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THE AUSTRALIAN COPPER LEAD AND ZINC SMELTING AND REFINING INDUSTRY

By A. Foulis

(Mr. Alan Foulis, M.A., A.A.S.A., A.C.I.S., a financial analyst with Broken Hill South Ltd., gave this address to a meeting of the Victorian Branch of the Society in Melbourne on 19 April 1972. His company has approved the publication of the address and Prof. Blainey the quotation from his book "The Rise of Broken Hill".)

The subject of this address is the Australian copper lead and zinc smelting and refining industry. I have been asked to give some Stock Exchange visibility to an industry which, I am told, is relatively invisible from this viewpoint.

I intend to spend some time describing the basic processes of the industry and outlining new developments in techniques. I will also attempt to place the Australian industry in a world context, and take a brief look at the markets for the metals concerned.

It is an interesting observation that the smelting and refining industry is relatively invisible from a Stock Exchange viewpoint. It is obviously an essential part of the mining industry, and is one that, in what I regard as an essentially cyclical relationship with the basic mining side of the industry, is in the process of becoming more important at present. I will refer to this again later, but basically the present stronger overall position of the smelting and refining industry can be put down to two factors:-

1. the normal swing of the pendulum - by which I mean that for some time past, up until two or three years ago, one could say that concentrates have been in relatively short supply with the inevitable consequence that, with competition between smelters for concentrate supplies, returning charge allowances to smelters had been pared down and consequently there was insufficient economic incentive for investment in new smelters or indeed for replacement expenditure on existing smelters; and

2. what I will call the current ecological outcry. I am not qualified and do not propose to enter into controversy on the merits and demerits of current hyper-sensitive awareness of pollution risks. The basic fact as far as it impinges on the smelting and refining industry is that it has, together with economic pressures, forced closures of smelters and refineries, largely in the United States, but also in Japan, and in other cases has forced smelters to work at less than full production rates. As a consequence it is quite possible that in some markets shortly we could have at one and the same time a shortage of metal and a surplus of concentrates. In some of the integrated American copper companies this position has already been recognised and concentrators at the mines have been cut down to 6 day, or even 5 day, operations while smelters are given the opportunity to work off a backlog of concentrate supplies. We are all also being made aware by frequent press references of the reportedly enormous stockpiles of concentrates being held by the Japanese smelting and refining industry.

After those preliminary remarks I will define my subject and issue a disclaimer. There are no doubt some among you who are technically better qualified to describe the operations of a smelter than I am. I am an accountant by trade and therefore an outsider looking in on technical matters. I will ask the more technically qualified among you to bear with me while I indulge in a little elementary technical description.

First my subject is restricted to the older base metals, copper, lead and zinc. We are therefore excluding reference to the newer industries, in the Australian context, the nickel and aluminium industries.

Generally by smelting and refining we mean that section of the industry which uses raw concentrates and scrap materials as its raw materials and converts these into market metals. The processes are various but in the Australian context we mean the process which commences with the sulphide concentrates produced by mine concentrators and ends with refined metal in ingot, wirebar or billet form, ready for the semi-fabricator.

As mentioned the two basic raw materials of the smelting and refining industry are concentrates and scrap metal. The importance of scrap varies from market to market and from metal to metal, but it could definitely be said that the more mature a particular market and the more mature a particular metal becomes the larger the proportion of the supply that is likely to be provided by recovered scrap metal. The scrap metal market in lead has been very aptly described as the largest lead mine in the world. On a world basis we could say that the three metals we are studying are supplied by scrap to the following approximate percentages -

Copper	40%
Lead	35%
Zinc	20%

I would emphasise, however, that these percentages are very broad and could be varied quite substantially by differences of definition. Scrap is recycled at many different stages of the smelting and refining operation and the recycling is a continuous process.

To ensure that we all have a basic understanding of the processes and terms involved I now propose to give a brief non-technical description of the processes involved in smelting and refining. To deal first with copper, the basic operations of a copper smelter could be illustrated in simplified form as in Diagram I.

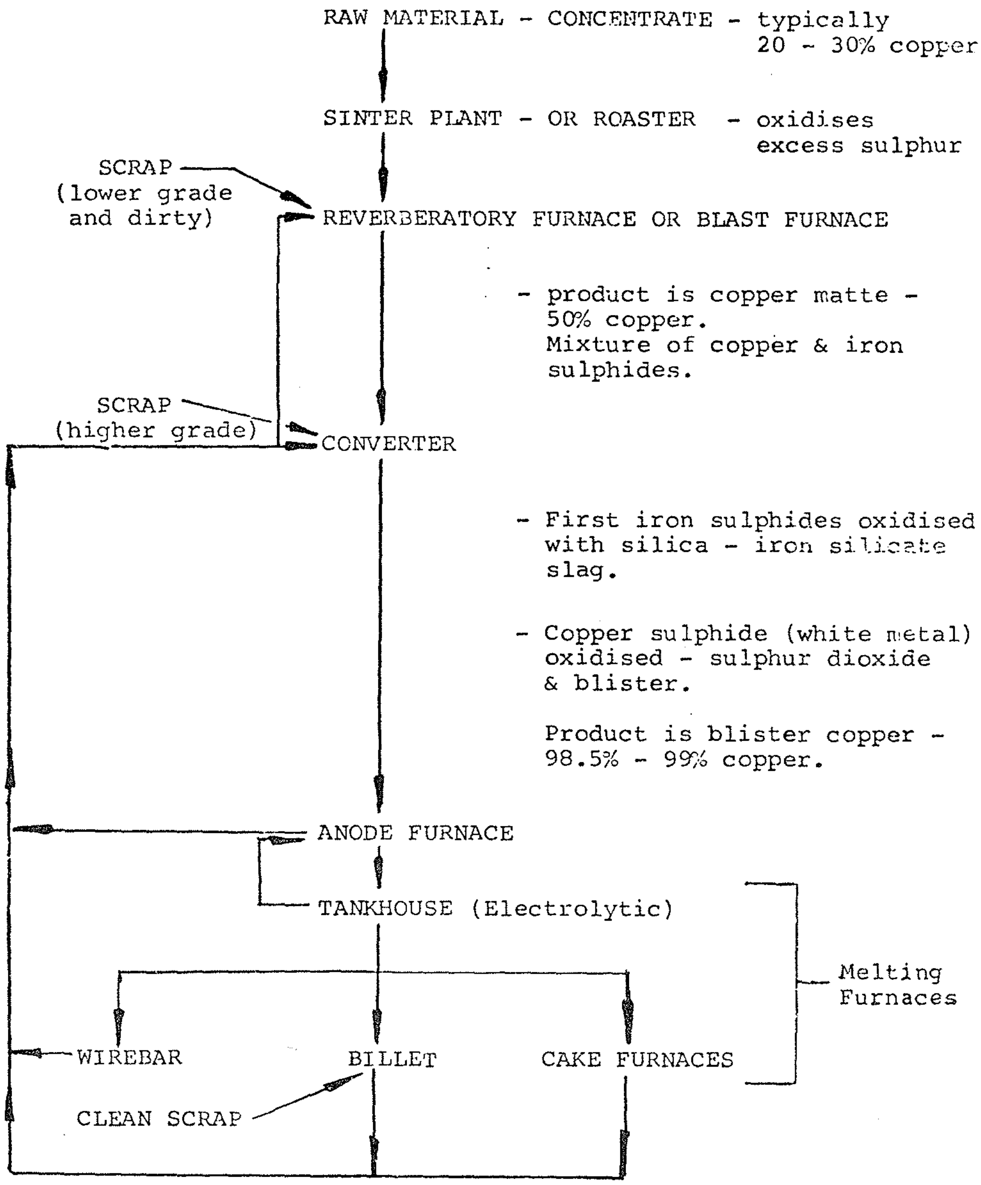
With zinc we deal with another metal recovered basically by the electrolytic process. This was not always the case and in fact the first commercial production of zinc by electrolysis dates only from the First World War when Consolidated Mining & Smelting Company (Cominco) at Trial, B.C., and Anaconda at Great Falls, Montana, established electrolytic plants. The Electrolytic Zinc Company of Australasia plant at Risdon was first established on an experimental basis between 1916 and 1920, with the public company being formed in 1920 and commercial production in a 100 ton a day plant commencing in 1921.

Prior to the introduction of the electrolytic process most zinc had been produced by distillation following the smelting of zinc ore to produce zinc vapour. Many of the zinc smelters which have been closing in the U.S. in recent years have been those using the old thermal process, though recent suggestions that the Anaconda plant at Great Falls will close in July of this year, under the joint pressure of economic and ecological factors, seem to indicate this particular wheel has gone full circle.

A basic flowsheet for a zinc refinery is illustrated in Diagram II.

The zinc ferrite residue, produced in the leaching process, leads on to a new development which is just in the process of being perfected by the Electrolytic Zinc Company in their residue treatment plant. It is interesting how often new metallurgical developments are paralleled in different parts of the world, or in different plants even in adjacent locations. This was certainly so when the flotation process was developed and perfected at Broken Hill by several different companies in the early years of this century. Likewise the electrolytic process for production of zinc was developed as a commercial proposition at almost the same time by two companies in North America and shortly thereafter adopted in Australia by Electrolytic Zinc. We see another example of this strange paralleling in scientific advances with the residue treatment plant which has been developed by Electrolytic Zinc and the Compagnie Royale Asturienne des Mines. Two affiliates of this latter company in Norway and Northern Spain were solving the problems of recovery of zinc from residues at the same time as E.Z. were making their own advances in this field.

Diagram I



This process could be considered more significant than has been realised. Zinc is regarded as a difficult metal to treat and the traditional payment by smelters to mines is for a maximum of 85% of the metal contained in concentrates, which payment has related to the recovery experience of the smelter. The reason for the relatively low recovery of metal in the concentrate is the problem encountered in the roasting process whereby iron atoms in the feed material combine with some of the zinc to form an insoluble zinc ferrite in a residue averaging some 22% zinc. The Jarosite Process consists of two stages:-

1. A leaching process in which the zinc ferrite is dissolved in sulphuric acid at near boiling point; and

Diagram II

	RAW MATERIAL	Concentrate, typically 48 - 54% zinc.
	↓	
	FLASH) ROASTER FLUID)	Product impure zinc oxide, called calcine. Sulphur dioxide given off.
	↓	
← Zinc ferrite Residue (also lead sulphate)	LEACHING	Dissolved in weak sulphuric acid - product impure zinc sulphate.
	↓	
	PURIFICATION	Removes impurities from solution - iron, copper, cadmium.
	↓	
	ELECTROLYSIS	Zinc deposited on cathodes. Solution - sulphuric acid - is returned to leaching process.
	↓	
	CASTING	Cathodes stripped. Zinc cast in required shapes and required purities

2. A precipitation-stage in which the iron is removed from solution as jarosite by adding ammonia or salts of sodium or potassium.

The zinc is subsequently returned to the normal electrolytic process. For E.Z. their residue plant when full production is achieved at 350 tons of residues per day, should, I estimate, produce for them 20-25,000 tons of extra zinc per annum. The significance of this when it is realised that the metal as such does not have any additional purchase cost to E.Z. and can be readily grasped.

The final metal we have to deal with is lead. The process for producing lead is in outline relatively simple and lead is metallurgically one of the easier metals to recover. A basic flow-sheet is given in Diagram III.

A relatively recent development at the Broken Hill Associated Smelters plant at Port Pirie, and one which has had a very significant effect on the results of B.H.A.S. has been the installation in 1965-67 of a Slag Fuming and Zinc Plant. In this the slag from the lead Blast Furnace, together with a proportion of cold granulated slag from the slag dump, are treated in slag fuming furnaces. With coal and blast air the zinc is vaporised and recovered as zinc oxide fume. The zinc oxide fume is roasted to remove chlorine and fluorine impurities and then the roasted fume is subjected to the same processes of leaching and electrolysis for eventual recovery of zinc metal, as described earlier. For B.H.A.S. at Port Pirie this process gives rise to the production of some 35-40,000 tons zinc per annum that would otherwise not have been recovered at all, which adequately demonstrates the significance of the slag fuming and zinc plant.

Before we leave this section of technical descriptions, one of two other developments should be briefly mentioned.

Diagram III

RAW MATERIAL	Concentrate, typically 70 - 75% lead. Mixed with fluxes and granulated slag. Product 6% sulphur.
SINTER PLANT	Sulphur roasted off as sulphur dioxide - taken to sulphuric acid plant. Bonding of material. Sinter Product 42% - 43% lead.
BLAST FURNACE	Coke as fuel and a reductant. Product lead bullion 98% lead with copper, silver, gold, antimony, sulphur and bismuth.
DROSSING	Removes copper
REFINING	Reverberatory furnaces. Normally oil fired. Vacuum dezincing - removes precious metals.

SLAG
to Slag Fuming
- typically
slag grade
2% lead
18% zinc

First the Imperial Smelting Furnace. This is a blast furnace in which both lead and zinc can be recovered at the same time without requiring electrolysis to produce the zinc. The advantages of the system are that it can operate on mixed lead/zinc concentrates of relatively low grade and it is therefore particularly suitable for treatment of the products of complex orebodies where successful production of high grade lead and zinc concentrates is not possible or only possible at the expense of low recoveries of metal in concentrates. Also, the prime fuel for the blast furnace is coke and the avoidance of the electrolysis stage in zinc production means that the system can be used where low cost electric power is not available.

The disadvantages are that to produce really high grade zinc, zinc refluxing has had to be introduced, while recent increases on coke costs have reacted adversely on or at least reduced the cost advantages of I.S.F. operation vis-a-vis electrolytic plants. Finally of course like all metallurgical operations the operation is a delicate one and very high standards of plant housekeeping are required for successful operation. The degree of delicacy is demonstrated by the results of the Avonmouth I.S.F., which in some 4 years of operations has run up losses in excess of $20 million and has yet to achieve profitable operation.

The next development which should be mentioned is the flash smelting process developed by the Finnish Company Outokompu Oy. which is being used by Peko Wallsend Ltd. at Mt. Morgan and Tennant Creek and by Western Mining Corporation for nickel at Kalgoorlie. This is a type of shaft furnace, with concentrate fed in at the top of the furnace, progressively being heated as it travels down the shaft and being ignited by updraft hot air. This is a continuous process and its advantages could be said to lie in relatively low capital cost and the even and high tenor of the sulphur dioxide gas - say 11 - 12% sulphur dioxide - which is produced. The product of the furnace is normal copper matte of approximately 50% copper.

Finally before we leave this section mention should be made of the various experimental processes aiming at continuous smelting from concentrate and scrap through to blister copper in the copper field. Of these probably the best known to us here is the WORCA process developed by C.R.A., but other similar processes could be said to be in similar stages of development by Noranda in Canada and by Mitsubishi in Japan. The advantages of these processes are that they are continuous, with considerable savings in obviating the need to reheat metal after cooling, they provide an even and high tenor sulphur dioxide gas and the aim is to take the process through to blister copper. Problems have been encountered in introducing the air blast which is required to oxidise the copper sulphide to produce blister copper and sulphur dioxide in the final stage of refining. There is some doubt whether a fully successful commercial operation has been achieved - though the Japanese plant being operated by Mitsubishi is apparently due to be unveiled later this year.

To briefly place the Australian industry in this sphere in its world context I will give world and Australian production and consumption statistics as given by the World Bureau of Metal Statistics. In copper in 1971 out of a free world mine production of 5.1 million tons (metric) Australia produced 174,000 tons or 3%. Out of world smelter production 5.5 million tons, Australia's contribution was 155,000 tons, a fraction under 3%. Refined production was 5.7 million tons and the Australian contribution 156,000 tons. Australian consumption in 1971 is recorded as 105,000 tons so you can see that export of copper was recorded at every stage along the line. I should also add that the figures for smelter and refined production include metal recovered as secondary refined material - probably some 30,000 tons in Australia - so that the incidence of export of copper in concentrate is higher than at first appears.

With lead the complete 1971 year figures are not available so I will quote the 1970 year which shows Australia producing 457,000 tons out of a world mine production of 2.6 million tons or 18%. At this level Australia no longer ranks as the leading lead producer in the world, a position which has now been taken by the United States, which, with the recent increases in production from the Missouri lead belt, had a production of 540,000 tons in 1970. As against mine production of 457,000 tons, Australia's refined production is given as 206,000 tons and consumption at 56,000 tons, again indicating the substantial scope for exports of both refined metal, and the intermediate products of lead bullion and concentrates.

Finally in zinc, and using again the 1970 calendar year figures, Australia had a mine production of 484,000 tons, 11% of a world total of 4.4 million tons. Against this zinc metal production was 257,000 tons out of a world total of nearly 4 million tons and Australian zinc consumption is given as 106,000 tons. Again the scope for Australian exports of metal and concentrates is evident.

To sum up then in each of the markets we are considering, Australia ranks as a significant producer both at the mine and at the refined level. In each of these metals Australian domestic consumption is relatively small and substantial exports are made to world markets both as metal and as intermediate products.

Up till now we have been discussing production methods and production volumes without touching on the vital subject, from your viewpoint, of the companies concerned. At this stage I will list the companies, their products and their ownership.

I will then try to look back into the past to the reasons for the particular establishment of some of those operations, will give some coverage of the present situation, the commercial relationships existing and the markets for the metals concerned, and conclude with some attempt at a look at the future.

The companies we are dealing with are relatively few in Australia. They are:-

	Approximate Capacity	
The Broken Hill Associated Smelters Pty. Ltd.		
Port Pirie	230,000 tons	Lead
Lead Smelter	40,000 tons	Zinc
Zinc Slag Treatment		

Ownership 50% C.R.A. Group, 30% North Broken Hill, 20% Broken Hill South.

	Approximate Capacity	
Sulphide Corporation Pty. Ltd. - Cockle Creek, N.S.W.		
I.S.F.	55,000 tons	Zinc
	25,000 tons	Lead

Ownership Australian Mining & Smelting Co. Ltd. (57.5% C.R.A., 42.5% N.B.H.C. Holdings)

Electrolytic Zinc Co. of Australasia Limited - Risdon, Tasmania

Zinc plant	in excess of 170,000 tons (possibly 200,000 tons zinc)	Zinc

Ownership - Listed E. Z. Industries

Substantial minorities in EZ held by

North Broken Hill Ltd. - less than 7%

Broken Hill South Ltd. - less than 5%

The Electrolytic Refining & Smelting Company of Australia Ltd. - Pt. Kembla, N.S.W.

Copper Smelter & Refinery	65,000	Refined copper

Ownership - Broken Hill South 60%, North Broken Hill 40%

Mt. Isa Mines Ltd., Q'ld.

Mt. Isa	150,000 tons	Lead bullion
Lead and copper smelters	in excess of 100,000 tons	Blister Copper
	being increased to 150,000 tons	Blister Copper

Copper Refineries Pty. Ltd.

Townsville, Q'ld.

Refinery	100,000 - 150,000 tons	Copper

Ownership MIM Holdings Ltd. (in turn owned in excess of 50% by American Smelting & Refining Co. Ltd. (ASARCO)

Peko Wallsend

Mt. Morgan, Q'ld. - Copper			
Flash Smelter	probably	8,000	Copper
Tennant Creek, N.T. -	Being installed -		
Copper Flash Smelter	Capacity not known.		

Mt. Lyell Mining & Railway Co. Ltd.

Until 1969 operated a copper smelter at Mt. Lyell, Tasmania. This Company has indicated that it might again undertake smelting operations, when its current phase of mine expansion and conversion from open-pit to underground mining is completed.

One point immediately becomes clear and that is that each of the companies is linked wholly or in part by ownership with companies that can guarantee raw material supplies to the smelters concerned. It could be said that the Australian position has been relatively stable for some time past and that therefore no clear case of a mine without smelter or smelter without mine has been seen.

I would argue however, that within the fluctuating world mine and smelter capacities the greatest relative strength can be gained by a company which has a balance of mine and smelter capacity. Such a company is master of its own destiny. A company having mine capacity but no smelter is, to my mind, in many ways as vulnerable as a company having a smelter but no mine. The market for concentrate swings pendulum-fashion and at times the smelter and at times the mine is placed in difficult trading conditions. In the Australian context we could quote the development of the West Coast Mines by E.Z. as a means of obtaining a certain source of at least part of the company's concentrate requirements. The doubling of capacity of the West Coast Mines to 600,000 tons per annum of ore (approximately 90,000 tons of zinc metal in concentrate) is a very significant move for E.Z.

Another similar move has been the move to smelting by Peko-Wallsend as soon as the company could guarantee sufficient length of mine life to justify the investment involved.

These moves could be paralleled overseas in other transfers of ownership aimed at balancing mine and smelter capacity. One particular case in point would be the option taken by Texas Gulf Sulphur over the assets of the Goldfields American subsidiary American Zinc. This company was making losses and therefore was closed down by American Zinc. However, for T.G.S. with their large and increasing production of copper, lead and zinc from the Timmins Mine in Ontario the zinc smelting and marketing abilities of American Zinc had a definite value and hence the option was taken.

Similarly in the nickel field American Metals Climax (Amax) purchased some time ago the Louisiana nickel refinery of Freeport Sulphur. Freeport had used this refinery to treat Cuban nickel matte. With the change of government in Cuba they could no longer guarantee supply to the refinery while Amax, looking to the future, could see the possibility of nickel matte supplies becoming available from its Botswana Roan Selection Trust associate with the Selibe-Pikwe nickel-copper deposits in Botswana.

Therefore the relationship between the mining industry on the one hand and the smelting and refining industry on the other, is a mutual and complementary one - with the mining industry providing essential raw materials to the smelting industry and the smelting industry providing an essential link in the access to markets of the mining industry.

There are some interesting questions to be raised on the subject of the location of some of the plants listed above. We will probably not now be able to answer these questions, because the answers are hidden in the mists of time. The location of the E.Z. smelter in Tasmania has an obvious reasoning in the availability in Tasmania of cheap hyrdo-electric power, a very important consideration, because power costs are a major factor in electrolytic production costs. Similarly E. R. & S. at Port Kembla can be said to be located to be close to coke supplies in New South Wales. E. R. & S. was originally established in 1908 to treat blister copper from Mt. Morgan, but also with an eye to scrap material, and this would, I think, have had an influence on the selection of a site near a major centre of population.

The location of the smelting operations of Mt. Isa ia also interesting. Mt. Isa achieves an almost perfect balance of inward and outward freight on the Mt. Isa. - Townsville railway. The inward freight consists largely of coal for electricity generation and copper smelting and coke for the lead smelter at Mt. Isa, while the outward freight is lead and copper in bullion and blister and zinc in concentrates.

The siting of B.H.A.S. at Port Pirie is perhaps the most intriguing question. As was indicated in our survey of Australian metal production and consumption, Australian consumption is even now a relatively small factor in Australian production and therefore the Australian smelting industry has had to be export-orientated. Therefore, the location of B.H.A.S. at Pirie at the nearest port to Broken Hill, seems logical. But it did not always seem so logical. As Professor Blainey has put it in his excellent book "The Rise of Broken Hill".

> "Most of the ore mined at Broken Hill in the first years was smelted close to the line of lode. In 1891 there were blast furnaces at the Proprietary, British, Block 14, Central and South mines, all breathing poison into the sky. Though the advantages of smelting at Broken Hill rather than on the coast were, presumably, discussed often by directors and managers, they are now difficult to ascertain. In the early 1890's, at least, the arguments in favour of Broken Hill seemed stronger than ever. That ubiquitous promoter of railways, the former Silverton newspaper man J. S. Reid, was sure that the smelters would remain at Broken Hill and in 1890 he was a vigorous promoter of the public company which built forty miles of railway from Tarrawingee to Broken Hill, simply to supply limestone flux to the smelters. The railway was opened in May 1891 with a great banquet and slurred prophecies of handsome profits. The limestone trains were no sooner running when some of the smelters at Broken Hill began to close. All had closed by April 1898.
>
> Most of the mines did not build smelters elsewhere, preferring to concentrate their ore and sell the concentrate to smelters in Europe. A few of the larger companies built new smelters on the coast: Block 14 at Port Adelaide, Central at Newcastle, and the Proprietary at Port Pirie. The cessation of smelting at Broken Hill thus transferred to the Australian coast or to German and Belgian cities the jobs of thousands of men. Fortunately the expansion of the mines enabled the population of Broken Hill to grow despite the loss of the smelters; but if Broken Hill had continued to smelt most of its own ore, it would have certainly

> become, early in this century, the largest inland city which Australia had known.
>
> The Proprietary owned at Broken Hill the biggest smelting works in Australia, and so the decision to remove all the salvageable machinery to Port Pirie, 253 miles away, must have been backed by strong arguments. The company had operated a small silver-lead refinery at Port Pirie since 1889, and had bought the British Broken Hill Company's small smelters there in 1892, so it was familiar with the relevant facts. As the cost of living at Port Pirie was cheaper, the company could pay lower wages there. Smelters are thirsty for water, and water would be cheaper at Port Pirie. Coke and coal would be much cheaper at Port Pirie, for it was the depot for all the fuel used at Broken Hill's smelters. The ironstone and limestone fluxes used in the blast furnaces could be procured more cheaply at Port Pirie, whereas they were carried into Broken Hill over private railways which charged dearly. These arguments in favour of the coast seem powerful. It is slightly disconcerting however, to find that all these arguments against Broken Hill existed - and indeed were probably even more powerful - when B.H.P. decided in 1885 to build its smelters at Broken Hill."

Professor Blainey suggests that the improvement of concentrating techniques would have been a factor in influencing the decision of the B.H.P. to move to Pirie and this must be a factor. I cannot help wondering whether the earlier decision to place the smelters at Broken Hill would not have been taken on the traditional basis - that smelters always were at the mines, and, therefore, why disturb a system that was working. Once established at Pirie the most important factor in keeping the smelting of the Broken Hill concentrates at Pirie was of course the very existence of the smelter.

The effect of the 1914-18 War and the impetus this gave to smelting in Australia is an oft-told tale and probably familiar to most of you. For those who want to read something on this I would refer you to the W. S. Robinson Memoirs "If I Remember Rightly" - which were also edited by Professor Blainey. Suffice it to say that the majority of the Broken Hill lead concentrate prior to the War had been smelted in Belgium and Germany. The companies, mainly North, South and Zinc Corporation, were therefore cut off by the war from their market and their urgent need for a smelter fortunately coincided with B.H.P.'s reduced interest in Port Pirie as the "Big Mine" at Broken Hill, as the B.H.P. was known, declined and B.H.P.'s interest in steel increased.

There is one other point concerning the commercial relationships between mines and smelters in Australia. This is, that despite any cross-shareholdings, the negotiations on concentrate sale and purchase are commercial negotiations in the fullest sense of the word. Security of supply or of access to a smelter, a need for a long-term contract, particular advantages in freight costs, either of concentrate or of finished metal - these considerations might have some effect on the final bargain struck in a sales agreement, but the basis for the agreement is always related to the going world rate for a particular job. I would stress that it is the world rate, because the industry is very much an international one and the terms on which a new smelting contract is let in Japan, or America or Europe will have an eventual effect on Australian contracts. It is immediately another factor to be taken into consideration in local negotiations.

The final consideration in this sector is an all important one which is too little stressed in the largely traditional copper, lead and zinc industries and that is the question of markets. It is, I think, significant that if any of you were asked for a break-up of the markets for some of the newer metals - such as say nickel or aluminium - you would be able to find this break-up. With copper, lead and zinc I think this is much more unlikely. I can say this with some confidence as, as you would be aware, International Nickel produce each year a break-up of the nickel market and the Aluminium Development Council is only too happy to do the same for Aluminium. On the other hand, it takes considerable trouble to find such break-ups for copper, lead and zinc. In fact, as far as copper is concerned, no Australian figures are available and, to the best of my knowledge no world-wide figures either. A production of the Economist Intelligence Unit on "the Production, Marketing and Consumption of Copper and Aluminium" (Martin S. Brown & John Butler, 1968) gives a market break-up for aluminium but none for copper.

The only figures I have been able to find for copper relate to the American market and my source for them is the American Metal Market. These figures show a split as follows:-

Transport (incl. Automotive Radiators)	12%
Consumer & General	24%
Machinery & Equipment	17%
Electric & Electronic	28%
Building & Construction	19%
	100%

These indicate a broad spread for this particularly versatile metal - and possibly this is one reason for the relative lack of concern with end-uses shown by the copper industry. Copper is a unique metal and its qualities of workability, heat transfer and electrical conductivity together with corrosion resistance fit it for so many different applications that it can probably withstand the loss of any particular market with relative equanimity. In fact, I am suggesting that substitution, which is always occurring and is a continuous process which is not, as generally regarded, a force to be feared, but just a part of the process of adapting the world's resources to the very pressing needs that we have. I feel that copper will continue to become a more valuable metal. The years since the last war have seen a continual lowering of the grade of ore mined in open pits down to 0.4% copper and lower. This has been made possible by the massive size of the operations undertaken to achieve economies of scale and also by, in some cases, valuable by-products - molybdenum, gold, silver - which render the lower copper grade economic.

These operations, together with large tonnages of overburden being removed, mean that the copper industry is handling today greater tonnages of material than the iron ore industry. I suggest however, that there will be some limit to the possibility for increasing the size of operations to achieve economies of scale and that at that time the price of copper will rise relative to other metals, and copper will of necessity be displaced from some of its uses, because it will become too valuable a metal for uses to which it is now applied.

Turning to lead the major uses for lead in the major countries of the free world are:-

Batteries	39%
Cable Sheathing	12%
Tetraethyl Lead	11%
Semi-manufactures & manufactures (Pipe & Sheet)	15%
Pigments and Chemicals	12%
Alloys (solder, antifriction)	7%
Miscellaneous	4%
	100%

These uses are of course not uniform from country to country. For instance, tetraethyl lead takes 20% of consumption in United States, against a world average of 11% and nil in Australia (our requirements of tetraethyl lead are imported).

For zinc major uses on the same basis are:-

Galvanising	39%
Die Casting	24%
Brass & Copper Alloys	19%
Semi-manufactures (rolled zinc)	7%
Zinc Oxide & Chemicals	6%
Miscellaneous	5%
	100%

Again uses are not uniform from country to country - the most obvious instance would be Australia's high usage of zinc for galvanising, 66%, against the world average of 39% - a testimony to those acres of corrugated iron roofs.

I will leave this short survey of markets at that stage and conclude by reference to some problems of the current situation and possibly a forward look or two. In the early days of Broken Hill the mining industry there struck what was known as the sulphide problem. The change from mining oxidised to sulphide ores originally created problems which were only solved when the techniques of differential flotation were mastered.

The problem facing the smelting and refining industry at the moment could be called not the sulphide but the sulphur problem. Some States in America have now adopted and set deadlines requiring compliance with a federal recommendation that 90% of the sulphur in smelter feed must be recovered. Many experts contend that this level is unrealistically high and certainly its adoption presents enormous problems for existing smelters. The problem for a copper smelter is that sulphur dioxide gas is given off in different strengths at different stages in the smelting process- at the roaster/sinter plant, at the reverberatory/blast furnace and at the converters. Reverberatory/blast furnace gases are normally considered too weak to permit efficient manufacture of sulphuric acid, while converter operation is a batch process producing intermittent gas only.

A further problem relates to the disposal of any sulphuric acid produced, as the market for sulphur is already over-supplied by the Canadian sour-gas producers. These producers are being pressed to supply natural gas for the rapidly expanding American market. However, with the natural gas they must inevitably produce sulphur which they must dispose of at any price.

The cost to the American copper industry alone of compliance with federal ambient air standards and with the 90% sulphur requirements has been estimated at between $600 million and $1.2 billion - figures which are so vast that they begin to lose all significance. It could be said however that if expenditures of this order are required their cost will have to be recouped from the consumers eventually, another factor underpinning the price of copper.

It is interesting to speculate where and how such changes would or will affect the Australian industry. It is almost tempting to say that Australia with our sparse population and wide-open spaces could afford lower environmental standards in order to attract to our shores a larger proportion of the smelting and refining operations. I do not think, however, that this is in any way an acceptable proposal. The nickel - copper smelter to be installed at the Selibe-Pikwe deposits being developed by Botswana Roan Selection Trust in Botswana, will have a 500 ft. stack to disperse sulphur dioxide gas - an interesting development when it is realised that, as has been pointed out, the Kalahari desert is virtually just up the road from the smelter.

Therefore, I do not think that any relaxation in environmental standards in Australia will be permitted - or should be considered. However, current concern about pollution may present Australia with a chance to increase the proportion of domestic metal production smelted and refined in Australia, provided domestic costs can be kept under control. It might be that in this context the vast deposits of natural gas which have been discovered might have some bearing - in providing cheap power or possibly even some more revolutionary break-through in treatment methods. Certainly I feel Australia should be able to provide smelting establishments more economically than say the crowded Japanese islands.

Fundamentally, I suppose the attitude one adopts to this sort of problem relates to one's own basic attitude - whether one is optimistic or pessimistic about the whole future of the human race. I must admit that I am an optimist. I cannot resist concluding with a quotation which may not be strictly relevant but does have some bearing on the question.

In the world of copper at present one man stands out as an international authority where pronouncements on the industry and its problems are always listened to with deep respect. That man is Sir Ronald Prain, Chairman of the R.S.T. International Group of Companies. When Sir Ronald quotes from some one else as an authority this becomes immediately of interest to me. In a recent address Sir Ronald quoted from a publication of Horace Stevens in 1903. The tone of the quotation is somewhat oracular and biblical, but nevertheless the message of optimism and faith in market mechanisms I think, makes it worthy of repeating. Horace Stevens wrote nearly 70 years ago:

> "There will be seasons when demand will follow so closely upon the heels of supply that prices will go skyward, and the fool will say in his heart that the market must forever advance. There will also be periods when the supply will far exceed demand, and the faint of heart will say that copper mining is overdone, and never more can be profitable, but in the aggregate

the great law of averages, immutable as the law of gravitation, will give to the world the copper for its imperative requirements, at prices not prohibitory to the consumer, yet sufficiently high to provide for the well-managed mines profits beyond the dreams of avarice."

It is on that note that I would like to conclude tonight.

REVIEWS AND NOTICES

THE MANAGEMENT OF CAPITAL INVESTMENT

(Journal of the Royal Statistical Society, Part 4, 1971)

This paper by four authors jointly on the subject of capital investment, including the use of operational research in the appraisal and management of capital projects, illustrates a somewhat different approach to that of the security analyst. The latter is outside an organisation looking in, and his information is limited to what has been published or can be ascertained through enquiry.

The authors through a series of case studies arrived at some conclusions of general interest. They found that more effort was devoted to estimating outgoings than returns, to controlling amounts invested than checking on results, to ensuring immediate liquidity than the securing of an adequate return - when failure to secure an adequate return could result in unsatisfactory financial performance and problems of liquidity in subsequent years.

They put forward the view that capital investment must be considered on a much broader base than in the past and that it overlaps many activities of a firm-sales, production, accounting, etc. Their concept of a total investment system covered the whole range from generation of new ideas, appraisal, financing and implementation to control, feed-back and post-mortem consideration of results. Operational research techniques could play a part beyond mere appraisal of particular projects.

SUGAR TO JAPAN

One item of interest to be gleaned from the survey of the Japanese sugar refining industry, recently published by the Industrial Bank of Japan, is that country's increasing dependence upon imports of raw sugar from Cuba. Over a period of 8 years the annual tonnage imported from Cuba increased from one-half to two times that imported from Australia.

Re-assembling the figures given in the survey, it can be shown that almost the whole of Japan's increase in imports came from Cuba -

Imports of Raw Sugar in thousands of metric tons from -

	Australia	Other Countries (ex Cuba)	Total (ex Cuba)	Cuba	Total
1963	328	809	1,137	164	1,301
1964	430	628	1,058	336	1,394
1965	376	665	1,041	380	1,421
1966	582	563	1,145	361	1,506
1967	639	462	1,101	506	1,607
1968	513	740	1,253	565	1,818
1969	578	594	1,172	829	2,001
1970	516	768	1,284	1,092	2,376