BRITISH MINING No.61

MEMOIRS 1998

Smith, R. & Murphy, S., 1998
"The Jenkin Furnace at the New CB Mill, Arkengarthdale, Yorkshire"
British Mining No.61, NMRS, pp.91-100

Published by the

THE NORTHERN MINE RESEARCH SOCIETY
SHEFFIELD U.K.

ISSN 0309-2199

THE JENKIN FURNACE AT THE NEW CB MILL, ARKENGARTHDALE, YORKSHIRE

by Richard Smith and Sam Murphy

SYNOPSIS

In his book on the Smelting Mills of Swaledale and Wensleydale, Raistrick referred to a patent double reverberatory furnace which was to be erected at the New CB Mill in Arkengarthdale. The furnace was novel in that the heat from the smelting hearth was used for roasting ore in a second hearth, situated in tandem. Considerable doubts have been expressed by subsequent authors as to whether the furnace was ever installed at the mill and there has been a general view that the project was abandoned at a fairly late stage. This paper reports the construction of the furnace and the results of the smelting trials, together with a technical appraisal and discussion of the siting of the furnace within the mill.

The installation of the Jenkin double reverberatory furnace at the New CB Mill, Arkengarthdale, Yorkshire, has aroused interest ever since it was referred to by Raistrick in the Appendix of his book on the Smelting Mills of Swaledale and Wensleydale.[1] The furnace was novel in that the heat from the smelting hearth was used for roasting ore in a second hearth, situated in tandem. Raistrick's description was taken from a broadsheet issued without date by the Patent Office and traceable to Patent No.906, April 23rd 1855.[2] Since then, several authors have referred to Raistrick's account, but most have questioned whether the furnace was ever built.

Tyson says that there is no evidence for installation of the Jenkin Furnace, but quotes the description of the furnace in the *Mining Journal* of 1858.[3,4] In the latest detailed assessment of the New CB Mill, Myers and Whitaker refer to both the 11/08/1855 and 4/12/1858 articles in *the Mining Journal*, but conclude that there is no evidence for the installation of any furnace in the south room and that the Jenkin furnace project was abandoned before the project was completed - possibly for financial reasons.[5] They have established that the extension to the south room took place after the first O.S. map survey of 1854 (published 1856) on the basis that the mill is shown as symmetrical on this, but not on later versions. Gill avoided the issue.[15] Earlier authors, Backhouse and Clough, have not referred to the furnace. [17,18]

HISTORY

A search of the *Mining Journal* for the years 1855 to 1858 revealed more detail which has apparently escaped attention and which settles the question. This shows that the furnace was actually built and operated at the New CB Mill, although it is not known if it was abandoned soon afterwards.

The furnace was first announced in the *Mining Journal* in an article on July 14th 1855 with the information that a furnace was "*to be erected at Arkindale*

near Richmond".[6] In the next issue, the following advertisement by Jenkin appeared and was republished in most issues until November 17th 1855:[7]

> *IMPORTANT TO LEAD SMELTERS - the INVENTOR is PREPARED to CONSTRUCT, upon liberal terms a DOUBLE REVERBERATORY FURNACE capable of making a saving of 50 per cent. FUEL over that of the best constructed furnaces in Europe; at the same time guarantees the general loss in smelting not to exceed 5 per cent.*
>
> *The inventor after 20 years experience both in England and various parts of the Continent, has discovered the method, in the regular course of smelting, and without any extra cost, of separating antimony from a certain class of silvery-lead ore, thereby rendering the lead free of all impurities, and, at the same time, the antimony in a marketable state - All applications to be addressed to the inventor, MR ALFRED JENKINS, Eyam, near Bakewell, Derbyshire. One of the furnaces will be at work by the end of the present month. A descriptive notice of the invention appeared in the Mining Journal of July 14th.*

This was followed in the issue of the *Mining Journal* Supplement on August 11th with a larger article and drawing of the furnace, similar to that published by Raistrick, with the information that:[8]

> *....The inventor and patentee has pleasure in informing the trade generally, that he is now putting in his first furnace on the new system in England at the C.B. Mines in Arkendale near Richmond, Yorkshire, where they have hitherto employed daily six ore hearths, this well-known mining and smelting company feeling convinced that it is high time to do away with the present extravagant mode of smelting - A. Jenkins, Eyam, Derbyshire.*

The *Mining Journal* of August 15th announced that the furnace would be completed and working in about one week and that a saving of 50% on fuel was expected.[9] On August 25th an extravagant report revealed:[10]

> *DOUBLE REVERBERATORY FURNACES - We understand that Messrs. Jenkin and Burgoyne have completed one of their furnaces, which on being tested, proved superior to the anticipations of the Arkendale Company, and even to the expectations of the patentees, inasmuch as they contracted to make the bottom of the hardest iron slags, commonly called puddle slags, being those proceeding from the cast-iron, on its being manufactured into malleable iron, and pledged that from the commencement of the melting of them to the finish, and which operation required nearly 20 tons, should be performed within a week; and with 10 tons of coal. The company at once offered to give their attestation for the public, but we understand*

that was declined until every process of smelting the ores have been effected, as the patentees wish is particularly to prove the high capabilities of their furnace in every part, before making any public statement repeating it.

This was followed by three months of silence, apart from the classified advertisements which, by mid-September, were included in alternate issues and finally stopped completely after November 17th. The response in the readers' letters of December 14th was almost predictable:[11]

LEAD SMELTING - Sir, I have looked very anxiously for a descriptive result of the trial of Jenkin's Reverberatory Furnace, which you informed your readers was erecting in the north of Yorkshire. Will any party concerned give the lead smelting community a faithful account of what it has done, and if Mr Jenkin has succeeded in carrying out what his advertisement sets forth? Being concerned in some lead smelting works, I have no other object in making enquiry than to improve our operations as much as possible - VERAX.

These authors are unable to guess the identity of *'Verax'*. However, there was an immediate response:[12]

An experimental trial of Jenkin's Double-Reverberatory Furnace is being made at the Arkendale Company's Works when its capabilities will be thoroughly tested. Mr Thos. Burgoyne, of Eyam will superintend the operations and forward the results for publication in the Journal. How near an approach there will be to the sanguine assertions of the patentee will be determined in a few days, and should there be a close approximation, then no doubt we shall recognise one of the most important inventions of the age. The coaling of reverberatory furnaces being so large an item in costs, 50 per cent. reduction becomes a consideration, and the loss of lead made by many furnaces being 8 or 10 per cent, a 40 or 50 per cent. saving thereon, if accomplished by this invention, will (adds our correspondent) ensure for it a welcome reception in every part of the mining world.

The publication of the results of the trial was made in the next issue:[13]

JENKINS DOUBLE-REVERBERATORY LEAD AND COPPER FURNACE - The result of a trial of this invention on 1594 cwts of ore; of a rather poor class, averaging from 68 to 70 per cent. is a produce of lead scarcely up to 60 per cent, 59 4-5ths being the nearest representation. Although the new bottom was not calculated to take much lead, being superior in that respect to anticipation, we may add that in this statement nothing is allowed for any amount of absorption by it, although the first charge of ore is included in the 1594 cwts. The oxide collected in flues attached to ordinary ore hearths, the flues

extending for (say) two fifths of a mile, would average from 2½ to 3 per cent; and the oxide or soot from reverberatory furnaces, having a similar length of flue is not inconsiderable - consequently, allowing for that the bottom is so perfect as not to absorb lead to a considerable amount; the point for further consideration is the amount to be added to the above per centage for oxide in the flue dust, regarding which each practical smelter will form his own opinion. We have reason for believing that some features in the furnace will be modified, and that a yet further increase in the saving of fuel and lead or copper will speedily be effected.

The furnace clearly did not return the same yield of lead as the ore hearths which the company operated. Losses as flue dust or as absorption by the hearth are given somewhat lamely as possible reasons, but there is no evaluation of their relative proportions.

Jenkin's whereabouts are uncertain after this, but on April 23rd 1858 he took out a second patent (No.901) under an almost identical title. This made slight modifications on the original one, principally by providing a cast-iron bottom to the calcining furnace under which the heat could pass, and it was claimed that the heat would be sufficient to melt only soft ores, and to calcine the rest. The address of Jenkin on this patent was given as Carrick Mines in the County of Dublin. The location of the Carrick Mines has not been conclusively identified, but we are informed that this is, in fact, a literal translation of a place name meaning 'the rocks on the little plain'. Although some ore was mined there, it is more important as the site of the Ballycorus smelter, where the Mining Company of Ireland smelted lead from its mines at Luganure in Wicklow. The smelter was expanded substantially in the first half of 1858 at a cost of £1,200, for which the services of an experienced consultant could well have been used. Much of the cost was accounted for by the extension of the flues and erection of a new chimney and so it is not known if a second Jenkin furnace was built in Ireland.

There are no references to the furnace in the index of the 1856 *Mining Journal* or in the first three issues for 1857, but in the issue of December 4th 1858 there is a short article introduced as follows:

DOUBLE REVERBERATORY FURNACE - In the Journal of Aug. 11th 1855, we published an illustrated description of a double reverberatory furnace introduced into this country and patented by Mr Alfred Jenkin, the furnace having been long previously known and used on the Continent, where it had given universal satisfaction. Amongst the patents recently granted we find a second patent has been obtained by the same gentleman, his experience at the smelting works of the Mining Company of Ireland having enabled him to make some trifling modifications which expedite the processes of calcination and reduction.....

The article then describes the design and working details of the second patent.

Jenkin was described as having 20 years' experience as a smelter in England and Europe in 1855, and Gill refers to Jenkin in his monograph on the Grassington Mines as coming from Cornwall, in July 1838, to become the Duke of Devonshire's smelting manager at Grassington cupola mill, until July 1847, when he was succeeded by Thomas Humphrey from Wales.[15,16] One of the 1855 accounts in the *Mining Journal* refers to him as being *"formerly of Swansea"*, although his address in July/August of that year is Eyam in Derbyshire. The address on the 1855 patent is *"Zell on the Moselle in the Kingdom of Prussia"*.

From the 1858 article in the *Mining Journal*, it is probable that in the course of his work in continental Europe he had heard of or seen the double reverberatory furnaces which were used in South Germany and which may have given him the idea for his patent. The ones described by Percy had one hearth above the other and appear to have been used in much the same way as two single reverberatory furnaces. Jenkin may have come across a local practice or proposal to use the upper furnace as a roasting hearth and to discharge this through into the smelting furnace beneath.

TECHNICAL APPRAISAL

The 1855 patent has clear drawings and a description of the method of operating the double reverberatory furnace shown in Fig.1.[2] Heat is provided from coals in the firegrate (F) of the smelting furnace (C). When the roasting furnace (E) is in use, the dampers (G,G) are opened, allowing hot gases to pass through at two positions to give a good distribution of heat for roasting. At the same time, dampers (H,H) are closed. When the roasting furnace is no longer required, dampers (G,G) are closed and (H,H) are opened and hot gases are passed downwards through the flue (I) to an underground flue and then away. The smelting and roasting furnaces are charged with material through hoppers (M and K), and the roasting furnace is emptied into an underground vault through an aperture (L) in the centre of the hearth. Aside from the arrangement of dampers and the tandem configuration of the two furnaces, the design follows conventional lines as far as the diagram shows, although the hearth profile of the smelting furnace is unclear.

There are three very obvious comments on the concept of the double furnace.

1. Considerable heat is required for the smelting furnace which has to run at about 900-950^{o}C with a moderately reducing atmosphere. Far less heat is required for the roasting furnace which would work at 700-750^{o} C with an oxidising atmosphere and where there is an exothermic reaction. It is difficult to see how the fuel savings could have been anything like 50%, as these were based entirely on eliminating the fuel requirement for the roasting furnace. The roasting reaction is sufficiently exothermic that in modern fluid-bed roasters no heat input is required once the furnace has

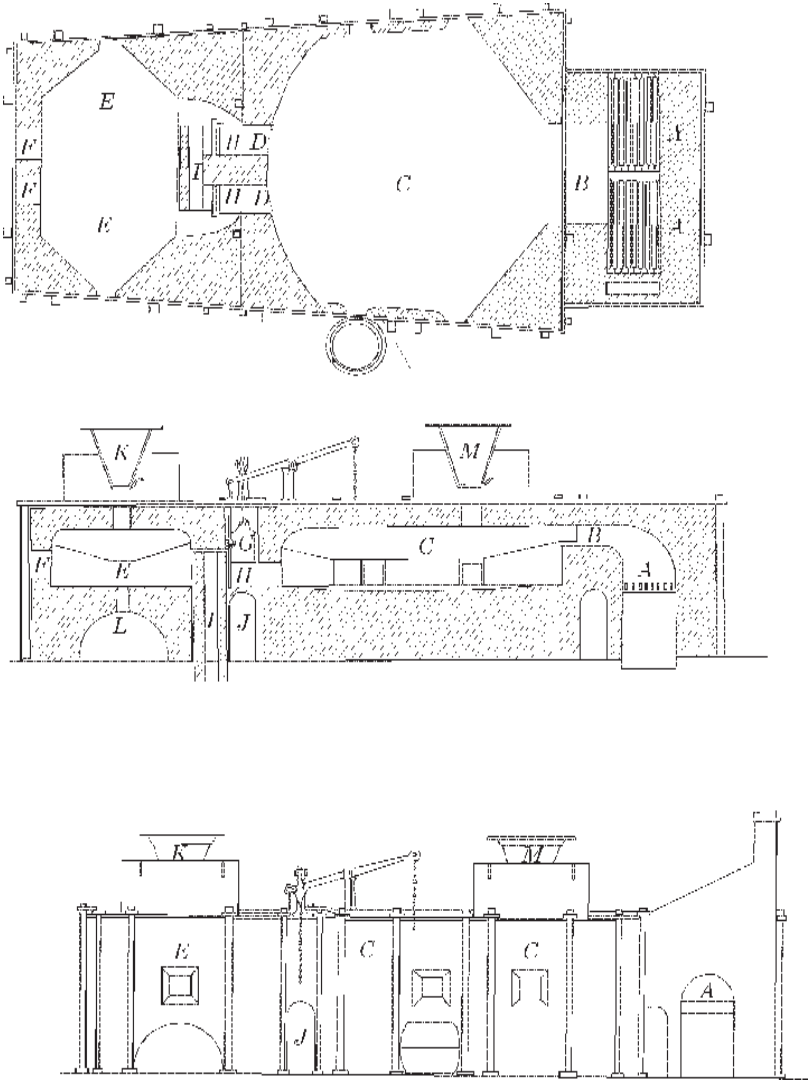

Fig. 1

reached operating temperature. In multi-deck roasters very little supplementary heat is required. The fundamental concept from the aspect of fuel saving seems flawed.

2. Because the gases from roasting have very little oxygen present (these should be a mixture of CO, CO_2 and nitrogen), some air has to be admitted,

presumably through the two inspection doors which are not ideally placed for this. The objective is to oxidise any carbon monoxide and produce a atmosphere of CO_2, O_2 and nitrogen. However, this reaction is exothermic and so even more oxygen must be added to cool the gases in order to operate at the lower temperature required for roasting. If this is not done, the ore will fuse to form a lumpy mass and the roasting reaction will come to a halt. The ultimate effect of adding air will be to produce a linear gas velocity through the furnace several times that of a conventional roaster. This can be expected to induce very high losses of fume and dust and this would certainly account for a large part of the poor yield experienced at the New CB Mill.

3. Because the additional air can only be introduced through the inspection doors of the roasting furnace, the first half of this furnace is subject to a hot reducing atmosphere which can hardly be expected to lead to good roasting. This can be overcome by transferring charge between the two parts of the furnace. Not only would this be very hot, unhealthy work, but it would also produce even higher losses unless the gases were diverted.

Some of this could be improved by diverting only some of the gases into the roasting furnace. Although this is possible, however, it would be very difficult to control if fuel savings were to be maintained. It is difficult enough to control a single reverberatory furnace fitted with a thermocouple to give the required oxidising or reducing conditions and still maintain fuel economy - it is all too easy to keep the damper wide open and have the fire roaring away. Take away the thermocouple, put together two furnaces with opposing atmosphere requirements, add a complex series of dampers and the result would become a control nightmare.

Jenkin's second patent described a similar concept, but most of the gases were passed under the roasting furnace shown in Figure 2.[14] The roasting furnace's hearth was replaced by a cast iron plate to allow some heat transfer from below and the roofs of both furnaces were concave in one direction, but convex in the other, to direct the flow of hot gases on to the hearth. A cast iron water-tank was placed under the roasting furnace in order to generate steam, which, on condensing, would precipitate fume particles in a long flue. The evaporation of water would also cool the flue gases and improve the collection efficiency of a long flue. Collection devices based on the implication of fume with droplets of water are generally regarded as being ineffective because of the high kinetic energies required to give impact and coalescence. Jenkin's system was subtly different and relied on the fume particles acting as nuclei for the subsequent condensation of water. The large particles thus formed will settle more rapidly in a long flue. The main drawback to such a system is the high heat transfer rates through the walls of the flue, which are required to give adequate condensation. As long flues were normally covered with earth, they can be regarded as fairly efficient heat insulators and, once warmed up, would not be very effective.

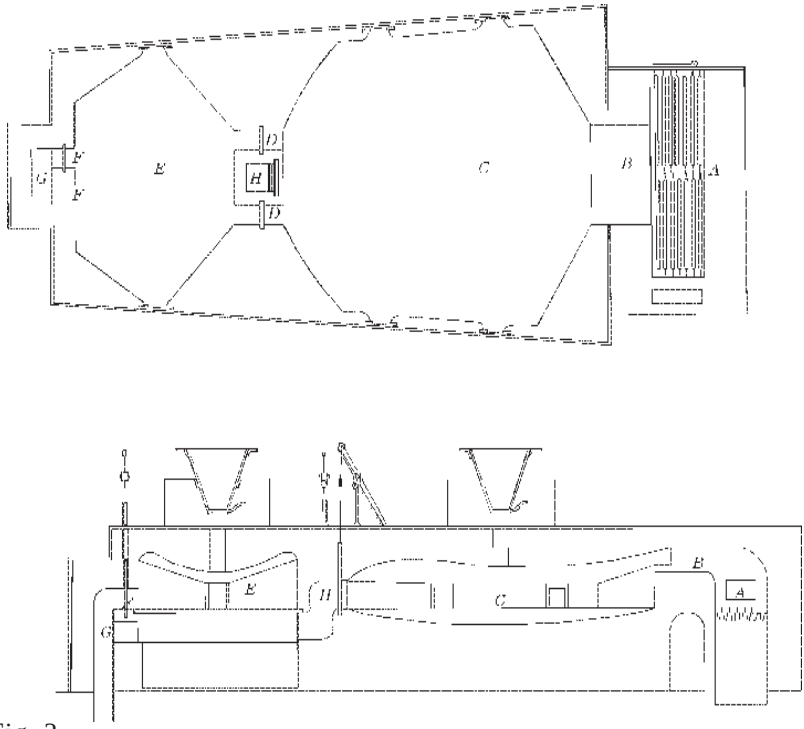

Fig. 2

These alterations would have overcome many of the objections raised above. The arrangement of dampers was such that control of temperature and atmosphere would have been improved and the problems of balancing the several process parameters would have been made much easier. Whether the saving of fuel for roasting would have been worth the additional complexity is questionable, as is the durability of the cast iron hearth. Other questions also arise. For example, although we have found no relevant information in the North Yorkshire County Records Office at Northallerton, was the furnace persisted with in Arkengarthdale? Was it installed in Ireland or elsewhere? Was it ever used in the copper industry? Perhaps future research may give answers to these questions - but certainly the advantages were not what they appeared to be at first sight and the Jenkin furnace was never adopted for sulphide metallurgy as a standard item of equipment.

INSTALLATION AT THE NEW CB MILL

The expansion of the south smelting room at the New CB Mill has been discussed in detail by Whitaker and Myers and is referred to above.[5] Now that the construction of the furnace at the mill has been established, it is natural to speculate on the position of the furnace.

The space requirements for a reverberatory furnace are much greater than the 'footprint' of the furnace alone. In addition to this, sufficient space must be allocated for working the furnace. In an ideal situation, this is determined by the position of an operator with a long rabble reaching to the far wall of the furnace. If a bar (sometimes known as a 'lazy bar') is used to support the rabble, this is usually placed at the door of the furnace and, to be most effective, should be near the centre point of the rabble handle. To this must be added the length of the rabble after withdrawal. The length of the rabble, therefore, effectively determines the working space needed and, although it is possible to make do with smaller dimensions (if the building roof is high or there is a convenient window or door), a well-designed reverberatory furnace house will conform to these criteria. (It is worth noting that the roasting houses at Beldi Hill, Surrender, Prosperous and Cobscar Mills appear to meet or exceed these dimensions).

The extended south smelting room of the mill meets these requirements (Figure 3). The width of the room (in an E-W direction) is determined by the space occupied by the three ore hearths and allows sufficient space for a reverberatory furnace to be worked as outlined above. Assuming the length of the furnace was similar to that in the broadsheet reported by Raistrick, the extension of the room in a southerly direction is sufficient for the furnace axis, plus a metre or so around the end of the firebox for general access. The extension of the room appears to be exactly that needed to accommodate the new furnace. The exit flue could have been easily connected into one of the ore hearth flues and the neighbouring flues sealed up. As the long flue effectively consists of two flues running side by side, one would expect little

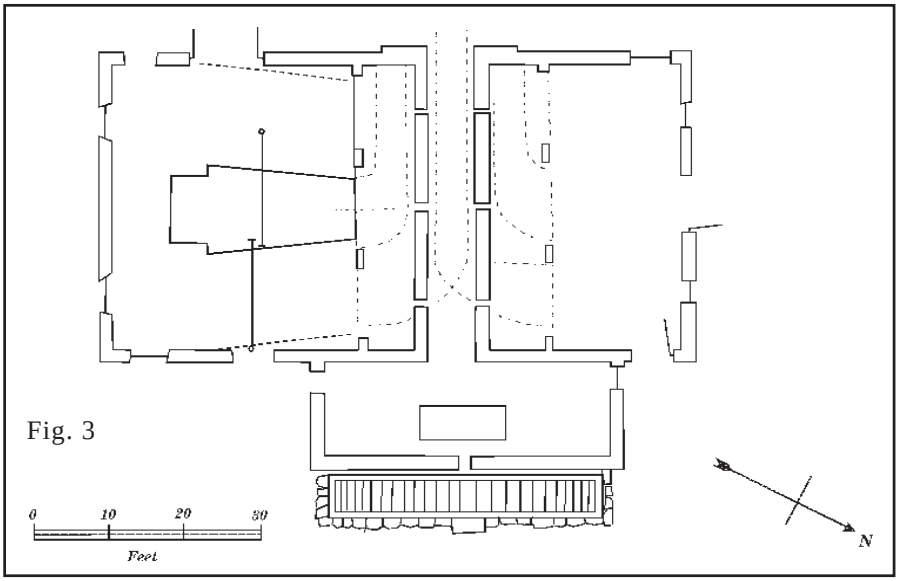

Fig. 3

interference between the draught of the Jenkin furnace and that of the ore hearths situated in the north room of the mill.

Had the Jenkin furnace not been installed in the south room, it is difficult to see where it would have gone on the New CB Mill site. It is possible that one of the outbuildings on the Octagon Mill site just across the road could have been used, although the internal construction of the mill itself would not have permitted a large reverberatory furnace.

REFERENCES

1. Raistrick, A. *The Lead Industry of Wensleydale and Swaledale - Vol. 2 The Smelting Mills* (Buxton: Moorland, 1975).

2. Jenkin, A. "Improvements in Furnaces for the Reduction and Calcination of Lead and Copper Ores", Patent No.906, April 23rd 1855.

3. Tyson, L.O. *Arkengarthdale Mines* (Keighley, British Mining No.53, 1995), p.69.

4. *Mining Journal (MJ)*, Vol.XXVIII, December 4th 1858, p.807, Col. 3.

5. Myers, J.O. and Whitaker,T.M. "The C.B. New Mill in Arkengarthdale – Some Photographic Evidence" *British Mining* No.48 (1993), pp.34-46.

6. *MJ* Vol.XXV, 14/07/1855, p 445.

7. *MJ* Vol.XXV, 21/07/1855, p 463.

8. *MJ* Supplement, Vol.XXV, No.1042, 11/08/1855, p.513.

9. *MJ* Vol.XXV, No.1043, 15/08/1855, p531.

10. *MJ* Vol.XXV, No.1044, 25/08/1855, p.543.

11. *MJ* Vol.XXV, No.1058, 14/12/1855, p.774.

12. *MJ* Vol.XXV, No.1059, 18/12/1855, p.795.

13. *MJ* Vol.XXV, No.1061, 22/12/1855, p.829.

14. Jenkin, A. "Improvements in Furnaces for the Reduction and Calcination of Lead, Tin and Copper Ores", Patent No.901 April 23rd 1858.

15. Gill, M.C. "Yorkshire Smelting Mills, Part 1: The Northern Dales" *British Mining* No.45 (1992), p127.

16. Gill, M.C. *Grassington Mines* (Keighley: British Mining No.46, 1993) p.133.

17. Backhouse MSS, Central Library Leeds, Microfilms (MIC 622.344 B127) and photocopies (F622.3444 B12Y).

18. Clough, R.T. *The Lead Smelting Mills of the Yorkshire Dales* (Keighley: The Author, 1962).

Paper submitted - July 21st 1997:

Dr Richard Smith
New House,
Spring Lane,
Cold Ash,
NEWBURY
Berkshire
RG18 9PL

Dr Sam Murphy,
The Corner House,
The Green,
TANWORTH IN ARDEN
Warwickshire