer Pond, 23, 24
 - Hawkins Pond, 23, 24
- Covert, Walter, 24
- Crawley (West Sussex)
 - Goff's Park, 15
- Crowhurst (East Sussex)
 - Crowhurst Park, 15

- Danehill (East Sussex)
 - bloomery, 3
 - Pollardsland Wood, 3
- Davies, A. F., 38, 48

- Doherty, A., 11
- Dudwell, river, 5, 6
- Dudwell valley, 5

- Ewhurst (East Sussex)
 - Ewhurst Furnace, 29, 34

- finery, 34
- firebacks, 27-30
- forge implements, 33-4
- Fuller family
 - gun production, 48-65
 - attitude towards, 54-60, 61, 63
 - letters, 38, 46, 48
- Fuller, John I (1680-1745), 49, 51, 52, 53, 54, 55, 56, 57, 58, 60, 62, 63, 64-5
- Fuller, John II (1706-55), 49, 50, 51, 52, 53, 54, 58, 59, 60, 62, 63, 64-5

- glass, Roman, 3
- Gratwicke, Roger, 24
- Griffin, F., 8
- guns
 - boring, 38-46, 57, 58
 - bar, 39
 - cost, 43
 - duration, 39-40, 42, 43-4
 - method, 39
 - tools, 39, 40
 - casting, 44-5
 - manufacturing, 50-1
 - agents, 60-1
 - profit/loss, 60

- Hartfield (East Sussex)
 - bloomeries, 8, 16
 - Cow Park, 16
 - Garden Hill, 15, 16
 - Pippingford, 16
 - Whitepost Wood, 8
- Hawkhurst (Kent)
 - Hawkhurst Furnace and Forge, 33
- Hodgkinson, J. S., 3, 14, 27
- Horsted Keynes (West Sussex), 15
- Hothfield (Kent)
 - Denne's Mill, 35
 - Hothfield Forge, 32-6
 - inventory, 33-4
 - Hothfield Place, 32, 33
 - Waterfall, 35
- imperial estate, 16
- iron, bar, 33
- iron ore, mining, 23-6
- iron workers
 - fineryman, 32
 - forgemaster, 35
 - forgemen, 33
 - hammerman, 32, 33
- Lansdale family, arms, 28
- LIDaR (Light Detection and Ranging), 24-5
- Lower Beeding (West Sussex)
 - Hammer Pond, 23, 24
 - St Leonard's Lower Forge & Furnace, 24
 - St Leonard's Upper Forge, 24
- Luxford, Anne, 33
- Luxford, Edward, 33
- Marcus Aurelius, 4
- Maynard, Richard, 29
- Miles, Jefferson, 49, 52, 54, 62, 65
- Missing, John, 34
- Missing, William, 35
- ordnance – *see* guns
- Ordnance, Office of, 57
- Parker, Matthew, Archbishop, 32
- Pelham family, 29
 - fireback, 29-30
- Pelham, Thomas, 29
 - baronetcy, 29
- Pichingham family, arms, 28
- pond bays, 21
- Pope family, 27
 - arms, 28
 - fireback, 27-9
- Pope, Nicholas, 28, 29
- Pope, Rafe, 29
- Pope, Sackville, 29
- pottery, 11-13
 - Colchester Ware, 4
 - East Sussex Ware, 4
 - Gaulish ware, 4
 - Iron Age, 9
 - West Kent Ware, 4
- Prus, J. L., 20
- Purbeck Beds, 6
- radiocarbon dating, 8
- Remnant, Samuel, 49, 52, 54, 59, 61, 62, 65
- Rotherfield (East Sussex)
 - Minepit Wood, 16
 - Saxonbury, 15, 16
- Russell, –, 33
- Sackville, Margaret, 29
- Sackville, Sir Richard, 32
- St. Leonard's Forest,
 - minepits, 23-26

Sedlescombe (East Sussex)

Footland Farm, 15

Sheppard, Edward, 36

Singleton, A., 32

slag

tap slag, 3, 14

wood-marked, 3, 14

Smith, T. J., 5

Standen, Edward, 32, 33

Standen, Elias, 32, 33

Standen, James, 32

Standen, Thomas, 32

Stevens, S., 8

Stone-cum-Ebony (Kent)

bloomery, 3

Huggit's Farm, 3

Stone-in-Oxney, 3

Thanet, Earl of, 34 – *see also* Tufton

Tottingworth, 6

Tufton, Elizabeth, 34

Tufton family, 35

Tufton, John, 32, 33

Tufton, Nicholas (1578-1631), 32

Tufton, Nicholas (1631-79), 34, 35

Tufton, Richard, 35

Tufton, Sackville, 35

Tufton, Thomas, 35

Tunbridge Wells Sand, Upper, 23

tuyeres, 20, 33

Wadhurst (East Sussex)

Bardown, 16

Wadhurst Clay, 4, 8

Waller family, arms, 28

Walshe family, arms, 28

Warbleton (East Sussex)

Warbleton Priory Furnace, 20, 21

water supply, 20-1

waterwheels, 20

power output, 20

Weston family, arms, 28

Westwell (Kent)

Longbeach Wood, 32, 33, 34