Two copies of this MS on lead smelting exist. One is in the library of the Literary and Philosophical Society of Newcastle upon Tyne (Lit and Phil) and the other in Wigan Archives Service, Leigh Town Hall, Lancs. The first and major part consisting of 118 pages is almost exactly the same in both MSS and one is clearly a copy of the other, but the Newcastle MS concludes with the Sixth Process on the reduction of litharge, and in the Wigan MS this is signed by the author and dated 6th January 1795. Whilst this is the end of the Newcastle MS, the Wigan MS continues with a glossary of terms used in the preceding account, which is included at the end of this transcript. The Wigan MS then follows with a description of the methods actually used at Langley Mill, concluding with some memoranda dated to 27 January, 1806. This account is given elsewhere as a PDF in Dukesfield Documents using the Wiagn Archives reference D/DZA/264. The two versions of the 1794 report are not in the same hand and there are differences in the spelling. Whilst subsequent authors have been uncertain about the date of the Newcastle MS, the annual report of the Lit and Phil show that the MS must have been finished by 1794. It was read to the Society over two meetings, in September and December 1794 (Lit and Phil: Hedley papers). A note from 1799 in the Lit and Phil archives, reporting on the death of Thomas Walton, suggests that James Mulcaster may not have been the sole author of the MS. It reads 'Mr Thomas Walton...to whom this Society is under particular obligation for the very elegant manuscript account of the smelting and refining of Lead in the works of Langley Mill, under the direction of Mr. James Mulcaster, illustrated by very accurate and highly-finished drawings by Mr. Thomas Wailes.' We are very grateful to the Chairman of the Lit&Phil, Paul Gailiunas, for his assistance in researching the provenance of the paper, and for making the original manuscript available to us. A transcription of the Newcastle MS, plus a glossary, was made by Elizabeth Tylecote and published in the Bulletin of the Historical Metallurgy Society *(Bulletin 5, 1971 pp 45 -62). This is an excellent piece of work, but modernises some of the original punctuation and changes most of the capital letters to lower case. The transcription here of the Newcastle MS retains the original manuscript pagination, notes, spelling and punctuation as well as the underlining of key words. It omits the glossary, which is not in the Newcastle MS.*

An Accot. of the method of smelting &c. Lead Ore, as it is practised in the Northern part of England, containing an explanation of the several Processes the Ore undergoes, from the time of its being brought to the Mill, to that of its being finaly manufactured into saleable Lead & Bullion there; Together with some accot. of the mode of washing Lead Ore so as to make it fit for Smelting, and a description of those Substances , mineral & fossil, with which the Lead Ore in Alston Moor is generaly accompanied, & the Effects they have upon it in Smelting.

By James Mulcaster

One of the Agents at Langley Lead Mill belonging to the Commissioners & Governors of the Royal Hospital for Seaman at Greenwich in the county of Kent.

1

On Ore Hearth Smelting.
Process 1st.

I call it Ore Hearth Smelting to distinguish it as well from what is done in the Slag Hearth, as from another mode of Ore Smelting which I hear Mr Gilbert* calls Cupola Smelting, but which I always, & I think with propriety, called Furnace Smelting, a Mode upon which, as I have never seen it, I cannot say anything, but having been long and intimately acquainted with the other, I shall endeavour to discribe it with such Abilities as I possess, hoping that if I shd. sometimes fall short of perspicuity, the Walk of Life in which I have moved, will be allowed to be my excuse.
The Form &c. of a Smelting Hearth being shown in the accompanying Sketches (See page 11) I now proceed to inform you that to commence smelting, the Bellows being put in motion, the Hearth is filled with Peats, a sort of Wall of the same is made in the front of

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* Mr. Gilbert is principal Agent to the Duke of Bridgewater, & is now working some Lead Mines in Alston Moor for Lord Carlisle & Co.-Mr. G. is also a Partner.

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it (for an use I shall shew presently) & a fiery or already kindled one is placed amongst them just before the Muzzle of the Bellows, from which a conflagration catches, & is presently communicated to every part of the Hearth; to increase which, & to give the fire more firmness, durability, & vigour, some shovels- full of Coal are cast upon the top, after which, & when it is seen that such mixed fuel is sufficiently in combustion, a quantity of Brouse is also given upon the top, which Brouse is a mixture of Ore imperfectly reduced to Lead & Slag, Coal cindered or half burned, and Lime, being a Stock formerly the contents of the same Hearth, & which has been drawn out of it at finishing its preceding fit of working; and as in the kindling of a common Coal fire, the cinders left at the time the fire has before been burning generaly enter first into the composition of a future one, so this Brouse, with now & then a Shovel full of fresh Coals, is at intervals given, 'til in abt. half an hour, the whole, and also the filling of Peats,

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those in the front excepted, is expended; then those last, being now well kindled, are taken down, & placed in a cast Iron Pot called the Sump, in order that it may be sufficiently heated for the reception of the Lead when that begins to flow, which it does not 'til several Watchings & Settings-up (Terms I shall explain by & by) are performed, and commonly not 'til some raw Ore is given, and the Brouse has acquired such a degree of heat as will dissolve between 4 & 5 Cwts. of Lead, a quantity wch. is generaly left at the end of every fit or shift of working, in, or for, the bottom of the Hearth called the Pan, where such quantity must be, and in fusion too, before any lead unfreed can issue: But this quantity being now

increased by the continual trickling down thro' the interstices of the incumbent brouse of such other Lead as is by this time exuding from the Ore, copiously or otherwise as that Lead happens to be free or refractory, this first receptacle of it overflows, & gives the workmen notice that they may, by tapping, take as much of it away as

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they suppose is made or extracted every fire, by which Fire is meant the times between the Watchings & Settings up of the hearth as they are called & which are thus performed.

One of the Smelters, for they always work in pairs, with a strong poker first stirs or heaves up the whole of the Brouse in the hearth, and then draws out about one half of it upon a sort of shelf or apron of cast Iron which lies joining the front or foreside of the Hearth. This is called the Workstone and in it is a Groove or Gutter which communicates with the Pan (of which this Work stone forms one side) & thro' which the Lead passes to the Sump from whence it is cast into Pig Moulds. This performance is called Watching, & during the time this is doing, the other watchman with his Shovel, clears the Muzzle of the Bellows of such brouse as is against it, & places his Peat (of which more hereafter) which done, the two men join in casting off the Slag, serving with the necessary coal and lime & replacing the Brouse in the hearth by casting it in at or upon the top, which being made Level, so much

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fresh Ore as they judge may be digested before another Watching comes on is given upon the top, where it undergoes a temporary roasting which fits and prepares it a little for its being brought as it is in the next Watching, into the most vehement part of the fire. These Watchings, and Settings-up, as replacing the brouse in the hearth is called, are generally performed once in every five Minutes, so that the labour of Smelting seems to consist chiefly in an often repeated pulling down & making up of the same fire, for which I shall endeavour to account; and first for the Watchings, which are as well Stirrings-up as Pullings-down, and are in both cases unavoidable, because without the first (a frequent stirring) the whole mass of the Brouse, tending as it always is to vitrifactions, would soon become so compact a Body that neither could the fire, agitated by the Bellows, pervade every part & cranny of it, as it ought to do to operate rightly upon it, nor could the Lead, as it perspires from the Ore or unexhausted parts of the Brouse in the hearth,

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find a passage down thro it to the bottom, where it ought to be speedily to be out of danger, for whilst it is suspended in the upper parts of the Hearth, it is in a state of evaporation & waste; but from hence it may be taken at pleasure, only the ordinary reserve in the Pan must be kept unimpaired. Such pullings-down, or rather pullings-out, of part of the Brouse are also necessary, because they give the Smelters in the first place an Opportunity of discharging that Brouse of such parts of it as can, in this Process, be no further operated upon, id est, the Grey or Ore Slag, and which is distinguishable from the rest of the Brouse by its being less heavy, and by its light red

glow, as being more intensely hot; in the next place, if they have judgment, such frequent drawings-out of part of the Brouse informs the Workmen of the state and temperature it is in, that if it be too hot they may lessen or if too cold, increase their ordinary quantum of Coals; that if they see it distempered by a Ropyness

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which will sometimes so seal up its Pores that no Lead can issue, but is confined to the wasting of it, they may by an increased application of well slaked Lime, effect a cure of that; And lastly the drawing so much of the brouse out of the hearth, & thus frequently affords an opportunity of properly, and in due time, renewing the Peat, from 9 to 12 Inches in length of which, if dry, is expended every Fire, and a very necessary Article it is, indeed this mode of Smelting could be scarcely carried on without it, for besides its being greatly auxiliary to the Coal, the position it is placed in that is, just before the muzzle of the Bellows, & being a light & spongy substance of itself, it causes a light lying in that part, of the other more heavy contents of the Hearth, and as the Wind -board of an Organ distributes the current of Air from the Bellows to every Pipe in that Instrument, so this, and a projecting of about 2 inches of that piece of Cast Iron called the Pipe-stone over the back upon which the Pipe rests, causes the Stream of Air, at its first

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discharge from the Bellows, to expand & carry vigour to the action of the fire equaly in every part of the hearth; and therefore it is that throughout the whole extent of it, a square of 26 Inches in length by 22 in breadth & 14 or 16 in depth, the Lead is extracted from the Brouse & Ore by the frequent Watchings mixed with it, and in my opinion not by a total & promiscuous dissolution or fusion of the Lead & Slag (which are the constituent parts of Lead Ore so far as smelting makes the Analysis of it), but by a progressive perspiration or exudation of the former from the latter 'til an almost total separation of them is effected: Thus upon the Brouse, or parts of the Ore so heated as to be accounted such, the Lead appears first in very small particles, but these, if the Ore be free, soon increasing in bulk, becomes too heavy to remain suspended, & falling upon others, are precipitated with them down thro' the Openings of the Brouse to the bottom, where they are imbodyed with that Stock of Lead, 3 or 4 Inches in depth, which I have said is, & for

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reasons I am going to give, ought always to be kept there; one of wch. reasons is that it greatly facilitates the labour of Watching, by preventing a growing or adhering of the Brouse to the bottom of the Hearth, which, if it shd. be suffered to do so, would render that work, already sufficiently arduous, almost impracticable. Another reason why such a stock is kept is, that as it covers the whole bottom, and has the whole of the Brouse floating upon it, it is thereby open to receive all such Lead at is continually falling off from that Brouse, as it is also to discharge by the Ricker or Gutter I have before mentioned, all such redundancies of the same Lead as from time to time happen.

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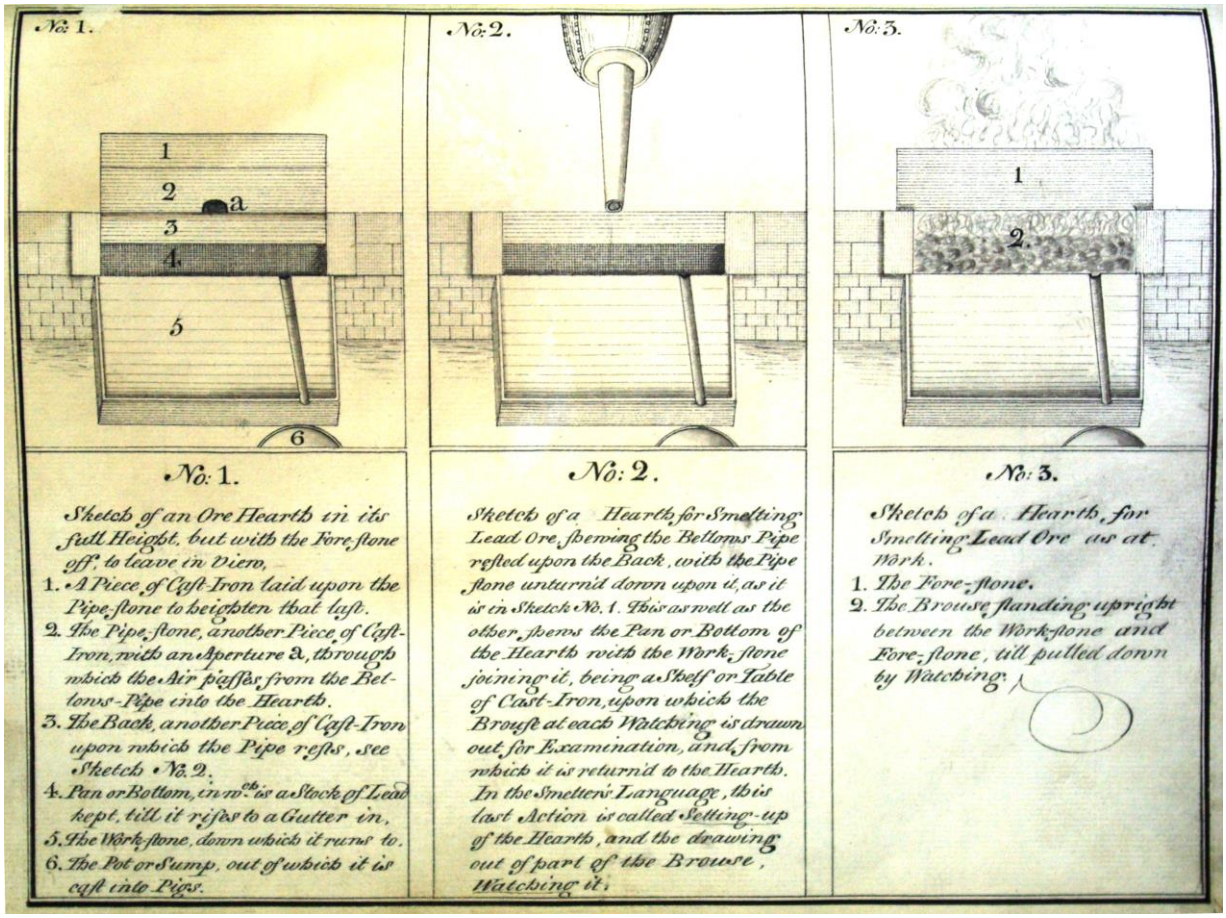

13

On Slag Hearth Smelting.
Process 2d.

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The Operation of smelting in a Slag Hearth differs from that of an Ore Hearth in this, that in the Ore Hearth the Ore to be operated upon does not undergo an entire liquefaction or fusion of all its parts, but only a partial one by having its Lead, or the greatest part of it, sweated out of it, as I have observed in my former Letter; on the contrary in this, whatever is to be worked upon suffers a total dissolution. This Hearth also differs from the other in its construction, & in the Materials of which it is formed, for the Ore Hearth is, and must be, composed of pieces of Cast Iron only, whereas this is composed of such pieces, and also of Free Stone.
The pieces of Cast Iron used, & the disposition of them, in the constructing of this Hearth are - first, one flat piece for a bottom or foundation, - next, & upon it, another piece 18 Ins. in height & 28 in length for a Back, upon which the Bellows pipe is rested at equal distances from its two ends

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& to which the back is joined, so as with it to form 3 sides of a Square (of a size I shall mention below), two other pieces 5 or 6 Ins. in height called Bearers, because upon their ends opposite to, & at 26 Ins. distance from the Back, are rested what are called the Fore-stones, consisting of 2, 3 or more pieces built one upon the other to the height of 33 Ins. includg. the 5 or 6 Ins. left vacant under them by the nethermost one being

supported by the Bearers. This Opening into the Hearth between the Bearers & under the Fore-stones is 18 Ins. wide, & is increased to 9 or 10 Ins. in height by a lowering of the Floor at the entrance or threshold of it to facilitate the descent of the Lead & Slag from the hearth to the Sump. What remains of the structure, i.e. from the Bearers on the sides & from the back upwards to the top is, and must be, of Free-stone laid in good Clay, because Cast Iron, or any other Substance yet tried, exposed in any of those parts, would presently be run down & wasted; and even Free-stone itself is not so durable, but that frequent,

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indeed daily reparations are found necessary. The Dimensions of this Hearth, when compleated, are 26 Ins. in length from the back to the Forestones by 18 in width, & 33 in depth, inside measure: - But to illustrate what I have now said of its form & Composition, & what I have yet to say of its manner of operating, 1 have enclosed Drawings of a Slag Hearth with References. (See Page 21.)

Having premised thus much of its form & construction, I come next to the manner of smelting in a Slag Hearth; preparatory to which the bottom of it to the height I have shown in the Section, the passage from thence to the Sump & the Sump itself are filled and covered with Coal Ashes, which I shall, as the Workmen do, sometimes call Dust; this done, a kindling, by a filling
of Peats is put in the hearth, & the Bellows is let loose upon them, by the action whereof the whole is presently in a blaze, and then some Cinders are superadded, which, from this time forward during the Shift, is the only sort of fuel made use of in this Operation, and

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upon which when well heated and when the Peats are expended or much charred, a part of such substance as is intended to be smelted, whether Grey Slags, or Litharge Slags & Test Bottoms, with a flux of Black Slags is given, which in this now intense heat, gradually dissolves into a sort of coarse Glass or Black Slag & Lead, which as they are formed descend together upon the Dust in the bottom of the hearth, where such Dust is for an use very similar to that of the Glands in animated Bodies, i.e. to cause a secretion or separation of the Lead - the more fire from the Slag - the more gross substance. In other words Lead is too heavy, & when in fusion too subtile a Body to float upon Coal-Ashes; Slag on the contrary is too light, and at the same time too thick a substance, tho' in fusion, to sink in such Ashes; consequently when two such substances are distinct (and passing thro' the fire of a Slag Hearth makes them so), and when they are deported, as here, upon that into which the one will sink,

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and upon which the other must float, a separation of them will of course follow. This Bed of Dust is of further use a proper conveyance from the Hearth to the Sump of the Slag upon, & of the Lead beneath, its surface. Down thro' it to the Sump the Lead spontaneously & imperceptibly makes its influx; but for the Slag, when the Workmen suppose there is a sufficient accumulation of it in the hearth, they open a passage by

tapping close under the Fore stone, when a pretty copious & intensely hot Stream of it generaly follows, as (if all goes right), it continues to do without intermission, 'til the Shift of 12 or 14 hours continuance is finished, this Stream being incessantly fed & supplied by such Slag as is formed in, & poured down from, the upper & interior parts of the Hearth and produced there by the fusion of such materials as are at the time under operation, and with which the hearth is charged occasionally from time to time upon a good fuelling of fresh Cinders. This course of the Slag is terminated by the covering of Dust upon the Sump

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being made hollow from its reception, where after many Wrigglings it expands into a sort of Cake (see Sketch No. 2 Page 21), cools so as to harden, & is turned off into a Corner where it is, or ought to be, broken, that any Lead which may have escaped with it may drain from it; after which being further cooled, it is wheeled out for the Stamp Mill, or sometimes brought back to the same hearth as a Flux for Litharge Slags & Test Bottoms or refractory Grey Slags. When there is a quantity of Lead gathered in the Sump is known by the Quaggginess of the Dust upon it, & if it is thought such that some ought to be taken away, in that case the stream of the slag is diverted into the Corner where the cakes of it are thrown, the Dust is turned up, a Pig is cast, the Dust is replaced, & the Slag is turned into its ordinary course again. This is the practice during the time of working. At finishing, the Sump is entirely emptied into Pig Moulds, at which time (contrary to the practice in the Ore Hearth when that stock

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called the Brouse always is, or ought to be, left unimpaired) as much as possible of it is expended at the close of every Shift by what the Smelters call Burning down, which is ceasing to give any fresh supply of Slags for some time before the Bellows is taken off. The well doing of any Shift depends much upon the Hearth being fortunate in the assumption of a Nose, which is a protuberance of coagulated Slag gathered about the entrance of the Bellows pipe into the Hearth, & which, if of a right form, (but that is quite fortuitous or accidental for no skill of the Workmen can give it), is of great use, because without it, as no Peat is used here as in the Ore Hearth, the stream of Air from the Bellows would be so poured in upon one part of the Fire as almost to destroy & extinguish it, whilst the other parts would be left as dead &inert as if no Bellows were in action; but by this nose, that stream is divided into several Channels, and is thereby poured diverse, as I have by the little Dartings from it in the Section endeavoured to show, by which means the whole Contents of the Hearth are pretty equally acted upon.

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I shall conclude by observing that as Ore Hearth Smelting makes a division of the Ore into Lead & Grey Slag, so this makes a subdivision of the Grey Slag into Lead & Black Slag. And that the subdivision, Black Slag is yet further divisible, which gives occasion for Process 3d according to my arrangement, i.e. Black Slag Stamping, washing & smelting - of which in my next - for tho' in fact the whole, or nearly so, of my substance that has fairly passed thro' a Slag Hearth is reduced to Lead & Black Slag, yet as those Slags are porous, some Lead will of course be lodged in them, and

some will also adhere to them, on which accot. it becomes necessary that they shod. be pounded.

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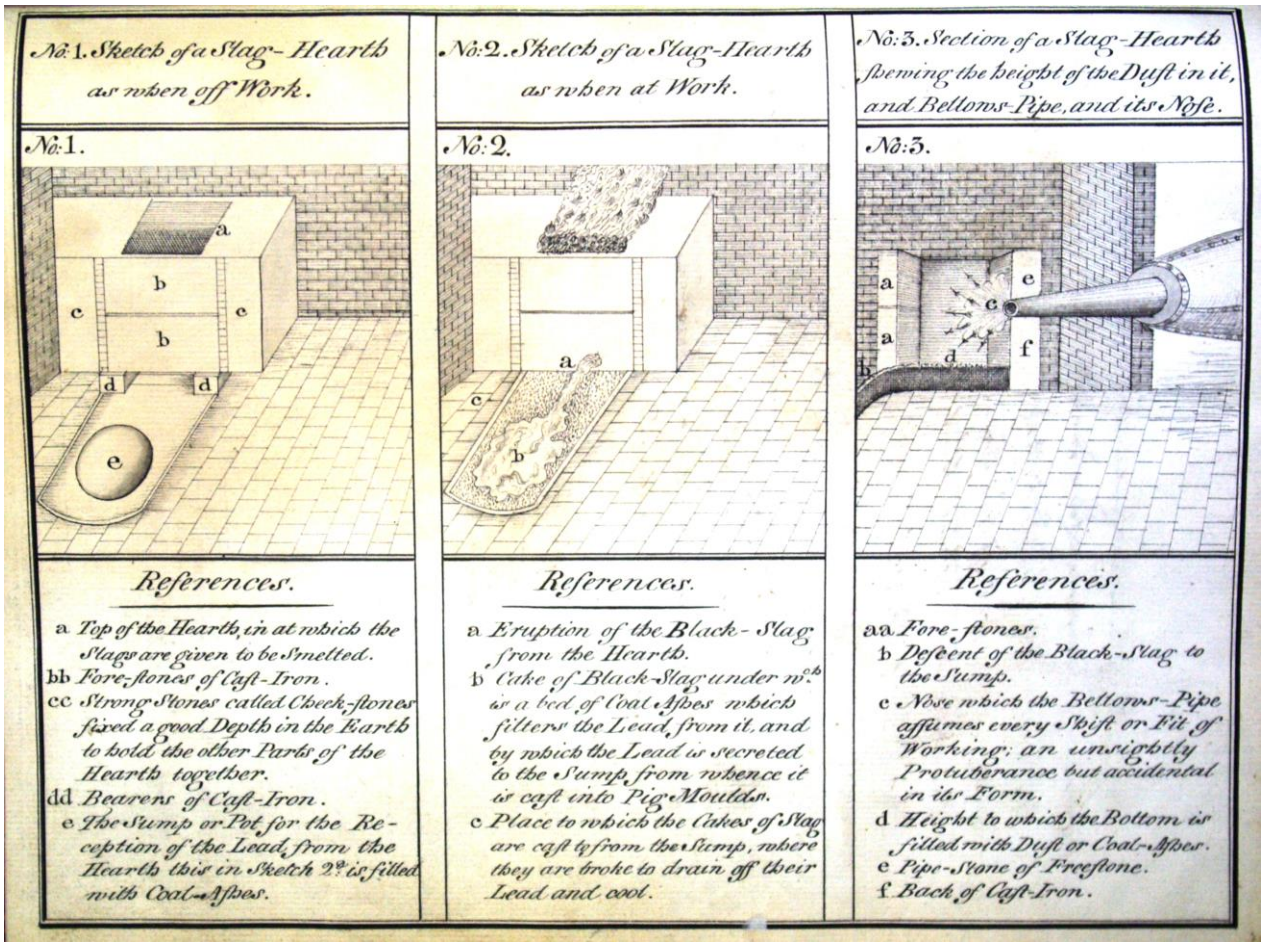

23

On the stamping washing & smelting of Black Slags (with a description of a Stamp Mill).
Process 3d.

In the close of my last I think that I observed that the Operation of Slag Hearth Smelting reduced such Substances as pass'd properly thro' it, into what we call Black Slag, a sort of coarse Glass, and Lead; yet the separation of them is not so entire but that in the Pores of the former several particles, & sometimes not small pieces, of the latter will be lodged, which cannot be wholly drained out of the Cakes whilst hot & recently turned off from the Sump, wherefore a further breaking of them has been found necessary and this was formerly done by means of the Bucker & Drag; the first, a sort of Hammer, such as is now used at the Mines for pounding the Ore, with a long shaft or handle & called a Brashing Bucker; & the other a strong toothed Iron Rake, wherewith to drag off or separate the less, from the more, crushed parts, after the Bucker had

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been used, in order to the picking of such larger pieces of Lead as happened to be beaten out, & to the small being carried to the Buddle, there to undergo a Washing, by which the smaller Particles (& upon the whole a good deal) of Lead were obtained; and that the Rounds (as they were called) might be thrown aside, as was the practice, in heaps, where they lay sometimes for many years, 'til some person, at an advanced price p[er] Fodder of Lead obtained, undertook a re-crushing & re-washing of them; and this was occasionally repeated several times, at perhaps very distant periods, and at a still progressive advance of price p[er] Fodr. at every repetition, 'til abt. 50 years ago, when a Machine called a Stamp Mill for the total and at once pounding of them was introduced into these Northern parts, I suppose from the Cornish Tin Mines; at least the first I ever knew erected was under the direction of a Cornish Man; since which time a Stamp Mill has been accounted a necessary appurtenance of a Smelt Mill, and now I think there are almost as many of the one

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as of the other, therefore any description of the form of a Stamp Mill might be thought unnecessary here; however to make the whole business more clearly understood, I have enclosed herewith some Drawings in aid of a short description of that Machine (See pages 37 & 39) towards the constructing of which A Water Wheel, with its Axle properly cogged, is necessary in the first place: At 4 inches distance from this Axle, two strong Planks of Wood, 8 ft. in length, 20 Ins in breadth & 4½ Ins. in thickness and mortised at foot into Sleepers well fixed in Earth are erected with their edges (not broadsides) to the Axle, and abt. 26 Ins. asunder, or so far as to admit between them 3 Wooden posts, each 6 Ins. square & abt. 8 feet long, together with one or two dividing Boards to each Post - viz just so many as, with the Posts, will fill the space between the containing Planks or Cheeks, but not so tight but that the ascending & descending movements of those Posts between the Boards may be with ease, and with as little friction as possible. Between those separating Boards or two sides, and between 4 wooden Bars put across from cheek to cheek, i.e. two in each side, and upon which those boards (See their Form Drawing

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No.2 d ---------) are hung by Notches or indentures, which renders them immoveable whilst the Posts are in motion, between those I say, each Post or Stamper moves upwards and downwards as it were in a Groove. Each Stamper is increased in weight by about 7 Stones, and in length by abt. as many Inches, of Cast iron fixed into a Mortise in the lower end by a Tenon formed of the Metal itself in the castin (See Dr. No. 2.M) Each Stamper has its respective Cos, commonly 4 in number, & is lifted by them by an hold or handle, which is a piece of Wood shod with Iron projected from it at abt. 23 Ins. from its lower end, into the Circle the Cogs describe in their rotations, (see manner of lifting Dr. No. 1.-----) The Cogs are so disposed upon the Axle that the Stamper furthest from the Grate (of wch. presently), is first lifted, after that the middle one and then that next the Grate, also so as that not more than one Stamper is lifted at the same time, yet that at the instant one is dropped, another is taken up, in order that the Strokes may be regular. I have only further to observe that the

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Mill is served with Slags by a quantity of them being cast into a sort of wooden Trunk or Hopper sloping at bottom, & into which a small current of Water is made to fall (See Dr. No.1 -8) by which, & a tremor occasioned by the motion of the Machine itself, they are carried under the Stampers, from whence when sufficiently pounded, to pass thro' it, they, with the Lead beaten out of them, are by the same Water, aided by the falls of the Stampers, discharged thro' the Grate (See Dr. No.1.6) fixed in the outer cheek upon a level with the floor upon which the Stampers fall, where they, with the water, are received into a wooden Duct called a Trough, by which they pass to the Pit, an Hole dug in the Earth, walled on the sides & paved at the Bottom, out of which they are cast & carried to the Buddle, which Buddle is only a piece of floor of Wood or stone laid very sloping abt. 6 ft. in length & 2 in breadth, on the one side whereof, a Board of the same length as that side & abt. 8 Ins. broad is set on edge & back'd with Earth to the height of itself; this is called the Buddles-Head, as a Gap or indenture

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cut at equal distances from its two ends for a small stream of Water to pass thro' is called its Eye.

This Buddle being charged with the pounded Slags & Lead intermixed with them as they fall from the Mill, to the quantity of 5 or 6 Bushels at a time, the necessary water, which is kept running near at hand for the purpose is turned into it, & a Channel made for it close to the Head-board of the Buddle; which done the Washer, with his Shovel or Coal- rake, begins to make new channels for it across the first, continually pulling or turning over a part of the heap to the side next him with the water running amongst it 'til he has passed in this manner thro' it to the other end, where he turns off such light (being supposed the worthless) parts as the water has driven to the skirts of the Heap, leaving the remainder in a semi-circular form. These Tails (they are called Tails at a Smelt Mill but at the Lead Mines Cuttings), being disposed of by being cast away, he again turns the water into

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the Buddle, & passes thro' the heap in the same manner as at first, repeating such puttings thro' of the Buddle, with the circumstances of diverting the water from it & discharging a quantity of Tails at every repetition 'til he judges his Work (what is still left in the Buddle) sufficiently dashed, as it is called, meaning made fit for the Tub & Sieve, to which I proceed, after having informed you that this just described is what is called the Running Buddle, to distinguish it from two others in use, the one named the Draw Buddle & the other the Trunk Buddle. Upon the Running Buddle I wd. observe, and then have done with it, that the several Strokes of the Washers rake or shovel being as so many Radii whereof the Eye, or In-falling of the Water, of the Buddle is the center, it is towards that point that the thing valuable (Lead here or Ore at the Mines) will be collected; its weight resisting the water, at the same time that the light & worthless substances are born down by its current to which they are continualy exposed by the action of the Washer above described.

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After such Buddlings have continued for several Days or Weeks, & sometimes Months & a good deal of dashed Work is laid up, in order to a Making-up, as a final cleaning is called, then a Tub is provided, abt. 3 ft. in height & 2½ in Diamr., filled not quite but almost so with Water, and also a Sieve, which is a small wooden Vessel with two Handles & a bottom of wove Wire. Into the Water of the Tub this Sieve, with a charging or loading of about one Gallon of such substance as is to be washed, is immersed nearly up to its brim, where being tossed to & fro' for some time, the minute parts of such substance are sifted thro' & sink in the Tub, whilst at the same time the lightest parts, which from bulk cannot pass that way, are thrown uppermost within the Sieve, and when they are supposed to be sufficiently so, then it is heeled or lowered on that side furthest from the person who holds it, with a very gentle heaving of its Contents, that the parts thereof which were once uppermost may continue so 'til the whole of

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those contents are got to the depressed side, and are almost ready to get over its brim. This is called a Setting, and is followed by what is called a Setting off, which is a bringing of the Sieve from its heeled into an horizontal position, continuing in the meantime the same gently heaving & tremulous motion thereby to cause the light parts, which were uppermost whilst the Sieve was stouped, to fall down upon the vacant part of its bottom, & to the skirts of its more heavy contents; which done, it is taken out of the Water and placed upon a Bar of Wood or Iron for a Rest, and laid across the top of the Tub, where, to skim off the light parts, which at this first setting are generaly fit only for the Waste or Cutting Heap, a small Instrument called a Limb is used, being a semicircular piece of Board abt. 8 Ins. long & edged with Iron on the curved side; and such is the disparity of the weight of Lead & Black Slag that the separation of them is effected by one or at most two such settings & settings-off. But at the Mines where

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there are many Bodies almost as ponderous as Ore, and where that Ore is frequently brangled in with those Bodies, such Settings must be repeated perhaps several times; first to take off what can be accounted only refuse, and then if the Work be much brangled, as is too often the case to discharge it of that which shd. be returned to the Knock-stone, there to undergo a further pounding; which is not the case with that wch. is now our subject, there being nothing intermediate between Lead & Black Slag, so that when the former is as much as may be cleansed from the latter, it is then fit for Smelting, or rather melting, for it is chip-lead, only some of it a little-drossy.

I come now to that part which has pass'd thro' the Sieve, which is called Smithorn or Smiddon, with which at times the Tub will be so filled that the bottom of the Sieve will strike upon it; and when this is observed, the Tub is then emptied of it, and it is carried to the Buddle, where with a less powerful

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stream of Water it undergoes as many Puttings- thro' in manner as before described, as will make it clean, and when it is so, it is joined to that prepared in the Sieve as being equaly fit for smelting; only at the conclusion of every Making or Dressing-up (as well

here as at the Mines) there will be a remainder, which cannot be made perfectly clean in the Buddle, but is too valuable to be cast to the Waste Heap, and upon which therefore a further Operation with the Sieve, called Letting-in has been found expedient, which is thus performed. - A Sieve with a bottom of smaller Wire and more close worked than the first is generaly chosen, upon the bottom whereof a bedding or cover abt. an inch in depth of chip Lead here, but of some heavy substance of Ore at the Mines, is spread, & which is of such a size as shall merely prevent its going thro' the Sieve but not larger. Upon this Bedding, a quantity, perhaps 3 or 4 Quarts of these Smithorn Tails as they

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are called, is laid, and which being levelled & smoothed over with the Limb, the Sieve is taken down from its rest, and with a very steady but gentle heaving motion is sunk almost to the brim in the water, where the same motion being continued for some time, by this means the whole contents of it, including the Bedding, are in some degree as it were afloat, during which the most heavy and most valuable Particles penetrate thro' the Bedding (the superior weight of which keeps it still undermost) & also the Wires of the bottom, and are deposited in the Tub, leaving the light & worthless part resting upon the Bedding, from which, the Sieve being taken out of the Water, it is skimmed & cast to the Waste Heap. A Dexterity herein is one great qualification in a Washer. No Process in washing saves more of a valuable Mineral, and at the same time makes it more clean then this when well executed. I have seen

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it so well done that scarce any weighing (I think all Washing is a sort of hydrostatical Weighing) could have better ascertained the comparative specific gravities of the following Bodies. In the Sieve when taking out of the water, the first layer was of the Mud Sand, or Grit into which the Stone of the Mine had been beaten; under that, & very distinct from it, was a layer of Black Jack, or Lapis Calaminaris; this was succeeded by another, equaly distinct from it of Sulphur; under which was the bedding of Ore: --but here I was concerned to see that the distinction was not so nice, for I observed that the lightest parts of the Ore & the heaviest parts of the Sulphur were so intermingled that they seemed to be inseparable by any mode of Washing, tho' nothing is more pernicious in Lead Ore than Sulphur. But to return from this Digression. If from time to time a surcharge of the Bedding of the Sieve shd. happen; as

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will sometimes be the case, it may be diminished by taking what is needful of the best of it, which with what has gone into the Tub after that has undergone two or three Puttings thro'of the Running Buddle, may be taken as fit for smelting, tho' being the produce only of Hinder-Ends, to borrow a Farmer's expression, it cannot be expected to be so hearty as that which had gone before it.

Upon the smelting of the produce of Black Slags there is little observable, only that it is done in the Ore Hearth; that in the treatment of it in smelting, it differs from Ore in this, that being almost all Lead, it produces but very little Slag; - that the Watchings to

discharge that need not therefore be so frequent; but that such Slag as is produced is returned to the Slag Hearth, & there smelted in a similar manner with other Slags.

(For Draughts of the several Instruments necessary for the washing or dressing of Lead Ore see Page 55.)

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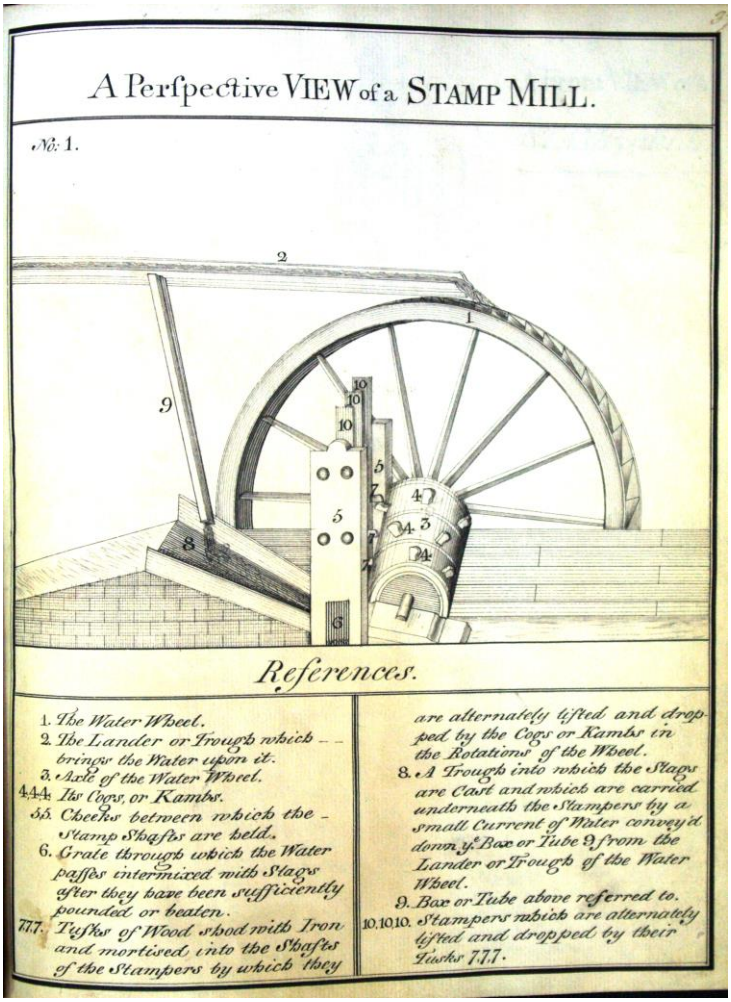

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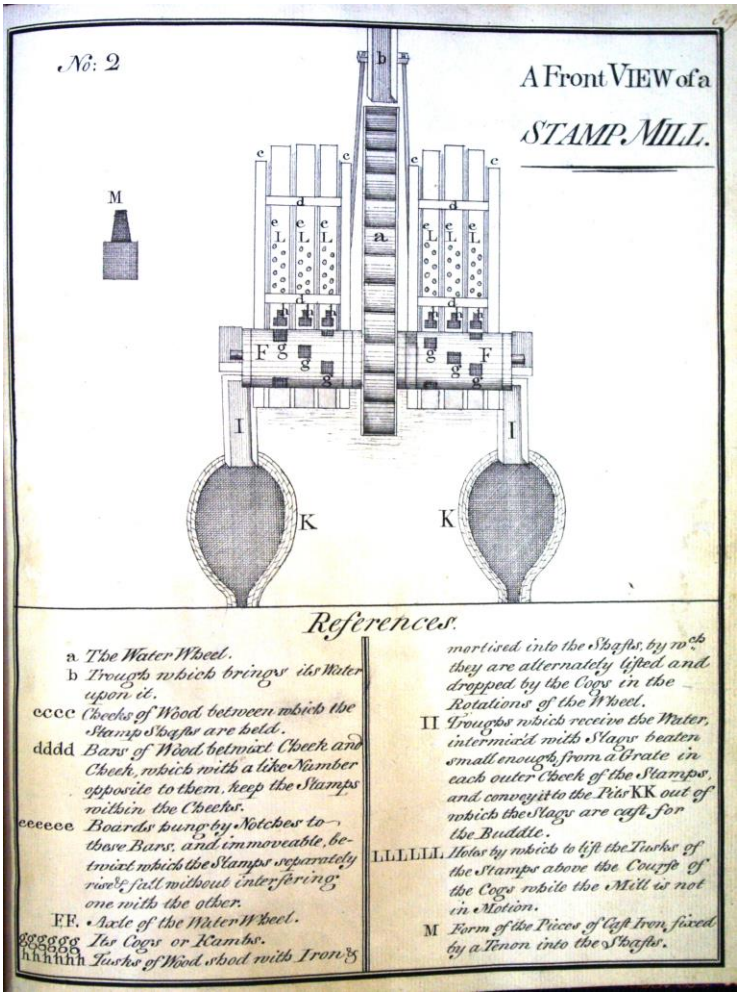

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On the washing of Lead Ore.

Having for a long time paid a particular attention to the washing of Lead Ore, because upon the well-doing of it a success in Smelting depended about which I could not be otherwise than sollicitous, being paid for my care therein; I have seen, and every one skilled in the business will admit, that towards the thorough dressing of any Ore, and that with as little waste of it as possible, the reducing such Ore and those impurities from which it ought to be cleansed to an equality in point of size, is a preparation highly expedient if not absolutely necessary. This will give the former the advantage of the latter under every mode in which Washing is practised. A Chip or particle of Ore being more ponderous will undoubtedly withstand a Current of Water longer than a chip or particle of Stone; or other matter from which Ore ought to be cleansed, of the same dimensions, but a chip or particle of Stone &c. may be of such a bulk as to outweigh such chip or particle of Ore, wherefore under such circumstances

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to associate them in washing would be improper. For instance, in the first operation of the Sieve, (the manner of doing which I have before endeavoured to explain) where

nothing shd. be above the size of a good Hazel Nut, pieces of Spar, common Stone, Black Jack, or Sulphur will in Water have a small degree of buoyancy which Ore has not, and which renders them separable from it, if in pieces of the same or nearly the same Dimensions; but let such pieces of Spar &c. be exposed with Smithorn to the impetus of a Buddle Water, and the result would be that they would resist it, whilst very valuable parts of the other wd. be born down by it. Or let the impure, but largest, particles (what the Washers call the rowny parts) of that Smithorn be exposed in like manner with what is commonly called Slime Ore, which is the smallest of all Ore and the result would be similar; therefore that each part may receive its suitable & respective treatment in the dressing, that the pure may outstand the impure in every mode of exposure

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to water, it is necessary that in the course of procedure in the Dressing, the Bouse* be so divided as that it shall ultimately produce -

Shaddered Ore
Sieve Ore
Smithorn
Slime Ore.

of all of which in their order, and first of

Shaddered Ore.

How it got, or why it has that name, I do not know, but think it wd. have been more properly denominated Hand-pick'd Ore, for such it is, being what those pieces of the Bouse called Knockings are broken into if clean, or if not what is broken off from such, the refuse whereof is called Pike-stones i.e. pick'd Stones; out of which, at some Mines, a good deal of Ore might be gotten if the use of a Stamp Mill could be had for pounding them, but the Ore got would not bear the expence of doing that by hand. This Ore needs no Washing, being picked as above, & carried to the Bingstead as clean, tho' it too often happens that it is not so, owing to

**The pieces of lead ore intermixed with spar, in the state they are when they come out of the mine.*
§ The Gov. Hse. have lately erected a stamp mill for this purpose nr. Nenthead, by means of which they gained last year from the pikestones about 300 bings of ore, and expect this year I understand to get about 500 more. J. M.

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sufficient care not being taken to clear it well from Stone &c. or by its being left in too large pieces, by which means particles of such stone &c. may be, & often are, hidden in it. A too anxious endeavour to make a great deal of this sort of Ore is a fault the temptation to which is that it is done witht. much trouble, and where this is practiced,

it also impoverishes the sort wch. immediately follows, & to which I now come, viz the

Sieve ore.

In the Sieve, however accurately it may be set, the most heavy of its then contents can but take that place in the Setting which in my last I have said the real clean Ore, or other matter proper for smelting, ought to occupy; but if in the Shaddering, all, or almost all of such clean Ore be taken away, and none, or very little but the most light, left, the brangled,or such as is part Ore & part Stone or other substance, shd. be returned to the Knock-stone for a re-pounding, and might after that produce good Smithorn, if not Sieve Ore; but such I say, also the most heavy of the Black Jack & Sulphur will be so nearly of

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the same weight with such light Ore as is left that after divers ineffectual efforts in the Setting the Washers find that they do not separate, thereupon pronounce that the Work wants a body, (of which they themselves have deprived it as has been shown) and that therefore it cannot be made good Ore and so it passes without being made so, leaving at the same time that part to which I come next, i.e. the

Smithorn

in some measure impoverished also, for if the brangled parts which are passed with the Sieve Ore were beaten down, the quantity of the Ore of this kind would be thereby increased, and such increase would also contribute to the bettering of its quality; for the more there is of any sort wch. requires the same mode of washing, the greater probability there is that that part will be well dressed, & how that sort which I am now upon shd. be managed to be so with the least loss of its quantity I have endeavoured to shew in my last Letter, i.e. by a sufficient Buddling, by the Workmen being not sparing in taking off the Tails & letting in those Tails; all which being done by good

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Hands, this will be well saved, and at the same time will be as valuable as any Ore; but the method of dressing this does not extend to what I have made my fourth & last Division, viz the

Slime ore.

As the Sieve Ore is derived from the Shaddered, & the Smithorn from the Sieve Ore, so is this last, as being of a still smaller size, derived from the Smithorn, being separated from it in a manner wch. I shall shew presently, and indeed to preserve the latter perfectly, they ought to be separated previous to the former undergoing any sort of washing; but in the dressing of Ore from the Bouse, the prices paid per Bing for washing will not permit that such a tedious Process shd. be carried into practice, so that this Slime Ore is either left in the Smithorn with its attendant impurity called Sludge;

much to its detriment in the smelting, or it is washed away, & goes to the Waste heap; the best that for a time can be made of it, for from thence it is recoverable, when the Cuttings are washed by

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the Trunk Buddle, or Lew, of the uses whereof I come now to speak, and first of the Trunk Buddle, which consists of a piece of Trough or wooden Acqueduct abt. 2 ft. in length & 10 or 11 Ins. in width & depth, next of a small Box 18 Ins. in length by 14 in depth & width fixed in the Earth somewhat below the level of the Trough, out of which Box is a passage (see Drawing Page 55) which expands to the width of the Trunk itself, which is a sort of flat Chest 9 ft. long, 3 broad & 10 or l2 Ins. deep with an Outlet for the water at the lower end of abt. 8 Ins. in width, which compleats the composition. The first use of this Buddle is to effect a separation of the Slime Ore from the Smithorn in order to their being dressed separately, & it is thus performed. A pretty strong Stream of Water is turned into the Trunk, into which one person (commonly a Boy) casts Shovels- full of the matter to be separated at Intervals as often as he sees it is born down by the current into the Box, when another keeps stirring and troubling it in the water, by which means the lightest & most minute particles are set afloat, & are carried over the above passage by the Water,

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and fall with it into the Trunk, against the Head- board of which the most valuable parts are deposited, whilst the more light & worthless are born further down (See Drawing Pa.55), from which however that nothing of value may escape, a quantity of still Water is constantly kept in the lower end of the Trunk by placing Stops or Obstructions (small pieces of Wood) in the Outlet for the water gradually and as the matter is seen to rise in it, so as that the water & that matter may be kept nearly upon a level. The principal object of this first procedure being to effect the separation just described, no part is by it made clean: Of that which remains in the Box & which as often as it is seen to be freed from the light & minute parts is cast out, the cleaning is compleated in the Running Buddle, & by Letting-in as I have elsewhere described, but that which goes over into the Trunk is perfected in its dressing there in the following manner. As soon as the Trunk is once filled or nearly so, the Water is turned off, & the most ory part, viz.

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that next the head board is cast out upon one heap; then what lies next, proceeding downwards, is cast upon another heap, and if what lies immediately behind that is also seen to contain some Ore, then a third heap is made of that, after which the Trunk is cleansed from the remainder which can only be accounted Refuse, and repetitions of what I have now been describing are made 'til the whole matter in hand is so gone or passed thro' or 'til the heaps cast out become such in quantity that a compleating of a dressing of them is seen necessary, which is thus performed. The Trunk is made clean, water is turned into it. which falls in an equally diffused Stream over the whole length of its Head- board, along which quantities of those Heaps taken upon a Shovel are drawn to & fro, the water washing them gradually off 'til the chest of the Buddle is

filled, the Stops in the Outgoing of the water being placed as in the first operation above described. At every passing thro' in this manner, the Ore approaches nearer to being clean, and at last if they are repeated sufficiently often, it will be perfectly so, not even excepting what is

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contained in the second & third heaps; only to make that clean will require a greater number of such repetitions. And thus much of the use of a Trunk Buddle, of which I have taken notice before that of the Lew & Draw Buddle. it being a more expeditious & in my opinion more safe mode, and therefore I think its use preferable to theirs; however, I shall endeavour to describe these two latter & their use. And first the Lew, which is a sort of Sieve, the wooden part whereof, for the sake of lightness, is made of Lath, & the bottom out of slight, but pretty close Canvas, having nothing to pass thro' it but water. In form it resembles those Sieves with hair or silken bottoms which are used for the bolting of Wheat Flour; only on each side of this is a sort of crooked handle, by which, when used, it is made to float & roll upon the water of a Tub, at the same time that there is a sort of effort made to depress it in it; by which double and seemingly contradictory movements, in the management of which some dexterity is required, their joint purpose is effected; the pressing

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downward being done that a springing up of the water thro' the bottom of the Sieve may put the matter wherewith it is charged into a sort of fluidity, of which state of it advantage is taken by the rolling motion, to throw out the most light parts, which go over its brim, and subside in the Tub, out of which they are taken & carried to the Draw Buddle, for the form of which I refer to the Drawings (See Page 55) and shall only observe that across the In-falling of the water is a piece of Board (which see in Dr.) upon which, when at work, the Washer stands with his face to the Buddle, and the matter to be washed being in small quantities & occasionally turned into the right hand Corner, he draws it with his Coal rake into the fall of water, as it pours over the Head- board in an equal stream of 10 or 12 Ins. in breadth (as in the Trunk Buddle), 'til the Buddle is filled almost to the height of the Head -board, when the work is sorted in like manner as is that of the Trunk Buddle, those drawings being repeated as often as circumstances require 'til the whole is thereby made clean, tho' not I think, either with that speed or safety wth. which the same

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may be done in the Trunk Buddle. What remains in the Lew to be made clean undergoes the same process as that which is left in the Box of the Trunk Buddle, wch. I need not repeat. I have only further to add that all sorts of Ore after the shaddered are made either from dash'd Work, which is prepared for the Sieve from the smallest of the Bouse as it is drawn from the Mine in the Running Buddle where the most gross part of its impurities are thrown off: or from Knock-back which is such as falls off in the shaddering & has passed upon the Knock-stone under the Bucker, or being found brangled in the Sieve is returned thither for repounding.

I shall only make one Observation more which is, that if Ore, to be well dressed & well saved, ought to be sorted as I have above sorted it, how absolutely necessary is it that each part of it shd. be so well done as not to require a re-doing at the Mill, whither all sorts are brot. & laid together promiscuously: for to rewash it well & with safety, an analysis or separation

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of it into its different sorts shd. be made, which would be too tedious & expensive, & is therefore never practiced.

I shd. advise that this Letter might be looked upon as No. 1, and then, from a recapitulation of what has gone before, it will appear that I have been endeavouring to shew 1st. By what sort of treatment Lead Ore after it is raised or gotten out of the Mines, is made fit for smelting, wth. the several modes of procedure therein. 2dly A Description, and as well as I have been able to give it, an explanation of the first process in Smelting called Ore Hearth Smelting. 3dly. The same of Slag Hearth Smelting, and 4thly. I have shewn the manner of Stamping, Washing & Smelting Black Slags, which last compleats the total produce of Lead to be obtained from the Ore by our present mode of practice, and which Lead is thus finaly fitted and made ready, either for immediate Sale, or for Refining, but to which of those uses it ought to be put, can be known only by that which I have proposed to call, Process 4th., or Assay-making, & wch. I purpose making the subject of my next Letter.

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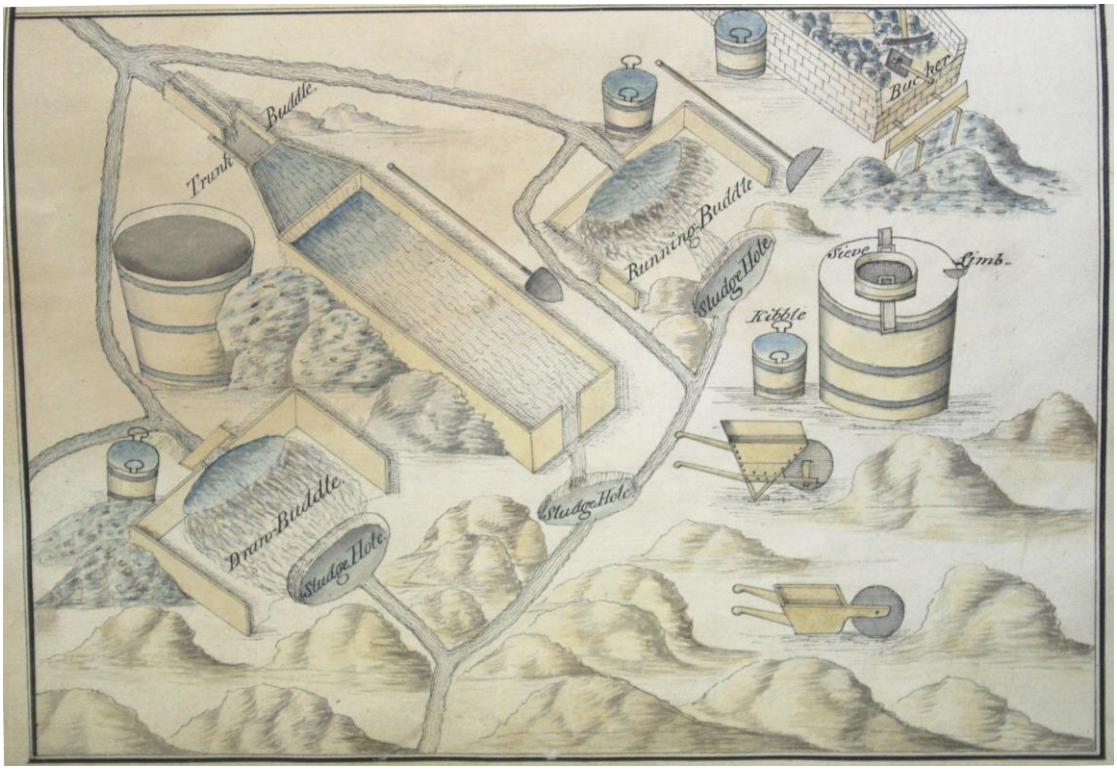

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On the Assaying of Lead
Process 4th.

———————

On finishing my last I think I observed that after the whole produce of Lead was collected from the Ore by means of the different Processes I have endeavoured to describe & explain, it remained to be determined whether such Lead ought to be sold, or detained for Refining, which could be done no otherwise than by that further Process which I have called Assay making, or by making an Assay of it: but I would be understood to mean of the Lead of those Ores only with the properties whereof we are unacquainted, or of wch. we are in doubt, there being several long worked Mines, the character of the Lead of which is so well established by repeated Trials, that any Assay of it would be unnecessary, yet as the Ore of the same Vein may be & often is raised from a variety of Beds or Strata and Variations of its Bearings of Silver* may consequently happen, frequent

* Variations in the Quantities of Silver produced from given quantities of Lead.

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Assayings are therefore requisite especialy of the Lead of such Ores as have been found to contain little more Silver than will just bear the expense of Refining or so little that it will not bear it at all for instances have been frequent of such Variations happening in each as that the one has fallen below refineable & the other has risen above it so as to leave a Profit worth attending to. - Ore Lead which has generally been found to contain from 8 to 10 Oz. of Silver per Fodder (21 cwt) will seldom fall below refineable. but the Slag Lead of the Ore may & often does, & therefore shd. not be passed either for Sale or for Refining without an examination <p[er]> Assay. A like examination shd. be made (and which we practise) of the Lead from which it was extracted, at the close or final cleaning up of every Cake of Silver, to know if the Refiners have done their Duty. - Having said all that is necessary of the Utility of Assay-making, I now proceed to the manner of doing it.

The Furnace in which we do it is in construction so simple that I shall hope the

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two Sections of it herewith sent (See Page 71) will be sufficient to enable any person so to understand it that a Description of it in words will be unnecessary. For the forming of the Assay Test, or Copal as I find the learned Assayists call it we take of the same Ashes the Refiners use, which is a mixture of abt. 4 parts Bone, & one Fern, Ashes, moistened so as that when pressed in the hand, they will not fall to pieces but continue in a Ball; these are beaten into a small iron Hoop abt. 5 Inches in diam. &1½ in depth til it is quite full, when with a round pointed Knife we scoop or hollow the Ashes in it, leaving those towards the brim the highest 'til we judge the concavity may contain

one pound, ½ a pound, or ¼ of a Pound of such Lead as is intended for an Assay. This Test, being first sufficiently annealed or dried, is placed as level as may be in the Furnace for the reception of the Lead to be tried, which, that it may be a just Sample of the whole, is taken a chip from each Pig of every particular parcel intended to be assayed, and those Chips being melted and well mixed together, so many Pounds, half pounds or quarter pounds as

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are designed for Assays are cut from the Lump so melted and mixed, and as soon as the Furnace & Test in it are thought sufficiently heated, one of the pieces of Lead is placed upon the Test, where it is presently in fusion, & takes a form, if I may be allowed to borrow a similitude from Milton, like "a Drop on Dust conglobing from the Dry" by which I mean that it assumes a partly convex surface, not a flat or rather concave one as water will when poured into a wet Vessel. Upon this surface the scum almost instantly breaks, if the heat be intense enough the whole Mass becomes as bright as Silver, & presently some Litharge is formed, and is seen to play to & fro upon it, a part whereof passing to the edges of the Metal, is absorbed by the Test or Copal, whilst the rest is carried off in Vapour, so that in about half or three quarter of an hour, if the Process be properly conducted, a quarter of a pound of Lead, by this double waste of it, will be wholly expended, and nothing left but such a particle of Silver as it may happen to contain,

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and with which no more need be done but to weigh it accurately & to calculate from the quantity of Lead in the Assay & the Silver produced from it, how much Silver in the same proportion one Fodder of such Lead will contain; and Experience having convinced us that this may be done with such precision that a very trifling disparity, if any. ever happens between the produce of Silver from Lead in the great work and of the same per Assay, we therefore confide in the latter for determining whether any Lead will or will not bear the expence of having its Silver extracted from it in that work which we call Refining, and which will be the subject of a future Letter.

To the Process of Assay-making I might here put a period having, I think, said all I can upon the usefulness of frequent Assayings, and of our manner of doing it, were it not that about two years ago our great practice herein suggested a Thought which I could not then help entertaining and which I own rather haunts

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me yet, and chimerical tho' it may appear (the Reverse of an old Man) yet I cannot let slip this opportunity of mentioning it: it will be an ease to me similar to that which some people experience in relating their Dreams however frivolous & uninteresting they may appear to others. This of mine I read to Mr. Hollier,* when he was at Langley Mill, & he seemed to think that I am right in the conjecture.

I set out by supposing from what is now doing at Bill Quay, Bells Close, & other places, that there are some mineral Substances which contain Silver from which it cannot be extracted unless such Bodies be first in fusion with Lead, with which it then incorporates, and from which it is extractible by that Operation which we call Refining,

& I have been led to think that we may not be quite sure whether the Silver which we obtain by that operation be

* A Gentleman who had the management a few years ago of a Refinery at Bells Close near Lemington

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realy inherent in the Lead Ore, or whether it may not be other yet unnoticed mineral Body intermixed with,or adherent to it, and which being in fusion with the Lead in the Operation of Smelting is Attracted by & becomes incorporated with it in quantities proportionate to the more or less there may be of such mineral Substances as I have supposed to contain Silver, or to the richness or indigence of them.

That all Lead contains more or less Silver, I have not the least doubt, but whether that may not be owing to every Lead Ore having an attendant or accompanying Silver Ore, variously circumstanced as to quantity and quality, I am realy in doubt, because there are some circumstances, indeed some Irreconcileables which seem to countenance such a Conjecture. Such as the yet unknown reason why all unrefined Lead does not produce Silver in equal quantity, but chiefly we observe that the Ores from which we obtain most of it are the least separable, nay that they are almost totaly inseparable from the other mineral Bodies wch. accompany them in their natural state

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in the Mines. Bodies which may and undoubtedly do cause part of their Lead to be wasted by protracting the operation of Smelting, but which may notwithstanding enrich it by the accession of their Silver.

It is also to be observed, that when an Assay is made of Ore, to know what proportions of Lead it contains, it is generaly, but very improperly, made of the most clean or pick'd parts of it, which is no just sample of the Ore in Gross, and when an Assay is made of the Lead so obtained to ascertain the quantity of Silver it contains, that has always been found to fall short of the Assay of the same Lead procured from this Ore in the gross, and in the ordinary way of Smelting. The disparity between the produces of Silver from the Ore & Slag Lead of the same Ore makes more <u>for</u> than <u>against</u> my Supposition, for Silver is easily soluble with Lead; an Ore Hearth Smelting Heat may bring the greatest part of it off, & what is left in the Slag may be only the draining of such Substances as I

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have supposed in like manner as the Lead got from the Slags may be called the final Draining of the Ore.

Be all this as it will, as our Cutting Ores of every sort are always ill dressed, have great quantities of every kind of matter with which they were intermixed & connected in the Mines, run down with them in Smelting, and consequently if any such substance as I have supposed should exist, they must have the greatest share of it; therefore we always think it right to make Assays of the Lead of our Cutting Ore

of every sort that a comparison of the produce of Silver from it, & from the Lead of the Bouse Ore of the same Mine, may be had.

At the time of writing this 1 know nothing of the result, but if it shd. be that the Lead of the Cutting Ore is found much the richest in Silver, I shd. not therefore insist that my Hypothesis was established, because I am aware that it may be objected, & with an appearance of reason too, that the lightest parts of the Ore, such as will go off in the

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Cuttings contain the most Silver; but to which I beg leave to reply that I think such light Ore will be of the refractory kind that it will not be easily discharged of its Lead, nor, if it has any, of its Silver; that it will be the most likely of any Ore to carry the most of each to the Slag Hearth and that consequently the Lead obtained there ought to be the richest, but wch. in no one instance has ever been found to be the case, and which I think puts it past a doubt that the least refractory parts of any Ore are productive of the most Silver; in confirmation of this it is said that in Air Furnace Smelting the Lead run off at the first Tapping will be found richly worth Refining whilst the After-Drainings, which must be the produce of the most refractory parts of the Ore, will contain but very little Silver, & this, it is said, is one great advantage of that mode of Smelting.

In the latter end of the year 1781, and subsequent to my writing the above, my Brother & I made Assays of the Lead of as many sorts of Cutting Ore as we had at that time by us, in

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order to make the comparison I had proposed, & the several results were as subjoined.

Names of the Mines from Wch. the Ore was raised.	Bouse ore ,Lead, Silver in the Fodder of it				Cutting Ore,Lead, Silver in the Fodder of it				Differences of Produces of silver			
	Oz.	Dwt	Gr.	10th	Oz	Dwt	Gr.	10th.	Oz	Dwt	Gr.	10th
Brownley Hill, Do.	7	16	9	2	11	10	7	2	3	13	12	
Moss Cross Vn., Do. North Vn., & Guddamgill Burn Cross Vein												
Carrs West of Nent	4	13	2	4	5	—	10	8	—	7	8	4
Blagill	7	7	—	—	9	1	7	2	1	14	7	2
Thorngill	7	7	—	—	9	2	12	6	1	15	12	6
Middle Cleugh	10	15	14	4	13	4	14	4	2	9	—	—
Rampgill	9	6	4	8	10	13	3	6	1	6	22	8
Scaleburn Moss Do.	8	6	14	4	11	—	12	—	2	13	21	6
(Cutting ore rewashed).*	—	—	—	—	9	11	2	4	1	4	12	-

From the above I think it is clear that if the Silver we obtain is realy inherent in the Ore, it is not equally so throughout the whole Mass of it. Scaleburn Moss Cutting Ore, you see, by rewashing

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* I have examined several Assays in my Father's possession made at Langley Mill, which seem to establish the certainty of Mr. Mulcaster's conjecture being well founded. (<Signed>) J. M.

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produced almost 1½ Oz. of Silver less p[er] Fodder of Lead than the same Ore did when smelted as send from the Mines, from wch. circumstance & from the whole of the above Comparative view of the Produces of Silver from Bouse, & Cutting Ore Lead, I think it is equaly clear that in the Ore washing we do cast off something which contains Silver, but whether that something is or is not a light Ore (an heavy Ore it cannot be), or some other substance, I remain in a Scepticism, towards the cure whereof the above Experiments have not at all contributed; on the contrary I have been led by them, perhaps ignis fatuus like, to consider what are the observable fossil & mineral substances which accompany the Lead Ore in the Alston Moor Mines, & this I shall make the subject of my ensuing Letter.

Assays made by Messrs. Mulcaster at Langley Mill

No.	Names of the Mines from wch. the Ore was raised.	Bouse Ore Lead Silver in the Fodder of it.				Cutting Ore Lead Silver in the Fodder of it.				Difference of the Produces of Silver.			
.	.	Oz.	Dwt.	gr.	10th	Oz.	Dwt.	gr.	10th	.	Oz.	dwt.	gr.	10th
1	1 Thortergill Syke & North Vn.	21	5	1	8						3	19	15	_
	Do. (Seemingly not fine)					25	4	16	8					
2	Slote (rather mixed)					8	16	9	6					
	Do. (pure)	7	14	8	4						1	2	1	1
3	Carrs. (Bouse & Cuttg mixed)	4	13	2	4									
	Do. (Cuttings only)					5	-	10	8		-	7	8	4
4	Windy Brow	17	12	19	2	13	14	19	6*		3	17	23	6
5	Nentsberry Haggs	20	18	22	8	27	16	3	6		6	17	4	8
6	Carrs West of Nent	4	5	18	-	8	18	20	4		4	13	2	4
7	Lough Vein	6	17	4	8	7	11	21	6		-	14	16	8
8	Brownley Hill North Vein	8	1	16	8	19	7	2	4		11	5	9	6
9	Guddamgill Moss	15	1	8	4	13	16	20	4*		1	4	12	-
10	Lough Vein	6	14	18	-	7	14	8	4		-	19	14	4
11	Windy Brow	8	4	3	6	8	1	16	8*		-	2	10	8
12	Brigal Burn	9	11	2	4	8+	11	12	-*		-	19	14	4
13	Hangingshaw & CowhilI x Vn.	4	13	2	4	7	9	10	8		2	16	8	4
14	Middle Cleugh	10	13	3	6	12	14	19	2		2	1	15	6
15	Lough Vein	5	10	6	-	6	2	19	-		-	12	6	-
	Longholehead	8	18	20	4	9	11	2	4		-	12	6	-
16	1791 Nov. 24 Cowslitts Cross vein	3	6	3	6						8	4	3	6

1792 Jan. 6 Do. Cutting	11	10	7	2

The above assays were made at different times from the year 1775 to the year 1793, & those Nos. marked * are the only instances where the produce of Silver from the Bouse Ore Lead has exceeded that from the Cutting.
+ Sandy coloured cutting.

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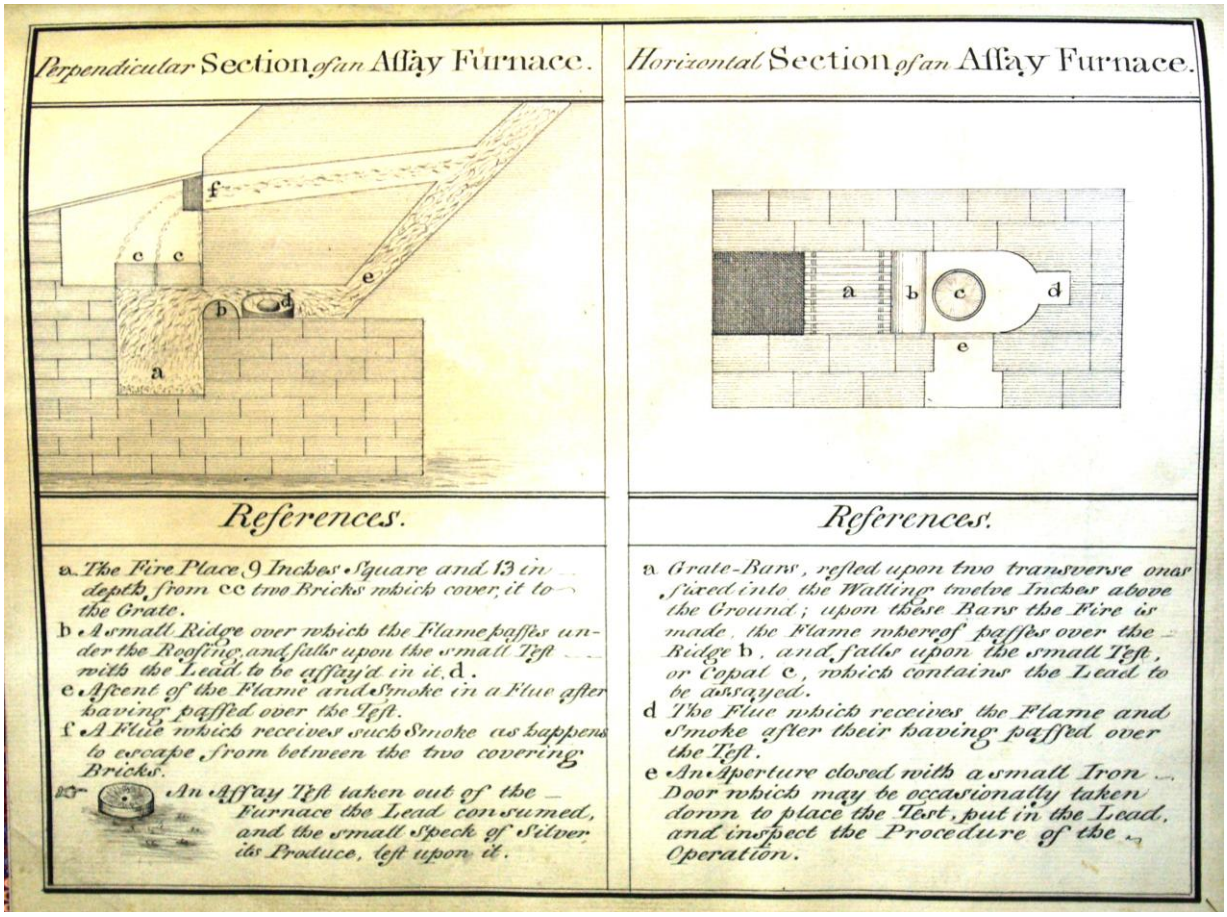

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Concerning those Substances wth. which the Lead Ore in Alston Moor is generaly connected or accompanied.

I now proceed to shew what are the observable or most obvious mineral & fossil Bodies which accompany or are connected with the Lead Ore in the Alston Moor Mines. I shall call them by the names they go by in that Country, for indeed I do not know them by any other, neither am I much acquainted with their respective properties further than as I have observed those properties to affect the operation of Smelting, when (as is too often the case) the Ore is not well dressed or separated from them at the Mines; and I give my Observations upon them, as will be seen more as an Appendix to what I have formerly said upon Ore washing & smelting, than with any

intention to shew the probability of some of them containing Silver, for which notion I acknowledge I have nothing but conjecture, founded on such reasons & results of Experiments as I communicated in my last. Indeed if there

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should be any Grounds for my suspicion what I have been doing in this Letter, i.e. - Distinguishing the substances with which the Lead Ore is found mixed - would be one necessary step towards the investigation. If, however, I were quite sure, which I am not, nor perhaps ever may be, that some of these Bodies did contain Silver, I should not therefore advise their being kept mixed with the Ore for the sake of obtaining it, for I am convinced that the doing so would occasion a Waste of Lead, in value more than equivalent to that of any Silver which could be gained: at the same time if it were certain that some of the following Bodies contained Silver, I am quite clear that it ought to be got in some more cheap way than that of fusing the substance which contained it with Lead itself; perhaps it might be effected with the Grey Slag of such Ore only (as is practised by Mr. Hollier with his Mineral or Minerals which contain Silver & we suppose Gold also but no Lead) 'til that Metal

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is communicated to & incorporated with the other, as it is produced during their joint fusion from the Grey Slags, and from which the more rich Metals are separable by the ordinary process of Refining, as I observed in my last. - It is beyond a doubt that there are somewhere Bodies which contain Silver without any admixture of Lead, and why may not some of those Bodies therefore be found in a Lead Mine?-

The Substances I have proposed to observe upon are I think distinguishable into. –
1st. Stone.
2d. Sulphur.
3d. Black jack
4th. Spar.
5th. Coke or Coky Spar.
6th. Copper Ore.
7th. Soil.
8th. Plate.

of all which separately, and in their order & first of

- Stone –

of different sorts & going by various appellations, such as Limestone, Hazel, Fire- or Free-stone, & Slate, as the Sills or Strata in which the Ore is found happen

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to be, but differing from Stone found in ordinary situations in this, that they are commonly more or less what the Miners call burnt, i.e. much hardened by having been in, or lain contiguous to, a Vein. The Stone found in the latter position is called Rider, i.e. that which forms two Cheeks between wch. the Veins which carry Ore are held. All the different kinds of Stone are extremely averse to

vitrification, and if brought into that state along with the Ore, they are to a Smelting Hearth (if I am allowed to borrow a Term which expresses an animal function) of hard digestion; by which I mean that Stone of any sort goes so hardly & with such difficulty - into Slag, that to continue the medical Style, the necessary evacuations, are interrupted, the whole mass of the Brouse becomes thereby vitiated, & the Hearth is surcharged with it; fresh Ore therefore cannot be exhibited, or but in very small quantities, consequently little or no Lead can be expected; and a remedy must then be sought, which is

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generaly in an application more Fuel, agitated by a more increased effort of the Bellows than is requisite for the reducing of the Ore itself, by which the produce of Lead is greatly wasted, besides that this remedy is often ineffectual; for I have frequently known Hearths thus circumstanced, so distempered, that the digestive quality of their Brouse has been quite destroyed, & it has not been but with difficulty & loss that a supply of the most clean & free Ore could bring about the necessary purgation, by a discharge of Slag, which alone could effect a Cure.

2d.Sulphur.

This is a most pernicious mixture in Lead Ore, and, as I have elsewhere shewn, is with the greatest difficulty wholy cast out of it. - Exposed to such a degree of heat as is necessary for the smelting of Ore, it becomes intensely hot, spreads an excessive glow throughout the whole of the Brouse or ordinary contents of the hearth, such as Lead cannot sustain without being wasted by it, goes but a very little of it into Slag or Scoria, but is mostly expended in its substance by evaporation,

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and causes an immense waste of the Lead in the same way. I suppose this is the Ore of Sulphur, properly so called, or Brimstone. A Person I saw at Keswick, an Agent for a Copper Work, informed me that when it abounds in the Copper Ore, they are obliged to roast it out before they carry the Ore to the smelting Furnace; that in so doing, by some sort of contrivance they collect a considerable quantity of good Sulphur or Brimstone, and that so inflammable is this mineral, that it need but be kindled once to burn with vehemence without the aid of any other Fuel. Having formerly been an Alston Moor Miner, he added that the Sulphur of the Copper Ore, so far as he could judge, does not at all differ from that in the Alston Moor Lead Mines.

3rd. Black Jack (or Lapis calaminaris).

In form this Substance often resembles the foregoing, and on that account is by some believed to be of the same quality & only differing in colour, viz. that the one is a yellow or golden coloured and the other a black Sulphur; from which opinion I

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differ, because having heated a piece of the former red hot and pass'd my Nostrils over it, I was sensible of a very strong sulphureous or brimstony smell; but having done the same with a piece of this, I could not perceive that my olfactory Nerves were affected at all: I therefore think that this is not a Sulphur Ore but suspect, from some appearances which I have observed upon it when hot, that it may contain an Arsenick.

This is a more common mixture with Lead Ore than Sulphur, & it is not less mischievous in the operation of Smelting. So deceiving also is it, that in the Mine & by Candle light it is often taken for the Ore itself; and even in day-light, if it be of the shining black sort, a sprinkling of clean Ore Smithorn, which the Washers are artful & knavish enough to give it, will so disguise it, that it may be, & often is, taken for good Ore, 'til a Shower of rain falling upon it discovers the fraud. - From what I have observed upon Washing, it appears that this Mineral being a lighter Body than Sulphur, the Ore might, by care & Honesty in the Washers, be more easily freed from it in the dressing than from the other, yet as it seldom is so where any of it is dug

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up with the Ore, I have had frequent occasions to observe its Effects upon Smelting, and have seen that if they are less violent, they are more lasting, and therefore equaly injurious to it as those of Sulphur. Like that substance, the greatest part of this is consumed by evaporation, but this being less, or perhaps not at all a combustible, the waste of it is more slow & vexatious. I have also observed that but a very small part of its substance goes to Slag, & that whilst it is extremely averse to taking that form itself, it hinders every other Body joined in operation with it from doing so; that when it abounds in any Ore, it causes the best tempered Brouse to go into a dark inert & heavy mass, which the Blast or Stream of Air from the Bellows cannot pervade, but which instead of preserving its horizontal direction & thereby invigorating the whole operation is repelled & wasted by being thrown upwards, wch. the Smelters call - The Metal not taking the Blast, that under such circumstances the perspirations of the Lead from the Ore are extremely slow, and

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the Ducts by which it ought to descend to the receptacle of it in the bottom of the Hearth are so shut up by the close texture of the Brouse, that the Particles of it hang in a slow but consuming Fire, & the produce is thereby greatly wasted.

4th. Spar.

If this be of the light, free, & almost transparent sort, it is the most harmless mixture which can be left in Lead Ore. Directly contrary to both the foregoing, this in a moderate Smelting Heat digests into a very light and distinguishable Slag, at the same time greatly promoting a like disposition in such other Bodies as happen

to be in the fire with it. Being a more light Body than most of the others wth. which Lead Ore is generally found mixed, a smaller quantity of it is therefore left in the Ore after Dressing, which is not a great fault, for the Ore wth. which it is found is most commonly of so free & fusible a quality of itself, & so exempt from other heterogeneous & refractory Mixtures, that it has no need of this as a Flux. Perhaps it might be used to advantage as a Flux in smelting some of our most refractory Ores, but indeed the Alston Moor Lead Mines

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do not produce much of it, at least very little of that sort, without which, as I have been told, there are some fat rich Lead Ores in the Yorkshire Sun-Dales, as they are called, that can scarce be got smelted and which is brought sometimes from a considerable distance to be used as a Flux.

5th Coke or Coky Spar.

Of this there is great plenty in the Alston Moor Mines. It is a close, heavy, opake and extremely refractory substance: sometimes so glitteringly white and also so very heavy that it is mistaken for White Lead Ore. In some of the Mines the larger pieces of the Ore, the shaddered especialy, are so veined & threaded by it as to be rendered inseparable from it without breaking the Ore down, greatly to its waste. No substance I have yet mentioned is more obstinate or more averse to going into Slag, in which form the hearth shd. be discharged of it, than this; indeed it can scarce be made to take that form at all, for I have broken pieces of Slag, of which this substance vitrified ought to have formed a part, & have found it rendered more brittle indeed, but not at all deformed by having been in the Fire, nay I have almost burnt out the Bottom of a crucible containing some of it without being

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able to effect more than a partial fusion of it - So that what has been said of the several sorts of Stone, as to their Effects upon the Operation of Smelting, is equaly applicable to this.

6th. Copper Ore.

With the Lead Ore of the North Vein at Middle Cleugh there is often intermixed an indigent Copper Ore, so poor that it is not worth preserving as a Copper Ore. When this happens, the connections between this & the Lead Ore are so close, & the transitions from one to the other so frequent, that they can never be got entirely separated; so that a good deal of this is carried with the Lead Ore to the Smelting Hearth. In a Crucible exposed to a moderate heat, this fuses wth. facility & in a smelting hearth its promptitude thereto gives the Brouse a wet-like creeping & Ropyness wch. no application of Lime can absorb or correct, but in the attempt to do which such a quantity is generaly used, that the Slags, thereby with difficulty obtained, can scarce be run in the Slag Hearth unless they are fluxed or mixed with those of

another kind of Ore on which no such profusion of Lime at the first fire was necessary. At the same time that this mixture

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impedes the Operation of Smelting & thereby wastes the produce of Lead, it also discolours it much, giving it a disagreable copper-coloured Freckle upon its surface, but I do not apprehend that it otherwise affects its quality, perhaps it may better it, for if there shd. be any Silver in the Copper Ore, which I suppose is possible, I have no doubt that the Lead will enrich itself by the attracting of it during their joint fusion in the Operation of Smelting.

7th. Soil.

This is so light a Body and often so like Garden Mould, that excepting some little which may adhere to the Shaddered Ore (which does not undergo the operation of Washing) all of it goes off in the washing, if that shd. not be very ill done indeed; and consequently as so very small a quantity of it ever continues with the Ore, 'til it is brot. to the Furnace, it cannot observably affect the smelting of it. Ore which has scarce any other mixture with it in the Mine but this is commonly of the free and productive sort.

8.Plate.

Of this Fossil many Beds or Strata are met with in the Lead Mines in Alston Moor,

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some of them several fathoms in thickness, between which are the several Sills or Strata of Stone of every sort. When this lies deep, & is compressed so much as to have acquired a great degree of firmness, it has the name of Plate (as I have called it) but nearer the surface where the compression is not so great & it lies more lax, it takes the name of Chiver, perhaps a corruption of Shivers, into which it goes on being loosened from its Bed, as does also the strongest plate on an exposure for some time to the open Air. Both of them 1 think, are rather of a clayey than of a stony or sandy composition, for they will grind, or may be trodden to a tough and cohesive Clay, which I believe wd. not easily vitrify in the fire; wherefore I conclude that if any Plate shd. be left wth. the Ore 'til smelted, it wd. not be easily got rid of in the way of Slag, & therefore wd. be an hurtful mixture; but as no great quantity of Ore is got in Plate Beds, & as what is got there is easily dressed from it, I can only conjecture what Effects it might produce in Smelting.

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On The Refining of Lead

Process 5th.

It is customary, & certainly right, when a person is taken into a Lead Manufactury as a Workman, not to employ him in the highest Branch of it, or that of the first repute all at once, but so make him acquainted with, & to prove him in, the subordinate parts first. In this manner it was that I had my initiation into it, & in this order it is that in my correspondence upon the subject, I have endeavoured but with what degree of information I know not, to conduct you step by step to that almost final Process in it wch. we call Refining, by which if the obtaining of Silver from Lead is to be understood, as doubtless that is its primary intention, in that case it is a Misnomer, it ought rather to be called Extracting; but if what is consequential of that extracting be intended, then the name is proper enough, for by it the Lead itself is refined so as to be of more Value, as Lead than any other that has not pass'd thro' the same Operation.

'Til of late I had been induced to believe that the practice of this Art was of no high antiquity in England, at least in these Northern parts of it; that it

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had not been of more than 100 years continuance, that 'til within that period we to our own loss & their emolument, sold all our Lead to the Dutch or Germans who alone possessed the Mystery of Refining or Extracting its Silver from it. But since a Journey I lately took to Keswick in Cumberland I have altered my belief as to the time that Refining may have been practised in this Island; for at a place called the Dutch Houses there, where several sorts of Minerals & the Slags or Scoriae of them had from time to time been dug up, I found that amongst other things, several pieces of the Litharge of Lead had been picked up, and I myself found some amongst the Rubbish. Now this Litharge could not have been found there unless a Refining had been carried on there at some time or other; of wch. time to inform myself I enquired of a very aged but intelligent man, who had lived all his life in that neighbourhood, if he could remember any sort of Work going on at the Dutch Houses, or if any of the Buildings had been standing in his time. His answer was that the spot of ground had born the same appearance it now has, i.e. mostly overgrown with Grass, Furze

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or Broom, ever since he could remember anything; neither did he ever hear the oldest people living in his time say that they had known it otherwise, but that they had a Tradition that the place got its name from a Smelting of Metals having been carried on there by Dutch People in former times. From these circumstances I am led to think that this Art has been practised for a much longer time, even in the North of England than I had once imagined.

In the Reign of one of our Kings, I have forgot which, History informs us that there came a People to England from some Country situated to the East of it, from wch.

circumstance they were called Easterlings, who brot. our Silver Coin then sadly debased to that Standard of Purity it has ever since retained, and from whom, by a contraction of their name—Easterling—it got the appellation of Sterling, which it has to this Day. Those people no doubt were Refiners, and perhaps were the first who introduced the Art into this Kingdom; and as the Dutch, from the situation of their Country wth. respect to us are Easterns or Easterlings, perhaps the Dutch Houses may have been occupied by some of

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them, & from thence acquired the Name.

But that wch. brot. Refining into such general practice in this Country was that Act of the Legislature, 6th William & Mary, intitled An Act to prevent disputes and controversies concerning Royal Mines - by wch. every proprietor of a Mine of Copper, Tin, Iron, or Lead, got a right to keep& work the same, notwithstanding its being claimed as a Royal Mine from its containing Gold or Silver; but with reserve, that the Crown, & all claiming under it, shd. have the privilege of purchasing all the Ore raised out of such Mine at the following prices per Ton – viz -
Copper Ore, made clean & fit for Smelting, £16 -. - ;Tin Ore (that raised in Devon &Cornwall excepted) £2-.-.; Iron Ore £2-.-.; and Lead Ore £9-.-.; which price is equal to £3. 12. - for our Bing (8 stones), a rate at which most of our Lead Mine Adventurers in these parts might be happy to have their O
re demanded, tho' it should contain what is thought a good deal of Silver; for if it did, it wd. be only by chance if the scanty produce of Lead did not bring it nearly an equal value with Ore which had not Silver in it worth the extracting at all, so that none in

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these parts need to fear having their Ore claimed on accot. of their Mine being supposed a Royal one.

That some sorts of Lead did contain more or less Silver & that it was extractible from Lead, wd. be discovered somehow & at some time, but how or when perhaps History itself is silent. These Discoveries may have been made from very remote Antiquity, and how they probably might be made I shall venture to give my conjecture, and the rather, as in the cause of doing that, I shall necessarily fall upon some Explanations in the Processes of Refining and Reducing, wch. I think I can convey as clearly in this way as I could when I come to shew our present mode of doing those Works.

That most sorts of Lead contained some Silver, I have conceived might have been discovered in some such way as that in which we now make our Assays - as thus - A quantity of Lead having been, perhaps fortuitously at first, exposed to a certain degree of the heat of pure flame,—please to take notice I here mean that Emanation issuing from any sort of fuel in bulk or substance whilst burning—I say Lead thus exposed wd. be observed to emit

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a Vapour from wch. it wd. be judged to be in a state of dissipation & waste; what had been seen to happen to Water under similar circumstances would naturaly lead to that. A sensible diminution of its bulk would soon be observable, curiosity wd. wish to see if

it were a totaly evaporable Body, & the result wd. be that some, tho' perhaps a very small part of it wd. be found not to be so; that a small something did remain upon which the Fire seemed not further to act, nay that ceased to be in fusion, tho' the force of the fire was increased & which upon examination, wd. be found to be pure Silver. - Now this is exactly our Assay making; this serves to shew us that there is Silver in Lead, & in what quantity; and would with repeated experiments serve to convince those first Assayists that Silver was obtainable from it - But here I apprehend they wd. be somewhat at a Loss. They wd. see that tho' it was obtainable, yet that it was not so but at by far too dear a rate; that exclusive of the tediousness of the process, and the enormous expence of fuel, it could not be procured but by the total consumption of the Lead, wch. at that time of however low a Value, would doubtless be of more than the Silver to be obtained.

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The means of extracting it without the entire waste of the Lead wd. then become a very desirable object, & no doubt many fruitless Experiments wd. be made in search of them, before the right modes, or those now in practice, were found out; 'til at last it wd. be noticed by some lucky observer; that upon the surface of Lead exposed to such an Heat as I have supposed, something more light then the rest & resembling Oil or Fat upon Water, did swim and fluctuate previous to its formation into, & flight in, vapour; and by a further felicity of thought, it might be conceived, that if that something, wch. wd. be & which I shall henceforth call Litharge, could be intercepted before its evaporation, there was a probability that it had parted from its share or proportion of the Silver preparatory to its <u>sublimation;</u> and also that some use might be made of it, if means for preserving it could be discovered, as a step to which a <u>Skimming off</u> wd. be judged the most likely and for that purpose the use of Bellows wd. be readily suggested. Litharge wd. be thus obtained, but then how to reproduce any Lead from it, if any
shd. be left in it, wd. remain to be discovered. Re-exposed to a similar degree of Heat wth. that which

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first produced it, it wd. be found to be a fusible substance; but on being suffered to cool, it wd. be found to retain all the Properties of Litharge, unless the Fire had been so vehement as to vitrify it. It wd. be found that in its conversion from the Lead, that had suffered a privation of something - its Phlogiston, Inflammable Principle or I know not what - by which all its properties as Lead, such as <u>Malleability</u> and <u>Facility of fusion</u>, seemed lo be totaly annihilated, but I fancy an Accident might soon discover that <u>that</u> lost something was restorable; that the putting this Litharge in such a heat as first formed it, i e. a Flame reverberated upon its surface, & at the same time in immediate contact with or touching any sort of fuel in substance wd. restore it; that by some sort of communication to it from the substance, not flame, of the Fuel, Lead became reproducible from Litharge with improved qualities as Lead, by the same process which had separated it wholly, or nearly so, from its Silver, as wd. be found by making an Assay of it. The Lead wd. be also purged of its more gross or earthy parts, that is it

wd. be refined. The

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manner of recovering Lead from Litharge which I have just been describing is what we call Air Furnace Reducing, & is what we practice here at a variable loss viz from an Eleventh to One Fifteenth part of the Lead originally refined.

Some Lead is also reproducible from its Sublimate or Fume which, is a whitish coloured Soot arising from the Sweepings of the Refining and Reducing Chimnies; but that any Lead was obtainable from this is a recent Discovery to the merit whereof I think my Brothers * &Self have a just claim; for 'til we found out that Lead might be got from it by a proper management, many Tons of it were cast away as useless, both at the Governor & Co. & Sir Thomas Blacketts Works; tho' with us here it has upon being smelted produced one half its weight of Lead, which is nearly as much as some of our middling sorts of Ore can be made to do. I have looked into Dr. Watson's Chemical Essays, but do not find that either he, or any of the smelting people he has

* Mr Mulcaster has two brothers, one Joint agent with himself at Langley Mill and the other principal agent at the late Sir Thomas Blackett's refinery at Blaydon

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conversed with, has known anything of Lead being obtainable from Fume, or, as he calls it, sublimed Lead. He speaks indeed of its being sold to the Painters at £10 - or £12 – p[er] Ton, & that it might be converted into red Lead probably to more advantage; either of these ways of disposing of it wd. no doubt be better than any smelting of it.

From what has been said above, it will be perfectly understood that the conversion of Lead into Litharge is not effected by the application to it of any sort of fuel in substance, however hot, but from the flame issuing or streaming from such fuel whilst burning; and that on the contrary Lead is not recoverable from Litharge by the heat of pure flame only, however strong that may be, unless the Litharge be at the same time in immediate contact with, or touching some sort of fuel or combustible matter in bulk or substance.

These particulars being explained, I now proceed to a description of our present method of doing the Business of Refining, and of the Apparatus necessary in it, to shorten which last I send some Drawings of the principal Articles used in it viz. 1st a Sketch of the Iron Frame into which the Ashes are beaten for a Test; 2d. Another of the same with the Ashes beaten

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into it, & scooped out as a Test fit for use; 3d. A perpendicular Section of two Refining Furnaces, & the shaft of their joint Chimney; 4th. An horizontal Section of two Refining Furnaces, the one with the Test represented in it, charged with Lead & with its surface ruffled into small Waves by the action of the Bellows as when at work, the other with the Test also represented in it but shewing the position in which a Cake of Silver commonly lies upon its bottom where it is taken off, i e. made clean. All which, by help of the References annexed to them, will I hope, be sufficiently intelligible. (See Pages 107 & 109)

By the two Sections it will be perceived that the Refining Furnace is a sort of Oven of a square Form, opening gradually into one more oval with an arched but unequaly curved roof and consisting of 2 Chambers, or Apartments, the one square, which is the place of the Fire, its bottom a Grate & roof sharp, the other more oval which is the place of the Test whereof that forms the bottom & over which the Roofing is flattish. Between those two parts is a ridge of Brick Work abt. 20 Inches in breadth & 18 in height, the reason for which is that nothing of the Fire but its Flame may pass to the Test with the Lead in it to be converted into Litharge. From the fire & over this ridge the necessary quantity of Flame is poured into the place of the Test, and as

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its passage from thence to the Shaft of the Chimney is only by two small Flues, it is so beaten back or reverberated upon the surface of the Lead as to have the effect desired. The preparation of the Test is as follows: The Iron Frame which is to contain it (See Drawing) being laid firm upon a Ground Floor, it is filled rather to a heaping, with a mixture of 4 parts Bone & one part Fern Ashes, moistened so as just to clod when grasped in the hand; & this mixture being beaten down with a sort of Iron Pestle other Layers of the same Ashes are laid on, and also beaten down 'til the Frame is quite filled, when wth. a small Spade & other instruments, it is scooped out so as when finished for use, to have pretty much the form of a flat bottomed Boat, as is shown in the Drawing. It is thus made ready for the Furnace, whither it is carried by two Men, and being placed upon a Fir Deal by that it is shoved in over two Bars of Flat Iron fixed into the Mason Work of the Furnace from which it is propped into its place, and its junctures with the Furnace are made very tight with Lutings of Clay to exclude the cool Air from without, & that no smoke or Flame may escape from within. To anneal or dry the Test without splintering it, a slow fire is at first put upon the Grate of the Fireplace, wch. is quickened

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gradualy 'til its humidity is entirely exhaled, which commonly is in 5 or 6 hours at farthest. It is then heated by a strong fire, to fit it for the reception of its charging of Lead, in quantity abt. 5 Cwt. which is given it at some places by that quantity being first melted in a Pot, and from thence handed into the Test by a small Iron Ladle or spoon, and at others it is filled by sliding the Pigs in at the feeding holes one after another with their ends within reach of the Flame, by which they are gradually melted off 'til the Charging is compleated * ; soon after wch., if the Fire has been sufficiently kept up, some Litharge will be seen to fluctuate upon its surface, & the Bellows is made to play upon it, by the stream of Air from which such Litharge as is formed, & continues now to be formed, is driven towards the Breast or Fore part of the Test; over or across which a Gutter, called the Gate, is cut by wch. the Litharge passes to the Hole in the entrance into the Test thro' which it falls to the Floor where it is suffered to gather into such Heaps or Clods as the Workmen find it convenient to bear away upon a Shovel. To replenish the Test with Lead in lieu of that wch. is

* Messr. Mulcaster have lately made experiments to ascertain which of these modes of

feeding the test is preferable and the result Is, that the former is found to be the most advantagious

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now constantly converted into & carried off in Litharge, a Pig of it is always kept in one of the feeding Holes, more or less within reach of the flame as its more quick, or more slow melting off is required, in order to keep up the proper Stock of Lead in the Test, in which the workmen are directed by observing to what distance backwards the Test is covered with Litharge, distinguishable from the Lead not litrified by its being of a less bright or of a cloudy red Colour. If the Test be covered far back with Litharge then the Pig is pushed forwards, or sometimes dipped in the hot Lead of the Test to hasten its melting off; but if the Lead not converted into Litharge or only partialy so, be seen very near, then the feeding Pig must be made to recede, otherwise a foul-running as the running of Lead imperfectly converted into Litharge is called, will ensue. This being more ponderous than Litharge, which is Lead calcined, is distinguishable from it by its falling quicker or with greater velocity from the Test, & rebounding more from the Ground or Clod on which it breaks; it is also known to a good & experienced Eye by its being of a more bright or white red colour than Litharge. But if the Gate or channel for the Litharge be firm & free from Flaws, with care in the Workmen & at no hazard of foul-running, a piece of Lead of 1 Cwt. will be run off in good Litharge in

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less than 20 Minutes; and a faultless Test will before it is worn out frequently run off 84 of such pieces, wch. is equal to 4 Fodders of Lead. A Test is worn out or becomes unfit for further use, either by the hot Lead corroding and eating up its bottom, to the danger of its bursting in that part, or by the channels thro' which the Litharge issues being so sunk, that a sufficient stock of Lead is not left in the Test; for as all the Silver wch. is to be expected from the Lead previously run off in Litharge from the same Test is necessarily involved in that Stock, however contracted it may be, it therefore becomes hazardous to continue working towards the latter end of the Test with a small stock of Lead in it; for besides the danger of loss by accidental but perceptible foul -runnings, experience has shewn that considerable quantities of Silver will pass off imperceptibly with Litharge formed upon the surface of very rich Lead; and therefore at Langley Mill (I do not think it is practised elsewhere), we run off our Stock out of the Test, by inclining it when it has worked abt. one half its quantity, close up the old channel for the Litharge, cut a new one, and refill the Test with such Lead as we then happen to be working upon; so that at the conclusion we have the Silver of each 4 Fodders of Lead in 2 or 3 pieces of

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perhaps 1 Cwt. each; which pieces when we have the produce of abt. 20 Tests, we farther contract by bringing them all into one Test by themselves, and by running them off in Litharge in the ordinary way, reducing the whole to about 2 cwt., excepting 5 or 6 pieces which are reserved for what is called the Silver Test, i e that in which the Silver is made perfectly clean. In the running of those rich pieces, both in this Test & the

former one, tho' the Litharge is made as perfectly such as may be, yet upon trial per Assay, we always find that the Lead reproduced from it is refineable,& therefore we reserve it for a second or repeated Refining, by which we have obtained sometimes more than 200 Ounces of Silver at the conclusion of each year for some time past.

The Silver wch. is intended for one Cake being all driven as it were into 8 or 10 pieces of Lead of abt. 1 Cwt. each, in the manner I have endeavoured to describe, a Test is prepared for its final cleaning or taking off as it is called. The preparing of this Test does not at all differ from that of any other, save that a little more pains is taken in smoothing its bottom, and making it somewhat more concave than those of ordinary working Tests are generaly made. This rich Lead being all got into the Test by a

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part of it being run off in Litharge, instead of one Channel for the Litharge to issue at, two are now opened, one at each extremity of the hole thro' which it falls from the Test; which are kept open & sunk gradualy to make way for the Litharge as it is seen to form upon the surface, & is pushed forward by the Bellows, which it continues to do & suffer 'til the whole Lead is run off from it & nothing remains but an expanse of pure Silver, the approach to which state is notified by a gradual dispersion of that cloud & fiery Vapour which 'til this period of the Process hangs & thickens upon the surface of the Metal; but this being at last dispelled, the Bellows is discharged, the flame retires to the roof of the Furnace, and a Lake of liquid Silver brightens up so as often to reflect the roof & surrounding Brick-work of the Furnace: Or if after the Bellows ceases to act upon it, any little impurity shd. remain, that is commonly exhaled by the unabated force of the Fire, whilst the Silver yet continues in a liquid state, as it does for some time after the Bellows is taken off. At last it begins to crust, or, as it were, ice over; the incrustation as it is formed, contracts & thereby compresses the yet fluid Metal under it so as that this last almost always breaks thro' some weak part of the Crust, & often forms very romantic Figures. A surprising change now

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takes place. That which a few Minutes before was in reality a Silver Lake of the most even & shining surface, seems now transformed into an Island with Mountains, Hillocks, & gushing Rills, all of pure Silver. In this situation it is suffered to remain 'til it grows so cool as to admit of its being taken out of the Furnace without any danger of deforming it; and when it becomes perfectly cold, in order that none of its pretty eminences may be lost by falling off, they are beaten down, & any Ashes of the Test, or Slag of the Bricks, which may happen to adhere to it, are dressed off, and then it is fit for the Market. Now tho' the Silver is at last thus left upon the bottom of the Test, yet it is not there any time previous to this final purifying of it. So long as there is any Lead with it, it is equaly diffused throughout the whole mixed Mass; that is, a Drop taken at the surface, if not litrified, would be found equaly rich with one taken at any depth in the Test. Silver being a more light Body than Lead cannot subside in it, but Litharge, which is to Lead what Froth or Foam is to Water, being more light than Silver, will float upon it, & as Lead is convertible into

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Litharge, it thereby becomes separable from whatever portion of Silver it may happen to contain.

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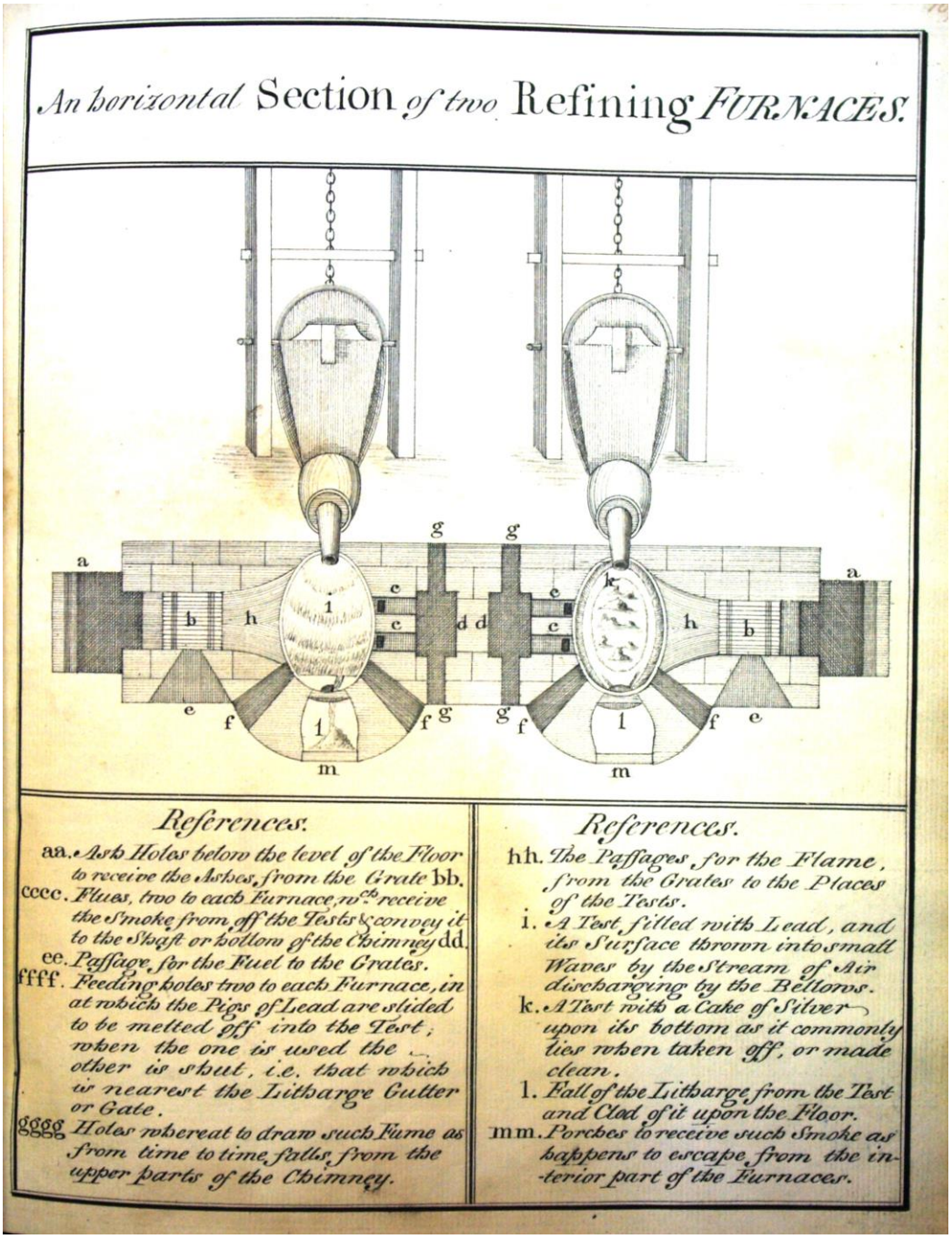

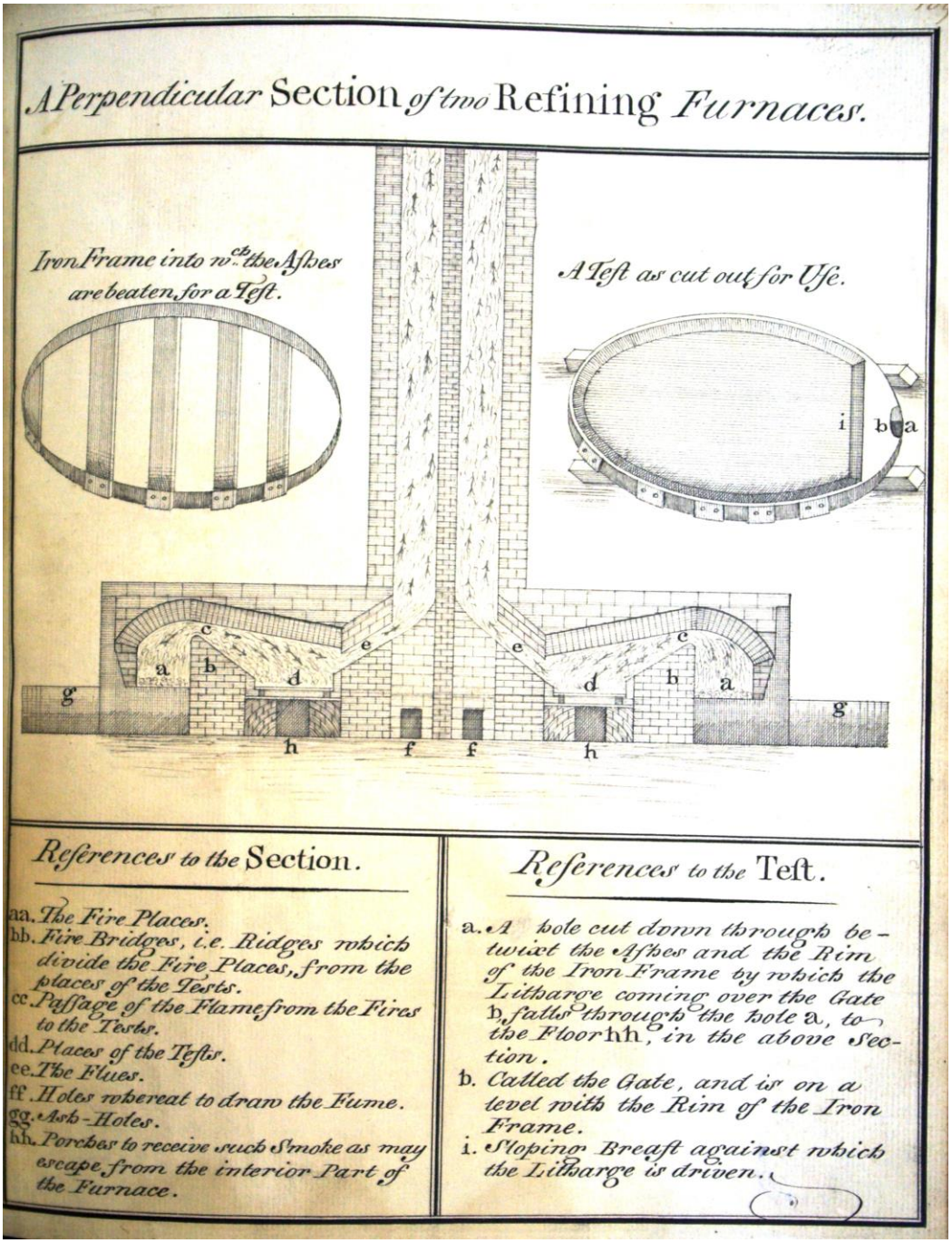
A Perpendicular Section of two Refining Furnaces.
Iron Frame into wch the Ashes are beaten, for a Test.
A Test as cut out for Use.
i
b
a
c
e
a
b
d
g
h
f
References to the Section.
aa. The Fire Places.
bb. Fire Bridges, i.e. Ridges which divide the Fire Places, from the places of the Tests.
cc. Passage of the Flame from the Fires to the Tests.
dd. Places of the Tests.
ee. The Flues.
ff. Holes whereat to draw the Fume.
gg. Ash-Holes.
hh. Porches to receive such Smoke as may escape from the interior Part of the Furnace.
References to the Test.
a. A hole cut down through betwixt the Ashes and the Rim of the Iron Frame by which the Litharge coming over the Gate b, falls through the hole a, to the Floor hh, in the above Section.
b. Called the Gate, and is on a level with the Rim of the Iron Frame.
i. Sloping Breast against which the Litharge is driven.

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On The Reducing of Litharge
Process 6th.

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I come now to that Process which I have named the last or final one in the manufacturing of Lead Ore, viz. the Reducing of Litharge; a Work which is done either in the Air Furnace as at Langley Mill & at Mr. Beaumont's Refineries, or in the Smelting Hearth with Bellows, as is practiced at most of Governor & Company's Mills; but first of the Air Furnace.

This Furnace, except being of somewhat larger dimensions, is in form much like the Furnace for Refining, described in my last, and it is also divided in a similar manner by a ridge of Brick Work into two Cells or Apartments, the one of a square form & a Grate at the bottom, being the place for the Fire, the other in form rather more oval and with an immovable bottom of 4 parts Bone & one part Fern Ashes, beaten into it to a considerable thickness, and incrusted with a Coating of Black Slag run upon it by a vehement heating of the Furnace, having been first formed sloping in every direction to one Outlet in the side called the Tap-hole thro' which the Lead issues by a Cast Iron Duct or Spout to

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the Pot, out of which it is cast into Pig Moulds hung upon Steel yards for adjusting the weight of the Pigs. The Furnace being first well heated, upon this bottom the Charging, which consists of about 32 Cwts. of Litharge interspersed with a suitable quantity of good but small Coals, is laid, and a strong flame being made to pour in upon it from the Fire place; that gradualy propogates a burning of the Coals, first upon its surface, and then in the interior parts of the heap; some Lead is continualy forming & oozing towards the Tap Hole wch. issues & is disposed of, as has already been noted, 'til the whole Charging is run off; in the course of which, as room is seen to be made by the dissolution & expenditure of the first laid in Litharge, more of it intermixed with Coals as at first, is from time to time given to abt. the quantity of the first Charging before the Furnace is drawn, i.e. hath the Slag taken out of it previous whereto, much & frequent turning of it over in the Furnace with long Pokers is requisite that the whole of the Litharge may be exposed to the Fire, & the Lead it produces sufficiently drained from it. This and the Drawing are pretty laborious to the Workmen

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as is also the re-charging with Litharge.

In my letter upon Refining I observed that Lead was convertible into Litharge by a pure flame acting upon it & not otherwise; & also that Lead was not reproducible from Litharge but by some sort of fuel in substance (Coals commonly) being put in immediate contact with it; that at the instant of its fusion there was a communication to it from the substance of the fuel of an occult something, which in the Refining it had lost, but wch. by such communication was restored, and with it all its former properties as Lead: Agreable whereto if in the Process now before us no heat shd. be applied, but

that which is made to pass in flame upon it from the Fire place, in that case Litharge would indeed be found to be a fusible body; a long continued heat of the sort would liquify it, but then it wd. be only Litharge liquified or in the state in wch. it falls from the Refiners Test; a still longer continued heat of the kind might probably dissipate the whole of it in vapour, or in time vitrify it, but without a mixture of some sort of fuel in

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substance with it, no Lead would be obtained.

Having given an explanation of the reproduction of Lead from Litharge according to my Idea and conception of it, and which I hope will be satisfactory, I pass to the other mode of Process, viz. Hearth-Reducing, which varies from common Ore smelting only in a few particulars. An Hearth rather large & a soft blowing Bellows are judged suitable for Reducing, otherwise the form of the Hearth & the Machinery for both purposes are the same; as is also the kindling with Peats and the forming of a Brouse or Stock for the Hearth; but after that is formed, as the accumulation of Slag in the Hearth is not frequent perhaps not more than once in an Hour, being chiefly formed from the coal consumed, for no lime is used, and the Litharge itself having been once pure Lead, most of its substance is run down in Lead again; therefore the reiterated Watchings or Drawings-out of the Brouse for the discharge of the Slag, which in Ore Smelting are necessary, are not so in this Process, yet as the Lead runs expeditiously, the serving of the Hearth with Litharge mixed with Coal, which is almost

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incessant, keeps one of the Workmen pretty closely employed. as the wheeling in of the Litharge & Coals & casting, scumming & setting up of the Pigs of Lead & other serving do the other during their Shift or Fit of Working: the length or continuance of which depends much upon the management of the person who attends the Hearth, in keeping the Cast Irons which compose it and the Lead cool, that the one may not be wasted, as they are liable to be, by a want of care or judgement, & the other not suffer in its quality by being run too hot; however the Shift is generaly continued to the running 2½ or 3 Fodders of Lead.

To a common Observer, this last mode of Process would appear the more neat, the Lead may be obtained by it looking better, as to outside, than it can at all times be had from the Furnace, and yet I do not know how it happens, but we are assured that Furnace- reduced Lead has the preference in the Markets, from its being found the more soft I suppose. Perhaps some of the more gross or earthy parts of the Lead may be exhaled in vapour from the Furnace, or may be detained with the Slag in it, which by the action

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of the Bellows upon the fire are run off with it from the hearth; but then one would suppose that the deficiency in quality might be made up in quantity, which however we believe is seldom the case; for happening to have a person practised in Hearth reducing, we made as accurate an Experiment as possible, & found the Furnace preferable in point of produce, & therefore we continue the use of it.

By either way of Reducing Litharge some Slags are made, which tho' light being

mostly composed of Coal coked or cindered, as has been observed , yet contain some Lead, which is obtainable from them by their being run wth. a flux of Black Slags in the Slag Hearth. We have also another substance which we call Test-Bottoms, being Strata of the Ashes of which the Refiners Tests are formed, and which have absorbed a good deal of Lead in the form of Litharge, to an Inch & half or two inches in depth. These rise in Cakes from the inside of the Tests, are very ponderous, and tho' refractory, may with a large flux of free Black Slags, be run in the Slag Hearth, and the Lead they contain be reproduced from them. The

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Slags of Litharge, & Test Bottoms formerly were, & now are, at some Mills, smelted separately, but having made trial of smelting them together, we have found it not only practicable, but that by the associating them we could, at a much less expense of Cinders & in the wear & tear of Hearths, obtain more Lead from them than we could when they were smelted separately, and therefore we continue the practice.
Excepting the Lead thus obtained from these Slags & Test Bottoms, which in the course of a year is not an inconsiderable quantity, our loss of it by Refining & Reducing may be estimated at about One Twelfth upon an Average.

Having now, I think, finished all that has occurred to me upon the Art of Smelting &c. Lead Ore, I shall only take leave further to observe that having from the beginning been determined to write from experience & practice only, I have scrupulously avoided looking into any Author for assistance, even in the manner of expressing Sentiments that I was quite conscious were my own, having resolved from

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the time you put me upon writing on these subjects, that whatever you got from me, whether good or bad, shd. be as original as possible, and if in the course of the Work I may have fallen upon any Thoughts or made any Observations that are new & interesting, I shall then look upon the time that I have spent in it not to have been unprofitably employed.

[This glossary is found only in the version of the paper held by Wigan Archives Service as piece D/DZA/264.]

Explanation of several Terms made use of in the course of the foregoing Account.

Bruce or Brouse	A mixture of Lead Ore imperfectly reduced to Lead and Slag, Coal cindered or half Burned, and Lime.
Shift or Fit	Time employed by the Workmen in performing any particular piece of Work or Working Business.
Sump	A Cast Iron Pot to receive the Lead which comes from the Hearth.
Brangled	Intermixed
Shaddered Ore	Pieces of Ore from the Mine, pick'd out as clean, and carried to the Bingstead, Without undergoing the Operation of washing.
Sieve Ore	Ore made fit for Smelting by means of a Sieve.
Smithorn	A smaller kind of Ore derived from the Sieve Ore.
Slime Ore	The smallest kind of Ore, derived from the Smithorn.
Bouse	Large Pieces of Ore mixed with Spar &c. in the state they are, when they come out of the Mine.
Fodder of Lead	Twenty one Cwts.
Litrifyed	Converted into Litharge.
Quagginess	The undulatory Motion of Lead when in a state of fluidity.