Bulletin of the Peak District Mines Historical Society. Vol.10, No.5. 1989

VOYAGE METALLURGIQUE EN ANGLETERRE

Translation by Hazel Martell and Mike Gill

Ore preparation is a branch of mining which has been ignored by historians for too long. Despite growing interest, however, much material is inaccessible, having been written by foreign observers in their native tongues. The following translation, by Hazel Martell, with technical and historical advice from Mike Gill, was felt to be of especial importance because the original was prepared by graduates of the School of Mines, in Paris. Wherever possible, the text has been presented as a literal translation, except where repetition or usage rendered this undesirable.

The mineral processing section represents part two of the second volume, of an extensive study of mining and metallurgy in Britain, of which the section dealing with lead smelting in reverberatory furnaces has been translated and published by De Archaeologische Pers (1). The "Voyage" was jointly written by Pierre Armand Dufrenoy, Jean Baptiste Armand Louis Leonce Elie de Beaumont, Pierre Leon Coste and Auguste Perdonnet, following a visit to Britain in 1823. It was first published in the "Annales des Mines" between 1824 and 1827, and then published as two volumes in 1830 (2). The second edition, from which this translation is taken, was published in 1839 after correction and considerable augmentation (3). Nevertheless, it must be remembered that the techniques described are those in place during the 1820's.

SECOND PART

MECHANICAL PREPARATION OF LEAD MINERALS (DRESSING)

The operations to which the minerals in England are submitted to bring them to the necessary degree of purity for smelting can be divided into three classes:

1. The sorting and the cleaning of minerals.
2. The crushing.
3. The washing.

Before describing these operations we will make known the apparatus which according to the places and circumstances are employed there.

APPARATUS FOR SORTING AND CLEANING.

These are sieves, running-buddles, and grills.

No.1. The big sieve, used in Derbyshire at the exit of the mine for sorting the mineral into big and smaller fragments, is a trellis of iron wire of which the mesh is one inch square (4).

No.2. A lighter sieve, of which the trellis is similar to that above, but which serves to clean [page 537] the large and the smaller mineral fragments in a tub full of water.

No.3. Sometimes, in Derbyshire, instead of this last sieve being used, the mineral fragments are stirred with a shovel in a standing-buddle.

No.4. The running-buddle both cleans and sorts the mineral at the same time; it is a flat surface of flagstones or of planks, very lightly inclined from the back to the front and bordered on the back and sides by small walls, of which one, that at the bottom, has an opening which allows a current of water to come in. The mineral is stirred with a shovel on this buddle and exposed to the current of water. Formerly this apparatus was the only one employed to clean the mineral extracted from the mines of Alston Moor. It has generally been replaced by the following:

No.5. The grill or grate {This is the same as that used at Poullaouen (5), by the name of the English grate}. It is composed of square bars of iron, 0.03m in thickness, and 0.6m to 0.8m in length, placed horizontally and parallel to each other, with intervals of 0.03m between them. Above is a wooden channel, which carries a current of water; underneath is an inclined plane which leads to a hemispheric basin [page 538] about 0.6m in diameter, in which the metallic dust lifted by the current of water gathers together.

No.1. APPARATUS FOR BREAKING THE MINERAL.

A certain number of years ago, the bucker was the only instrument used in England to break the mineral (6). These buckers are formed of a plate with a base of 3 inches, which has in its lower part a loop, in which is a wooden handle. In the neighbourhood of Alston Moor, they have been replaced by crushing cylinders; but even today, in Derbyshire, the bucker is generally used to break the fragments of mixed mineral, which are called knock-stone-stuff.

In the mines of this county the knockers' workshop has a very strong stand, or a wall 3 feet high, behind which is a flat surface, a little higher than the wall top, and 4 feet deep; on this surface, bordered at the back and the sides by a little wall, the mineral which needs crushing is placed. On the stand or the front wall is placed a very strong stone or cast iron plate, 7 feet long, 7 inches wide, and 1.5 inches thick, called the [page 539] knock-stone. The workmen sit in front of the knock-stone, on which they crush the mixed mineral with blows of the bucker.

No.2. THE CRUSHING MACHINES.

The crushing machines are now generally used, in the neighbourhood of Alston Moor, for crushing the mixed mineral and are operated with great economy. They have been known there for 25 to 30 years (7).

This machine is composed of a pair of fluted cylinders y,y (fig.1, plate XV) and two pairs of smooth cylinders zz, and z1z1, which crush the mineral between themselves. The two cylinders of each of the three pairs turn simultaneously in opposite directions, by means of gear wheels m,m,m (figs.2 and 3) on the axle of each which engage each other. This movement is given by a single waterwheel, of which the circle, a,a,a, represents the exterior circumference. One of the fluted cylinders is placed on the end of the axle of the driving wheel, which has on the outside a toothed cast iron wheel, D, which engages with the toothed wheels e,e fixed on the axles of two of the smooth cylinders. Above the fluted cylinders is a hopper S, which, by means of a particular mechanism, feeds on to them the mineral which is carried by the waggons, A. These waggons roll on a wooden track to place themselves above the hopper, [page 540] and are discharged by means of a trapdoor which opens outwards in the middle of their base. Underneath the hopper is a little trough, called a shoe, down which the mineral descends to be thrown without cease on to the cylinders as a result of the continual shaking given to it by a rod of wood i (fig.3), which is attached there and supported on the teeth of the gear wheel m. The position of the shoe is controlled so that it never lets enough mineral fall onto the cylinders to overfeed them. A little stream of water arrives in the shoe and goes on to the cylinders and prevents them over heating. After having passed between the fluted cylinders the mineral falls onto the inclined planes n,n, which throw it onto one or other of the pairs of smooth cylinders. As can be seen, the cylinders, fluted as well as smooth, are the principal parts of this machine. They are made of iron and those with the smooth surface are turned with care. The axles move in the brass bushes fixed in the iron supports K, attached by bolts to the framework which serves as the base of the whole system. These supports each have a long slot, at one end of which is solidly fixed one of the boxes of one of the cylinders f, and in the rest of which slides one of the boxes of the other cylinder g - an arrangement which permits the two cylinders to be [page 541] in contact, or to distance themselves a small amount as necessary. This mobile cylinder approaches the fixed cylinder, by means of iron levers X, which carry at their ends the weights P, and which are supported on the corners M which can glide on an inclined plane N. These corners then press the iron bar O and make the mobile cylinder approach by pushing the bushes which support its axle. With this arrangement, if a very big and very hard fragment happens to present itself to one of the pairs of cylinders, one of them separates and lets it pass without the machine suffering any damage (8).

Outside the three pairs of cylinders which essentially make up each crushing machine, there often exists a fourth which serves to break the mineral which is not in large fragments, for example, the medium rich material and the chats and cuttings produced by the first sieving on the brake-sieve (see further on page 557). The cylinders which make up this accessory piece, and which, because of their most usual usage, are called chats rollers, are smooth and similar to the cylinders zz and z1z1. One of them is ordinarily placed on the end of the axle-tree of the waterwheel, on the opposite side to the principal machine, and the other, placed at the side, receives the movement from the first by means of a gear wheel [page 542].

No.3. The stamp mill is used concurrently with the crushing cylinders, its particular purpose being to pulverise the minerals whose gangue is too hard to be easily crushed by the cylinders, and still more often those which have already been reduced to a certain degree of fineness but nonetheless need to be broken more finely again. The stamp mills employed in the neighbourhood of Alston Moor are each powered by a waterwheel (9). They are rather like those we described in the mechanical preparation of tin.

SIEVING APPARATUS.

No.1. The hand sieve consists of a trellis of square mesh, made of interlaced iron wire, mounted on a circular body of 18 inches in diameter, on a length of 17 inches; the trellis has 58, sometimes 60, and even 72 iron wires. The workman holds the sieve in both hands, by means of two handles, and agitates and shakes it in a circular ore vat, sometimes keeping it in a horizontal position, and sometimes inclining it in many directions.

No.2. The brake-sieve is rectangular, as is the tub in which it is shaken. The trellis is made of strong iron wire [page 543] crossed over to form a square mesh of 0.375 inches. This sieve is suspended at the end of a forked lever (brake), turning on an axle by means of two vertical arms about 5 feet long, having holes by which they are assembled, by means of bolts, to the body of the sieve as well as to the ends of the two branches of the lever. The two arms are of flat iron, and the lever of wood: the latter gives the movement. A child positioned near its end jumps continually, making it move up and down in a lively manner which shakes the sieve suspended at the opposite end.

In Cumberland, M. Sentis, graduate mining engineer, has seen shaking sieves used in which the trellis was replaced by a cast iron grill of which the slots had a size of 0.125 inches. Movement is given to the sieve by an axle fitted with a crank handle, and this axle is itself set in motion by a waterwheel and a conical gear.

APPARATUS FOR WASHING THE MINERAL.

After the sieves, in washing the mineral, the running-buddle, described on page 538 No.4, is used and, in addition, the various boxes or buddles which follow. [page 544]

No.1. The trunk-buddle, which can be translated as a washing box, is a kind of German box composed of two parts: a trough or box into which a current of water flows, and a large pit, with a smooth, horizontal bottom. The mineral to be washed (or trunked) there is placed in the trough; the workman, armed with a shovel with curved sides, stirs it and from time to time lifts the biggest parts which stick there: whilst the lighter are carried away by the water and deposited in the next buddle.

No.2. The stirring-buddle, or box to clean the slimes, analogous to the German box, is also composed of two parts, namely: No.1. a trough or box which receives a current of water from a plug hole, which can be opened or closed, more or less, according to the force of current which one wishes to obtain; No.2. a pit with a smooth, horizontal bottom. The metalliferous mud or slime, is completely diluted in this water, which, when it runs out, deposits it on the surface; the purest parts are deposited first and gather together towards the top.

No.3. The nicking-buddle is analogous to the twin tables. It has, in its upper part, a transverse channel running the length of the table, in the middle of which is a plug hole through which the water arrives. At the side of this channel is a slightly inclined plank, called a nicking board, [page 545] corresponding to the head of the twin table, and above this latter, a flat and seemingly horizontal surface. The operation is carried out by taking a thin layer of slime on the nicking board and passing over the surface a very thin sheet of water, which, on going through it, divides itself into little currents which lift the slime little by little and deposit it on the lower flat surface in order of its specific gravity.

No.4. The dolly-tub (fig 5, 6 & 7, pl.XV) is fitted on a vertical axle carrying a flat AB (dolly); the whole is put in motion by means of the crank handle. This apparatus suspends the fine mineral, which is already almost pure, in the water; after which, when the water is still, the metallic parts separate themselves from the earthy parts. This separation is helped by banging on the sides of the tub during the precipitation; this keeps the earthy matters suspended without stopping the metallic parts.

No.5. The slime pits. In the diverse operations of cleaning, crushing and washing in which a current of water is used, it is impossible to prevent some of the lightest particles of galena which have been suspended in this water from being carried away with it. To recover them there are labyrinths, called buddle holes in Derbyshire, slime pits on Alston [page 546] Moor, into which the water goes after having been used. These are placed a little distance from where the operations already described are carried out.

The basins are about 20 feet in diameter and from 2 to 3 feet in depth. When the stream which escapes from the crushing machine, the washeries, or other washing apparatus, enters the slime pit, the mineral which is suspended in it falls little by little to the bottom, and the water which becomes almost clear again, is allowed to escape.

SORTING AND WASHING OF LEAD.

1. IN DERBYSHIRE.

In Derbyshire, the mixture of stony matter and galena; which is extracted from the mines, and which goes by the name of bowse, is discharged, at the exit of the workings, onto the striking-floor, by a workman called a striker, who also sorts the fragments into three categories, according to their size.

A. The biggest, called knockings, are separated by hand; the rest is put on the sieve (described on page 537) as a result of which one obtains the other two divisions.
B. Those which stay on the sieve, called riddlings or picking-stones. [page 547]
C. The soily bits, which pass through the sieve, are called fell and are put to one side in a heap called the fell-heap.

The mineral "a", called knockings, is taken to a place called the bank, where a workman, called the banksman and armed with a sledge hammer, breaks them and sorts them in the following manner:

A' Solid mineral taken to the bingstead.
A" Fragments composed of stony matter and mineral, more or less intimately mixed, of the size of a walnut: these are taken in this state to the knockers whose job is to crush them more finely.
A'" Fragments consisting only of stony matter, which are rejected.

The pieces "B", which remain on the sieve and which are called riddlings or picking stones, are given to the swillers or pickers, who begin by cleaning the mud off them. For this purpose they use either a sieve (page 537 No.2) or a trough called a standing-buddle (page 538 No.3). In the first instance a certain quantity of riddlings is placed on the sieve and agitated in a tank full of water; in the second, the riddlings are thrown into the trough, which is also full of water, and stirred with a spade. In each case, the mineral fragments are cleaned of the mud which was attached to their surface, and this falls to the bottom [page 548] of the washing water. In this state they are carried onto a table, where the women, called pickers, proceed to sort them into three lots, as follows:-

B' Solid mineral.
B" The mineral to be taken to be broken (knock-stone stuff).
B'" Mineral to be rejected.

The first is taken to the bingstead in the ore-coe.

The knock-stone stuff, which is entirely made up of fragments with a mixture of stony matter and mineral, is taken to the knockers' workshop.

This series of operations divides the mineral into four lots as follows:-

A' & B'	Solid mineral.
A" & B"	Knock-stone stuff.
C	Fine mineral which passes through the sieve.
A'" & B'"	Stones to throw away.

We will see later, on page 553, which operations the second and third lots undergo.

2. IN CUMBERLAND.

Around Alston Moor in Cumberland the cleaning and sorting is generally carried out [page 549] on the grill which we have indicated on page 538 No.5.

The broken mineral (bouse-ore) is placed on the grill in such a way as to receive the current of water which is brought in the channel. There it is stirred with a rabble and, as much by the effect of their own weight as by the action of the current, all the little parts called currings pass through the grill and gather in the basin underneath, while the grill retains all the fragments the size of a walnut and over. The workers lift these fragments and break those of differing richness, dividing them into four lots.

1. The mass of mineral which appear pure.
2. Little clumps of mineral which are a little mixed.
3. Mineral which is very mixed with stony matter.
4. Stony matter, entirely denuded of mineral. This last lot is rejected.

If the fragments of quite pure mineral which form the first lot, are too big, they are crushed with hammers and then carried to the bingstead.

The fragments of slightly mixed mineral, which constitute the second lot, are carried to a particular workshop where they are crushed with an iron beater, until they are no bigger than a big hazel nut. The mineral thus [page 550] crushed is washed in the running-buddle or on a sieve. It is then carried to the bingstead. The fragments in which galena is quite mixed up with the stony matter, and which are called knockings, must go through a crushing and a complete washing. If the little parts (cuttings) which have passed through the grill, are sufficiently rich,they are carried directly to the sieving shop; if, on the contrary, they are very poor, they are brought to a more suitable state by being passed through a crushing machine or by being crushed with blows from a bucker.

By various operations, the bouse is divided into four parts; namely:

a. Lumps of rich ore, ready to smelt.
b. Mixed mineral, ready to be crushed.
c. Rough mineral, in fine parts; destined, according to its richness, to be directly sieved or to be crushed again more finely.
d. Waste or rejects, which are thrown away.

LEAD CRUSHING IN DERBYSHIRE.

1. IN DERBYSHIRE.

In Derbyshire, the fragments of mineral (knock-stone stuff), resulting from [page 551] operations "a" and "b", already reduced to the size of a big walnut, are crushed by a bucker; known to the work people as knockers, whose workshop has already been described (page 539 No. 1). Sitting in front of the knockstone, they use a little board to lead a certain amount of mineral which is broken to pea-size and forms a pile at their feet. The mineral thus crushed, "d", is called knock-bark and is passed on to the washers.

2. IN CUMBERLAND.

On Alston Moor, the fragments of mineral "b", which are very mixed up with stony matter and which, after cleaning on the grill, form a separate lot in the sorting, are first of all, when they are very big, broken by blows from a hammer, until they are no bigger than an egg. They are then taken to the crushing machine or grinder, where they are greatly pulverised. After this they are taken to the sieves.

After that operation, which includes the small parts which passed through the grill but were too poor to be delivered directly to the sieves, the rough mineral is divided into three parts, namely: [page 552]

a' Mainly mineral, good enough to smelt.
b' Mineral to be sieved; coming from the crushing of minerals "b" & "c".
d. Rejects.

SIEVING AND WASHING OF LEAD.

1. IN DERBYSHIRE.

In Derbyshire, mineral D (knock-bark - page 551) and mineral C (fell), which were put to one side at the exit of the mine (page 548), are first of all sieved in a hand-sieve, described on page 543, No. 1. The washer, after placing a certain amount of one or other of the minerals in his hand-sieve, plunges it partially into an ore-vat, nearly full of water, where he stirs it by shaking to bring the stony parts and in general all the light substances to the surface. These are then removed with a little board edged with iron, known in English as a limp, and in the mines of Brittany as a lime. The first matter thus removed, called fleet or fastage, does not contain a trace of galena and is rejected. The second, called toots or rounds, richer than the first, is put to one side to be rebroken on the knock-stone. After having charged the sieve several times with new mineral "D", [page 553] a considerable quantity of mineral which can be considered pure is obtained at the bottom of the sieve. The biggest pieces are found in the upper part, whilst the finest form a bed which collects on the trellis of the sieve. The upper part, called peasy-ore, is then removed and taken to the mineral shop or heap, called the peasy-heap, while the bedding of fine mineral, which covers the trellis of the sieve and makes the subsequent sievings easier, is carefully saved. It is especially useful in the operation which follows.
During sieving, many small parcels of mineral and stony matter pass through the sieve and gather in the bottom of the tank. When it is two-thirds filled with them, the water is allowed to run gently and the sediment (smitham) is taken out and put in a heap. Water is again poured into the tank; a child then takes the smitham deposit uses it to charge the sieve which once more conserves a bed of fine mineral on its trellis. The siever stirs and

shakes it in the water almost like the first operation. From time to time he uses the limp to remove the light matter which comes to the surface. This matter, which is no longer fit to be washed in the boxes, is called buddlers-offal, and is thrown into a hole called the buddle-hole. The mineral which accumulates [page 554] ceaselessly on the trellis of the sieve, is removed from time to time and thrown into the tank, into which during this operation also fall the very fine particles of mineral, as well as some small stony particles. When all the deposit removed from the tank has undergone this sieving, the mineral thus obtained is cleaned by one last operation.

This operation, called buddling the vat, consists of stirring the water round in the tank, with a spade, and gathering the mineral in a heap in a corner of the bottom, from where it is taken it with a short-handled spade, called a groove-spade. Afterwards it is carried to the mineral shop, where it forms a particular heap, called the smitham-heap. The mud, which the washing water carries in suspension, is received in a hole called the buddle-hole, which serves as a receptacle for all the very minute particles, such as the sweepings and the mud which again contain a little mineral.

These very fine particles can no longer be put to profit except by a new series of operations called buddling which is carried out by means of a small current of water and involves two kinds of boxes: a jagging-buddle and a trunk-buddle. As a result of these operations, which are much like those which take place in the neighbourhood of Alston Moor, and which will be described after this, come two new kinds of mineral [page 555]. The best or biggest is called hillock-ore or pippin, and the finest, which is to all effects powder, belland.

2. IN CUMBERLAND.

For a long time the hand-sieve was the only one used in the mines of Alston Moor, but it has now generally been replaced by the shaking-sieve. There is only one instance in which the first of these sieves is used today; this is for the cuttings which have passed through the grill, and which, whilst not being poor enough for it to be necessary to begin by crushing them finer, they are nevertheless too poor to be sieved with advantage in the shaking-sieve. They are simply passed through the sieve, with no intention of producing any other effect than that of separating the fine parts from those which cannot pass through the mesh. When a sufficient quantity of the latter has collected, a workman takes a round hand-sieve, loads it with them and stirs it circularly in the water of a tank, with much speed and skill, until he attains the separation of the very poor parts, called cuttings, and the parts mixed with pure mineral, called chats. He removes these first two lots with a wrought iron scraper, called a limp, and finds [page 556] underneath a certain quantity of mineral, which can be regarded as pure. The separation of the cuttings and chats would not be so well effected on a brake-sieve as on a hand-sieve, because the former always remains horizontal; whilst the washer, in agitating the second, nearly always holds it in an inclined position.

With this particular exception, all the sieving is carried out, in the neighbourhood of Alston Moor, by the brake-sieve, described on page 543. As soon as the sieve is loaded with mineral, a child placed at the end of the lever begins to shake it by jumping. Each shake, not only makes some of the fine mineral pass through the grill, but also changes again the respective positions of those which remain on the trellis. As a result of this brusque and speedy agitation, the purest and heaviest parts go towards the bottom where they become concentrated. Above these are found the fragments of mixed galena and stony substances, called chats, and in the upper part the lightest, completely poor pieces, called cuttings. First the latter are removed with the limp, then the mixed pieces, or chats, and finally the pure mineral which is taken to the bing-heap [page 557].

The cuttings are handed over to a group of workmen, who, by a new sieving, divide them into seconds cuttings (which are entirely poor stones) and mixed mineral, similar to chats, which undergoes the same treatment.

The poor mineral, hereafter called chats, is taken to the crushing-machine, where it is crushed again between two rollers especially designed for this purpose (chats rollers), or, in default of this, between two ordinary smooth rollers, which crush it as fine as a similar machine could do. After this it is sieved again, giving results similar to those of the first.

By these different operations are obtained:

Pure mineral (sieve-ore) of which the size varies from that of a big pea to that of a big broad bean;
Rejects, which are thrown out;
Fine matters, the treatment of which is described below.
These are the small particles of mineral which, after passing through the grills of the sieves, collect in the bottom of the tanks. On Alston Moor, this deposit is called smiddum. When a tank contains a certain amount of it, it is removed to be washed in a

running-buddle (page 538), firstly by [page 558] a stream of water strong enough to perform this operation. The washer is provided with a rabble which he runs round the sides of the smiddum heap at its highest part, in a way which retains the particles of purest mineral at the top of the buddle, whilst the poorest and the lightest, called smiddum tails, are carried away towards the base. Those which are extremely fine follow the current of water and are only deposited in the slime-pits, in which the water stands before leaving the washing shop. When the smiddum has undergone two or three operations of this nature, or an even greater number according to circumstances, the part which stays near the top of the buddle in the final operation is to all intents and purposes pure and is taken directly to the bingstead. The smiddum tails which have been carried towards the lower part again contain a considerable quantity of mineral, but they are mixed with so much stony matter and clinging mud, that they have to undergo two new operations before pure mineral can be extracted from them. They are taken to a kind of German box, called a trunk-buddle in Cumberland (page 545 No. 1). Here they are put in a compartment at the upper part of the table, into which a strong current of water flows, and they are stirred with a shovel. The [page 559] biggest grains of mineral and of stony matter are deposited there by the water and are continually removed and made into a heap apart, while all the fine particles, mineral as well as stony matter, are carried away and deposited on the horizontal base of the lower hole, at distances which depend on their richness. Those which contain the most mineral are deposited towards the top, whilst those which contain very little are carried towards the bottom by the water. The operation continues until the interior of the table or hole is full of this matter, then the water is stopped until the table has been emptied.

The mixture of mineral and stony matter which has been removed from the box at the head of the table, in which all the smiddum tails have been stirred with a shovel, contains particles of galena, lead, pyrites and stone of almost equal size. The galena is separated from these by the following method.

The washer places a layer of fine sievings, called bedding, about two inches thick on the trellis of the sieve to prevent the fine mineral passing through too quickly. Above this bed, a certain quantity of the above-mentioned mixture is loaded and, with the help of a lever, the sieve is stirred in the ordinary manner, but very gently. [page 560] By virtue of their specific weight, the mineral particles separate out of the mixture and enter the bedding through which they descend slowly to fall into the tank, where they are contaminated by only a small quantity of substances which are near their specific weight. All the rest stays above the bedding, from which it is easily separated with the limp and taken to the washers of very poor matter. This rather delicate operation is called letting in. If the bed which covers the sieve is well prepared and the sieve is working well, the mineral which falls into the tank is ordinarily pure enough not to need any further preparation other than being passed once through the running-buddle, in order to be cleared of any fine particles of earth with which it might still be contaminated. After that, it is taken to the bingstead.

The unequally rich deposit (page 559) in the lower hole, is divided into three parts, as follows:

a. That deposited near the head.
b. That deposited towards the middle.
c. That deposited towards the bottom.

This last part, which only contains a very small portion of mineral, is given over to the washers of very poor matter, who wash it again, as described below, until [page 561] they have extracted all the mineral which can beneficially be obtained. The other portions, "a" and "b" are washed again separately, in the same box, in the following manner:-

The washer, standing with one foot supported on each side of the box, takes in his shovel (scoop) a certain quantity of mineral, which he spreads across the length of the breast board of the box, on which the sheet of water flows. The contents of the shovel are carried off by the water little by little and deposited at the bottom of the box. At the same time, a child, situated at the bottom of the box, runs a wooden rabble from the the middle to the top and the bottom to the top of the surface of the material which is deposited there. This prevents the mineral escaping and also maintains a firm, smooth surface on the deposit, which contributes to the steadiness of the operation. It is repeated on the same mineral once or twice, or even more times, until the mineral is pure enough for its preparation to be completed in the dolly-tub.

To use of this apparatus (Pl. XV, fig. 5, 6 & 7; page 546), the tank is refilled with water to a certain height and the vertical plank, called a dolly, is placed in it. The dolly is turned rapidly in such a way as to set the water moving in a circular manner. During this time, slime-ore is poured in little by little and agitated [page 562] until there is sufficient quantity of it. As soon as all the mineral is perfectly distributed in the liquid, the vertical plank, or dolly, is pulled out. The workmen then hit the boards of the tank for quite a long time with hammers or big pieces of wood, to make the mineral fall to the bottom. The lightest particles of mineral, that is, those which consist almost entirely of waste matter, only fall when the banging stops. Then the water is run out and the extremely poor mud which forms the upper part of the deposit is removed and thrown away. At the bottom of the tank pure mineral is found and this is removed and taken to the bingstead, after which the operation is repeated. This manner of treating slime is very good, because it makes the mineral purer and allows less of it to be lost than by any other method. Also, by this means, the blende which always accompanies the galena is very well separated.

Because the mixture is much more considerable, there is greater difficulty in extracting the mineral by washing from the fine particles, called cutting-smiddum, which passed through the sieve when the poor particles from the first sieving were resieved, than from the fine mineral, called bouse-smiddum, which results from the first sieving. The mineral obtained (from the cutting-smiddum) being less pure, it is ordinarily sold at 20 shillings (25 fr.) a [page 563] bing less than that obtained from bouse-smiddum.

In order to wash the very poor mud, c, called cuttings-smiddum, obtained (page 561) in washing about the deposit boxes of the sieving tanks, the mud is first cleaned in a cleansing box, called a running-buddle, as has already been said, and the mineral which is obtained in the compartment in the top part, is subjected to the process called letting-in. The mineral which is carried by the water and deposited on the surface of the running-buddle, is called sludge. It is extremely fine and can no longer be treated in the previous (ie. aforenamed) box, but is washed successively on two new tables, called the stirring-buddle, (running-buddle for mud (page 545 No.2)) and the nicking-buddle, which is kindred to the twin tables (page 545 No.3).

In the stirring-buddle, the sludge, removed from the trunk-buddle, is submitted to the action of a stream of water until the biggest part of the foreign matter has been carried towards the lower part of the box, and the remainder has acquired the adhesiveness of slime. In this state, it is removed and taken to the nicking-buddle.

On this last table (page 546), the slime is placed in very small quantities on the inclined plane which forms the head, and a flow of water is run onto the surface where it divides into [page 564] a large number of little streams, which break against the grooves left in the mineral by the workman's shovel. The entire mass of mineral is soon carried away across the length of the inclined plane, as far as the table, at the bottom of which, the different particles are deposited in the order of their specific weights. From time to time, the washer, when he is not occupied with spreading out new mineral on the inclined plane, flattens the surface of the deposit with his shovel, in order to make it firm and smooth, a condition which is necessary to make sure nothing escapes. A similar portion of slime undergoes this operation several times until a sufficient quantity of rich mineral is obtained from it. This is finished off by washing in the dolly-tub, the use of which has already been sufficiently explained.

The deposits which form in the slime pits are very thick and very sticky; also, when one wants to wash them in the ordinary apparatus, one is always obliged, before taking them to the nicking-buddle, to agitate them with clean water in the stirring-buddle. This partially destroys the strong adhesion the different parts have for one another on leaving the slime-pits, by separating from them a considerable quantity of fine mud and clay. The washing is finished off in a dolly-tub [page 565].

These procedings are not followed when the first form of basins are used.

COST OF MECHANICAL PREPARATION.

In Cumberland, the workmen employed in mechanical preparation are paid for piece-work and not for the day. A certain quantity of unrefined mineral is delivered to them and they are paid for their work at the rate of so much per bing, a measure containing 1400 kilogrammes (10) of mineral ready to be smelted, which they obtain. The price varies according to the richness of the mineral. Certain portions are washed at the rate 2 shillings 6 pence or 3 shillings (3 fr. 10c or 3 fr. 75c) the bing, whereas others cannot be less than 8 shillings (10 fr.).

The richness of the mineral varies from 2 to 20 bings of galena by shift of mineral. The shift contains 8 waggons.

DISTRIBUTION OF WATER.

A sufficiently strong stream of water, taken from another, slightly stronger, one, falls on the grill, which is generally placed a short distance from the horse level, which also serves as the adit, so that the water coming from the mine is used. The two preceding currents then unite, to drive a big waterwheel which is in a lower position and which drives the crushing machine and the shaking sieves. Near the latter are the smiddum-buddle, trunk-buddle etc, and lower down the deposit basins. The water needed for washing is, as can be seen, easily [page 566] detached from the side stream to the washery. The railway from the haulage gallery extends as far as the grill, and then continues in such a way as to link the latter with the crushing machine.

Not having exact data on the richness of the washed mineral, or on the quantity of galena in granules or in concentrates which are obtained, we could not express a positive opinion on the perfection of this kind of mechanical preparation, or compare it with those used in Saxony or Britanny. Nevertheless, according to what we know about the beauty of the concentrates, the richness of the scraps and the quantity of matter washed daily in the different countries, we believe we can make the following observations:-

1. In Cumberland, the cleaning and sorting of minerals are carried out with care and promptness. These operations, entirely kindred to those of the mines at Poullaouen, appear to us inferior to the cleaning on the tiered grills of Saxony, an operation which, at the same time as it cleans the minerals, has the advantage of classifying them into lots of different size.

2. The breaking and crushing by means of a crushing machine is much more expedient than that done by beaters, and not only does this machine have the advantage of bringing forth a greater economy in the cost of breaking, but also it considerably diminishes [page 567] the loss of galena because minerals which have been stamped are often put through the cylinders and part of them is carried away by the stream of water escaping from the stamp.

The crushing machine also replaces with great advantage the dry stamps used in some establishments, most notably at Huelgoat. One must, therefore, consider the introduction of cylinders as one of the most successful innovations which have been made in mechanical preparation.

3. The shaking sieves appear to us to be preferable to the hand sieve (11). To be certain of this, it would be necessary to compare experiences, which we have not been able to do; but it appeared to us that the quantity of mineral submitted to the shaking sieve was bigger than that sieved by hand in the same amount of time, without injuring the purity of the granules obtained.

4. The system of washing commonly used in Cumberland differs essentially from that used in Britanny. In Cumberland, all the gravels produced by the stamps, a part of those coming from the crushing machine, and the deposits called schlamms [mud] in Germany and France, are washed on tables known as the trunk-buddle and the stirring-buddle, which are kindred to those called German boxes. [page 568] Only some extremely fine deposits are washed on the nicking-buddles, and these muddy deposits have already been cleaned on the first kind of table. In Britanny in contrast, the German tables are intended only for the deposits from sieving and the very large gravel from the stamp. All the fine deposits are washed on the twin tables, of which the slope is very slight and on which no more than a thin wave of water is allowed.

5. The settling tanks are constructed with much less care than in France or Germany. Never, in the latter, do they have these long returns on themselves, which have been given the name of labyrinths. This form is probably the reason why these final deposits, which are washed with advantage in France and Germany, could not be so in Cumberland. There is reason to believe, nevertheless, that the introduction of shaking-tables would permit the collection of the deposits which are neglected at the moment (12).

From what we have said about the system of washing and the settling tanks, it can be seen that the system used in Cumberland is more speedy than that used in Britanny, but also that it gives a less pure mineral and that it occasions considerable losses. These losses are proved, [page 569] since there is often an advantage in taking the waste up again and submitting it to a new preparation.

Nevertheless, we dare not rebuke this method, because, in this country, with fuel being at a very low price, and labour on the contrary very expensive, it is possible that there is a greater advantage in smelting the less pure mineral and losing some parts of the galena, than in increasing the number of washing operations.

6. Finally, the apparatus which we have called the rinsing tank, and which in English is called the dolly-tub, appears to us to need to be adopted in those places where the galena is mixed with much blende, because we have seen some concentrates which appeared very clean to the eye, and yet from which a considerable quantity of blende was separated by stirring it in this sort of tank.

THE METHOD OF MECHANICAL PREPARATION IN YORKSHIRE.

The method of mechanical preparation in Yorkshire is very much like that which has been adopted in Cumberland but, as there are a few slight differences, we will describe them in a few words. As at Alston Moor, on leaving the mine, the minerals are placed on a grill, with bars about an inch apart, onto which a stream of water falls.

Product "A" is obtained on the grill and a product "B" underneath it. Product "A" is separated by hand, on a small [page 570] table, into three new products of which a' and a" are crushed separately by a crushing machine. Product "B", underneath the grill, is sub-divided into B1 and B2. B1 forms heaps nearest the grill, and B2 is made of finer parts, which are carried to a greater distance by a stream of water. A small vertical board separates them. B1 is passed to a shaking sieve, B2 is rejected or, if the mineral is rich, it is cleaned.

The crushed mineral is carried to the head of a kind of cleaning table, which is divided into two compartments. The mineral which stays in the upper compartment is passed to a shaking sieve, while that which is deposited in the lower compartment is washed in a German Box, known as a nicking-buddle, which is similar to those used in Cornwall for copper. Washing in the nicking buddles also takes place in the same manner as in Cornwall. Sometimes, when the deposit in the lower channel is very impure, they begin by cleaning it.

When a portion of mineral not originating from the crushing machine is passed on to the shaking sieve, three products are obtained: rich; average, which is sent to the crushing machine; [page 571] and finally an inferior product, which is also sent to the crushing machine.

The part which goes through the cleanser and the product which is deposited at the top of the cleaning chest are passed to the shaking sieve again, whereas the mud is rejected. When the minerals which are to be crushed pass to the shaking sieve, the upper part of the layer which remains on the sieve is ordinarily sent to the stamps, which reduce it to powder. It is divided thus into a grainy part, which is washed in the German boxes, and slime, which is cleaned or rejected. If, after being washed in the German boxes, the concentrates do not appear rich enough, their purification is finished off in a dolly tub. An iron spindle with vertical wings is placed in the centre of the tub and turned with a crank handle. Then, after a certain time, it is removed and the mineral is allowed to deposit itself.

CRUSHING MACHINE.

At the time of our stay in Grassington a crushing machine was constructed which we were able to examine in all its details, and of which we will give a description (13).

The mineral is poured by a hopper onto the first pair of fluted rollers, from where it falls onto a pair of smooth rollers, then onto a mobile sieve which separates it into two products.

The cylinders are all 14 inches in [page 572] diameter and 14 inches long. They are driven by a waterwheel 25 feet in diameter and 3 feet in working width and, by means of a proper gearing system, they all receive the same speed.

The cylinders are supported on a mounting, or vertical frame, of cast iron. Fig. 9, plate XV, is the section following NN' (fig. 8) of the framework A: mn are the slotted parts to which are fixed a means by which the pins travel to the edge, as indicated in figure II, following section rs (fig. 9). The cast iron pieces I and K go between the slots and support the brass bushes which serve as supports to the axles of the crushing cylinders. The parts I are supported in a manner which cannot slip in the slot. The parts K, on the contrary, are free.

Two projections P are each pierced with a hole which receives a spindle around which can turn a lever L (fig. 10). The extremity B of this lever is charged with a weight P, and the other extremity C, rests against one of the parts K (fig. 9), thus the cylinders F & E or G & H press one against the other with a force which depends on the effect of the counter-weight. The advantages which result from this arrangement are evident. Not all the pieces of the mineral are of equal size and they can be mixed up with stones of a greater hardness which would dislocate the machine if [page 573] the cylinders were fixed, whereas, with an apparatus like that we have described, one believes that experience must shortly show that the counter-weight is most advantageous and causes the machine to give the best product. In effect, in using it, a finer material is obtained, but it is necessary to use a greater force and the cylinders wear out more quickly.

All the cast iron frames are carried in a frame of wood.

They have assured us that this machine could crush a tonne in four or five minutes (14).

The waterwheel, which drives it, also drives the wet stamps which are used to crush the hardest materials. Above all, these crushing machines appear appropriate for replacing the dry stamps, but they do not appear convenient for every kind of mineral. The harder and less rich are generally stamped in water.

END OF THE SECOND PART.

The rest of page 574 onwards is the metallurgical treatment of lead minerals (viz smelting) which has not been translated

NOTES.

1. Coste, P.L. & Perdonnet, A.A. Smelting of lead ore in reverberatory furnaces as performed in Great Britain (1830). Ed. Alex den Ouden, De Archaeologische Pers, Eindhoven, 1986.

2. P.A. Dufrenoy 1792-1857; J.B.A.L.L. Elie de Beaumont 1798-1874, P.L. Coste 1805-1839 and A. Perdonnet.

3. The National Union Catalogue, pre 1956 imprints, Vol. 124 Cortissoz, R. to Counihan, N. page 335.

4. Gough, J.W. The Mines of Mendip, David & Charles, Newton Abbot, 1967, pp. 147-150. A lawsuit, bought by the Society of the Mineral and Battery Works, in 1582, to enforce patents claimed by William Humfrey, indicates that wire sieves were used in Derbyshire and the Mendip from the mid 16th century. See also: Kirkham, N. Derbyshire Lead Mining Through The Centuries, Bradford Barton, Truro, 1968, p. 74f.

5. Poullaouen is in Brittany.

6. Buckley, J.A. Tudor Tin Bounds West Penwith. Dyllansow Truran, Redruth, 1987, p.66. Stamps were used on British mines from at least 1493, when a stampyng mylle was recorded at Treneer Wolas, near Helston, in Cornwall. This precludes their introduction by German miners, as is generally claimed, in Elizabethan times. (See: Collingwood R.G. Elizabethan Keswick, 1912, Reprinted by Michael Moon, Whitehaven, 1987). Later references to stamps show that the technique became established by the late 16th century (Carew, R. Survey of Cornwall, 1811 Ed. p39). They were also recorded at Cymsymlog and the silver mills near Talybont (Pettus, J. Fodinae Regales, London, 1670). It is interesting that Hooson's Miners Dictionary has no entry for stamps, suggesting that, despite his claim to have over forty years experience at the mines in the High and Low Peaks in Derbyshire, Shropshire, south and north Wales, and the north of England, he was unaware of them. Hooson, W. The Miners Dictionary 1747, reprinted by the Institution of Mining and Metallurgy, London, 1979. The richness of most lead ores, and the friable nature of most gangues, probably served to restrict the use of stamps to crushing the black slags derived from smelting.

7. Taylor, J. Notice On Some Improvements In Dressing Ores, Quarterly Mining Review, No.11, 1831, pp. 82-87. This would place their introduction around 1800, agreeing with Taylor's theory of their simultaneous adoption in the north and the south-west; where he claimed to have made the first use of roller crushers for copper ores at Wheal Crowndale, near Tavistock, in 1804.

8. An example of a roller crusher may be seen at the Earby Mines Museum, at Earby, Lancashire. This was recovered from the Old Providence Mine, at Kettlewell, in Wharfedale, where it had been built in 1866/67.

9. Raistrick, R. & Jennings, B. A History of Lead Mining in the Pennines. Longmans, 1966, p. 137. The London Lead Company built stamps, in 1737/8, at its Jeffrey's and Acton smelt mills, near Blanchland, Northumberland. By May 1741, others had been built in Swaledale, probably at the High (Old) Moulds Mill, which were visited by the Grassington Barmaster, Solomon Bean, and Stephen Barrat (Bolton MSS Grassington Mines Dues 1735-1743/Grants 1735-1753). In 1742/3, stamps were added to the Buckden Low, or Birks, smelt mill (Raistrick MSS R/131-133).

10. This is an error, a bing of 8 hundredweights equals 406.21 kilogrammes.

11. John Taylor made great use of mechanisation at the Grassington Mines. For a general discussion, see: Gill, M.C. "The Mechanisation of the Grassington Mines, Yorkshire" British Mining No.25, NMRS, Sheffield, 1984, pp. 45-50. Taylor was appointed as the Duke of Devonshire's Mineral Agent, in 1818 , and instigated a modernisation programme at the Grassington Mines, part of which was the mechanisation of mineral processing. Captain John Barratt, one of Taylor's appointees, was moved from Wheal Friendship, in Devon, and

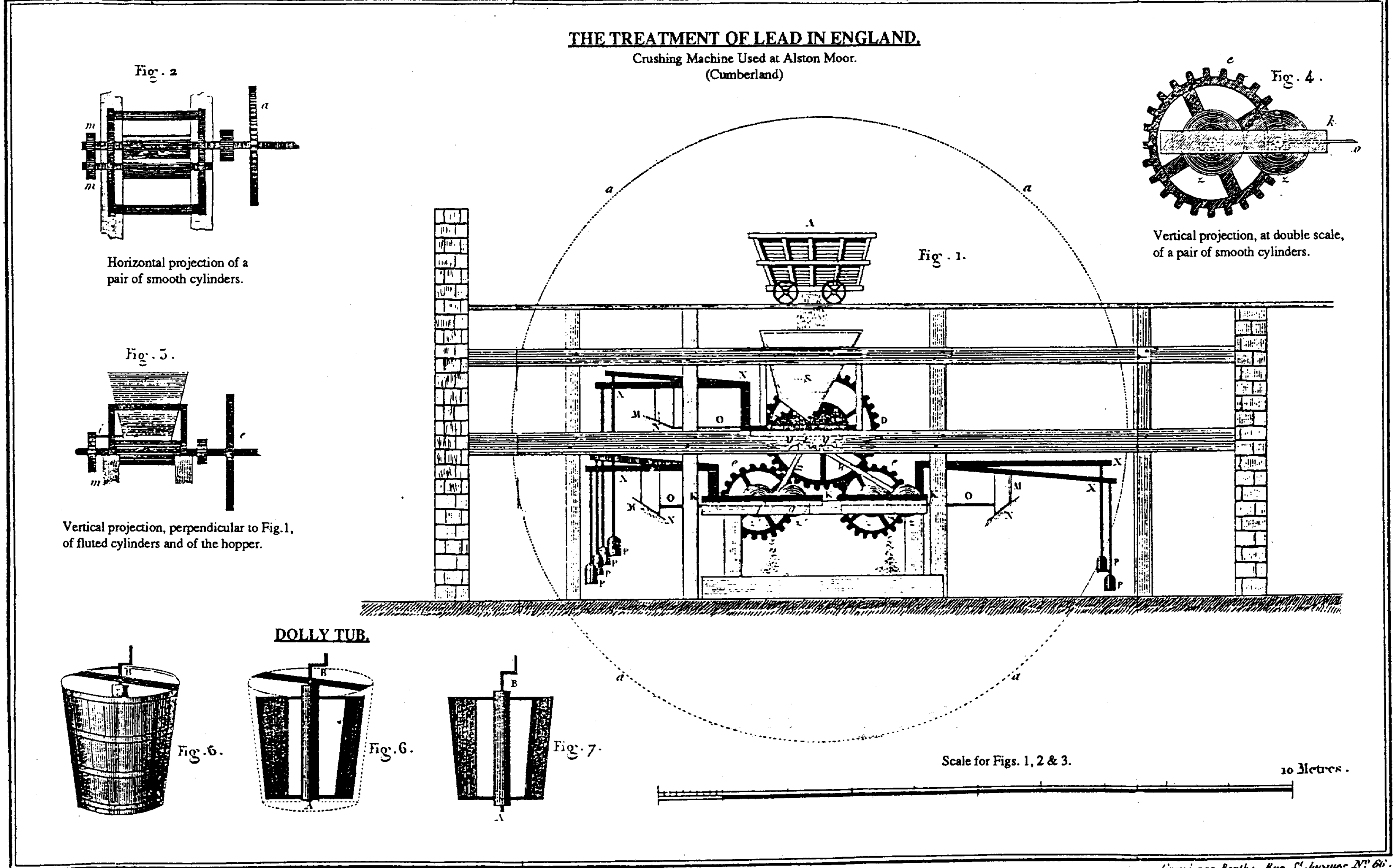
he was responsible for the plant seen by the French students. He also arranged for several sieves, suspended in water, to be worked by one small waterwheel and Taylor wrote of it that "the effect is excellent, and the expense of the process is so much reduced, that very poor work is returned with profit, that would not have paid upon the old plan". Taylor, J. "Improvements".

12. Raistrick, R. "Ore Dressing in the eighteenth and early nineteenth centuries", Mine and Quarry Engineering, May, 1939. A type of shaking table was installed, by Robert Stagg, at the London Lead Company's Nenthead Mines in 1828. Unlike later tables, however, the concentrate was confined to the table, where it was allowed to form a bed six inches in thickness before being removed. Burt, R. British Ore Preparation Techniques in the eighteenth & nineteenth centuries. De Archaeologische Pers, Netherland, 1982, p. 67. Draws attention to Stagg's table but continues; "Credit for the development of the shaking table is usually given to the German, Ritter von Rittinger, who during that decade (the 1840's) devised a percussion table..". Nevertheless, it is clear that both gentlemen were anticipated by the French development.

13. This diagram is not included but it is very similar to the machine used at Alston. The Low Grinding Mill, at Yarnbury, was built in 1824, when it was equipped with a crushing machine, and, by the summer of 1826, a stamp mill had been incorporated. The Coalgrovebeck, or High Grinding Mill, on Grassington Out Moor, was commenced in Autumn 1825. It too had a crushing machine and, in the autumn of 1830, stamps were added.

14. Phillips, J.A. and Darlington, J. Records of Mining and Metallurgy. London, 1857. p.123. An analysis of 18 crushing mills shows that the size of the crushers used at Grassington had increased and that the rate of crushing was then claimed to be 80 tons per 10 hours.

Plate XV referred to in the translation above was not bound in with the French volume used, but an almost identical version was found, numbered as Plate VII in another edition and is reproduced here with the captions translated into English.



THE TREATMENT OF LEAD IN ENGLAND.

Crushing Machine Used at Alston Moor.
(Cumberland)

Horizontal projection of a pair of smooth cylinders.

Vertical projection, perpendicular to Fig.1, of fluted cylinders and of the hopper.

Vertical projection, at double scale, of a pair of smooth cylinders.

DOLLY TUB.

Scale for Figs. 1, 2 & 3.