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THE NEWNAM HEARTH FURNACE

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Lead ore smelting in an ore hearth has long been practised in the industry with increasing success, culminating in the Scotch Hearth furnace which was used up to the Second World War. Eventually, the introduction of the high capacity blast furnace, capable of treating low grade ores, caused the shut-down of most of the hearth furnaces.

The blast furnace, whilst being a high producer of bullion, required a high degree of skill on the part of the operators, greater than any other type of furnace. The consequences of faulty blast furnace practice invariably meant hammering away at the lost tuyeres for hours to regain the furnace - 'muscular metallurgy' as it is called, or 'Armstrong's formula'. At worst, if the furnace failed completely, a long and expensive shut down occurred, resulting in lost production and recriminations.

Between the war years many attempts were made to up-date the old hearth furnace and it was the advent of the Newnam Hearth that gave a further extension of life - about thirty years - to the smelting of ore in the hearth.

ORE HEARTHS

The smelting of lead ore in the hearth is based on two reactions;-

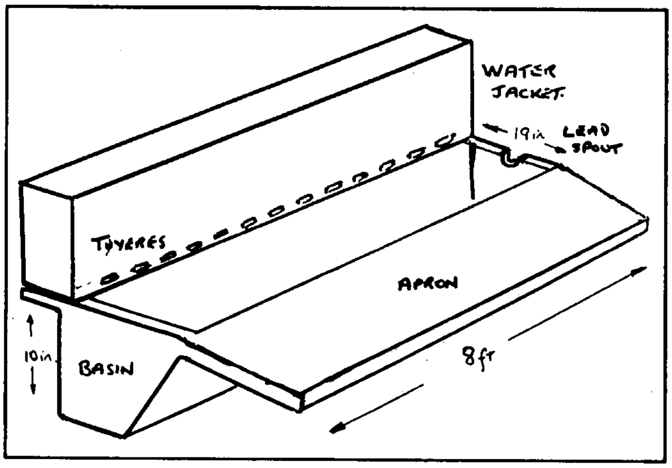
1. The roast reduction reaction, wherein lead sulphide(galena) reacts with lead sulphate and lead oxide to form lead.
2. The reduction of lead oxide by carbon (coke breeze) or carbon monoxide to give lead.

These reactions are amazingly complex in the process and have given rise to many different sets of chemical equations, none of which were understood by the average foreman, least of all by the furnace operator.

The function of the hearth was to transform the lead ore and the coke breeze into fume, SO_2, hearth slag and lead, all disposed of immediately from the operation. The fume settled in the flues and the baghouses where it was collected, mixed with the lead concentrates and treated in the hearth. The SO_2 went straight through the gas trail (ie. the flue system and the baghouse) and emerged via the stack into the atmosphere. The hearth slag which contained a proportion of lead reported to the blast furnace for removal of lead. The lead from the hearth and the blast furnace needed only a small amount of refining for the market.

Ores suitable for hearth treatment contained at least 70% lead (pure galena contains almost 87% lead). Silica and iron, especially iron pyrites, were harmful. Lime and magnesia in small quantities helped the slag formation, but fluorspar was harmful, giving a fluid slag which prevented the roast reaction. Zinc ore was not unduly harmful in small quantities but as the zinc reported (ie. goes to) to the slag and then to the blast furnace, an enraged blast furnace foreman explicitly asked why the ore operators persisted in filling the blast furnace shaft with zinc accretions, usually the death knell of the blast furnace. Copper traces were allowed but over 2% tended to foul up the ore slag and caused accretions in the ore basin. Arsenic and antimony in small amounts increased refining time and costs, plus giving rise to dross that had to be recycled.

During optimum operation of the hearth, approximately 80% of lead was extracted and 15% of the charge mix was produced as slag. This slag contained between 25 and 40% lead, about 10 to 15% of the lead in the charge mix. Ore hearth smelting gave a great deal of fume, approximately 35% of the ore mix charge. containing about 65% lead, mainly as sulphate. However, the fume was recycled with the charge and, being sulphate, helped with the roast/reduction reaction. When the charge or the hearth were giving operational trouble, there was an inclination to leave out the fume addition from the mix. The residual fume would then grow by frightening amounts and required vigilance and discipline to reduce to manageable proportions.



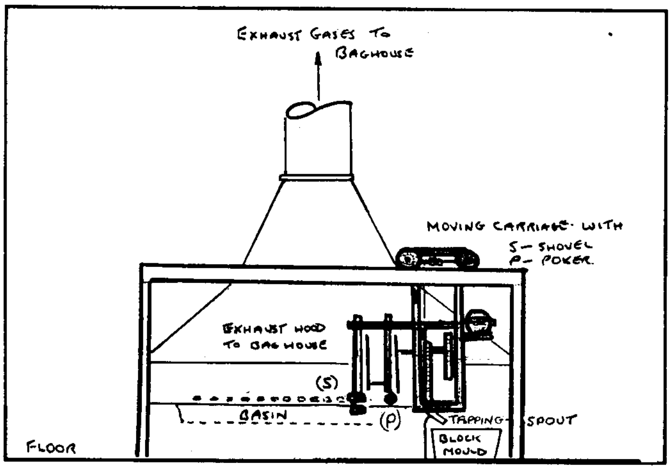


Fig. 1 (top). Basin, Apron and Tuyere housing.

Fig. 2 (left). Front view of hearth and moving carriage.

Fig. 3 (opposite centre). The action of the poker.

Fig. 4 (opposite bottom). The action of the mechanical shovel.

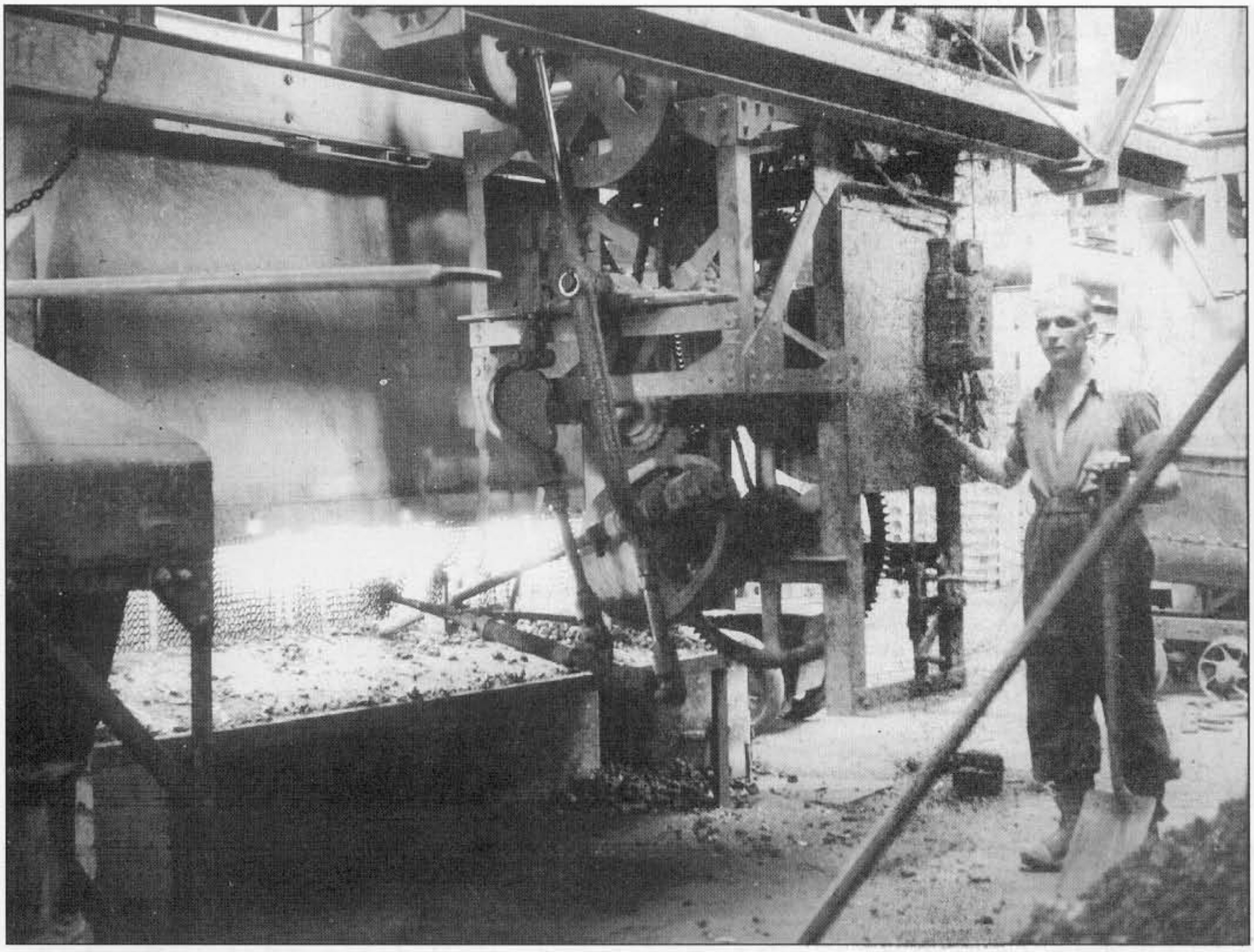
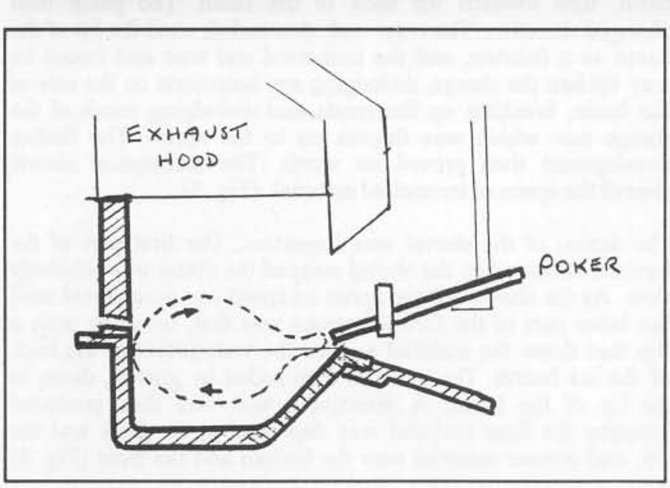
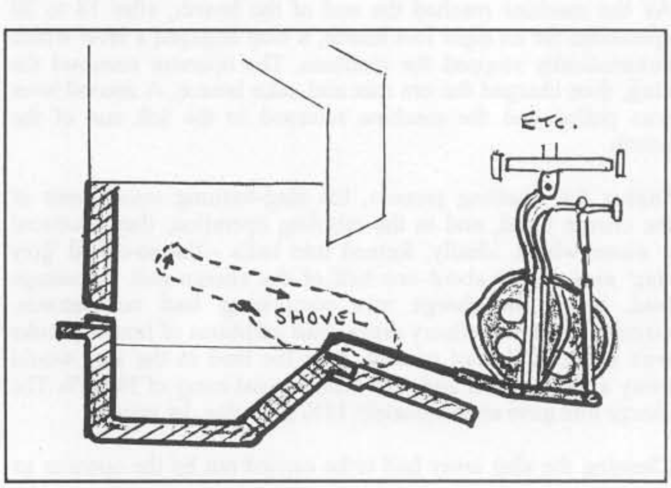


Fig. 5 (above). The front of the Newnam Hearth at Enthoven's, Darley Dale, March 1950.





THE GENERAL ARRANGEMENT OF THE NEWNAM HEARTH

The hearth was essentially a cast-iron trough with an apron running along one side and along the opposite side was a water-jacketed housing containing the tuyeres through which a blast of air issued to smelt the charge (Fig. 1). The basin held a bath of molten lead and had a syphon or spout at one end for removing molten lead into containers at intervals. An overhead rail that carried the mechanical poker and the mechanical shovel ran the length of the apron, the action of the mechanism replicating the action of an operator in poking the charge to expose it to the blast and shovelling the spillage off the apron. The action of the mechanism in travelling along the rail looked like something from Heath Robinson (Fig. 2) .

A steel hood carried away the fume to a balloon flue and then to cooling tubes which conducted the exhaust gases to the baghouse. A further canopy ventilated the front of the hearth and theoretically the natural draft cleared any fumes from the apron and maintained a curtain of air between the working face of the hearth and the operator.

The charge was tipped in front of the hearth and the operator carried out the five steps of the process:- charging, rabbling, sorting, shovelling back, tapping lead. A complete cycle lasted approximately 4 minutes and apart from a short interval after the charging period, the hearth was always in blast and smelting was continuous.

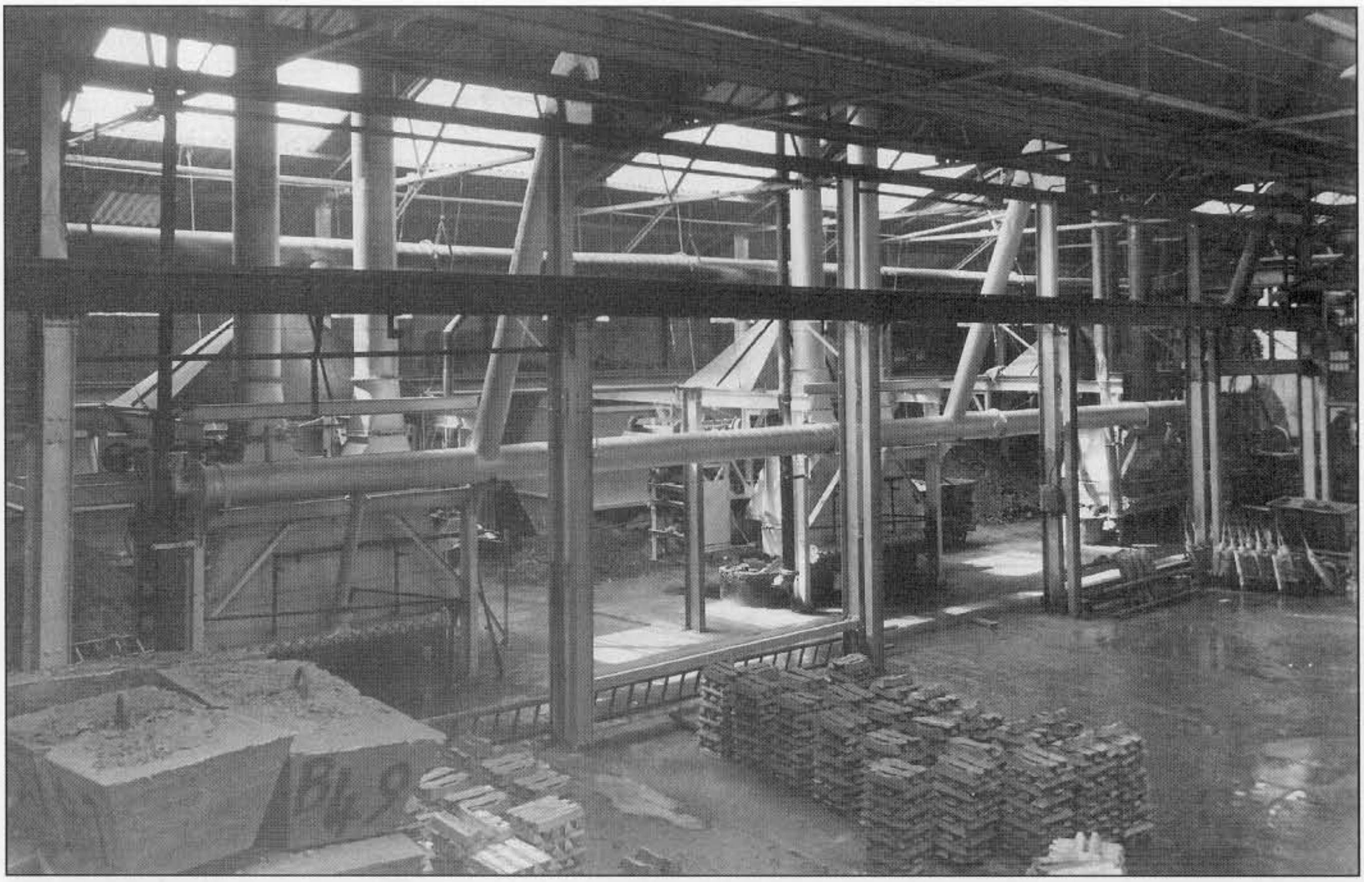


Fig. 6. Three Newnam Hearths being installed at Enthoven's, c.1948.

The hearths in operation on the Continent and in the States were usually 8 ft. long. The two at Associated Lead Manufacturers in Chester (now Cooksons) were unusual in being 12 feet long. They smelted ore from Halkyn in North Wales and sometimes ore from Greenside. They were installed about 1955 and ceased production about five years later, probably due to shortage of ore and environmental pressures. In Derbyshire, a battery of at least three Newnam Hearths was installed at H.J. Enthoven's in 1948 and operated into the mid 1950s. In the latter years the hearths were used mainly for secondary materials such as battery plates.

The hearth was started up by filling with ingot lead or scrap material and a coke fire lit inside the hearth to melt the lead. A bar was inserted into the spout at the end of the basin to retain the lead. Hot ashes were spread along the surface of the molten metal, the blast turned on slowly and the charge mix was spray-shovelled along the length of the basin. Gradually the blast was increased, making sure that sparks from the embers did not shoot up into the flues and set fire to the baghouse. In some plants gas firing was used to melt the bath of lead.

The molten lead seeped through the charge, entered the basin, raised the level and was tapped off into blocks at intervals. A temperature of almost 1000°C was possible at the smelting zone and the lead temperature in the basin was about 600°C. The thickness of the charge floating on top of the molten lead was 4 to 5 inches.

During smelting, crusts were formed in the charge. If these were not broken up, the blast could not penetrate the charge and smelting was retarded. Before the development of the Newnam Hearth, the operator had to rabble the charge by hand and break up the crusts. The Newnam device used a mechanical poker for rabbling and a later development was the MacMichael automatic shovel incorporated in the device.

Progressing from left to right, the rabbling operation was carried out with a poker, 1½ in. diameter. The poker, at right angles to the face of the ore hearth, was thrust downwards through the charge layer near the lip of the basin, into the bottom of the basin, then towards the back of the basin. The poker then changed direction. The outer end descended, used the lip of the basin as a fulcrum, and the immersed end rose and forced its way up into the charge, dislodging any accretions on the side of the basin, breaking up the crusts and dislodging much of the charge mix which was thrown on to the apron. The further development then proved its worth. The mechanical shovel cleared the apron of unsmelted material. (Fig. 3).

The action of the shovel was important. The first part of the forward stroke when the shovel scraped the apron was relatively slow. As the shovel left the apron its speed was accelerated until the latter part of the forward stroke was fast, finishing with a flip that threw the material against the waterjacket at the back of the ore hearth. The material then rolled by gravity, down to the lip of the basin. A selective action was thus produced whereby the finer material was deposited at the back and the top, and coarser material near the bottom and the front (Fig. 4)

As the machine reached the end of the hearth, after 18 to 20 operations for an eight foot hearth, a stop engaged a lever which automatically stopped the machine. The operator removed the slag, then charged the ore mix and coke breeze. A second lever was pulled and the machine returned to the left end of the hearth.

During the smelting process, the slag-forming constituents of the charge fused, and in the rabbling operation, they produced a sinter which, ideally, formed into balls - the so-called 'grey slag' assaying at about one-half of the charge mix percentage lead, ie. if the charge mix comprising lead concentrates, circulating fume, refinery dross, plus additions of lime and coke was about 72% lead content, then the lead in the slag would assay at between 35 and 40% with a usual assay of 38% Pb. The charge mix gave approximately 15% grey slag, by weight.

Cleaning the slag away had to be carried out by the operator as quickly and efficiently as possible in order to maintain a high rate of production. Any accretions that were not removed by the poker during its travel along the basin, had to be prised off immediately otherwise the end of the poker would catch under the accretion and throw the poker and shovel mechanism off the overhead railtrack, a devil of a job to replace with the radiant heat of the hearth doing its best to cook the operator and any help he could muster.

The level of the lead was maintained slightly below the lip of the basin. This determined the depth of the charge at the tuyere zone, giving optimum penetration of the blast and creating good smelting conditions. The lead was tapped by removing the bar that closed off the lead-spout and letting the overflow run into block moulds, or pig moulds mounted on a casting wheel. The slight red colour of the molten lead indicated the proper temperature of the bath. Tapping the lead was usually carried out during the travel of the poker along the basin.

As the process lent itself to bonus working, it was essential that the foreman measured the height of the lead in the basin at the end of shift to prevent the operator from 'milking' the basin and thus giving the on-coming shift a busy and unprofitable time in bringing the level of the lead up to the mark.

What about the operator? The Newnam hearth was, of course, both a technological advance and in terms of physical effort a social advance in that a great deal of hard work was saved by using the mechanical poker. Similarly, the advent of the MacMichael shovel eased the task. Nevertheless, the work was arduous. All the charge had to be shovelled manually on to the hearth, with the heat of the process constantly sapping the energy of even the strongest operator. All the slag had to be removed manually and, despite the best exhaust extractions of the time, the process gave rise to high levels of dust and fume which rendered the conditions worse.

At Associated Lead and Enthovens, the hearth required a team of two operators, one working the hearth for a short period of time while his mate did the ancillary work such as removing the blocks of lead, taking away the slag cars, and recuperating for another bout of hard work, more often than not stripped to the waist.

The remuneration was usually good, better than the general run of leadworker, with opportunities of substantial bonuses, especially with high-grade ore or good battery plates - but it needed to be!

My friend Mr. Vic. Benson, a native of Matlock, used to work at Enthovens. I met him when both of us went out to South Africa in 1952 to work in the smelter and refinery that was a joint venture of Associated Lead and Enthovens. The establishment in South Africa was a secondary lead, tin and antimony works(ie. mainly scrap recycling) and was based on the traditional reverberatory/blast furnace recovery process of that period. Often Vic used to recall working at Darley Dale and how he worked in what nowadays would be called appalling conditions on the Newnam Hearths, treating battery plates etc. After a stint shovelling the charge on the hearth, a break when his mate took over was more than welcome - it was a physical necessity. Vic volunteered to go out to South Africa to become shift foreman at the works near Germiston in the Transvaal. Even though the operators on the blast furnace and the reverberatory furnace were completely raw and many had no experience of working in industry, the work in South Africa was a doddle compared with working on the Newnam Hearths.

With the age of environmental awareness and better smelting methods, the Newnam Hearth became a smelting memory. In the U.K. secondary metal industry, the reverb/blast furnace had a spell as high tonnage metal producers, to be superseded by the short rotary furnace, two of the biggest in the world at present operating with exemplary environmental standards at Enthovens.

At the height of the Newnam Hearth's use, the Federal plant (ASARCO) in the United States developed the MacMichael shovel and it was reputed that the team was reduced to single man operation, though probably most of the ancillary operations were performed by other workers in the battery of thirty one hearths. From a 24 hour daily charge of 18 tons of mix at 72% lead per hearth, about 10 tons of lead was produced. This bullion was melted in a pot and the dross from the melt, mainly dissolved lead sulphide, was returned to the charge mix. Between 8 and 9 tons of good ingot lead requiring very little, if any, further refining, was produced.

Galena (a smelting plant in Kansas) reported 28 tons of charge mix with a very high lead content in the concentrates - over 80% - treated on each hearth in 24 hours, with a production of 19 tons of pig lead produced. When the lead content of the concentrates dropped to 60% the production slumped to less than 5 tons of pig lead per day, underlining the claim that the Newnam could treat only high grade ores with any degree of economy.

In Austria at the Bleiberger Bergwerks Union (BBU), three Newnam hearths operated in 1936. A rotary hearth was installed, which was a failure. However, further developments resulted in a successful rotary hearth in production by 1942 after which the BBU operated for many years. The hearth was ring shaped and rotated round an axis. With this construction it was possible to allow the charge to be held in a hopper and fed continuously on to the hearth, thus removing a manual operation. The next work station was the mechanical stirrer or poker, based on the same principal as the Newnam. The poker was of heat resisting steel and water cooled. The mechanical shovel was similar in action to the MacMichael shovel. The complete hearth was covered with a large hood to carry off the fumes from the smelting process. A working aperture for removal of grey slag etc. was the only opening, thus reducing the radiation of heat and making the work of the operator less arduous. Two rotary hearths could produce 48 tons of lead bullion using high grade 76 to 77% Bleiberg lead ore, containing zinc. It was reported that most of the cost of smelting the grey slag were borne by the recovery of zinc. Similar to Enthovens in Derbyshire, the hearths were successful in treating battery plates. When installed, there was no thought of treating battery plates, since high grade ore was readily available and scrap batteries from cars etc. were not plentiful. With the advent of mass motorcar ownership, scrap batteries have become an increasingly important feedstock.

Eventually, methods of treating lead ore, residues etc. by high tonnage, low labour, and environmentally clean installations put an end to the hearth smelting. "Good riddance! "the hearth-smelters would say.

ACKNOWLEDGMENTS

To my friend Vic. Benson, who worked at H.J. Enthoven and Sons Ltd. South Darley Smelter, and Rotherhithe until 1952 and then at Ento-Fry in South Africa. He is now retired.

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