The impact of the Imperial Smelting Furnace on non-ferrous metallurgy

S. W. K. MORGAN

IN 1936 at the Avonmouth Works of the National Smelting Company in England, zinc was produced by both the Horizontal Process and by the Vertical Retort Process, then recently installed under licence from the New Jersey Zinc Company.

In the Research Department we were not satisfied with either process. The Horizontal Process was intermittent in operation, and was a heavy consumer of fuel. In addition, the vast number of small retorts which were used, required a considerable amount of labour, and the work was hot and arduous. The Vertical Retort Process represented a considerable improvement, in that it was continuous in operation, and the considerably fewer retorts required much less labour and the thermal efficiency was higher. It was still essentially a small unit operation however, maintenance costs were high, and to make good briquettes, a coal of special quality was required, which was in limited supply.

In the Research Department we decided that a new process was required and if it could be based on the blast furnace it would have the benefit of large unit continuous operation. The main problem to be overcome was that of condensation. This had defeated all previous attempts to make zinc in a blast furnace.

We were encouraged to believe that the condensation difficulty could be overcome by a suggestion made by a colleague, Mr L. J. Derham, that by immediately quenching the molten gas leaving the furnace in a spray of molten lead, it woud be shock-chilled and the molten zinc formed after passing through the dew point would be absorbed in the molten lead before it could be reoxidised by carbon dioxide.

A little work on a small scale was carried out at Avonmouth to test this suggestion, and promising indications were obtained. The war, however, interfered and work was not commenced in earnest until 1947, when a small pilot furnace was built. This again showed promise and in 1949 construction began of two larger furnaces which, it was hoped, would be commercial units.

The results from these furnaces were at first disappointing. Many modifications had to be carried out before a reasonable standard of continuity of operation was reached. During the course of this work it had clearly become apparent that, as well as producing zinc, the furnace could also produce lead, and this entailed alterations, particularly to the sintering process. Eventually, however, in 1957 it was decided that sufficient progress had been made and the construction of the first large-scale furnace was begun at Swansea.

A number of other companies have since licensed the process and built furnaces. Altogether 9 furnaces, based on the original Swansea furnace, are now operating at:

Cockle Creek	Australia
Noyelles Godault	France
Kabwe	Zambia
Duisburg	Germany
Copsa Mica	Rumania
Belledune	Canada
Befu	Japan
Katowice	Poland
Hochinohe	Japan

SYNOPSIS

The Imperial Smelting Process is a blast furnace process for the simultaneous recovery of zinc and lead. Developed at Avonmouth, England, by the Imperial Smelting Corporation, the first commercial furnace was built in 1959 and there are now eight others operating under licence in various countries. It is estimated that in 1968 the furnaces in operation will produce together some 430 000 tons of zinc and 220 000 tons of lead. It can therefore be claimed that the process has already made a considerable impact on non-ferrous metallurgy.

The reasons for acceptance of this process and the possibilities of its greater influence in future are given in the paper. The economics of the process as a producer of zinc are summarised and compared with those of other competitive processes. Details of the advantages which are peculiar to the process—that it can produce lead simultaneously, permitting high recovery of copper, gold and silver, and the ability to treat bulk concentrates and lower grade materials, particularly those high in iron are also given.

Mr S. W. K. Morgan, Imperial Smelting Process Ltd., Avonmouth, England.

Furnaces are under construction in the following countries :

Tito Veles	Yugoslavia
Porto Vesme	Sardinia
Shau-Kuan	China

All these are based on the Swansea furnace and have a shaft area of 185 sq. ft. With adequate ancillary equipment this size of furnace has shown itself capable of producing annually 70 000 tons of zinc and 40 000 tons of lead on high grade concentrates. On lower grade concentrates, the output is somewhat less.

At Avonmouth, our Company has replaced the last of the two original experimental furnaces with the largest furnace yet built. This has a hearth area of 292 sq. ft. It came into production at the beginning of this year. When the initial teething troubles are overcome, we are confident that the annual production of zinc and lead will reach 100 000 tons and 60 000 tons respectively, and ultimately exceed these figures.

In 1967 the total production from these furnaces was 311 000 tons zinc, 165 000 tons lead. By 1972 when the furnaces now under construction are operating, we expect the annual production from Imperial Smelting Furnaces to be 800 000 tons of zinc and 500 000 tons of lead. We estimate that of the total new zinc capacity installed in the world between 1963 and 1968 of 660 000 tons, 47% was based on the Imperial Smelting Process.

One is justified in saying therefore that the process has already had some impact on non-ferrous metallurgy.

The competitive position of the zinc blast furnace

Zinc is almost unique in that there are at least six different processes in full commercial use for its production. Table I shows an estimate prepared by Brenthel of the production of slab zinc during 1965 by the various processes.

TABLE I World zinc production in 1965 (3 500 000 tons) according to processes

Process	%
Horizontal retorts	11·5
Overpelt	8·5
Vertical retort	12·5
Electrothermic	7·0
I. S. F.	6·5
Electrolysis	54·0
Total	100·0

A detailed study of all the factors which influence the choice of process for a new plant, to be built today, is most complex, and cannot be attempted here. These are general considerations which, however, can be broadly applied.

The first four processes in Brenthel's list are essentially retort processes and attack the difficult, but vital problem of condensation by avoiding dilution of the retort gases by combustion products. These processes have made, and are making, a major contribution to zinc production. From the point of view of general applicability, however, being retort processes they have one serious disadvantage, in that in every case the residues left after the zinc has been eliminated must be extracted "dry" and therefore cannot be allowed to fuse to any major degree. This restricts the application of these processes to high grade concentrates relatively low in iron and also limits the reaction temperatures which can be applied, thus restricting throughput. This was the main reason which, during the early days of the blast furnace project, led us to the view that retort processes would have but limited application in the future.

The electrolytic process which was commercially developed during the 1914–18 war by the Anaconda Company in the USA and the Electrolytic Zinc Company of Risdon, represented an entirely new approach to zinc metallurgy. It has been very successful. The difficulties to be overcome in the early days were considerable. Electrolysis can only proceed in solutions of extreme purity, since the process depends on maintaining high hydrogen over voltage and this is affected profoundly by trace quantities of a number of elements. With some difficulty, adequate methods of purification were worked out and the process became firmly established in the 1920's. In recent years, further improvements have been made. The modern silicon rectifiers have reduced power consumption. Leaching practice has been improved and higher current densities are in use. Recent development of a mechanised method of cathode stripping offers the possibility of reduction in the labour force, but the overall economies of this move do not yet seem clear.

Undoubtedly the main advantage of the electrolytic process is that, of necessity, it produces a zinc of high purity. With normal practice, metal containing 99·95% zinc is made, but by using modified silver containing anodes, adding an extra purification stage and making additions of special reagents to the electrolyte most, if not all, of the output can be produced as Special High Grade, containing over 99·99% zinc (25–30 ppm lead). This advantage of high purity production, coupled with the fact that the whole technique is now firmly established makes the electrolytic process a very powerful competitor to anyone attempting to introduce a new zinc process. What has the blast fnrnace to offer as a challenge to this and the other well entrenched processes ?

Performance of the modern Imperial Smelting Furnace

Before dealing with the competitive posi ion of the Zinc Lead Blast Furnace, it would be relevant to describe the performance which is now being attained, after the experience gained since the first large commercial furnace began operation at Swansea in 1960. As has been stated before, nine furnaces similar in size to the Swansea unit are now in operation in various parts of the world and three more are under construction. A larger furnace, 292 sq. ft. in hearth area has been built at Avonmouth and came into operation at the beginning of this year.

The output of these furnaces naturally depends upon the grade and type of ore treated. At Swansea, Noyelles Godault, Cockle Creek and Berzelius the feed is relatively high grade, consisting mainly of a mixture of normal zinc and lead concentrates and ores, together with a proportion of bulk zinc/lead concentrates produced specially for the process. Under these conditions, at Berzelius—the latest of the four to be built—the furnace has shown itself capable of producing at an annual rate of 70 000 tons zinc and 40 000 tons lead. The consumption of carbon as coke to produce this output is of the order of 60 000 tons. There is every reason to believe that these figures will be exceeded in the future.

The efficiency of the process is high. At Berzelius the overall recovery of zinc for the whole smelter—including the sintering plant—is 93%. The overall recovery of lead is 94%, but this covers all the lead fed to the smelter. Some, of course, occurs in the zinc concentrates used, and for this little or no charge is made. The marginal rccovery on lead concentrates bought deliberately for the charge is high and exceeds 99%.

Silver and gold and also copper are recovered in the bullion tapped from the furnace bottom. 98% of the silver reports in this way. The proportion of copper recovered similarly varies between 75 and 85%, rising as the copper content of the feed increases.

The consumption of labour (for the furnace) calculated per ton of zinc produced is 3·8 man hours for operating labour, and 2·2 man hours for maintenance. On the combined zinc-lead metal output, these figures become 2·3 and 1·5 man hours respectively.

Performance on lower grade charge

As previously stated above, the Swansea, Noyelles Godault, Cockle Creek and Duisburg furnaces operate mainly on normal concentrates. In Rumania, Zambia and Belledune the furnaces treat much lower grade material. In Rumania the charge is based on a high iron charge, relatively rich in copper. An analysis of the sinter fed to the furnace is :

Zn	27%
Pb	15%
Fe	12%
Cu	1·5–2·5%

A feature of this operation is the relatively high recovery of copper. Bullion containing up to 15% Cu is successfully recovered.

At Zambia the charge consists of zinc-lead flotation concentrates from the mine, zinc-lead flotation tailing and also residues from the electrolytic zinc plant.

The appropriate analysis of the sinter fed to the furnace is :

Zn	25%
Pb	20%
SiO_2	10%
Fe	11%

A feature of this charge is the relatively high silica content which increases the slag fall. At Belledune in Canada, the furnace feed is bulk New Brunswick concentrates which could not be treated economically by any other process. These again have a high iron content and the average analysis of the sinter charged to the furnace is :

Zn	28%
Pb	19%
Fe	14%
Cu	0·5%

Thus, while the furnace has shown itself capable of operating at high efficiency on normal zinc and lead concentrates, it is also becoming used to an increasing extent on lower grade materials which would be rejected by other processes. This advantage of the process will become of increasing importance in the future.

The No. 4 furnace at Avonmouth

Most of the furnaces so far erected have been based on the design and dimensions of the original 185 sq. ft. unit installed at Swansea in 1960. When originally installed, it was thought that this size furnace would produce 30 000 tons of zinc per year and 20 000 tons of lead. It has already shown itself capable of producing double these quantities. Whilst it is true the ultimate capacity of this size of furnace is unknown, and these outputs will almost certainly be exceeded in the future, in 1966 we decided at Avonmouth to build an even larger furnace, 292 sq. ft. in area. This was to replace the 133 sq. ft. furnace which had been built as a commercial prototype in 1951 and on which most of the development work had been carried out. This new large furnace commenced operation at the beginning of this year. Only experience will show what is the ultimate capacity of the furnace but we see no reason why annual production figures of 120 000 tons of zinc and 80 000 tons of lead cannot be attained in the relatively near future.

Whilst this furnace represents a saving on capital cost, and also labour per ton of zinc and lead produced, over those achieved by the standard 185 sq. ft. furnace, the problems of raw material supply and of marketing are increased and its application is unlikely to be as widespread as the smaller furnace.

Capital cost

Statements of capital cost of plant are of little value unless they are subject to much qualification. Accuracy can only be obtained if each example is worked out in detail under local conditions.

To give some rough indications of the order of costs involved, however, estimates have recently been made, assuming a 185 sq. ft. furnace of the Swansea type was erected in the U. K., on a 'green field' site with no existing facilities. Such a furnace would be capable of producing 70 000 tons of zinc and 40 000 tons of lead, assuming a feed of normal grade concentrates. Sufficient refluxer refinery capacity would be installed to produce all the output zinc as 99·99 metal, if required. The figures are as follows :

	£10[6]
Furnace	3·2
Sinter plant	2·1
Zinc refinery	2·0
Cadmium plant	0·3
Site facilities	1·5
Lead refinery	0·6
	9·7

In our opinion it is improbable that equivalent capacity by any other process could be installed for the same cost.

The Imperial Smelting Furnace as a lead smelter

The furnaces of the Swansea type, being of the same equivalent hearth area, have the same carbon burning capacity of approximately 180 tons per day. The heat liberated by the carbon has two main functions—to reduce zinc oxide and to melt slag. The allocation between these functions is roughly given by the empirical formula.

Carbon requirement=0·936 zinc volatilisation+0·217 slag melted.

This formula gives a good indication of the capacity of a furnace on any particular charge.

Lead compounds in the charge are reduced to metal by the gases high up in the furnace, after they have completed their main task of zinc oxide reduction. Since the reduction of lead oxide by carbon monoxide is slightly exothermic, it makes little or no demand on the furnace heat balance. For these reasons the furnace can produce large quantities of lead without affecting the zinc production. In many cases adding extra lead concentrates to the charge actually increases zinc production, since with high lead charges sinter of sufficient hardness can be produced without the necessity of adding silica. This reduces the production of slag from the furnace and enables more heat to be released for zinc production. In such cases, the addition of extra lead brings a large bonus to furnace revenue.

The I. S. F. was developed as a zinc-producing process and this remains its most important function. Because the lead splash condenser is an essential part of its operation, some lead must be used in the circuit and a minimum amount must be added to compensate that which leaves in the slag, and the other losses which occur in the sintering and smelting operation. This minimum amount of lead is an essential requirement of the process. It is not possible to operate without it and hence it must be regarded as a basic charge on zinc operation. For a furnace producing 70 000 tons of zinc per annum, this minimal amount of lead is of the order of 1 140 tons. Once it has been supplied, most of the losses are fully saturated and the recovery of any extra lead added to the system is almost 100%.

It has previously been shown that considerable quantities of extra lead can be smelted in the charge (up to 80% of the zinc produced) without reducing zinc production. Since standing charges, such as capital and maintenance costs, also labour and fuel costs, are justifiably charged to the zinc operation (since they are almost unaffected by the amount of lead treated), the true cost of treating lead in an I. S. F. is low and is generally less than in standard lead blast furnace practice. If, as frequently happens, the addition of extra lead concentrates permits extra zinc to be produced, since it enables silica addition and consequantly slag production to be reduced, then an additional credit is gained and lead smelting in an I. S. F. becomes very profitable.

It is not necessary to smelt lead in an I. S. F. Zinc can be produced competitively with the addition of little more lead than the 'minimum' previously described. The furnace has, however, a considerable latent capacity to smelt large quantities of lead at practically no cost. This capacity is already beginning to be used and we estimate that in 1968 some 160 000 tons of lead will be produced by the process.

Recovery of copper

During the early days of furnace development, attempts were made to encourage the formation of a separate matte phase, in order to improve copper recovery. To do this, some sulphur was left in the sinter, but condensation efficiency was affected and the attempts were abandoned. As the copper content of the charge was increased in the absence of sulphur, it began to appear in the bullion. Since this is normally tapped from the furnace bottom at temperatures above 1000°C the carrying capacity for copper is high. With the development of a bottom tapping forehearth, it has been found practicable to produce and tap bullion containing up to 15% Cu, and this is not necessarily the limit.

The copper can be removed from the bullion during cooling with conventional drossing methods. Probably due to the fact that the bullion from an I. S. F. contains little sulphur or arsenic, the copper is produced as a dry dross which does not present difficulty in handling.

This ability of the furnace to produce copper is becoming of increasing importance. At present, the amount which can be treated depends on the lead content of the charge, as does the recovery attained. A furnace producing 40 000 tons of lead per year could also produce 8 000 tons of copper at a recovery exceeding 90% under these conditions.

This ability to recover copper is already exploited on a major scale in Rumania and at Belledune and is yielding additional revenue for most of the other furnaces. This is a promising development, the full potential of which has not yet been realised.

Conclusion

To return to the title of this paper - what has been the impact of the process on non-ferrous metallurgy and what part is it likely to play in the future ?

It has already proved itself as a commercial process and has shown many of the advantages of blast furnace operation—large units can be built at competitive capital and operating costs. If the ores are available, considerable quantities of lead can be smelted with the zinc at practically no additional cost. This makes the furnace, in many cases, a more economical producer of lead than a standard lead blast furnace. When the full potential of this is realised, the process will obviously affect lead smelting practice in the future. The ability of the process to produce lead enables silver, gold, copper, antimony and bismuth to be recovered, and thus almost all the values in an ore can be recovered in one operation.

A further advantage of this ability to smelt zinc and lead together is beginning to affect mining and milling to an increasing degree. It is now no longer necessary to use differential flotation to separate zinc and lead into individual concentrates. At a number of mines they are now recovered together in a single bulk concentrate for treatment in an I. S. F., thus improving recovery and reducing treatment costs.

Perhaps, however, the most important single attribute of the process is its ability to smelt high-iron, low-grade concentrates. All its competitors are restricted in the main to high-grade materials. The annual consumption of zinc in the free world is of the order of 3 500 000 tons. Over the last ten years, it has been growing at an average rate of over 120 000 tons per year. There is little reason to doubt that this rate will continue, if not increase, in the future. The recent remarkable growth of continuous sheet galvanising, and the widening use generally of zinc for the protection of structural steelwork alone, will ensure this. Growth of this order over the next twenty years is certain to pose problems for the exploration and mining companies. High-grade concentrates will surely be at a premium and the zinc smelting industry will be driven to increasing use of lower-grade materials. Recovery of all values at both mine and smelter will become increasingly important. In this context the blast furnace process would appear to have no rival.