

# Robert Erskine's letters of 1770 about the British iron and steel industry

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*ABSTRACT: In 1770, the engineer Robert Erskine toured England, Wales and Scotland to collect knowledge about the iron industry. During this tour, he wrote a series of letters detailing the materials, processes and products that he saw. He described blast furnaces, blowing engines, forges, foundries and casting, and steel works. Erskine brought these letters with him to America in 1771, where he had been employed to manage an ironworks begun by Peter Hasenclever in 1764. The introduction includes a brief biography of Erskine and a description of his tour and correspondence and is followed by a transcription of the letters.*

## Background

Robert Erskine (1735–1780) was the only surviving child of the second wife of Ralph Erskine (1686–1752), a member of the well-known Secessionist Erskine family from Dunfermline, Scotland (Lachman 2004). His father was a poet as well as a minister and his mother was the daughter of a Writer to the Signet (an association of Scottish lawyers), so he came from a literate background. This is fortunate for us, since he used his literary skills to describe, as accurately as possible, the iron and steel industries in England, Scotland and Wales in 1770. As the fifth son, he did not enter the ministry but instead attended the University of Edinburgh to study engineering. He used his scientific and engineering skills as a consultant and inventor: his major patented inventions were a continual stream pump for de-watering ships and a Platometer to find latitude at sea. However, unfortunately for him and fortunately for us, he also attempted to go into business. His business efforts failed, leaving him with a burden of debt and requiring him to move into a new field, the iron and steel industry.

The American Iron Company had been started by Peter Hasenclever in New Jersey in 1764 but Hasenclever

overspent and returned to Germany. Erskine was hired to take his place and manage the failing ironworks. This was the impetus for the letters, as Erskine knew little about the industry. He took a two-month tour through Wales, England and Scotland to observe iron and steel works, and he wrote down everything he saw. Erskine mailed these letters to his employer in London, who then returned them to him prior to his departure.

Erskine sailed for America a few months after being elected a Fellow of the Royal Society. The American Iron Company, built between 1764 and 1767, consisted of four ironworks villages, each with a blast furnace, forges with multiple hearths, stamping mills, coal houses, blacksmiths' shops, houses, saw mills, reservoirs, ponds, bridges and roads (Hasenclever 1773, 1970 edn, 6). Not only had Hasenclever overspent, but he had lost control of his German workers who realized that they could make higher wages elsewhere in America. Erskine did his best to fulfil his obligations to the American Iron Company until 1777, when he became the Surveyor General to the American Army at the request of General George Washington. Thereafter, Erskine travelled the north-eastern United States, collecting and making maps, until his death from a fever in 1780. His earlier

interest in surveying is demonstrated in the letter from Temple Sowerby (Oct 27 1770), which is accompanied by a sketched estimate of the height of nearby Cross Fell (Fig 2).

When Erskine moved to America he lived at Ringwood Manor in northern New Jersey. After his death the letters stayed there. Later ironmasters, the Ryerson family, donated the majority of Erskine's papers to the New Jersey Historical Society, but these letters may have stayed on the site or taken a different route: Abram Hewitt, a 19th-century ironmaster, living in Ringwood, was inspired by them to name one of his own sons Erskine. Hewitt's descendants commissioned the only biography of Erskine. Albert H Heusser, a professional writer and printer, gathered the material, and the biography was first published in 1926 (Heusser 1966 edn, xi). The letters are addressed to Richard Atkinson Esq, of Nicholas Lane in London and often make reference to a Dr Fordyce, to whom Erskine was sending samples of ore and iron. This was probably Dr George Fordyce (1736–1802) a Scot and a noted London physician (Coley 2004) with wide scientific interests, who lectured on chemistry and whose papers relating to minerals survive in the library of Glasgow University. There are 13 letters, written between September 15 and November 10, 1770. They range in length from two to six tightly-written pages, in which Erskine described the processes used in the iron and steel industries. The working men at the ironworks were generous with their knowledge, and the owners were often helpful also. Thus we have a rare chronicle of working processes in the iron industries of England, Wales and Scotland in 1770.

Erskine's goal in writing the letters was to transcribe every detail he saw to the best of his ability. In the first letter he wrote about his intention of not distinguishing between things of greater or lesser importance, since, not having experience with the iron industry, he could not discriminate.

## The itinerary

During the period between September 15 and November 19 1770, Erskine stayed in Monmouth, Brecon, Abergavenny, Birmingham, Shrewsbury, Chester, Lancaster, Temple Sowerby near Penrith, and Glasgow. From these lodgings he visited Redbrook (30 miles west of Gloucester), Abbey Tintern, Pontypool, Matthew Boulton's Works in Birmingham, Wilkinson's works at Bilston, Broseley, Coalbrookdale, Wrexham, Backbarrow and the Carron Works near Falkirk in Scotland. He also visited other smaller mines and works

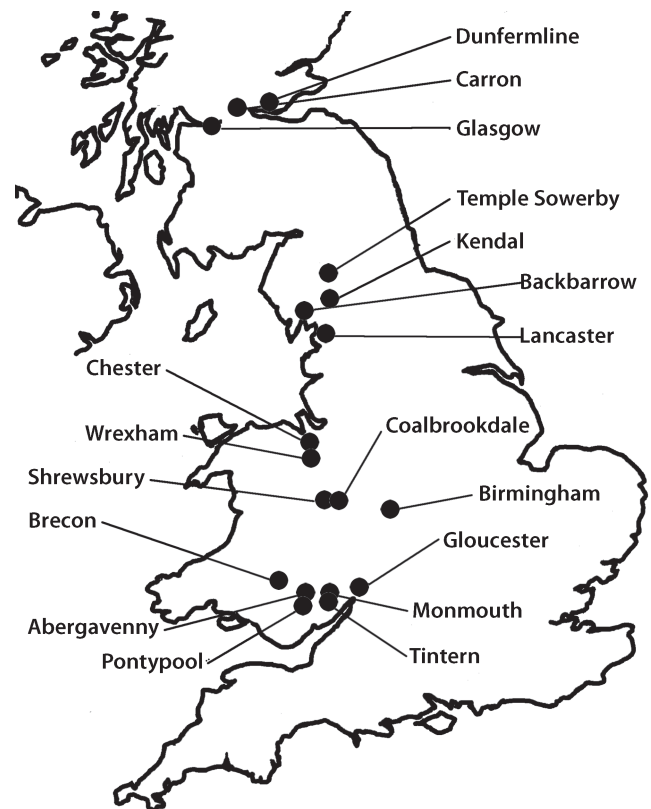


Figure 1: Map showing the principal places visited by Erskine and those from which he wrote his letters. The itinerary begins at Monmouth. He worked his way north via Brecon, Birmingham, Shrewsbury, Chester and Lancaster to Carron and Dunfermline, the latter his family home.

in the areas through which he passed on his travels.

Judging from the dates of the letters, he spent approximately 15 days in Wales, 12 days between there and Birmingham, four in Shrewsbury, three in Chester, two in Lancaster, seven in transit to Temple Sowerby and 14 days in transit to and visiting works in Scotland. These estimates are based on the dates of the letters but it is probable that they are inaccurate, especially in the break between South Wales and Birmingham, which may suggest missing letters. Figure 1 shows the places on Erskine's route.

The conditions of travel were often poor. Erskine wrote

'I here of so many different works in Wales, that I cannot propose seeing them all the roads and accommodation being very bad' and 'Five miles of the road was very bad, hilly, narrow and stoney' (Sep 19).

Sometimes he found new ironworks by talking to people at the last works he visited: there were no national registers of industries to consult and, since he was new to the trade, he had no network of contacts. Communications in England was more developed than

in Wales: Erskine were surprised to find that between Birmingham and Shrewsbury:

'In this Country there are Waggon Ways for several miles together in which the tracts for the wheels, are all of Cast Iron' (Oct 15).

Like many writers of his day, some of his writing reflects the difficulties of travel, the weather and the welcome sighting of lodgings.

## The letters

The table below summarizes the existing letters. It is possible that there are missing letters from the series,

since on October 11 Erskine writes 'At the steel work I mentioned in my last', yet there is no mention of a steel works in the previous surviving letter.

The majority of the letters are included in a scrap-book made by Alfred Heusser, called the 'Manor and Forges of Ringwood Compilation, 1759–1923'. Heusser compiled this collection with financial support from the Hewitt family, who occupied Ringwood Manor, Erskine's home, from 1836 to 1936. The scrap-books are at the New Jersey State Archives in Trenton. Four letters are still at Ringwood Manor, the site of iron works which Erskine managed from 1771 until his death in 1780. There are also scientific papers, day-books and business journals

Table 1: A summary of the dates, places of origin and principal subjects of Robert Erskine's letters.

	Date (1770)	Letter sent from	Places described	Details described
1	September 15	Monmouth	Furnace at Redbrook (30 miles W of Gloucester)	Furnace and blowing engine. Lists samples of ore etc and cast iron sent to Dr Fordyce.
2	September 16	Monmouth	Redbrook	Reverberatory ore-roasting furnace, slag-crushing mill, operation of water wheel and bellows.
3	September 17	Monmouth	Redbrook	Blast furnace charge. Copper works.
4	September 19	Monmouth	Tintern Abbey (10 miles S of Monmouth)	Forge and furnace: furnace dimensions; water-powered blowing engine; process using American pig. Mentions but does not describe wire-works.
5	September 21	Brecon	Near Monmouth	Describes forge: conversion of American pig iron for making gun barrels; hammer-scale used in the finery; fining techniques; forge hammers.
6	September 27	Abergavenny	Pontypool	Mines; furnaces: charging methods; forges: use of white and grey pig iron.
7	September 29	Brecon	Abergavenny	Summarises his understanding of chemistry. Mr Hanbury's furnace and experiments.
8	October 11	Birmingham	Mr Bolton's works (Matthew Boulton)	Cementation and crucible steel production, using Swedish iron. Dr Small on partial decarburisation of pig to make tubes.
9	October 15	Shrewsbury	Bilston; Broseley; Coalbrookdale	Wilkinson's Bilston works: dimensions of furnace, and charge used; steam-blown air furnaces; pipe and flywheel casting; coal-seams on fire. Broseley: water seals; cylinder blowers; steam-pump returning water to wheel; air furnaces; casting cylinders for steam engines; cannon. Coalbrookdale: 12 furnaces worked by coke. Casting a large thin-walled pot.
10	October 18	Chester	Broseley; Ketley; Wilkinson's works at Wrexham	Broseley: third furnace. Wood's patent for converting pig. Ore mines. Ketley: Water returned to wheels by steam pumps. Wrexham: details of blowing engine; casting cannon.
11	October 20 and 24	Lancaster and Kendal	Wrexham; Backbarrow	Wrexham, further detail, particularly boring mill. Backbarrow: furnace burden and control; cast-iron cylinder blower; water-cooled tuyeres; peat as a furnace fuel. (Refers to [Anthony] Bacon's Glamorgan furnace [Cyfarthfa]: 60ft high).
12	October 27	Temple Sowerby	Cross Fell	Measures the height of Cross Fell for Atkinson (Erskine's employer) and meets Atkinson's brothers.
13	November 10	Glasgow	Carron Works (Falkirk)	Furnace dimensions; several types of blowing engines used; water-blown air furnaces; moulding techniques, for large kettle and pipe; casting and boring cannon; ore roasting at Carron compared with Redbrook.

written by Erskine at the New Jersey Historical Society in Newark. Most of Erskine's work as Surveyor General to the United States Army was destroyed in a fire in Washington DC in 1812, but some maps remain with the New York Historical Society. The letter of October 27 transcribed below, and Figure 2, demonstrate his expertise in surveying.

### Blast furnaces and other plant

During the journey, Erskine saw or heard about approximately 30 blast furnaces (as well as over a dozen reverberatory furnaces), nine of which he describes in detail. He had a systematic way of describing them, nearly always including the dimensions (Table 2), the charging techniques, and the mechanism for creating the blast. He mentions the methods for testing iron (breaking it and studying the structure). He sent samples to Dr Fordyce, in London.

### Ores

Erskine paid close attention to the types of ore, flux and fuel that were used. For instance, at the furnace at Redbrook, Gloucestershire, ore from the Forest of Dean was used, which did not require roasting, also old bloomery cinder, and Welsh ore, roasted in a reverberatory furnace. Abbey Tintern furnace used ore from the Forest of Dean, cinders (referred to as 'scoria'), and Lancashire ore, which also did not require roasting. At Pontypool, they used 'crop, found in lumps near the surface', 'pin ore' and 'vain ore'. There, the ore lay in heaps and 'that which turned rusty soonest, they looked on as the best' (Sept 27). At the Carron Works there were various ores (nodule and strata), either from the area or brought by sea from the coast of Fife. Erskine sent samples of all of these ores to Dr Fordyce.

Much of the ore was roasted or calcined in common brick kilns for two or three days. At Redbrook, the  
'Welsh Ore it is roasted in Reverberatory Furnace, and

is 2 or 3 hours adoin' (Sep 15).

Later Erskine gave more detail, that in a common kiln it would require 24 hours but in the reverberatory furnace it would require only four (Sept 17). The funnel of that reverberatory furnace was about 20 feet in diameter and the fuel was called 'pit' or 'stone' coal. At the un-named furnace near Birmingham

'The ore is Calcined, not in kilns but by being built up in heaps on the ground, intermixed with small Charcoal'.

At Carron, the ores were calcined on the ground with raw pit coal (Nov 10).

### Fuels, furnace burdens and charging techniques

In the letters from Wales, charcoal is shown to be still the fuel most frequently used. After Erskine reached Birmingham, coal was the fuel most commonly recorded. Erskine wrote:

'all the Ore, between Shrewsbury and Birmingham is smelted with Coke, or pit Coal Cinders, which is materially different from Charcoal' (Oct 15).

He noticed that the use of limestone as a flux was more frequent in the coal furnaces than in the charcoal furnaces. At Bilston he wrote:

'the great proportion of limestone at this and the other works I have since seen, is certainly to absorb the remaining sulphur of the Coal. for every where the Ore is nearly similar to that at Birmingham, yet they use lime in much greater proportions, than with Charcoal' (Oct 15).

At Coalbrookdale and Carron the furnaces smelted with coke. He saw thick strata of coal at Bilston and noted that:

'one of the pits was on fire which they said had kindled of itself: and about an hundred yards to the Eastward

Table 2: Blast furnace dimensions in feet as described in Erskine's letters

Location	Height	Tunnel Head	Bosh Width	Bosh Location*	Tuyere Location*	Crucible Width	Crucible Depth	Notes
Redbrook	30	3	10	10	1	2	1	
Tintern Abbey	30		11	8 or 10				
Abergavenny	24	3		4 or 5	1	2 ½	1	Bosh only 6' above Loc.
Near Birmingham (un-named)	30	2	8 or 10	8 or 10	Across shorter axis	18 inches by 3'	1	Dam - brick of Stourbridge clay
Bilston	32	2	12	12		20 inches	5 ½	
Carron (four furnaces)	36		16	10 or 12	Across shorter axis	1 by 4	18 inches	

\* from the bottom

of the Furnace, the surface (and to a Considerable depth) of the ground was all on fire, and has been burning above ten years' (Oct 15).

Mr Wilkinson, of Backbarrow furnace, brother of the owner of the Bilston works, successfully experimented with using turf or peat as a furnace fuel.

At Redbrook the ore was charged by weight, but at Abbey Tintern the workmen judged by basketfuls. At Redbrook

'they knew when to supply the furnace, by an Iron rod about 2½ feet long suspended to another in the manner of a flail — when the materials had sunk that depth, then they put in more' (Sep 15).

The following is an example of the level of detail at which Erskine wrote: at Bilston

'Their charge is 53 bushel baskets of Coke, 81 Bushel Baskets of Mine, and about 3 of limestone ...' (Oct 15).

He systematically described the portions and types of ore, whether it had been 'Calcined' (burnt), and the portions of charcoal or coal and limestone. All in all, he concluded:

'From the different works I have seen, it may in general be inferred, that with proper management, any sort of Iron may be made from any kind of Ore' (Sep 29).

### Power sources

Many of the furnaces which Erskine saw were powered by waterwheel and bellows. However, as he travelled north, he also saw some of the first steam engines in use. He described the power sources in detail. He often calculated the power produced:

'One Revolution of the Waterwheel worked each Bellows 4 times and as the Wheel performed a revolution as nearly as I can judge in half a Minute, the quantity of air thrown into the furnace every minute is 1120 Cubic feet' (Sept 16).

At Tintern he saw a wire factory where the bellows were placed ten feet high, to be out of the way, and

'the Air was conveyed down through Tubes of Tin, the Turnings right Angles (which is certainly wrong, but two other forges which I have seen, have the same fault)' (Sept 19).

At Ketley he saw and described the return of water to the wheels by steam pumps. At Backbarrow, there was a cast-iron cylinder blast machine with water-cooled tuyeres. Erskine wrote:

'was of great advantage to have what they called a Water tuiron, which is to have the conical Tube made of hammered Iron, double, so that a current of water may be continually passing round it to keep it Cool this circumstance I heard nothing of at any other forge, and here I discovered it only by accident, the Term in discourse happened to be mentioned' (Oct 20).

In Wilkinson's Wrexham works, there was a new type of blowing-engine which used the rise and fall of water in a pair of cylinders. Overall, many different types of power for the ironworks were used, sometimes the old existing beside the new.

### Casting

Erskine provides detailed descriptions of various casting processes. In his letter of October 15, he describes how, at Broseley, air furnaces were used for casting cylinders for steam engines, cannon and ordnance. In the same letter he describes the casting of a large pot one eighth of an inch thick at Coalbrookdale, and the details of casting a flywheel at Wilkinson's Bilston works. In Wilkinson's Wrexham works Erskine wrote about casting cannon for the Emperor of Morocco, 50 eighteen pounders on which was written 'Mohdmetan Esq 1184'. He also describes the process for gun-boring, by a small cog-wheel turned by a larger cog on the axis of the water wheel. One cannon could be bored in an hour, but:

'it made a very disagreeable noise which at a distance was much like that of Geese' (Oct 18).

At Carron, air furnaces were used for casting cannon, and Erskine also described in detail a moulding technique for a large kettle.

### Conclusion

As Richard Hayman (2005, 9) has written, 'evidence of the forge trade shows that technological developments were established slowly and were used in conjunction with earlier technology'. Later, in the 19th century, even when railways connected England, Wales and Scotland, the iron and steel industry retained its regional character and knowledge was still carried by individual workers. Erskine's journey provides an impression of this varied regional expertise. His letters were systematic, the only way a non-skilled person could carry technical information across an ocean, other than by hiring experienced workers. When ironworks were first built in the Colonies, they were comparatively primitive. Since they could still rely on charcoal they did not innovate to the extent necessary in 18th-century Britain. When the United States caught up with Britain in the middle of the

19th century, it did so by the oldest method of knowledge transfer. The Lehigh Crane Iron Company lured David Thomas away from Yniscedwyn Iron Works, bringing knowledge of how to use anthracite coal to America (Williams 1994, 30). Thomas' innovations ushered in the age of 'Big Steel' but, earlier, Erskine's letters document the importance of independent regional innovation.

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## Acknowledgements

Robert Gordon, author of *American Iron 1607 to 1900* (Baltimore 2001), suggested that these letters would be of interest to the readers of *Historical Metallurgy*. Sue Shutte from Ringwood Manor found and scanned missing letters. Richard Sher, who has written about the Scottish Enlightenment, helped me place Robert Erskine in the context of his family. Sue Deeks, Paul Frost and Ralph Colfax are fellow travellers on the journey to document the works of Robert Erskine.

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Table 3: The archives where Erskine's letters are deposited.

	Date	Origin	Location
1	Sept 15	Monmouth	New Jersey State Archives, Trenton, NJ
2	Sept 16	Monmouth	New Jersey State Archives
3	Sept 17	Monmouth	Ringwood Manor, Ringwood, NJ
4	Sept 19	Monmouth	New Jersey State Archives
5	Sept 21	Brecon	New Jersey State Archives
6	Sept 27	Abergavenny	Ringwood Manor
7	Sept 29	Brecknock	Ringwood Manor
8	Oct 11	Birmingham	New Jersey State Archives
9	Oct 15	Shrewsbury	New Jersey State Archives
10	Oct 18	Chester	Ringwood Manor
11	Oct 20 Oct 24	Lancaster Kendal (both in one letter)	New Jersey State Archives
12	Oct 27	Temple Sowerby	New Jersey State Archives
13.	Nov 10	Glasgow	New Jersey State Archives

## Robert Erskine's 1770 Letters

Transcribed by Carol Siri Johnson

This transcript retains the original spelling, capitalization and punctuation. The only departure from the original is that the line-breaks have been omitted, as they are not significant and impede reading. I have retained Erskine's mis-spelling of pig iron as 'peg'. If Erskine inserted a word or phrase, it is included between square brackets. Unreadable words and phrases are bracketed thus: {.....}. I have omitted words that Erskine crossed out. In general, each page was filled to the edges with writing.

### Letter 1

Monmouth Sept 15.th 1770

Dear Sir

I have seen some furnaces and forges of which I beg leave to give you an account, and that I may not omit particulars which hereafter may be useful, I hope you will excuse me in this and all my future Letters, for giving a detail of my observations, in the same order in which they occurred; by following this rule, tho I may mention some things trivial and of no avail, yet I shall run the less hazard of overlooking things of Importance.

About 10 or 12 miles from Gloucester the redish hue of the Rocks and stones seemed to indicate that the Country abounded with Iron, and at a Village called Colford about six miles from this place, I observed a boy picking stones out of a Brook, as I supposed for the purpose of making Iron, because the banks and bed of the Channel had a very ochery appearance; the boy told me they were to be carried to the furnace at Red Brook, about two miles from this place, and which to day I have been to inspect.

They had run off and moulded their metal about an hour and an half before I got there, the number of Pegs were about 50 and the weight two Ton and an half. The Furnace was in Blast again, and from time to time they supplied it with Ore and Charcoal; but first let me describe the Bellows, which were two, worked alternately by a [overshot] Water Wheel about 30 feet Diamr, they were upon the Common principle of Kitchen Bellows about 14 feet long, four feet at the Greatest end, and tapered to the nozel, they [were] expanded about 4 feet, in order to be filled with air, by means of a Lever loaded at the opposite End, and four Coggs upon the Axis of the water Wheel pushed them down, Alternately, to give

the Blast, which was very strong. I have got sketches of the Machinery etc—

The furnace was about 30 feet high, the widest part was about 10 feet, from the bottom; there, it was 10 feet Diamr. from thence to the Top it Tapered to a Yard; at the bottom where the reservoir was for the melted Iron, it was two feet Diamr. the reservoir being two feet wide and a foot deep the nozels of the bellows were upon a Level with the surface of the reservoir, and the air entered at a hole about 2 ½ Inches Diamr.

The Scoria (which they send to Bristol to make Bottles) began to run off whils I was there, (about 12 noon), but it would be three or four next morning before the Reservoir would be full of Iron to draw off.

There were several sorts of Ores, which they put in at the same time together with the Charcoal: they knew when to supply the furnace, by an Iron road about 2 ½ feet long suspended to another in the manner of a flaille—when the materials had sunk that depth, then they put in more. There were put in, first 4 baskets of Charcoal, which held I suppose 3 or 4 Bushels a piece, afterwards there was put in by weight, 5 large scuttles fulls of Oar from the forest of Dean (this did not require roasting) nearly the same quantities of Old Cinders, from works which had formerly been wrought, and about two large Scuttle fulls of Ore, from near Neath in Wales\_\_ Samples of the Different Ores I have sent to Dr. Fordyce by his desires, a description of which I beg to leave here to subjoin, because I have not time on acct. of the posts going off to write two letters.

- No. 1 Is Welsh Ore, some dug & some picked up on the Sea Shore
- No.2 The Same Ore Roasted. NB. it is roasted in Reverberatory Furnace, and is 2 or 3 hours adoin\_\_
- No. 3 Forest of Dean Ore dug out of Mines there, small and very magnetical does not require Roasting (not magnetical)
- No. 4 Larger pieces of the Same
- No. 5 Some Curious pieces from the Forrest of Dean
- No. 6 A Flux, which they do not use as they say it is too hot, and there is flux enough in the Dean Ore to answer the purposes of lime, &c.
- No. 7 Sample of Cast Iron from Red Brook furnace at the Forge
- No. 8 Do. of Do. which produces Red shot Iron
- No. 9 Do. of Do. which produces Cold Shot. Do.
- No. 10 Cast Iron from America, they could not tell the place
- No. 11 Do. from Red Brook makes good Bar Iron

The Samples of the American, Red shot and Cold shot Iron I had from a forge within a ¼ of a mile of this. but as they were not today at work I shall not have an opportunity of seeing it till monday when they begin to Convert pig Iron into Bars. by Saturday next I shall be at Built BrecknockShire

– I am

Dear Sir

Your most oblig'ed huml Sert  
Robert Erskine

P. S. I am ashamed of the inaccuracies of the above [letter], but hope you will excuse them. as I have not time to copy it.

Letter 2

Monmouth Sept. 16 1770

Dear Sir

I omitted in my last of yesterday to mention that the welsh Ore which was roasted in a Reverberatory Furnace was done by pit Coal, or as the Workmen called it, Stone Coal. The funnel of this furnace was about 20 feet high and the furnace appear'd to be within about 5 or 6 feet Diamr. There was another place for roasting like a Common Lime Kiln, which did not appear to be much or frequently used, in which they roasted some of the Large pieces from the forrest of Dean. The workmen seemed to smile at the Ignorance of the question, when I asked them whether or not they could make Iron from one sort of Ore only, answering no Sire\_\_ from the dimensions of the Bellows they emitted at a blast about 70 Cubic feet of air. One Revolution of the Waterwheel worked each Bellows 4 times and as the Wheel performed a revolution as nearly as I can judge in half a Minute, the quantity of air thrown into the furnace every minute is 1120 Cubic feet. There was a pounding mill for part of the Scoria which was not so fully vitrified, and contains a good deal of iron, about the size and form of great and Small shot. it is washed in the pounding and the Iron remains under the pestle. what is thus procured is Commonly sent the Forge.

I found not the least difficulty of access, and the workmen were very Communicative, and a few shillings was a very agreeable present to men who with families of 6 or 7 Children earned only 12s/ a Week if more workmen were wanted I suppose it would not be difficult to secure them

I am Dr Sir

Your most obliged huml Sert  
Robt Erskine

P.S. I have sent Dr. Fordyce advice of the Samples. They will be in town next Friday The Monmouth Waggon Puts up at The George in Snow hill

Letter 3

Monmouth Sepr. 17th 1770

Dr Sir

As I wanted to know a little more of the furnace at Red Brook with the reasons for mixing the Ores Etc. I went there again to day. After putting in about 16 bushels of Charcoal they added 400 Wt of Pre Yiz 170 £ Cinders about the same quantity of Forest of Dean and 56 £ of Welsh Ore. The Cinders were thrown in first the Welsh next, & the Forrest last. The Charcoal was as large as possible, the small pieces they sent to the forge, The reason of being at the Expence of bringing the Welsh ore was because it added toughness to the Iron, The Forrest of Dean by it self would be too Red Shot. I saw them preparing to roast some of the Welsh Ore in the Common Kiln, where it would require 24 hours, I was Informed that in the Reverberatory Furnace it would do better in four. tho they chose the other, as less expensive. As near [as I c]an judge, the different Ores produce about half their weight of Metal. The Water Wheel revolved in about 25'\_\_ The flux of which I sent a Sample and which they called too hot is procured at some lime quarries within Sight of the Furnace

There are very Capital Copper Works within a ¼ of a Mile of Red brook which I went to see. The whole process is very simple the Ore is Roasted in a Reverberatory Furnace for 24 hours, it is then Melted in a furnace of the same Kind, it is afterward pounded and sifted fine and Calcined again, it is then melted [a] second time, and comes out a Course Copper, it is melted a third time, and is then quite pure. The Whole operations are done in reverberatory furnaces, and pit coal is used at the Roasting and first and second Melting, They use some Charcoal along with pit coal at the last. They were here preparing the copper for coining half pence at the Tower, and stamp Them out Round, ready to receive the impression of the Dye

Tomorrow I propose seeing some great Iron Works furnaces and Forges about 10 miles south of this, at a place called Abby Tinton\_\_

I hope mine of the 15th & 16th have come save to hand. & I am

Dear Sir



Your most Obliged humb sert  
Robt Erskine

P.S. I endeavour to make memorandums of the particulars I write you, but as I may omit some Circumstances, the preserving my letters for perusal again will be necessary

Letter 4

Monmouth Sepr. 19th 1770

Dr. Sir

I went Yesterday to Abbey Tinton (or Trintorn as it is in the Map) about 10 miles south of this on the [River] Way, as four or five miles of the road was very bad, hilly, narrow and stoney, I went round by Chepstow to come here again; at Chepstow the tide commonly rises about 54 feet pers. sometimes above 60 feet.

They were repairing the Furnace at Abbey Tinton so that I could not see it at work, I saw however the Ore they Smelted, which was of three Kinds, viz Forrest of Dean, Cinders, and Lancashire I have sent a sample of the Lancashire (and to make up a package four sorts of Copper Ore) to Dr. Fordyce. The Ore at this Furnace was not, as at Red Brook, put in by weight, but left to the judgement of the Workmen who put it in by basketfulls, about equal quantities of Each. Between the furnace and the Forge, there were larger Works for Wire drawing, the Whole process of which I saw.

I staid a Considerable time at the forge to see the process—There were two Bellows about 7 feet Long which blew into a single hole of about an inch &  $\frac{1}{4}$ ; as the bellows were placed about 10 feet high, to be out of the way, the Air was conveyed down through Tubes of Tin, the Turnings right Angles, (which is certainly wrong, but two other forges which I have seen, have the same fault) There is a continual succession in converting the Pegs into bar Iron, kept up A mass of Iron which had already been under the hammer is heating to be beat into Bars, or any other shape, at the same time that an other mass is preparing, from the Melting of the Peg Iron, which at first melting falls down to the bottom of the hearth, from thence it is again and again poked up to the Surface of the fire above the blast, in order as the workmen said, to get its Nature [In doing this they are almost Constantly Employ'd] from the first melting of the peg to its being ready to go to the hammer is about an hour. There is an hole [on the level with the] bottom of the hearth, about six or 8 inches under the blast which the Workmen open by thrusting in their pockers [this hole is] to evacuate the

dross. On asking why the Iron did not likewise run out. I was informed that having got under the blast it was not so hot, but that the dross continued liquid, I supposed that at the first time of melting, before it was raised up again, the metal would run out too, which they agreed to, but this they avoided. The dross itself in Cooling stops the hole; and they know when to open it, by practice, and what sticks to the end of the pocker. The dross which flies off in beating, they again put into the fire, as it carries Iron with it. I think I have got such an Idea of all the Machinery that I need not describe it, for the sake of recollection. I saw likewise at the Furnace very good Stamping mills for pounding the Cinders to procure the small Iron like shot, the construction of which I cannot forget. The Workmen, work by the Ton, for which they have 10 shillings there are three to an hearth, and they can make about 3 Ton a week.

The Furnace at abbey Tinton was about 30 feet High and about 11 feet at the Widest. which was about 8 or 10 feet from the bottom. it was every where stopt up, and one of the men told me he has known a furnace so stopt for 11 [eleven] weeks, and when ever it was opened, burn up clear Immediately. it was full of Ore and Charcoal. The Bellows and Water Wheel were [of] the same dimensions as that at Red Brook, and at a Forge about 5 miles from here, I was informed that the Lancashire ore made the best Iron, and they had their peg Iron from Abby Tinton on that acct. They had likewise at this forge [which is] called New weir, American Peg Iron from near New York on which was marked Forrest of Dean, which they used to make a course Iron, they called mill Iron. This forge consisted of 4 hearths and two hammer, besides [a] Slitting mill, and making plates Etc. and they have the whole water of the River Way, which is larger than the Colne at Denham.

The Lancashire Ore does not require roasting, therefore before I leave Wales I shall endeavor to see some more of their Iron works because the nature of what is here called Welsh Ore, comes nearer to that with which I am likely to have to do. I here of so many different works in Wales, that I cannot propose seeing them all the roads and accommodation being very bad; There are some Considerable Works near Cardif, but as that is upon the Sea they very possibly use Lancashire Ore there. the works more inland are therefore likely to answer my purpose better.

Tomorrow God Willing I set out for Brecon, and by the end of next week, hope to have seen as much as necessary in Wales. this is my fourth letter, and I hope the three preceding have come to hand & I am

Dr Sir  
Your most Obliged humb sert  
Robt Erskine

## Letter 5

Brecknock 21st September 1770

Dear Sir

Since I left the environs of Monmouth I have not seen any Furnaces at Work, but have heard of some Works and Mines about 15 miles from this, which I propose going to see, chiefly on account of the Mines. I once thought of going to the mines in the forrest of dean but found the access difficult, they were in general very deep, and in some places it was necessary to Creep through narrow passages upon hands and knees, I suppose as the Strata of the Ore lay; which I was informed, sometimes run in thin Strata, and at other times, large masses as big as a room were met with. It would hardly have been prudent in a Stranger, without attendance, or being recommended to some of the overseers, to trust himself above an hundred yards underground, with miners of whom he know nothing; especially as the passages must be intricate, and accessable only to those, who by habit had acquired the dexterity of a Rat.

I have seen three very good Forges, two, of four, and one of six hearths each in my last I did not particularly distinguish between the different forges, and as their operations are very similar, such minuteness would be unnecessary. At the forge at Monmouth some of the workmen were very free in showing the different qualities of the Iron. It was from thence I sent samples of Red shot and Cold shot, and they there show'd me a species of peg Iron, from some part of america, they supposed; it was imported at Bristol, there were two letters upon it I think W. B: this Iron I was informed was so good, that it might be beat from the first forging, as small as my whip Cord; and was used for Gun Barrels. I had a Bar Broke; its appearance was small bright granules like steel, and not the least Fleaky like some of the samples I sent; towards the middle and bottom of the peg, the grain was much smaller than at the surface. I think I can know the same species again. though I could not conveniently procure a Sample.

In my last I described the process from Peg to malleable, but I believe omitted mentioning that they sometimes throw some of the Scoria from the Hammer upon the Coals. this they did after the Peg had been melted and stirred up to the surface again, above the blast, they said

it was for a flux; and no doubt the Iron is more and more difficult to melt, as it acquires the nature of Malleability, when it is first stirred up, it appears in different masses, and when there is enough for one forging, they push the peg which was melting, out of the Blast, and keep stirring the metal til it unites in one mass, about the size and shape of a Round half peck loaf. it is then lifted by mere strength of hand, under the hammer, by one of the forge men; the other in the mean time regulating the Stroke, which is at first slow and then gradually increases to about two beats a second. Habit certainly increases there strength very much. as a lad much more slender than I, can take a Peg of about and hundred & half, carry it with seeming ease, and throw it behind the Fire. When the hammer moves quick the strength of the Blow is very much increased, by its being thrown up against a Wooden Beam made to act as a Spring, which beam when it moves Slowly, it does not aproach by 4 or 5 inches. At the first operation they beat the Iron into a mass of about 18 or 20 Inches long, and about 4 Inches thick octangular; at the next they form it with great dexterity, into what shape they please, such as Bars, Implements for Plows, Waggon's Etc.

The furnace at this place was not at work, but I pickt up three different kinds of Ore which I have sent to Dr. Fordice it is roasted in Common Kilns\_\_

It will be necessary to carry [abroad with me] some of each of the different samples I procure in case some kinds of Ore be overlooked in america, which may be better than that they use. The Reverberatory furnace seems the only proper expedient for overcoming the Obduracy of the {\_\_\_\_\_}. I hope God willing to be at Hereford on my way to Birmingham by tomorrow night or sooner. it has rained almost incessantly all day which with bad Roads makes traveling disagreeable.

I am

Dear Sir

Your most oblijd humle Sert  
Robt Erskine

## Letter 6

Abergaveny Sepr 27th 1770

Dear Sir

For these four days past, it has rained almost incessantly, which has detained me the longer in this country. To day I have been at Pontypool and see the forges, furnace and Mines.

The Forges are pritty much similar to those I have before

seen, the Bellows are about the same size, there is only a small variation in the manner of working them, and instead of being raised by a Counterpoize, the going down the one raises the other; they being connected with a lever: to make good Malleable Iron they use two sorts of Peg Iron, which is distinguished by white & gray. the white is not granulous but fleaky, similar to some samples I sent from Monmouth. They had once a kind of Peg Iron from America marked B.C. of which they could not make Iron at all, it being too thin and running out with the Dross. While I was at one of the forges, for want of water, the blast was too weak, so that the mass would hardly unite.

The Furnace was not at work which gave an opportunity of seeing it more minutely, it did not differ either in size or Construction from those I have already seen; the water wheel and Bellows are nearly of the same size with the others. all the Ore they smelt is procured from parts adjacent. and may be divided into three kinds [which they call] Crop, found in lumps near the surface; Pin Ore, likewise found in masses, and Vain Ore, of which there are two kinds, one from an Inch and half, to two Inches thick, and an other above a foot or two feet. They put in at once into the furnace by Weight  $\frac{1}{3}$  pin ore  $\frac{2}{3}$  Vain, Wt of both 700 [Cwt]. 200 [Cwt] of Charcoal, and about 100 [£] of lime. Sometimes they use equal quantities of Each Ore the Pin Ore is very rich, producing  $\frac{3}{4}$  of its weight of Iron, the Vain  $\frac{1}{4}$ . The pin Ore they say, by itself would be too rich, making white Iron, and could run too thick the vain is added to give it the proper quality. I saw some pegs, which when broke were speckled the white and gray Iron being intermixed in such a manner, that there was no necessity of mixing them when they came to the forge. One of the Workmen said that a great deal of the quality of the Iron, depended upon the proper quantity of Charcoal, be the Ore what it would. The Ore which lay in heaps had acquired a Rusty hew, which it had not when fresh from the Mine, and that which turned rusty soonest, they looked on as the best sort. some was near 12 months in acquiring that colour.

The mines I saw were worked much in the same manner as stone quarries, by digging down the side of the Hill, without proceeding underground at all. at the bottom where there ran a rivulet, there was a Strata of fine Coal, which had little or no stone roof and therefore I suppose could not be undermined. Above the wall were Strata of Slate or thinish Stone and a bas or kind of Crumbling Coal, the Pin Ore lay here and there above; it has got that name, I suppose, from its being when dug out in Roundish Masses, about 100 ft. some more some less. they easily break into smaler pieces when thrown against

each other. the Vain Ore the farther in runs in the earth turns harder [& {Pender}] till at last it comes to a Stone unfit for use. The Ore is Calcined in Common brick kilns and is burnt in about two or three days. I have sent samples to Dr. Fordyce.

The Whole Town of Pontypool, now a pritty considerable village, has been built within 60 or 70 years, in consequence of the Iron works Established by old Mr Hanburry, who I was informed, by an old man there, was very Curious in his works. He had a Small furnace [and other apartus] in which he tried Experiments with all the different kinds of Ore, by which means he found out the proper proportions to be used of Each. The old gentleman alledged that now they did not attend to his lessons, and that many of his instructions and researches are lost, for the Iron is not near so good as formerly, which he evidenced by the losses the Workmen at a Wiredrawing manufactory there sustained, by its often breaking Etc\_\_ an immense fortune has been acquired by these works, and now several of them are neglected particularly the making Tin plates. The japan work here is Curious. the Iron is floted between Rolers, and then folded double till at last there is Eight ply of plates done at once. I did not however see the Mills they being about two miles out of the way, and I must have neglected objects more material.

There is another set of Works [& Mines] within 5 miles of this, which I shall inspect tomorrow and with which I shall conclude my researches in Wales\_\_ and proceed as fast as I can to Birmingham and northward.

I should be very happy to have Dr Fordyces opinion on what I write, and whether or not there is any thing material I overlook, that I may be aware of it in future for it would give me great pleasure to know that my Journey is likely to answer the end proposed. I shall be with his friend in Birmingham Next week God Willing, I am

Dear Sir

Your most obliged huml Sert  
Robt Erskine.

Letter 7

Brecknock Sepr 29th 1770

Dear Sir

From the different works I have seen, it may in general be inferred, that with proper management, any sort of Iron may be made from any kind of Ore. if the Furnace is overcharged with Ore, or which is the same thing, is dif-

ferent in Charcoal, than the Iron produced will be what is called White Iron, or what I termed Fleakey; the richer the Ore then, the more fewel will it required to make it Gray, or what I named Granulous. The Gray is certainly the purest, most ponderous, and freest from Sulphur, as appears from some samples I sent with the Ores; where, in the same piece, it was gray at bottom, and white at the Surface. At a furnace I saw yesterday, they could, and did from the same Ore, produce either sort at pleasure, by altering the quantity of Charcoal (and I suppose by altering the quantity of Lime which the call a flux, the same effect might be produced) They had assortments of both kinds, the white is [much] more brittle than the Other. At an adjoining Forge they use equal quantities of Each to produce Malleable Iron. Some Pegs are intirely white, some all gray, and others are mottled, but the gray is in general nearest the bottom. The reason then of mixing different Ores, seems to be, not to alter the quality of the Metal, but to save Fewel and work at the least Expençe. As bodies combine Chymically only in a certain proportion; with Ore too poor, a good deal of Fewel would be wasted, and with rich ore, the fewel cannot be applied fast enough, and Ore at a Medium may be conceived, which would require mixture. I hope you will Continue to excuse the incoherence of my letters, because I put down my Ideas as they Occur, that I may furnish matter for Dr Fordyces farther instructions, who will set me to right, where I Err.

I was told at the last Furnace, that the White Iron was proper for some uses, particularly Hammers and Anvels, several of which I saw they had Cast. I saw likewise an attempt they had made to cast a Cannon but their Iron they said ran too thick, was not liquid enough I imagine and I should suppose, that for the last purpose, it ought to be remelted in a reverberatory Furnace.

I frequently mentioned a small furnace for Experiments and was glad to find my idea coincided with old Mr. Hanburrys method of proceedings; [which I mentioned in my last] for from all the works I have seen, it appears, that different Ores, require a different treatment, and tho a general knowledge may be acquired, yet the particular manner of treating an Ore we are as yet unacquainted with [so the best advantage] can only be learned from Experiment. As Experiments can be oftener repeated, and better ascertained in small than large, I should be happy, with Dr. Fordyce's assistance, to be provided for making them in the best manner.

The different works I have seen, and may see, will certainly be of great service, were it only for furnishing an opportunity of making enquiries at One place, after

particulars which were omitted or not recollected before, and several such enquiries I have still to make, particularly the different kinds of Malleable Iron: and which indeed cannot be learned from one set of Workmen, without asking so many different questions, as would appear too inquisitive and prying, which of consequence would produce shyness.

I saw a Furnace near Abergavany which was empty and afforded an opportunity of Seeing its Construction. it belonged to Mr Hanburry, was about 24 feet deep. the receiver at bottom was stone about 2 ½ feet Diamr. and a foot deep, the Blast Hole a foot from its bottom. the Widest part was about 3 or four feet above the blast hole, and did not seem above 6 feet at most; fro thence it tapered to the Top to about a Yard. when the Matter sunk a yard they filled it again. A Sample of three kinds of Ore used at this furnace [and a bit of Iron], I have sent to Dr. Fordyce, which makes the fifth box I have sent him. They all come by the same Waggon and the last box will be in Town on Friday tonight. The Workmen at this furnace had only 8/6 week. At Pontipool they had 10/6 p Ton for Malleable Iron, and the furnace men when at Work 12/pr Week There are Iron Works near Aberystyth, where from a description of the Ore they use, it appears to be Lancashire, the same with the sample I sent.

If I was furnished with intelligence where abouts the steel and other works in Yorkshire were, it would perhaps be better than enquiring after them myself, at the Iron works; I suppose however I may learn this at Birmingham, and need not therefore trouble you on this acct. I am Dear Sir

Your most obliged humle Sert  
Robt Erskine

Letter 8

Birmingham Octr. 11th 1770

Dear Sir,

At the Steel work I mentioned in my last, I had an opportunity of [seeing] the inside of a Furnace, for converting Iron into Steel, which was building; The length was proportioned to that of a long bar of Iron above 15 Feet, and the breadth 8 or ten Feet; This space was covered by a low arched Roof of Brick, in the Center of which was an hole about 7 Inches square, which communicated with a Chimney about 15 Feet High. If you suppose four lines drawn the longest way, at equal distances, through the furnace, they will divide it into five equal spaces; three of which, viz. the middle and the two sides, are

for building the Chists where the Iron is Converted, the other two are for the fewel, which is put in at both ends\_\_ the middle space is built of solid Brickwork Breast high, as likewise are the Other two at the sides, the two intermediate spaces which remain, are open to the Ground, and grated over for the purpose of holding the fewel\_\_ There are consequently three Chists for holding the Iron, which, are every way a Brick thick. The bottom of the Chists are supported upon a number of Rows of Bricks, two Bricks high and about six Inches apart, that the fire may pass freely around the whole of the Chists. In these Chists the Iron Bars (with the materials for Conversion) are placed Edgeways, so as not to touch each other, and then Covered up Close (I suppose with Brick and Mortar) The Chists are about 3 feet deep & 18 Inches Wide [and hold about 8 Tons]. There is a Space of about 8 Inches between the Outer Chists and the wall of the furnace, that the heat may get round them. The Iron is put in at the holes in the wall at the Top of the Chists, and taken out Steel at opposite holes, all which holes, while the operation is performing, are stopt with Brick and mortar, The fire is kept up six days, and then it is left [to] Cool, to such a degree, that a person can go into the furnace and [lift &] push the Steel Bars out of the Chist. (Tho this description may not be intelligible to an other, yet it will inable me to make a drawing if necessary) it is only Swedish Iron that they here convert into steel. Steel made of English Iron will not Weld etc. To make Cast Steel it must be twice Converted, or undergo a second operation similar to the above. there is a visible difference between the steel which has once or twice undergone the operation samples of Each and likewise of Cast Steel before and after hammering I shall send to Dr. Fordyce. The Steel in order to be melted is broke into small pieces, and put into a Crucible about 5 inches Diamr and 15 Inches high. The Crucible is placed in a furnace of live [Cinder] cock. There are several Furnaces in a Row, about a foot & ½ Square Each and 3 Feet Deep, the access to which is like D.r Fordyce's furnace. the Covers shut Close and are of Brick and in a frame of Iron, and the Draft of Air [is] from below. The Chimneys (I suppose) are 30 feet high. And the fewel is put in by lifting off the Cover, which when it is off allows the Top of the Crucible to be seen which has a Cover to prevent the Cinders falling in\_\_ There appear to be some faults both in Converting and melting furnace, in the Converting, the middle Chist I think must be the hottest, and in the melting, the bottom of the Crucible stands upon the grate which supports the Coals, and therefore, I should think, cannot get hot enough.

In the Same bar, even of Swedish Iron, there is often two kinds of Metal a White and grayer kind. The White Mr. Bolton finds to his purpose to have Chizzed out

and separated from the other. The Science of knowing the different natures and properties of Iron, is not to be acquired in a day, I must Content my self with knowing as much of it in general as I can, and the Chief thing necessary seems to be, to know how to make good Malleable Iron, neither Red not Cold Shot, and how to make the best Peg Iron to produce this kind.

By Conversing with Dr. Small who has been ingaged with Mr Bolton in various experiments upon Iron. peg Iron, I find, may be made Malleable in other ways than I have seen. The Application of Calcarious Earth or Burnt bones will absorb the superabundance of Phlogiston in peg Iron and Convert it into Malleable so that a peg like a Gun barrel, may have the [Exterior] part Malleable and the inner part remain hollow by letting the unconverted pig Iron run out Part of this process (which they Carried farther) is in Keanmear, or Schlotter on mines.

At a Smelting furnace near this, they have two kinds of ore procured from Coal pits, the only difference between the Ores is, that one is richer than the Other. The Ore is put in by basket fulls, each weighing about ¼ CrWt. four baskets of the best and five of the Inferiour with three baskets of Charcoal, which hold about 3 bushels Each are put in at a Time. the Iron is drawn off Every 12 hours, and the Weight of it is from 24 to 26 CrWt. in the Space of 12 hours the furnace is fed 16 or 18 times and to 18 baskets of Ore, there is added one basket of Lime. The ore is Calcined, not in kilns but by being built up in heaps on the ground, intermixed with small Charcoal The Furnace is about 30 feet high, the receiver at bottom is 18 Inches by three feet, and a foot deep, the bellows blow across the shorter axis, the Widest is 8 or 10 feet from the Bottom, is Round and about 8 [or 10] feet Diam.r from thence it tapers to a square aperture of two feet at the top. The Bellows are of the Common Sort. The Dam to keep in the Iron is a large Brick of Sturbridge Clay, and a Sample of the Stone of which the hearth is made, and which lasts several years I have procured, and sent to Dr Fordyce with samples of the Ore.

At Mr Boltons Works Mechanices are in perfection, both in animate and alive, but I must give the preference to the Machinery, some engines being so Constructed that a man or a boy will execute the work equally well, and in many cases, a blind man could do as well as either, at some Machines the artist not only employs his feet, and his hands, but his elbows, by pressing down of which a material movement is Effected. Among the numerous branches here executed none are more striking than the Derbyshire Spar, which is made into vases, urns, Branches, Candlesticks, and Variety of

ornamental pieces of furniture, highly decorated with Chased & gilt ornaments, the spar of variety of Colours shining through which, has a very pleasing effect. I saw several things of this kind which were executing for his Majesty and the Queen\_\_\_\_\_.

I have sent samples of Ores, Iron, different steels, lime and furnace stone to Dr. Fordyce and am

Dear Sir

Your most obliged huml Sert  
Robt. Erskine

P. S. One of the Workmen at the Steel Manufactory affirmed positively [from experience] that the Steel acquired no addition of weight in Conversion, provided the Iron was not rusty, if it was then it acquired a small matter and blistered &tc.

Letter 9

Shrewsbury October 15th 1770

Dear Sir

Though the works I have now seen, are much superior in point of Mechanism, to those I have already given you an account of, yet the necessity of my viewing the furnaces I first described, is now very evident, because all the Ore, between this and Birmingham is smelted with Coke, or pit Coal Cinders, which is materially different from Charcoal. The last may therefore furnish me with Mechanical focus, but the principles of something must chiefly be deduced from the first.

I luckily met Mr Wilkinson at Birmingham on his journey to London, who gave me an order to see his and several other works, had I missed him, I should have been much at a loss. At his furnace near Bilstone, the Bellows is an Iron Cylinder about 6 feet diamr. Worked by a fire Engine: The stroke is between 5 & 6 feet; the Cylinder is fixed, and the piston enters at the bottom, and Works upwards, the piston rod from the beam of the fire Engine, branching into four rods, which descend on the outside of the Cylinder. when the piston rod ascends the air escapes through two Tubes at the Top; but were such a body of air Confined to the pipes which conveyed it to the furnace, some part of the machine must give way, and the blast would likewise intermit; the Tubes from the Cylinder therefore Communicate with two Cast Iron Vessels about 8 feet Diamr. Inverted in Cisterns of Water, very much loaded to prevent their being buoyed up, in these, the Air, by forcing out the Water, expands it self, and the pressure of the water returning into them, Continues the Blast,

when the piston is going down; the Air returns through the same pipe it entered the Air vessels, and as Valves prevent its again entering the Cylinder, it passes through a [square] Tube made of Wood, to the furnace. The furnace is 32 feet high the bottom for the Metal 20 Inches Diamr. Continued the same width for 5 ½ feet, when in 6 ½ feet more it expands to the Width of 12 feet, from there it tapers to about two feet at the Top. Their Charge is 53 bushel baskets of Coke, 81 Bushel Baskets of Mine, and about 3 of limestone. the great proportion of limestone at this and the other works I have since seen, is certainly to absorb the remaining sulphur of the Coal. for every where, tho the Ore is nearly similar to that at Birmingham, yet they use lime in much greater proportions, than with [Charcoal.]

Adjacent to the Furnace is a Casting house where Engine pipes etc. are Cast. The pig Iron is again melted in reverberatory Furnaces, and, for things of a large size, is allowed to run out into the Mould prepared below it; the preparation of which mould seems the Chief part of the operation. For pipes of a foot Bore, the Core is a Cylinder of Cast Iron about 6 or 7 Inches Diamr and ¾ of an Inch thick, every where perforated with holes of an inch Diamr & 3 or 4 Inches distance: this Cylinder is wrapt about with ropes of hay or straw which are covered with Casting sand by which means its diamr Is increased to that of the Inside of the Tube; were it not for the holes, the Tubes would not be sound, as they allow the air to escape. The moulds are Confined in iron frames, and the manner in which one thing is done, may furnish Ideas for the performing of others. I saw the manner of preparing the Mould for Casting one piece of Work rather uncommon, which was a Wheel for a Circular Fire Engine. The Rim of the wheel is hollow, and if you conceived two Broad hoops Concentric, the Diamr of the largest about 8 feet and distant from the inner hoop two inches, and both sides Covered by a flat hoop. (the Concentric hoops being 8 Inches Broad), [this] will afford an adequate Idea of the hollow of the Wheel, which was cast in three pieces, and must join together to be perfectly steam Tight, the Core for forming the Hollow in the middle, was supported upon Broad headed nails, which remained in the Metal after Casting.

After a Furnace is built it is filled with fire to the Top and shut up for two or three weeks, it is then opened and the ore put in, [which is] allowed to descend gradually so that it is 8 or ten days before that which was first put in arrives at the Blast. this process affords an other reason for making Experiments in Small.

The Furnace I have now described, is surrounded with

Coal pits, the Strata at the Coal is amazingly thick, being above ten yards. while I was there one of the pits was on fire, which they said had kindled of itself: and about an hundred yards to the Eastward of the Furnace, the surface (and to a Considerable depth) of the ground was all on fire, and has been burning above ten years, the ground burnt may be about an acre. On viewing this Conflagration and the Effects of it, I could not help thinking, that some Centuries hence it may afford matter of speculation to a Naturalist, who instead of the Worlds having been drowned, may produce specimens to prove that it has been burnt, for here are Calcined Stones beds of Clay converted into brick, and other phenomena in abundance, perhaps native Iron, for bushes and shrubs fall down through the Cracks where they may soon be converted to Charcoal, and meet with Iron Ore in plenty.

From Bilstone I went by Sturbridge to Brosely, Crossing the Severn at Bridgenorth which is the most curious romantic situation I ever beheld.

Near Brosely there is a very large Iron work, which has been 5 years Idle, I had an opportunity however of Inspecting the furnaces and machinery which I dare say did not cost less than 10 or 15,000 L.

There was a very large Tub Bellows worked by a fire Engine. The Bellows were of Wood Hoop'd with Iron, there was no piston; the manner of its operating, tho I could not see its construction within, I conceive was as follows. One Tub about 8 feet Diamr. and 7 or 8 feet high was fixed and Open at bottom, where an other Tub reverted entered, but I suppose did not touch the side of the Inverted Tub by two inches, because the visible part of the Lower Tub was larger than the upper Fixed one, by so much: had the Upper Tub then been away, the lower one would have appeared, like a smaller pail Inverted into a larger one. The fixed Tub occupying part of the space between the double sides, which space being filled with water it makes the machine air tight, and works without friction, which appears to be a very good Construction. the air was conveyed into three different air vessels inverted in water, the same as before described, and I suppose afforded air enough for two Furnaces, a larger and a smaller one, as appeared by the Tubes of Communication. There was a third Furnace supplied with air by bellows (I shall afterwards describe as I saw the same kind at work in other places), worked by a Water wheel, there was likewise a fire Engine for returning the water, some part of the Construction of which was defective, as it did not perform well. there were several Reverberatory furnaces and apparatus for Casting the largest Cylinders, one of which I saw bored

and finished, was 6 feet Diamr. There were likewise moulds for Casting Cannon Balls, Bombs, gradades, etc. from inspecting of which it is easy to conceive the manner of Casting, but as I expect to see them at work in making cannon at a furnace belonging to Mr. Wilkinson, in Denbeigh Shire, I shall not now attempt the Description.

From Brosely to Colebrook dale is about three miles, I crossed the Severn at an horse ferry, the Boat was connected with a Rope about 200 Yds. long one end of which was fastened to a Stake, and the other passed over a pulley at the Top of the mast, so that by means of the Rope and the Rudder, the Boat swung over by the assistance of the Current only. About Colbrook dale there are above a dozen furnaces within less than that number of miles of Each other, all worked with Coke, two of the principal of which only, I inspected. At the first I saw the manner of Casting great variety of things, such as Engine Cylinders, Tubes, Boilers, pots and kettles, etc. etc. the Chief nicity of doing all which, lies in preparing the Mould properly; for some things such as large Boilers the metal Runs directly from the smelting furnace, for others such as pots kettles, Checks for grates, etc. it is melted in the reverberatory furnace. to give an Idea of the other operations I beg leave to describe the manner of preparing the Mould for a Common Iron pot, which here they Cast so thin as the 8th of an Inch: There is a Mould of brass, of that Thickness, in two pieces, these are put together, and placed in a square frame, which likewise separates in two: the moulding sand is then stuffed within and all around the mould very hard, the frame is then taken assunder and the mould taken out, and when put together again there remains just the thickness of the mould for the Metal, which is poured in at the bottom of the pot, the pot being Cast with the mouth downwards. The Bellows are two Iron Cylinders, about 7 feet Diamr. Worked by a Water wheel, and the Stroke of the piston is about 2 ½ feet. the pistons are pulled up by a Counterpoise, and forced down alternately by Cogs in the axis of the wheel, and the manner of giving the perpendicular stroke is rather Complex, and might be performed better otherwise. As I hinted before in this and all the other furnaces, the proportion of limestone to the ore is very great being nearly One third. The Ore is very good and seems to contain [very] little sulphur & is easily Calcined being burnt upon the Ground, the lime must therefore be an antidote to the Coke. they have not yet been able to make Malleable Iron properly from Coke Pig Iron, tho I was Informed at Birmingham, that one Mr Wood there has a patent for making hammered Iron of Coke; a Copy of the Specification of which I think it would be proper for Mr Sill to procure.

In this Country there are Waggon Ways for several miles together in which the tracts for the wheels, are all of Cast Iron. I saw some mines, the manner of Boring Cylinders, and an other Furnace, the Description of which I must defer to my next, and am

Dear Sir

Your most oblig'd huml Sert  
Robt Erskine

I have sent Samples of Ore etc. to Dr. Fordyce.

Letter 10

Chester October 18th 1770

Dear Sir

In my last I omitted to mention, that the third furnace at the Iron Works at Brosley. was supplied with air from a Bellows consisting of three Cylinders, worked by a Water wheel with a triple Crank on the Axis [which must give a Constant and equal blast]: The hearth or stonework was taken out at one of the furnaces, and the Brick work was a square, of about 10 feet Square and as much in height, from whence it taper'd to the Top, to an aperture of about 2 feet.

I have got acquainted with one Mr. Perry of Liverpool a Surveyor, who has likewise some Iron Works in this Country: he informs me that at Colebrook Dale they make Good Malleable Iron with Coke, from Coke peg Iron, at one of the furnaces there; for which they have a patent, of about three years standing. The Iron is melted in a Wind furnace upon a Test, under which is a Run of Water; to regulate the heat; the water does not Touch the test, by several Inches; when the Iron is melted and got to the Consistance of Pap, it is stirred about and Crumbled and then Cooled, and melted over again into a Mass for the hammer: the worst sort of Iron, such as cannot be made malleable with Charcoal it is said they make into good Iron: a Copy of the specification of this and Mr Woods Patent, therefore, I think absolutely necessary, for tho the process is certainly different from that with Charcoal, yet Dr Fordyce will, from this be able to make improvements on both methods, and perhaps establish a Theory for making good Malleable Iron, upon Certain principles. had there not been a patent for the Above I should have returned back on purpose to have seen the process; but, as in patents, the principles must be minutely described, it renders inspection less necessary, tho the not seeing it vexes me not a little. In the second melting the dross is let out as at a common

forge. Mr Wood is said to make good Iron of any kind, only in the bad there is more waste.

In my way across the Country I saw seven Iron mines; those I looked into were not above 30 feet deep. though I find the depths are various. the iron stone is found in nodules, lying in a bluish kind of loom; which tho pritty hard when dug, Crumbles in the air. From the appearance of the Ore in general, all over the Country, it seems to be of the Nodulous kind, very little or none of it lying in strata.

I saw an Iron work at Ketley about 12 miles from Shrewsbury where there were three furnaces. the Construction of the bellows, seemed simple and very good; the Bellows Consisted of two Iron Cylinders 7 feet Diamr. the Stroke of the piston  $2\frac{1}{2}$  feet [worked by a water Wheel] they each throw the air, before it reached the furnace, into what they Called a regulator, a Close Iron Box, the Contents of which might be about 6 Cubic feet. the whole worked dry, and little or no Air Escaped at the pistons, which had a perpendicular motion from {C\_\_\_\_ed\_eud,} the radius of which was {\_\_\_\_\_} 20 feet, the Center of Motion of which appears to be Improveable. at these works the water was returned by two large fire Engines, which produced a very Considerable Constant stream. the reason of not applying the fire Engines directly to the Blast, I suppose, is owing to the difficulty of Communicating the power to the Different furnaces; In looking into the Blast holes of all the furnaces worked by Coke, I observed that very little of the fire was visible, the air making the Cinders next to it black, whereas in Charcoal the heat is very vivid and White within a few inches of the nozel of the bellows.

At Mr Wilkinsons Iron work near Wrexham, there are a pair of Bellows quite Philosophical, and very simple; to conceive the principles of which, suppose a Tube inserted into a Close Vessel & reaching almost to the Bottom; if water is poured in, it will Condence the Air in the vessel, and if the air has any way of escape, will force it out; let a way of escape then be provided, and the vessel will be filled with water and the air in forcing out, will have made a Blast: the vessel [being now] full of water, [to repeat the blast] it must be emptied again; for this purpose, let a Siphon be likewise inserted, which, when the vessel is full, shall divert the water; [however] to allow the Siphon to operate, there must be a Valve opening Inwards to admit the air again into the vessel; and then by pouring in water, the blast will be repeated a second time, and so on. Upon these principles the Bellows are Constructed to make the Blast Continual,



there are two Close Vessels [of Wood] (designed to work alternately) 12 feet square and 8 feet high. the water enters the vessels through a Tube about a foot Diamr. and 8 or 9 feet higher than the upper part of the Vessel. a sluice is opened to lett the water run in, and when the vessel is full, and the Siphon begins to operate, the water running from the Siphon acts upon a Board connected by rods to the end of a lever, which shuts the Sluice, and prevents the water from running in: when the siphon has drawn off all the water, the sluice is opened by a Counterpoise at the other end of the lever, and so the blast is repeated: it is easy now to conceive that two vessels produce a Constant blast, and provided there is water enough, work Continually without attendance: this however I find was not the case here, the working of the two vessels being sometimes irregular, and required a little looking after, but this inconvenience, it is certainly practicable to get over. From the height of the nicks of the Siphon, above the vessels, there is an unnecessary waste of water there are likewise some other minutia to be attended to: and from the whole Bellows very lasting and simple may be constructed, where there is water, and fall enough.

From what I saw doing at these works, I have got a pritty good Idea of Casting in general. they were executing an order from the Emperor of Morocco, for 50 eighteen pounders, one of which I saw Moulded and Cast [(upon them was the Mohametan Esq 1184)]. The inspection of only one half of a spherical body can be made perfect in sand, because, if sand is put round the whole of it the mould cannot be extricated without destroying half the figure, in general therefore all moulds must be so constructed {\_\_\_\_\_} the sand and have their impression intire on which account the Moulds of all bodies not perfectly Conical must be in separate pieces. The patern for a Great Gun, I believe Consisted of about 8 or 9 pieces; to each of which pieces [is appropriated] a frame of Cast Iron, separating in two, and key'd together with wedges, like the bolt of a Window shutter. The paterns are turned in a leath, and at each joining they are Countersunk into each other. Suppose the pattern of the Breach then, set in its frame, and ramm'd round with sand; the frame belonging to the next piесе of the patern is put above it, and key'd fast (for each Frame not only seperates in half length ways of the gun, but is likewise keyed to its neighbour so as to make the whole immoveable) and that part of the patern belonging to it put in, and ramm'd round with sand; and so on, till the whole of the patern is inclosed in the Iron Case, now all in one mass: it is then seperated, and the different pieces pulled out, and the several parts of the frame (now filled with a Crust

of sand 1 ½ Inch Thick) set to dry in a furnace. The different parts of the frame are then regularly joined and set perpendicular in a Sand pit (but I should have mentioned, that at the Breach there is a Center for the Core, supported by three Radii of hammered Iron, which remain always in the Gun, the metal running round them) when the frame is put together in the Pit and ramm'd round with sand, the Core (which is an Iron rod surrounded first with straw and then with loom (or moulding sand) to make it nearly the Diamr. of the bore) is by pullies lowered Cautiously into the Mould, the hole in the end of it, going upon the pivot in the Center, a Candle being let down by a string to guide it properly. A Ring with three radii with screws acting upon the upper frame, is put over the Top of the Core working it is adjusted in the Center, at top: there is likewise an Iron bolt which passes through the Iron rod in the heart of the Core; to prevent its being buoyed up by the liquid metal. I should have said, that likewise at the Breach, [there was put] a plate of Cast Iron to take off the force of the metal, falling at fist above 12 feet: this plate however soon melts with the rest.

Everything being prepared, and troughs formed of sand, from the Mould, to three reverberatory furnaces, one of them was opened, and the metal suffered to run in: two people held stoppers to keep back any dross of Scum just before it entered the mould, and one by partially stopping the hole of the furnace, regulated its running, there was a director, who order'd the metals running faster or slower, and an other who was looking into the mould all the while; which I likewise did, with great safety and without offence to my eyes from the heat, by Cutting a small hole in a letter and looking through it; just before one furnace was out, an other was tap'd, and a third, til the mould was full. A Strong flame ascended up through the Center, and the ignated air past through above a foot thickness of sand, ramm'd hard, and set fire to boards, which encompassed the sand which surrounded the frame. The manner of boring Cylinders and Guns I bed leave to refer to my next. and am

Dr Sir

Your most oblised huml Sert

Warrington Oct 18th,

I hope {\_\_\_\_\_} to be at your Brothers tuesday or wednesday next

—

Robt Erskine

## Letter 11

Lancaster Oct. 20th 1770

Dear Sir

As I am not quite Certain that I mentioned it in my last, I beg leave to inform you, that when the metal first run into the Cannon Mould, it fell upon a plate of Cast metal to prevent the Mould from being injured by the height of the fall, which plate when surrounded with liquid Metal melted too. With respect to the Philosophical bellows I described, one circumstance is rather paradoxical, tho they seemed positive as to the fact, which was, that they required more water than Bellows worked by a Wheel; at present I am apt to think this is owing to some defect in their Construction.

The Boring Machines are very simple; the Borer or Drill is fixed in the axis of a water wheel, and for Cannon or things of a Small diameter performs an equal number of Revolutions [with the wheel]: if the Cylinders are very large, the Borer is upon the axis of a Small Cog Wheel, turned by a larger, on the axis of the Water wheel; which gives the last a Mechanical advantage of about 4 to one. the thing to be Bored is fixed on a Carriage, where it is adjusted paralel to the Borer. the Carriage is upon four wheels, and is moved forwards or back, by a Rope or Chain, made fast to the forpart, and then passing one round a Capstan it goes under the Carriage and round an other Capstan, when it is fastened to the back part of the Carriage. a man [thus], easily moves the greatest weight with an handspike, and gradually advances upon the Borer: in the Borer for Canon there are four steel Cutters the Edges of which are not quite paralel to the axis having an obliquity of about 3 or 4 degrees. for an 18 lb.r they were about 4 inches long To Cut off the Iron pivot which kept the Core in the Center, there is a Common double Edged Drill. An Eighteen pounder might be once bored, in about an hour, as the few minutes I stood by, the dril advanced near a foot; it made a very disagreeable noise which at a distance was much like that of Geese. The Boring of large Cylinders is in every respect similar to that of Cannon, only the Cutters must be placed upon the Edge of a Circle nearly the Diamr of the Cylinder, and I was informed the whole Cylinder is not bored at once only the lower part of it, and then it is turned Round. if therefore there was a provision to turn the Cylinder slowly the Contrary way, while it was aboring, its figure must be truer. Upon the mouth of an 18 Lb Cannon there is a Mass of about a foot [to be cut off] the weight of which is designed to make that under it more Solid, this is Cut off by putting a piece of Iron in the Cannon (which fits in a square in

the Axis of the water wheel, the same as the dril) and making it fast with wedges, the whole Cannon then Turns round, and a Chizel is applied (not by hand to be sure) which cuts it off in an hour.

Kendal – 24th

I have been at Backbarrow, than which, with respect to water, there cannot be a better [situation] for a Manufactory in Europe; the River which flows from a lake called Winender Mire, is about the size of the Colne, and, on account of the great Capacity of its fountain, is never lyable to be flooded at any season of the year. The Lake is about 85 yds perpendr above the Tide so that there must be fall enough for many additional works. I met with a kind reception from the Gentleman to whom your brothers letter was addressed, who showed me a Charcoal furnace and forge. The furnace is blown with Leather Bellows the same In every respect as I have already described, at the Forge their Bellows are Cast Iron Cylinders. The Ore is the same with the Lancashire of which I have already sent a sample, it is dug out of Pits near Ulverstone, and is delivered on board Ship at Twelve shilling p Ton. Besides this Redish ore, they use along with it a small portion of Iron stone, which is put into the furnace without being burnt, none of the Ore here being Calcined: a Charge is Six baskets of Charcoal about 2½ bushels Each 4 lbwt and 6 Stone Lancashire Ore ½ & Iron Stone and a small quantity about 5 or 6 stone of limestone: about 35 hundred Ore yeilds a Ton of Iron. Their manner of accounting for White and Gray Iron was the same as I have formerly mentioned, the greater of less proportion of Charcoal. The furnace had not been in blast above a week, and the Iron produced was very gray on account of the Great proportions of Charcoal. On the surface of some of the pegs there were glistering scales which they called Kish, and which show'd [that] the proportion of Charcoal was much too great, and that it would have been able to have Carried a good deal more Ore; the furnace not being come to its proper Temper. it was filled with fewel on fire for eight days, and then Ore was put in along with the Coal, for about eight days more, by which time the ore had reached the Blast then and not before they began to blow. The dimensions of the furnace was much the same with those I have already described. I found they were here [as at other places] at a loss to account for Cold shot and red shot Iron, only in general if the white Iron was predominant it was apt to be red shot tho a great deal dependes on the workmen, gray pegs with bad management turning out red shot too. At all Forges there is a Conical Tube placed in the wall for the air to pass thro [into the fire]; this here they call a Tuiron.

it was of great advantage to have what they called a Water tuiron, which is to have the conical Tube made of hammered Iron, double, so that a Current of water may be continually passing round it to keep it Cool, this circumstance I heard nothing of at any other forge, and here I discovered it only by accident, the Term in discourse happening to be mentioned. In Converting peg Iron into Malleable it loses about a fourth of its weight. The size of the hearth is about a foot square and nearly as deep the blast is over the Top. The mass of Iron before hammering when taken out of the forge is [here] called a Loop. when hammered once is named Bloom. and after the second hammering Anchony [ancony].

There is an other furnace and forge about four miles from the above, belonging to the same Company, in every respect similar to the other, however Mr. Dixon and I were on our way to see it when we met with a Brother of Mr. Wilkinson, with whom I turned back and spent the evening, thinking I should reap more benefit by discuss-

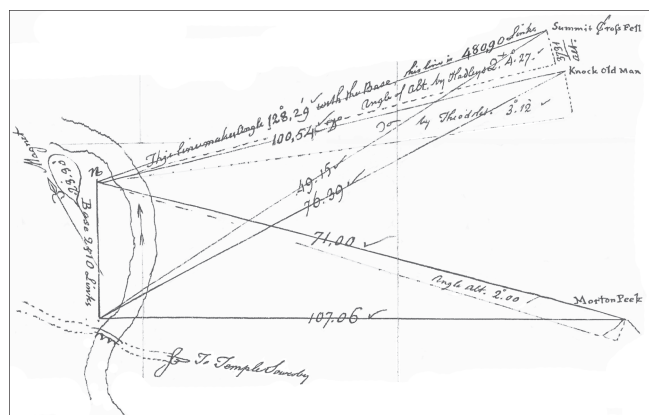


Figure 2: Sketch-elevation for calculating the height of Cross Fell (11 miles east of Penrith).

ing with him, than by seeing the same thing repeated. He, like his Brother with whom he is connected, has been in the Iron way, all his days, and has seen, I suppose, all the Iron works in England, [Scotland] and Wales, and lately was in Ireland & saw several furnaces and forges there; which he went on purpose to look at. Among other Works, he told me There are furnaces in Glamorgan shire very large, particularly one belonging to Anthony Bacon Merct. worked with Coke, which is Sixty feet high, they let the metal run from the furnace into Water to granulate it, and what is not small enough is pounded under Stampers, one Wheel carrying eight 4 on each side; it is granulated to be made Malleable with raw Coal. For this purpose a number of Crucibles or pots about 6 Inches deep and a foot wide are prepared, these vessels are filled with the small Iron, only in the middle there is a piece of Wood about an Inch and half

or two Inches Diamr. the Pots are put in an oven or reverberatory furnace, and when the metal begins to run Break. the Breaking of the pots is the signal to take it out, the design of the wood is said to be for making a hole in the middle of the mass for the Conveniency of moving it. It is now Cooled, and again granulated, and the operation repeated a second time when it is taken to the hammer. I am not very certain whether or not Mr Wood is Connected with these Works. I think Mr Wilkinson said he was.

Last year, at Back Barrow furnace, Mr Wilkinson tried the Experiment for making Iron, of Coal made of Turf or peat, which succeeded very well and I believe they are now providing a quantity of Turf and going to build a furnace for working it somewhere in the neighbourhood of this.

The large Water Bellows I described at the Works near Brosely served three Furnaces, such a bellows I think may be made very simple and instead of a fire Engine may be worked by a Counterpoise of Water. what particulars I have now omitted I shall endeavour to recollect, and Write from Temple Sowerby and am

Dear Sir  
Your most obliged huml Sert  
Robt Erskine.

Letter 12

Temple Sowerby Oct. 27th 1770

Dear Sir

I yesterday Measured the height &tc. of Cross Fell &tc. from a meadow at the Bridge, the following and the Data

The above is not laid down to any Scale, because when I protracted the Triangle to the Summit, to a Scale of 32 Chains to an Inch, it measures 16 Inches long.

By Calculation the Distance of the Summit from the N. point of the base is 480.90 which is 6 miles and 90 Links, and its perpendr. Hight above the Instrument which was about 4y.ds higher than the Water is 3731 which wants only 269 of half a mile. To the altitude however should be added the dip of the Earth which in 6 miles I believe is nearly 17 y.ds We only had time to take the altitude of Cross fell by Hadleys Quadrant. the other altitudes are by the Theodolit, however as it agreed with Hadleys to three minutes in that of Cross fell, I fancy the Whole

may be looked upon as pritty accurate. When the Quick Silver was first poured out, there was such a Scum upon it, that totally prevented the reflection, and we were obliged to strain it through an hankerchief which took some time &tc.

The Old Gentleman was so civil as to remain uncovered during the Whole of our operations, which was the more polite, as he had not been so long bare headed for many days before; he put his Cap on however so soon as we were done, and there it now remains.

Your brothers have been so kind as give me letters for introducing me to two Iron works between this and Carlile I have likewise Drawn for £30 and shall write again to day to mention some things I have hitherto omitted with respect to the Iron works I have seen. The post now going away I am Dear Sir

Your most Obliged huml Sert.

Robt Erskine

P.S. As I have been longer out than I expected should be much obliged to you, to desire Mr. Dixon or any of the Clarks to call on Mrs. Erskine to see if she wants money\_\_

Letter 13

Glasgow November 10th. 1770

Dear Sir

Last night I came here from Carron where I was from Wednesday afternoon, till yesterday morning. Mr. Gascoigne was gone for London, which however was far from being a disadvantage, for he might have engaged me in other pursuits, and had he accompanied me through the works, my view must have been more Cursory and superficial, nor could I in his hearing, have taken the liberty to ask such questions at the workmen, as I did when by my self. The mentioning my name and acquaintance with him, I found a sufficient Introduction.

They have great plenty and variety of ores, all procured in the neighborhood or brought by sea from the Cost of fife. they had indeed a small portion of Lancashire of which they used only one Basket in ten, but an ore everyway similar to this, is [now] found a few miles north of Stirling, for which they have only to dig about 18 feet, and when this mine is worked, all the materials will be procured from within twenty or thirty miles of

the Works, Chiefly by Water Carriage. Except the ore like Lancashire, the rest are either strata or nodules. The difference of the Ores of the Strata kind, seemed to consist Chiefly in their coming from different places, for in other respects they were very similar, and in general had much the appearance of the Ore used at Ketley near Shrewsbury, being very black. The Nodules came from the opposite Cost of fife, at a place called Lime Kilns and are found on the side of an hill, lying amongst sand or Clay. Besides these, there is an other kind of Iron stone picked up within high water mark on the Cost of fife opposite to Edinburgh. Samples of several kinds I have procured; and on my way here, went to see a mine of Iron stone near Kilsyth, which they will have only to convey a mile by land Carriage to the Canal, when that Communication is opened. This mine was found by the Strata Cropping out on the banks of a Rivelet. I entered the mine by a passage in the side of the hill; there were two strata, an upper and lower, about 5 or 6 Inches apart, the upper about 5 and the Lower about four Inches thick, the substance between and above [the strata] was a kind of Blackish stone which when broke, had a gritty-dark-gray appearance. There were Ores from other places the strata of which was 8 or 10 Inches thick, and one kind found below or above a Coal, from one to three or four inches Thick. The stones from the sea shore had a dark redish appearance, though it was with difficulty I could find one which had not been burnt [in calcining]. All the Ores are Calcined on the Ground with Raw pit Coal, and in the Furnaces are smelted with Coke. The Charge at one furnace was 6 baskets Coke, about Two bushels Each, Ten of Ore and four of Limestone. they said it was 40 hours of descending to the Blast, and if two Baskets of Lancashire had been put instead of one, it would make the Iron thick like Tar.

There are Four Blast and 5 [Reverberatory] furnaces. The Blast Furnaces (all of which seem nearly of the same dimensions) from the description I had of one) are about 36 feet high 16 feet at the widest, which was about 10 or 12 feet from the bottom; the Cistern one foot by 4, and 18 Inches deep [(nearly the same with a Cistern I saw fitting up at Belsham Wales, belonging to Wilkinson)] the Blast across the narrowest part. One of the furnaces had Common Leather Bellows, but the other three were supplied with Cylinder Bellows which produced a most Impetuous [Blast] that with the Common Bellows did not yield above half the quantity of Iron, with the others. The Bellows of two furnaces were Exactly Similar. each consisted of four Cast Cylinders, about 4 feet Diamr. and the stroke about 5 feet. the Cylinders stood two & two, at the Opposite Extremities of Two Levers about 18 or 20 feet Long, which levers were moved alternately by

a double Crank on the axis of a Cog wheel, which was turned by an other Cog wheel of twice the diamr. on the Axis of the Water Wheel; which I suppose was near 30 feet Diamr and 4 feet Broad, and revolved about 4 times in a minute; but without a second watch such remarks are not to be depended on, nor the Strength of the Blast accurately ascertained. The Inside of the Cylinders were polished Clear, I suppose by the Black lead used at the piston; each pair threw the air into a Box of about 5 or 6 Cubical feet, from whence it was conveyed in Cast pipes about 8 Inches Diamr. which joined in one, before they reached the furnace, and ended in a pipe which tapered to[wards] the Blast hole, to about three inches Diamiter. The other Bellows Consisted of three Cylinders abreast of Each other, worked by three arch headed Levers, and a Triple Crank on the axis of a Water wheel about the same dimensions with the other, and which revolved about five Times in a Minute. The Cylinders were about 5 [five] feet Diamr. and the Stroke of the piston 6 feet. the Cylinders received the air at the Bottom and threw it out at the Top, which was Covered, the piston rod moving through an hole. the air came into a common receiver of perhaps 8 or 10 Cubical feet, from whence it went in a single pipe to the furnace. Both bellows produced a very equal and unintermitting Blast, of nearly the same strength, [for] the difference could not be distinguished, though between these, and the Leather Bellows it was very perceptible to the Ear.

At Carron I think, I [have] almost finished my apprentice ship in Moulding. I had before seen moulds prepared for large Boilers and Vats for Soap Boilers but did not see the manner of their being made; give me leave therefore to describe the Construction of a mould for a Large Boiler, that from thence things of a Similar kind may be conceived. Suppose then a Circular plate of Cast metal 5 feet Diamr and a foot Broad supported upon Bricks a few inches from the Ground, let [a perpendicular] axis be fixed in the Center of this plate, turning upon two pivots, one at the Ground, and the other at a Beam of the Roof. To this Axis let a Board the Shape of the Section of the Vessel, be fixed; and then by one revolution of the axis, this board will describe [one of the surfaces of] the Vessel, in the air; but it must describe it on Loom too, and therefor it is readily conceived that it must be filled up till it touch every way; but were it filled solid, the Effects on Casting would be more tremendous and fatal than the Bursting of a Bomb. from the Explosion of air rarified by the heat; and therefore peculiar care is, and must be taken, to allow this subtite and elastic body to get off as quietly and quickly as possible; for this purpose the Inside of the Mould is hollow, being built up with a single Row of Bricks and Clay, till an

hole of about 6 or 8 Inches diamr. is left at the axis the Board is turned round at every Brick being laid, they are every where about an inch distant from it: this space then is filled up with Loom, and so the shape of the Inside of the vessel completed, all but the hole at the Top; live Coals are now put within to dry it [(which was the reason for setting the Plate upon Bricks)] and then the Board is shifted farther from the Center (or an other applied) to form the thickness and the Outside. but the Matter which forms the thickness must be taken out, and that it may separate from the Inside Mould, this is washed over with Charcoal dust and water previous to the Thickness being laid on; the thickness itself is then washed in the same manner; and the outside plastered above it: but as the outside must be pulled off to Clear the thickness away, you will easily conceive that besides loom the outside must be strengthened with Iron hoops and Cross pieces mixed up with the Loom, with holes [or hooks] in some of the pieces of Iron, by which it may be suspended. Before the thickness is taken out however, the whole is put into the pit together, after it is thoroughly dried: When properly placed in the Casting Pit, the outside is pulled up, and the Thickness Cleared away the hole that we mentioned at the Top of the inside where the axis went down, is now plugg'd up with a stopper of loom prepared for that purpose, the outside is now let down again in its place, and the whole ram'd round with sand till the pit is entirely filled up. [To cast] this Vessel the metal runs in at the Center of the Bottom [being Cast the mouth downwards]: The space which formed the thickness is filled with Common Air, this air cannot well escape at the hole where the metal Runs in, there are therefore three or four holes perforated in the Outside cover, to let it get out; and that it may evacuate the faster, so soon as the metal begins to run, lighted straw is held over the air holes, which immediately sets it on fire, these holes are fill'd up with metal which is easily broke off, and [the surface is] Chizzeled smooth like the rest: but I should have mentioned that when the Outside is replaced it is loaded with a great number of weights to prevent the liquid metal from buoying it up, which if it did, the metal would Escape at the bottom, Run away among the sand, and occasion Explosions both terrible and fatal to every one near it. such accidents have happened. When the Top is Loaded, wooden plugs are placed in the air holes and place or places where the metal runs in, wheights and all, but the Top of the plugs are hid and Covered up with Sand Ram'd hard; there is likewise a Communication with a Wooden Tube from the Inside hollow, to the Surface of the Ground so that the air [may Get off] which occupied that space & which must Expand by the surrounding {t\_\_\_\_\_} Pipes are Moulded much on the same principles, the Outside

being formed by Turning on a kind of Lathe. Over the Outside a covering is laid strengthened with Iron hoops and Barrs, intermixed with the Loom; the inside is then pull'd out and a Core placed [in its room] to form the Hollow and the Thickness; this core, in Casting is kept down by weights, and for a pipe 9½ Inches Diamr. the Metal Runs in at two places opposite; the mould stands perpendicular: however in this and some other articles the Curron Company are excelled by Mr Wilkinsons.

The Aperture from whence the Metal runs from the furnace is stopt up with fire Brick Clay, and it is with great difficulty they make an hole through it, for the metal to run, with an Iron Bar and sledge hammer: a piece of wet Clay is put on the End of a Rod of wood, with which the hole is plugged up again I never saw this operation any where else, and don't much admire it.

Cannon here are Moulded Exactly as at Mr. Wilkinsons at Beasham [(the Iron Rod for the Core is Grooved)], but they are cast directly from the smelting Furnace, which must require great care in the Charges, and I should be afraid [the Metal of a] Cannon would sometimes turn out to be of different kinds in the same piece. The Boring too is very similar, only the Carriages do not run upon wheels: they have a separate Wheel for cutting off the Mass at the mouth of the Cannon, at Mr. Wilkinsons the same Wheel & Carriage serves both purposes.

I saw [the] manner of moulding [variety of] different things such as pots [with the frames of the Mould Cast Iron] Pans & their Covers, Bath stoves, Rollers, smoothing Irons [Gates] Box Irons, the mould of which is in four pieces, etc. etc. which it is needless particularly to describe; for from knowing the general principles of Casting, the manner of executing any particular piece of work, may with a little Thought and attention be easily Conceived. The Fire Clay is found above a Coal and ground between Rollers. – The Moulding sand is mixed with Charcoal Dust; a fine sort of sand the grain very small is procured from the new Canal. If holes are required in plates such as the Cheeks of Bath Stoves pellets of dried sand are stuck in the mould.

There are forges at Carron, but at present very little Iron is Converted into Malleable. I saw an operation however which may throw some light on Mr. Woods process.

When the metal is ladled out of the Reverberatory furnaces, some will remain at the Bottom which is difficult to get out. when the Men leave Work the furnace Cools and this remnant is sometimes in whole, sometimes partly Converted into [the Nature of] Iron. (samples of Both I

have got.) This mass is taken out when they go to work again, and Carried to the forge [(some of this they sometimes brought from the Furnaces in London)] where it is worked with raw Coal like the Newcastle and when the Different Pieces run into a Mass it is, as at other forges hammered into a Bloom (or an Octagonal Piece 4 or 5 Inches Diamr. and two feet long.) In reducing this to a Mass, I observed that the pieces from the furnace, broke to about the size of the hand, were put immediately opposite the Blast, the Coals lay all around, but no Coals were ever put over them, till just before the mass was taken out, pieces were added as the former sunk, and the Scoria from time to time let off; This Scoria was preserved for the Blast furnaces, when they had an order for Ballast. The Iron they made, was fit for large things, but the workman said it was too Cold shot for horse shoes. There we have malleable Iron, without ever a piece of Charcoal being over it, from the Ore, to its present state.

The Bloom, to be further beat out, is heated in a Crusted fire place, such as I described in a former letter. the Warmth of such a fire place is very great. Three pieces of Bar Iron to be hammered into plates for Engine Boilers, were in a white Welding heat in a very few minutes. The Scoria from the Coals and the Iron could be seen boiling like a pot, when lookt at through a small hole; and is let off occasionally. in this fire the Iron is no where in contact with the fewel but the end were it rests.

The Anvils, instead of being fixed on a large block of wood, stand in a Mass of Cast Iron about a Yard Diamr. and near 4 feet thick. There was likewise at the Forge a Water wheel which turned a leathe and two Grind Stones, the Construction of which is simple and easily conceived.

I am Dear Sir

Your most obliged huml Sert  
Robt Erskine

### Invoice of Samples Directed to Messrs Mure Son & Atkinson

- No. 1 Lime Kiln Ore, being part of Nodule the shape & size of an Ostrich Egg
- No. 2 Iron Stone from Weems, picked up within high water mark\_\_
- No. 3 Strata adjacent
- No. 4 Nodulous Strata from a Coal Pit
- No. 5 Calcined ore. Curious\_\_
- No. 6 Scoria of the Forge where the Iron from the Reverberatory F. was made Malleable

- No. 7 Curious Blast furnace Scoria
- No. 8 Iron Almost Malleable from the Reverberatory,  
the same as put into the forge
- No. 9 Iron which stuck to the pocker in the forge, when  
Converting
- No. 10 Piece half Converted and half not from the

- Reverberatory the Cast Iron was the Lowest side
  - No. 11 More [Blast] Furnace Scoria
  - No. 12 More Nodulous Strata
  - No. 13 Upper Strata of the Mine I saw
  - No. 14 Lower Do of Do. \_\_
- Please order the Enclosed to the penny post