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We regret that some of the pages in the microfiche copy of this report may not be up to the proper legibility standards, even though the best possible copy was used for preparing the master fiche.

The paper presented by the U.N.I.D.O. Secretariat deals mainly with "The Present State of Lead and Zinc Industry in Developing Countries". It is characterized by the availability of the four groups of the countries which have different positions in lead and zinc consumption and production.

The <u>First Group</u> is formed by the country-consumers, where lead and zinc apparent consumption is more than 10,000 tons a year. The members of this group are Argentina, Brazil, Mexico, India, China (Mainland) China (Taiwan), Pakistan, Philippines, Thailand, North and South Korea. The majority of the group has not developed the metal production to meet the whole local demand and so is importing the metals for internal needs.

The <u>Second Group</u> contains exporters of the metals and concentrates who are smelting lead and zinc without considerable home consumption, and their industry depends mainly on the world market situation. They are Peru, Zambia, Burma, Tunisia, Morocco and Congo (Kinshasa).

The <u>Third Group</u> is exporting only the ores and concentrates. The production of the smelted metals is the task for future development. Nowadays only four countries could be named as miners of lead and zinc: Algeria, Iran, Bolivia and Honduras.

The <u>Fourth Group</u> includes all the developing countries which were not put into the first three groups. It means that the consumption or production of the metals in these countries is lower than 10,000 tons a year and consequently the influence of lead and zinc on their economy is not strong.

Each group of the developing countries have their specific problems and of course these are different for consumers and exporters of the metals.

Analysis of the groups shows that the number of developing countries where the home demand in lead and zinc is higher than home production, is more than the number of the country-suppliers.

Only six countries of the second group, plus Mexico and North Korea, possess at present surplus capacities for smelting lead and zinc. Some of them are smelting only one of these metals but eventually all of them as well as four countries of the third group, could smelt both.

Hundred thousand tons of ingots, concentrates and ores exported by these twelve to the world market gave the impression that developing countries are lead and zinc suppliers. Up until now the quantity of metals consumed by the developing countries is less than the volume of their mine and ingot production, but it is not expected that the number of developing countries exporting lead and zinc would be increased greatly during the seventies. Only Turkey has a firm intention to join them soon.

At the same time there are already nine of the developing countries with a lead and zinc consumption of more than 10,000 tons a year, without adequate home production and about ten where apparent consumption of the metals is several thousand tons. During the Second Development Decade this group of the developing countries would grow up from year to year increasing general lead and zinc consumption of the developing world and if the rate of ingot metals production is the same as it was during the sixties the developing countries would be net importers not only for zinc but for lead metal as well.

It is understood that problems dealing with smelting lead and zinc in the developing countries are more important than any others in this respect. Practically all of the developing countries have to think about new smelting installations. They need them for home utilization of the ores and concentrates which are now exported or for production of unable to meet local demand, which cannot be covered only by import.

Because of this, technical assistance submitted to the developing countries should be aimed first of all at a decision of the techno-economical questions for lead and zinc production under specific conditions in different countries to find the most suitable way of meeting the existing requirements.

Some projects have been implemented already by the United Nations through its bodies in this field. In [illegible] the "Survey of Lead and Zinc Mining and Smelting in Burma was finished, which helped the country in planning some measures to develop resources for lead and zinc production.

The example of this meeting presents another form of assistance to the developing countries. It is aimed at a collection of experience and technological achievements in the lead and zinc industry of the developed countries, to consider possible ways of their application under specific conditions in the developing world.

During the discussion the participants agreed with the U.N.I.D.O. approach to the problems which are existing in the lead and zinc industry of the developing countries and expressed the necessity to support the following projects:

<u>Suggestion from India</u>

1. <u>NEEDS</u>: Training of Mining Engineers in Metalli-Ferrous Mines.

2. <u>OFFER OF ASSISTANCE TO OTHER COUNTRIES</u>:
   (a) Joint venture for development of zinc and lead mines and to export the concentrates obtained from such mines to India.
   (b) Supply of expert officiers from Geological Survey of India for development of new mines.
   (c) Supply of mining and beneficiation machinery.

Suggested Work Plan

To secure help from experts to make a project evaluation to determine the technology and most suitable Potential raw materials for processing to useful products (such as coal).

After this pilot plant testing could be carried out to find the most useful methods of utilizing the materials and deposits either to make metallurgical coke or for any other use.

[illegible]

[illegible]

In considering the increase of performance of the standard size of I.S.F. [illegible] 17.2 m² shaft area constructed at most of the smelter sites. The first unit at [illegible] was designed in [illegible] to produce [illegible] tons of zinc per year. The unit is now capable of producing [illegible] tons of zinc per year from high grade concentrate. [illegible] have recently estimated that a further [illegible] increase is [illegible] in the future. Improvements in smelting efficiencies have also been proposed since 1960 i.e. carbon [illegible] etc. One important improvement that can be noticed is the prolongation of campaign lives from fifteen weeks in 1960 to now over two years due to the development of blast techniques for removal of accretion from the furnace shaft. The limit of campaign length now lies not in opperational or metallurgical aspects but rather in the need to make design improvements or modifications as the I.S.F. is still in the state of further development.

[illegible]

[illegible]

The I.S.P. does represent a simple flow sheet [illegible] permits a "clean cut" separation of zinc and lead from a complex feed or [illegible] we suggest results in eliminating the additional operation of recovering zinc from lead blast furnace slags by fuming to obtain a [illegible], and also the recovery of lead and other [illegible] from the lead plant residues of an electrolytic zinc plant.

In the paper "A Review of the Main Factors Affecting the Possibility of Development of Lead and Zinc Industry in the Developing Countries" V.V. Tsyganoff examined the very numerous factors influencing the possibilities of development of the lead and zinc industry in a country. These are mainly:

(a) The prospects of the internal domestic market in connection with the objectives of development of other, consuming, industries in the country.

(b) Possibilities of sale of lead and zinc for export determined by the situation on the international market.

(c) Availability of raw materials, in other words the existance of explored reserves, high metal content in the ore, favourable geological and mining conditions.

(d) Availability of technical means, i.e. the necessary amounts of power, fuel, water, equipment, materials and transport systems.

(e) The availability of personnel.

(f) The choice of flow sheets.

Summing up the results of the analysis (made in this report on the basis of the publications available and the experience of the industry in the USSR) of the main factors which may have a significant impact on the development of the lead and zinc industry in the developing countries, we may conclude that there is a possibility for the industry in these countries to be profitably developed.

This conclusion is confirmed by the following generalizations:

- The production and consumption of lead and zinc both in industrialised and developing countries for the last 12 years have been steadily but slowly increasing.

- Lead and zinc prices at the international market are keeping more or less stable.

- The inner lead and zinc market in the developing countries, being though in the stage of creation, is nevertheless promising and perspective.

- Raw materials conditions in the majority of the developing countries are favourable though not fully investigated yet.

- Due to the development of other industries in these countries the lead and zinc production development cannot be handicapped by the absence of general technical means.

- Transport communications mainly depend on the economical and geographical conditions of every particular country.

- The personnel supply problem can be solved by training specialists abroad.

- The existing and newly developed processes for the production of lead and zinc are highly efficient.

- A contributing factor to the development of the lead and zinc industry in a country is the possibility of producing by-product metals extracted in the production of zinc and lead, such a gold, silver, cadmium, bismuth or selenium, and expecially the need for sulphuric acid, zinc vitriol, sodium antimonate and other chmical by-products.

- When estimating the possibility and profitability of the development of lead and zinc industry in the developing countries, the interdependance of many factors should be considered. Therefore this problem should be solved for every country individually by the way of thorough technological and economical comparisons of the calculations made for different schemes of the material processing.

- The most promising and significant process for the treatment of complex concentrates containing zinc, lead and copper is form our point of view the so-called KIVCET method, developed by the soviet specialists. The word "KIVCET" is the Russian abbreviation for the "oxigen-flash-cyclon-electrothermal process.

This process provides for the smelting of five materials in the blowing stream containing oxigan in amounts varying from the usual percentage in air and up to 100%. The product obtained is then treated electrothermically.

According to this method:

a) Smelting fine materials in the blowing stream can be either flash as a straight torch or as the torch winded by the cyclon action or any other means.

b) Further treatment of the molton metal takes place both in an electrothermal device directly connected with the smelting equipment and in the separately located device connected with the smelting section by means of a launder used for molten metal conveyance.

In case the sulfide material containing more than 20% of sulphur dioxide.

If the oxidized or poor-in-sulphur concentrates are to be treated then some gaseous, liquid or solid fuel should be added into the smelting process.

The advantages of the KIVCET process are generally as follows:

Granulation and sintering processes are eliminated;
high rate of desulphurisation is achieved;
small volumes of gases leaving the equipment are rich with sulphur dioxide (70-90%), making recovery as cheap sulphuric acid, elementary sulphur or liquid sulphur dioxide economically attractive;

heat evolved from the oxidizing reaction taking place in the charge is utilized within the process itself for smelting and additional heating of the charge components (this reduces significantly the energy consumption during the whole process in comparison with many other methods);

the consumption of high-grade coke is eliminated;

the process provides for the treatment of lead-and-copper complex concentrates which in turn makes it possible to use the bulk floatation method, permitting higher rates of metal recovery from ores into concentrates;

the continuous processing of the material within a single plant is readily adaptable to automatisation of the main units of the system.

In the paper "Prospects for Lead and Zinc Industry in the Developing Countries in the 1970's" by J.R. Carlson it was stated that the prospects for the lead and zinc industries in developing countries were closely tied to the forward estimates of these metals consumption in world economy. Most of developing countries enjoying deposits of lead and zinc ores and producing both metals are exporters of concentrates or metals.

There are several methods of assessing future consumption of metals. The most precise, based on determining of end uses, can be adopted bu in case of highly industrialized countries. The sutdies "Resources for Freedom", "Resources in America's Future" and "U.S. Demand for Selected Non-Ferrous Metals End Use Projections to 1975" allow to assess with fair exactitude the volume of lead/zinc consumption in the United States up to 1980.

The method based on correlation of consumption and expansion of industrial production or production of durables can be adopted in assessing lead/zinc consumption in world economy. The above methods are of no avail for the developing world with its highly differentiated structure of industrial production. From studies made by Economist Intelligence Unit it is inferred that a satisfactory relationship between the increases in GNP and lead/zinc consumption can be established. For African countries such a relationship was not established, however. No doubt the projection of metal consumption can be made for any developing country, taking into consideration specific conditions of its economy; it would be advisable to make respective studies in countries intending to start lead/zine production to meet domestic demand.

Independently from adopted methods of projecting the demand for lead and zine in world economy and average annual rate of growth in consumption of these metals, forecast in most papers recently issued, shows a notable convergence and falls within the limits

2.0 - 3.5 per cent for lead
3.0 - 5.0 per cent for zine

The last eight years period indicates that these projections are correct in principle because the average annual rate of growth in consumption of lead in world economy in course of these years amounted to 3.7 per cent and that of zinc to 5.5 per cent although that growth was not steady and in some years temporary declines in consumption were pronounced.

The characteristic feature of those eight years was a relatively sharp increase in lead and zinc consumption in developing countries overcoming by far the developed ones in that respect. The average annual percentage rate of growth in consumption in developing countries amounted to 9.2 in case of lead and to 9.7 in case of zinc. There are reasons to believe that some stabilisation of world market in lead and zinc during the discussed period and the growth in consumption of these metals are not accidental but brought about by a planned action.

The activity of the International Lead and Zinc Study Group set up in 1960 and comprising nowadays thirty member countries, amount which the foremost producers and consumers of these metals, seems undoubtedly to influence the stabilisation of the lead and zinc market. The growth in lead/zinc consumption is being influenced also by research works leading to find out new applications for those metals and to improve the methods of processing zinc semi-products. The coordination of these research works carried on by International Lead and Zinc Research Organisation is not without significance. The rapid growth in lead/zinc consumption in developing countries is mainly due to the fact that these countries are striving to attain better standard of living and due to the initial stage of industrialization. Comparing the per capita lead/zinc consumption, which in Latin America amounts to only 10 per cent, in Asia and Africa to only about 1 per cent of consumption in developed countries potential possibilities of growth in consumption of these metals in developing countries can be seen.

In that case also the activities of Zinc Developing Association and Lead Developing Association, initiated a few years ago, can have good effects. Indian Lead/Zinc Information Centre in Calcutta established in 1962, Overseas Developing Fund and further plans to provide technical assistance in view of processing lead and zinc in developing countries are and will for sure stimulate in future growth in consumption of lead and zinc in these countries.

Considering the above mentioned studies on the projection of lead/zinc consumption in world economy, the actual rate of growth in consumption of these metals over the years 1960/1968 and the lively activity of international organisations it can be assumed that the average annual rate of growth in consumption over 1970-1980 would in all likelihood amount to:

2.5 - 3.5 per cent for lead
4.0 - 5.0 per cent for zinc

and in developing countries:

6.6 - 8.9 per cent for lead
7.6 - 9.9 per cent for zinc

The consumption of lead in 1980 in world economy excluding the centrally planned economies would then reach 3,860 to 4,320 thousand tons and that of zinc 5,900 to 6,600 thousand tons.

The consumption of lead/zinc in developing countries during last eight years was rising more sharply, yet the production of both concentrates and metals was expanding at a considerably lower rate than in developed countries. During that period the production of lead concentrates in developed countries by [illegible] per cent and in developing ones by only 2.3 per cent. The production of zinc concentrates increased in developed countries by 64 per cent and in developing world by 38 per cent only. The production of lead rose in developed countries by 31 per cent, still, in developing Asiatic and African countries dropped and in Latin America rose by only 4.3 per cent. In developing countries solely the growth in zinc production was more rapid (61%) than in developed ones (4[illegible]

The approximate forward estimates of new production capacities in individual countries for next 2-3 years indicate that mine and smelter production would continue to expand at a slower rate in developing than in developed countries. New mine capacities of lead and zinc ores are reported only in Argentine, Bolivia, Iran and their slight increase in Peru and Korea. No new production capacities were reported only in Algeria, India with poor increases in Mexico.

To estimate the expansion of lead/zinc production in the world and in developing countries to meet the demand for consumption forecast over the period 1970-1980, the reserves of metal ores at the disposal and new mine/smelter capacities are to be assessed. The world measured and indicated reserves in lead and zinc can be assessed approximately to [illegible] million tons of lead and 75 million tons of zinc, fair enough to meet the demands in 1970-1980. An analysis of the lead/zinc consumption balance over these years, allowing for net import from centrally planned economies should be made to assess new production capacities required to be put in operation in 1970-1980.

Having regard to the balances of production/consumption over the years [illegible]/1968 and to the fact that all the rapid addition to production of lead and zinc in socialist countries is matching the equally rapid growth in consumption it can be assumed that in 1970-1980 net import from centrally planned economies would be maintained at the level of about [illegible] thousand tons for lead and [illegible] thousand tons for zinc.

Assuming full equilibrium of the consumption/production balances and no occurring of essential changes in non-commercial stocks it can be forecast that depending on the adopted projection of metal consumption new lead smelter facilities would be required within the limits [illegible] to 1,007 thousand tons and in zinc smelter facilities within the limits 1,[illegible] to 2,260 thousand tons. Respective figures for new mine capacities amount from [illegible] to 900 thousand tons of lead and from 1,[illegible] to [illegible] thousand tons of zinc. The expansion of new [illegible] capacities in world seems give favourable outlook for stimulating the production of these metals in developing countries. [illegible] would help the consumption of these metals to go up faster in countries like India, Argentina, Korea. In countries exporting now mainly metal concentrates the expansion of smelter facilities would enable to improve the foreign trade balance. Among these countries

Morocco, Tunisia, Bolivia, Honduras, Peru, Algeria, Congo, Mexico, Burma and Iran can be numbered.

Finally, in many developing countries there are deposits of lead and zinc ores not yet mined. With the production of both metals coming into operation in these countries, up to now poor consumers of lead and zinc, their industrialisation would be possible and the development of applications for these metals would be stimulated.

As suggested from the above considerations there is favourable outlook for quick expansion of lead/zinc industry in the years 1970-1980.

To secure the share of developing countries within that expansion framework in conformity with their reserves in ores and with their needs for industrial and social progress some efforts from the organizations of United Nations devoted to that aim and from Governments of both developing and developed countries would be required, however.

The basic condition of lead/zinc expansion in the whole world, first of all in the developing countries, is the stabilisation of the metals consumption/production balance and of metals prices at the level adequate yet competitive to the substitutes. This is the main target of the International Lead and Zinc Study Group and its activity along with the cooperation of the member Governments, particularly of the United States in respect of non-commercial stocks releases policy, is likely to secure such stabilisation within suitable limits.

Further liberalisation of trade, removal of quota system and lowering of import duties are additional factors having substantial effects on the production of metals in developing countries. These are problems which UNCTAD and a number of other international organisations are dealing with.

In developing countries specialist in lead/zinc industry are generally not available. Due to their absence the best economic and technical programmes of the expansion of that industry based on domestic reserves are hampered. The assistance of the United Nations experts in preparing such programmes in individual countries or in individual state enterprises could be very useful. "Survey of Lead and Zinc Mining and Smelting in Burma" made in 1966 within the United Nations Development Programme is an example of that aid. The correct evaluation of offers for construction of complete mines and smelters is another difficulty the governments of developing countries come across occasionally. An objective evaluation of these offers made by United Nations independent advisers can suggest the best choice.

The expansion of lead/zinc industry in developing countries demands training of local staff. The gradual Zambianization of Broken Hill plant at Kabwe proves that the most sophisticated technology can be mastered by local staff. It would be desirable, however, to train specialists and labour force before a new plant enters into production; the United Nations assistance to the developing world could be then of great service.

To some management posts in enterprises taken over by developing countries or in newly commissioned ones local specialists cannot be appointed at once since they are not available there. Experienced administration officers to supervise lead and zinc industry enterprises or other forms of managing the industry often lack in developing countries. Until local specialists acquire appropriate professional qualifications there is need for United Nations advisory service in assigning these posts to their experts.

Technical schools and universities in those countries which enjoy opportunities for the expansion of lead/zinc industry should ensure suitable education to the future specialists in these fields. An essential form of the United Nations assistance to developing countries is providing them lecturers with educational qualifications if they are absent on the spot which is often the case.

In many developing countries the expansion of lead/zinc industry is tied to problems concerning foreign trade policy. The specific features of foreign trade in lead/zinc concentrates and metals also requires special experience. Until foreign trade officers in some of developing countries acquire necessary routine the assistance of United Nations experts sent there on request of the interested Governments seems advisable.

In all the above mentioned cases the service of the United Nations experts should be temporary. Education and training of local specialists involves long-term stays in highly developed countries as an opportunity to gain practical experience. Trainings of that sort sponsored by the United Nations could help the developing countries to complete their own teams of experts.

It may be hoped that the present Expert Group Meeting organised by UNIDO will be a further step towards the expansion of lead/zinc industry in the developing world.

Conclusions

1. The projections of lead and zinc consumption to 1980 assess that the average rates of growth fall within the limits:

   2.5 - 3.5 per cent for lead
   4.0 - 5.0 per cent for zinc

2. The total world consumption, excluding centrally planned economies would then reach:

   3,860 to 4,320 thousand tons of lead
   and 5,900 to 6,600 thousand tons of zinc

3. To meet that demand the new mine capacities and smelter facilities would be required within the limits:

   440 - 800 thousand tons of lead in concentrates
   1,780 - 2,530 thousand tons of zinc in concentrates
   630 - 1,100 thousand tons of lead
   1,560 - 2,260 thousand tons of zinc

4. The consumption of lead and zinc in developing countries during last years was rising more sharply than in developing ones, but the production of both concentrates and metals was expanding at a considerably lower rate than in developed countries.

5. To secure the share of developing countries within the expansion of world lead and zinc industry the following efforts fr the organisations of United Nations and from governments of both developing and developed countries are required:

- the stabilization of metals consumption/production balance and of metals prices.
- further liberalization of trade, removal of quota system an lowering of import duties.
- the assistance of the United Nations experts in preparing th best economic and technical programme of the lead/zinc industr expansion.
- the objective evaluation of foreign offers for construction of complete mines or smelters.
- the assistance of the United Nations experts in training of local staff, temporary assigning the management posts in industry and foreign trade enterprises, technical schools and universities.

In the paper "Lead and Zinc Industry in Peru" by A. Labarthe the Peruvian position as related to world lead zinc production was described as well as it's character, its structure, its possibilities and its problems. The paper submitted contained information not generally available about distribution, points out ore reserves and describes its technology for mining, concentration and reduction. It also illustrates the changing pattern of production marketing and indicates the role of foreign investment in the development of the mining industry. Finally it describes the participation of government as well as the legal structure of mining and gives information on a specific project for the installation of a zinc refinery.

Peru is a mining country as can be ascertained from the figures given in the paper. When the Andean Mountain emerged dividing Peru into three different regions it created a very difficult problem for the integration of the country but as a counterpart it provided intense and diversified mineralization which constitute a fundamental resource for Peruvian economy. Early Peruvians of the Inca empire were already mining gold, silver, tin and copper. This diversified and intense mineralization and the early mining vocation might be the reason for having had in Peru always important productions in the hands of national companies.

The country's economic dependance, present and future, on the mining industry can be illustrated by the following figures. In 1950 mineral exports represented 24.5% of total exports while in 1968 this percentage has grown to 51.1%. Dollar wise this means an increase from 46 to 442 millions.

To the latter figure, lead exports contribute 30 million, zinc 33 million, but silver contained in the lead-zinc exports amounts to 50 Million dollars which makes the total value of lead-zinc products 113 million dollars or roughly 25% of total mining exports.

Peruvian lead-zinc exports account for about 11 to 12% of total international trade of these metals.

Peruvian production growth of lead in the last ten years has been equivalent to the world production increase percentagewise - that is, about 2.1%. Zinc production has increased at a rate twice the world rate that is 10.7% versus 4.9%.

Participation of Peru in the international trading will increase even further according to present developments in areas of known reserves.

Lead-zinc ores explcited in Peru consist as a rule of complex minerals associated with copper and silver. As it was already mentioned , silver is the most important in value. As exceptions to the rule, in the last few years two important deposits are being developed in which zinc is the only valuable metal.

As to the geographical distribution, lead and zinc productions are located in the Central Andean region, most of the mines being situated at altitudes in excess of 4,000 meters above sea level. This region is connected to the port of Callao by good all year round roads as well as by railroad. This will no doubt be always the most important mining zone for lead-zinc, but other areas that did not have transportation facilities in the past shall become important contributors to production.

It should be pointed out that 23 mines produce 90% of the total lead-zinc exports.

Estimated ore reserves by recent calculations are of 2 million metric tons of recoverable lead and 4 million tons of zinc. At the present rate of extraction this means a 12 year supply of lead and 13 years of zinc. If prospective reserves are added we have lead for 35 years and zinc for 50. The important point, however, is that reserves are being increased every year and that exploration in Peru has yet a long way to go.

The Government has a very ambitious program of exploration which should start yielding results within the next three to five years.

Practically all mine production of lead-zinc ores is concentrated by flotation. Machinery for small plants up to a 300 day capacity is manufactured locally. Larger plants are mostly imported. Differential flotation to produce two or three concentrates is generally practiced. Separation of copper from lead is successfully accomplished by using potassium dichromate to depress the lead sulfide minerals and in other instances, sodium cyanide is used to float the galena concentrates from copper. Here I would like to comment on the difficulties encountered to produce bulk lead-zinc concentrates from Peruvian ores for their further treatment at an Imperial Smelting furnace. Most lead-zinc ores that present difficulties for difficulties for differential flotation contain also pyrite and chalcopyrite. The idea of making a bulk concentrate is a very attractive proposition but difficult to attain. At least we at Banco Miner laboratories have not obtained good results. The main reason is that the concentrates are dilutes by the pyrite and even the recoveries for lead and zinc are lower than with standard practice. Since the idea is convenient and if successful procedures are develoved an important source of concentrates for the process can be assured it is justified to plan an intensive research program.

The only smelter for lead and zinc in Peru is located at Oroya and belongs to Cerro de Pasco Corporation. Oroya smelter is a highly complex metallurgican centre with a great variety of products Its treatment plants have been described in detail in technical articles so often that it is unnecessary to extend its description in this paper. It should be pointed out that Oroya has made important contributions to metallurgican knowledge and will no doubt continue doing so.

At the lead plant Cerro's own concentrates as well as lead concentrates purchased from other mines are treated. The treatment scheme is standard blast furnace practice; lead bullion thus produced is refined electrolytically by a modified Betts process. Slimes from the refinery are treated for the recovery of silver, gold, bismuth, antimony, slenium and tellurium.

The zinc plant produces 60,000 tons per year of electolytic zinc most of which is of four nines purity. Concentrates treated are part of Cerro's own production. The circuit includes fluid bed roasting, single batch leaching, purification and electolysis. Total zinc recovery at the plant is 77%. Treatment of residues which has been recently started will probably bring this figure closer to 90%. It has been the practice of Cerro to treat their highly marmatitic concentrates in Oroya and export the cleaner concentrates. Plans for expanding the capacity of the zinc plant to 90,00 tons per year are being considered.

The growth of lead and zinc productions and forecasts to 1972 are presented in the paper offering interesting data collected from each company. Forecasts were not extended beyond 1972, because the high priority and incentives program announced by the Government for the mining industry might cause considerable changes to production figures after 1972. In other words it is believed that production will have further increases but that there are not sufficient elements at present to qualify this expansion.

The projections presented give an increase of lead growth rate of 7 to 8% and the past growth rate of zinc production is maintained at 10.7%. Lead expansion comes mainly from operating units that have enlargement plans underway while zinc production figures will benefit from both expansion of operating units and from new mines coming into production. According to these figures zinc production will be 500 thousand tons of pure metal content which will mean almost one million tons of material to be shipped if no additional facilities are installed for metal reduction.

Marketing of Peruvian Lead/Zinc Production

The graphs presented in the paper show the changing patterns of exports of lead and zinc which are different for metal and for concentrates.

For simplicity three markets have been considered, namely, Europe, the U.S. and Japan.

In the metal export picture Japan, who started imports in 1963 discontinued them in 1965 for zinc and 1967 for lead. Europe has maintained imports of zinc slabs between 10 and 20 thousand tons per year. On the lead picture after maintaining imports of over 20 thousand a year, Europe declined sharply since 1965 to less than 5000 tons in 1967.

The U.S. which from 1959 to 1965 imported around 10,000 a year increased her imports to 32,000 tons in 1967 and her lead imports from 20,000 to almost 65,000 tons a year.

On the concentrate picture the pattern is quite different. While lead concentrates have been exported without important changes to the U.S., Europe and Japan, in the zinc graphic Japan has become by far the larger importer from a mere 20,000 in 1963 to almost 160 thousand in 1967.

Role of Foreign Capital in Lead Zinc Production

That the role of foreign capital is fundamental in Peru can be easily understood if we consider that of the 447 million dollars of mining exports in 1968, 80% proceeds from foreign companies, while only 20% derives from national companies. Its preponderance is larger in copper and iron production than in lead and zinc. Foreign participation is 50% in lead and 71% in zinc.

Foreign capital brings into the country not only funds but also technology and modern systems of administration. It also promotes local industries.

As it was said at the begining of this presentation, the development of the country depends primarily on minding exports and these can only increase significantly through foreign investment. This fact is well recognized and legal provisions have been enacted to garantee and stimulate foreign investment. This can be emphasized further by indicating that for the expansion of the project already defined a total investment of 465 million dollars is required between now and 1975.

The paper describes the legal structure of the mining law which is of a promotional nature.

Finally reference should be made to the project of installing a zinc refinery which is being promoted by the government. Since the objectives of this project correspond very closely to the aims of Unido it should be of special interest to this meeting from which very valuable suggestions should be obtained. As it stands today the project calls for a production of 60,000 tons per year of electrolytic zinc, 70,000 tons of sulfuric acid and 90,000 tons of ammonium sulfate. Sulfuric acid will be totally absorbed by the fertilizer plant. Basic objectives are:

- To export natural resources at a higher stage of elaboration, increasing thus the aggregate value.

- To provide urgently needed fertilizers at low price.

To attain these objectives several processes were investigated and finally three feasibility studies were prepared for the following processes:

Horizontal retort with the Overpelt Single Condenser.
Imperial Smelting process.
Electrolytic process.

The last one was selected on the basis of rentability and the fact that Peruvian zinc concentrates even if they come from different mines do not present special problems for the process. It uses existing hidroelectric power not depending on imported coke and in general the process uses a larger proportion of locam insumes. Also the initial investment is lower which is important when financial capacity is limited.

Total investment is estimated at 30 million dollars working capital included. 10 million will be provided by the State and 20 million will be externally financed. Under these conditions the operation will provide sufficient funds to service the debt in 10 years.

From the first year of operation there will be a gain of foreign exchange revenue of 4 million dollars and after amortization the annual gain will be of 10 million dollars. It is hoped that the presentation of this paper will help to understand the problems of a developing producing nation. Knowing the problems and possibilities of producers and consumers will help for the most rational production of lead and zinc and attain the stability of the industry that will benefit everybody.

Conclusions

1. Peruvian Mining Industry is an export industry, and accounts for 51.1% of the earnings of foreign currency of the country U.S. $442.3 millions - from this total 7.5% corresponds to zinc and 6.6% to lead.

2. It is estimated that 65.3% from the total foreign currency mining earnings - U.S. $288.8 millions is used in the country to pay salaries. Service supplies, taxes and re-imbursements

3. Lead/zinc production dervies mainly from the exploitation of complex minerals that contain silver, zinc, lead and copper. The most valuable metal in these ores is silver, which accounts for U.S. $50 millions - 702,000 kilos - zinc accounts for U.S. $33 million and lead U.S. $29 millions.

4. 83.5% of Peruvian lead produation which was 157,627 metric tons in 1967 proceeds in from the central Andes. 89% of total production of lead comes from twenty-one mines.

5. Peruvian Zinc Production, in 1967 was 328,904 metric tons; it also proceeds from the central Andes on 89.8% of the total volume. Twenty-three mines produce 96% of the total zinc.

6. 32% of the lead production and 19% of the zinc are refined in the country, the rest is exported as concentrates. At present there are all the basic conditions for the installation of a much larger zinc refining capacity.

7. In the decade of 1959 to 1968 zinc production had an actual growth rate of 10.7%. It is estimated that this rate will be maintained through 1972 mainly due to the fact that the mines Madrigal, Farallon and San Vicente will enter into production and also for the re-opening of Gran Bretana mine at a larger production scale. Contributors to this high rate of growth will also be the expansion planned by Cerro de Pasco, Minera Atacocha, and Milpo.

8. In the decade of 1959-68 Peruvian lead production grew at the rate of 2.1% per year. This rate it is estimated will rise to 8% during the period 1969-72 due to expansion of operations of the companies mentioned in paragraph 7.

9. Foreign companies established in Peru produce 50% of the lead, 71.8% of zinc and 49.5% of the silver contained in the lead/zinc ores.

10. Foreign investments in Peruvian mining industry are indispensible for the development of the country. Legal structure guarantees such investments.

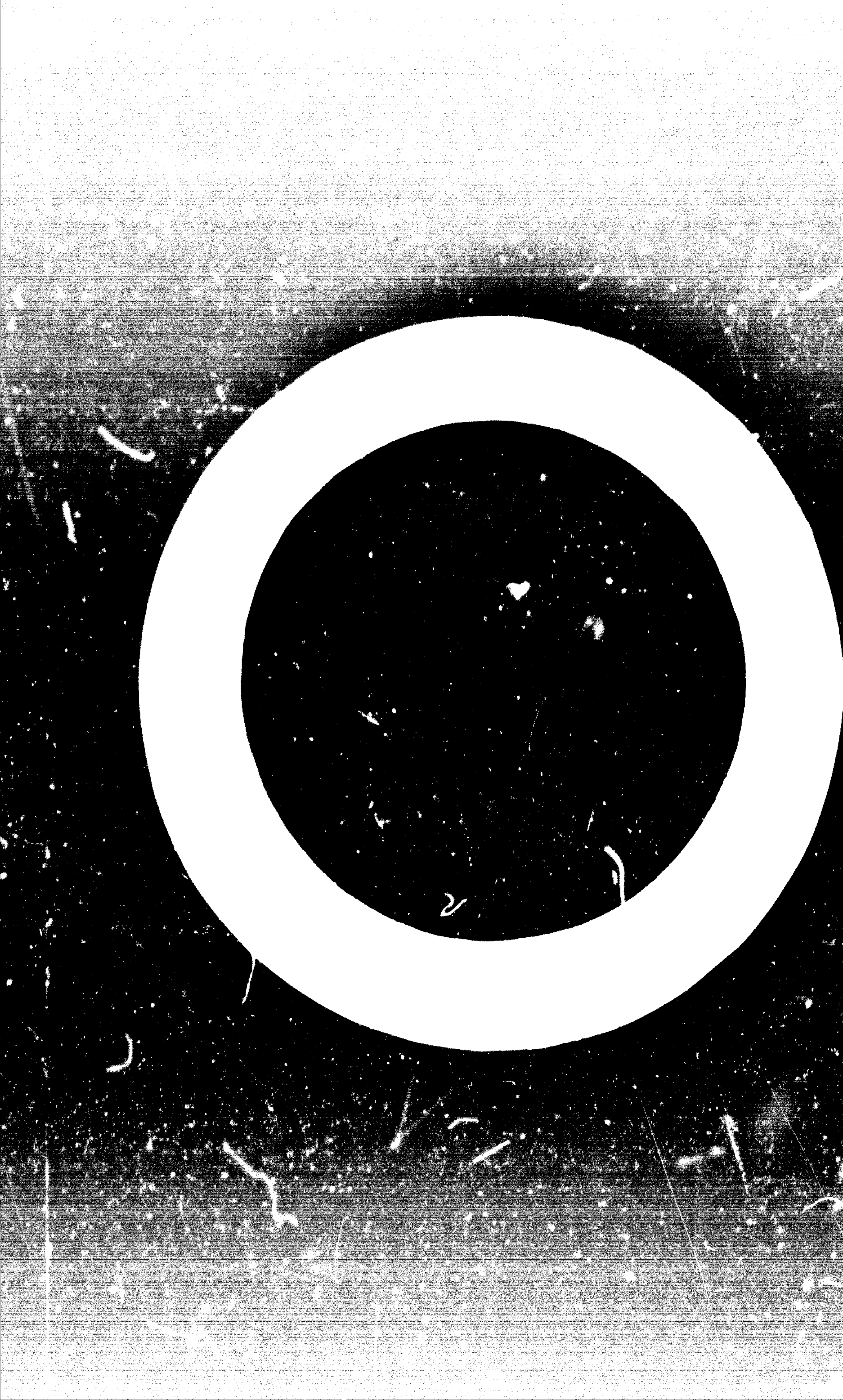
11. Exports of refined lead and zinc are marketed fundamentally to the U.S. - 96% of lead and 87% of zinc. Zinc concentrates are exported mainly to Japan - 60% lead concentrates to the U.S. European Common Market and Japan.

<u>Recommendations</u>

1. It is recommended that an intensive research programme be made with the objective of establishing procedures and conditions for production of bulk lead/zinc concentrates from complex ores by flotation.

2. It is recommended that industrial nations refrain from installing smelting and refining capacity of lead/zinc in excess of their requirements of these metals for otherwise they are competing in the international market and preventing the [illegible] developing countries.

3. It is recommended that industrial countries eliminate tariffs and quotas for the importation of these metals or of concentrates from developing countries.



The paper "Recent Improvements and Trends in Lead-Zinc Extraction Metallurgy" by Jan H. Reimers the paper did not deal at length with lead and zinc extraction process many of which are covered in detail in other papers presented to the meeting. It is confined to recent developments in both conventional and new processes.

By way of introduction it is well to remember that increasing demands for both metals have led to the need to exploit ores containing a large variety of impurities, often in large amounts, while at the same time consumers have become increasingly demanding with respect to metal purity. For example the U.S. specification for the purest grade refined lead calls for a maximum bismuth of 0.05% but some large customers now specify 0.0025%. In the case of zinc the galvanizing industry because of the development of continuous galvanizing now demands large tonnages of 0.1% lead grade whereas a few years ago this section of the market was satisfied with metal containing 0.2% - 0.4% lead. In another important section of the zinc market the Special High Grade specification with regard to lead has been reduced from 6 ppm to 3 ppm, tin from 3 ppm to 1 ppm and iron from 5 ppm to 3 ppm in both the U.K. and the U.S.

Conventional sintering and blast furnace smelting practice is still prevalent and if large lead smelters are built in the immediate future they will probably be based on this technology, but including of course modern materials handling and control methods. Oxygen enrichment may possibly be used in future blast furnace plants, and added to existing plants to increase output and reduce coke consumption.

A modern sinter plant requires a substantial investment which is economically justifiable only for a reasonably large output. New processes which do not require sintering, such as the Boliden, Outokumpu and St. Joseph Lead Company processes, might therefore be chosen in the future for smaller projects. Of these, only the Boliden process is fully developed at the present time.

Fire refining will undoubtedly be used for refining lead in the future, and these lead refineries will include modern features such as vacuum dezincing and continuous decopperising if of sufficient capacity.

In zinc smelting the trend in recent years has favoured the electrolytic and Imperial smelting processes, as shown by the following figures giving the distribution of processes used in the world (in % of total world zinc production capacity):

Process	1959 %	1968 %
Electrolytic	51.0	59.2
Imperial smelting process	0.6	10.5
Electrothermic	4.1	5.7
Vertical retorting	10.9	8.6
Horizontal retorting	33.4	16.0

During the last decade the growth of the Imperial smelting process has been spectacular. From a new process only used in a couple of plants belonging to Consolidated Zinc Corporation (now Rio Tinto Zinc), the organisation which developed and owned the process, the Imperial smelting process has become an accepted process in most parts of the world where lead and zinc are processed, with the notable exceptions of the United States and the Soviet Union. The Imperial smelting process will continue to grow in the immediate future as several Imperial smelters are now in the construction and planning stages.

However, the writer believes that the largest share of future zinc plant expansion will be based on the electrolytic process, particularly in developing countries. The reasons for this thinking are the following:

1. The electrolytic process produces directly zinc of the highest purity and this is very important in view of the continuing trends towards higher purity requirements for all metals, including zinc.

2. The electrolytic process is suitable for comparatively small productions and an electrolytic plant can be gradually expanded as required.

3. New residue treatment processes, in particular the jarosite process, will result in the highest obtainable overall recoveries for zinc and other values in zinc concentrates.

4. No zinc metallurgy is simple but the electrolytic process is still probably the easiest to operate well in developing countries with limited technically qualified personnel.

5. The buildings and a large proportion of the equipment required for an electrolytic plant can usually be supplied locally in a developing country.

In contrast, the Imperial smelting process produces the lowest grade of zinc on the market, of which an increasing proportion will have to be refined in the future; several existing Imperial smelters are therefore now installing or expanding zinc refining facilities. The fact that the Imperial smelting furnace is the largest zinc production unit available can be an advantage in industrially highly developed countries with large zinc markets and access to capital for large investments, but can be a disadvantage in developing countries where it is usually wise to get started with a plant of more modest size. Also, the Imperial smelting process is best suited for industrially advanced countries because it is a complicated process requiring the highest level of technical supervision and sophisticated control equipment to achieve good performance.

The Imperial smelting process will however probably get an important share of future zinc capacity, particularly in industrially developed countries and in cases where both lead and zinc raw materials are available in a suitable ratio. In this connection one must remember that there is still room for improvement in the Imperial smelting process and that its performance undoubtedly will be further developed in coming years.

The horizontal retort process is doomed to gradual extinction but existing vertical retort and electrothermic zinc plants appear to still be competitive. However, it is believed that little new capacity will be based on these processes, and that this new capacity will mostly be expansion of existing plants. It should here be remarked that the St. Joseph Lead Company electrothermic process has become a highly efficient zinc process with high recoveries and large units; however, it uses both coke and electric power and usually one of these energy sources is the most advantageous, the Imperial smelting process becoming a natural selection where coke is the cheapest and the electrolytic process where electric power is the cheapest. Nevertheless, there could be cases where the St. Joseph Lead Company process would be attractive, although little attention seems to have been paid to this process by outsiders.

Pressure leaching of zinc concentrates with elemental sulphur recovery offers interesting possibilities. However, the process is not yet ready for commercial use and it would not be particularly well suited for developing countries because of the sophisticated high pressure equipment and expensive materials of construction needed.

In the paper "The new lead processes" by G. Bjorling it was indicated that in spite of the metal's relative nobility the metallurgy of lead is not so simple as one would presume. This is caused both by its occurence as sulphide and by the low melting points and the high volatility of the metal and its compounds.

The old Scotch hearth process offered a simple way to take advantage of some of these circumstances and enabled the direct production of lead from high grade galena ore. Its adaptability to low grade ores and ordinary concentrate was, however, not so good, and the blast furnace process became the most important smelting procedure for lead and practically the only used around 1950.

The benefits of the hearth process were not forgotten, and when the supply of rich galena concentrates has become more abundant there has appeared some new processes grounded on the same basic principle, the roast reaction, which can be expressed as the partial oxidation of galena to metallic lead:

$$PbS + O_2 \longrightarrow Pb + SO_2$$

Of the new processes the round hearth process is a direct conversion of the old straight hearth process whereas the self-fluxing smelting has same new features. These two are both characterized by excess oxygen in the basic reaction written above and therefore require a slag reduction treatment as a substantial complement to the smelting proper.

Another type of processes works with deficit oxygen in the basic reaction and therefore must be eliminated sulphur from the bullion. The most important process of this type is the Boliden process where the partial oxidation is performed as flash smelting in the upper part of an electric furnace; the residual sulphur is removed in a converter.

The blast furnace process for zinc (the ISF process) gives lead as a large-scale byproduct and has turned up as an important lead producer. Thus it must also be discussed as a new lead process.

To make an objection-free comparison of the newer lead processes both among themselves and with the standard blast furnace smelting is very difficult if not to say impossible. There are always some important parameters which are not comparable such as size, composition of galena concentrate, prices on local facilities (labour, fuel, energy), relations between these, local regulations on air and water pollution and possibilities to evaluate zinc and other minor metals in the raw material.

(over) Table 41 gives consumption figures for the different processes. Such expenses as costs for overhead, for licences, for assaying, for other staff than direct labour besides repair and maintenance etc. have not been taken into consideration as they differ much from one site to another. The figures in columns S refer to a small plant with a throughput of about 10,000 t/yr (30 t a day) and L to a larger plant of about 50,000 t/yr (150 t a day)

(Attached) In table 42 each main item in tab. 41 has got a characteristic relative number 0 to 5 where 0 means a not significant cost and 5 a very dominating cost. The sum of these numbers give a relative estimation of the competivity of a process and how it varies with the size of the production.

(Attached) Finally, fig. 41 tries to illustrate these variations graphically.

Table 41. Basis of cost calculations for smelting a ton of galena concentrate with 72 % Pb.

S small plant, L large plant. ISF considered not fit for use for large tonnages of additional lead burden.

Scale / Process	Blast furnace		ISF	Round hearth		Self-fluxing		Boliden	
	S	L	S	S	L	S	L	S	L
[illegible] hour [illegible])	9.7	3.2	[illegible]	[illegible]	3.4	7.1	[illegible]	4.0	[illegible]
[illegible]									
	19.3	6.4	-	85	52	[illegible]	74.0	-	-
	150	150	-	[illegible]	13	-	-	12.5	[illegible]
	-	-	-	[illegible]	150	24	24	-	-
[illegible] in kWh	[illegible]	195	50	[illegible]	60	161	45	750	596
[illegible]									
[illegible]	44	44	113	[illegible]	40	-	-	200	200
[illegible]	-	-	-	15	[illegible]	7.4	7.4	-	-
[illegible]	5.5	2.2	1.1	3.4	[illegible]	6.0	4.0	3.0	[illegible]
[illegible] costs $	16.1	8	4.5	12.1	8.9	16.9	14.0	15	[illegible]

In spite of their simplicity and apparent ability to extract lead at low production costs the roast reaction processes have definite limitations in their adaptability. The most important is their exclusiveness to sulfidic concentrates and specially to high grade ones. For the round hearth process and the self-fluxing smelting, described above as the roast reaction processes with oxyde excess, comes further the fact that they operate in small furnaces, it is not clear that a larger production can be performed in larger units so probably this requires enlarged number of units which increases the costs of both labour and equipment. Finally, these two processes seem to be suitable only for concentrates with basic gangue.

The Boliden process (and eventually also the Outokumpu method) should be competitive for medium and big smelters. It requires medium-grade concentrate, the capital costs are relatively high but the need on labour is small even if it must be skilled in order to handle the complicated equipment. If electric power is cheap and coke expensive, there is no doubt that this process, perhaps in combination with the basic ideas of the Outokumpu process, is very applicable for the treatment of good concentrates. A drawback is the handling of large quantities of flue dust which, however, can be mechanized to a great extent.

For large tonnages of concentrates of low and average grade the blast furnace process still is a good alternative. It has the greatest adaptiveness of all processes and is suitable also for oxidic minerals like cerrusite $PbCO_3$ and anglesite $PbSO_4$. It requires both expensive fuel as coke and is not very low in costs for labour, repairs and construction but like the old blast furnace for pig iron it has proved very reliable, so even if existing lead plants should be rebuilt today most of them should still use the blast furnace method.

There is one important limitation and that is if the lead concentrate can be treated together with sufficient quantities of zinc concentrates. In this case the ISF process can produce lead to a cost below that of every other lead producing process.

Conclusions

1. In spite of their simplicity and apparent ability to extract lead at low production costs and roast reaction processes have definite limitations in their adaptability. The most important is their exclusiveness to sulfidic concentrates and specially to high grade ones. For the round hearth process and the self-fluxing smelting, described above as the roast reaction processes with oxyde excess, comes further the fact that they operate in small furnaces; it is not clear that a larger production can be performed in larger units so probably this requires enlarged number of units which increases the costs of both labour and equipment. Finally, these two processes seem to be suitable only for concentrates with basic gangue.

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4. There is one important limitation and that is if the lead concentrate can be treated together with sufficient quantities of zinc concentrates. In this case the ISP process can produce lead to a cost below that of every other lead producing process.

Table 42. Relative characteristic cost of different processes.

S small plant, L large plant.

Process	Blast furnace		ISF	Round hearth		Self-fluxing		Boliden	
	S	L	S	S	L	S	L	S	L
Labour	5	2	1	5	3	4	3	3	[illegible]
Fuel	5	5	-	4	4	3	3	-	[illegible]
El. energy	1	1	-	1	1	1	1	5	[illegible]
Materials	1	1	1	1	1	1	1	2	[illegible]
Maintenance	5	2	1	3	2	5	4	3	[illegible]
Capital costs	5	3	1	4	4	5	5	5	[illegible]
Sum	22	14	4	18	15	19	17	18	12

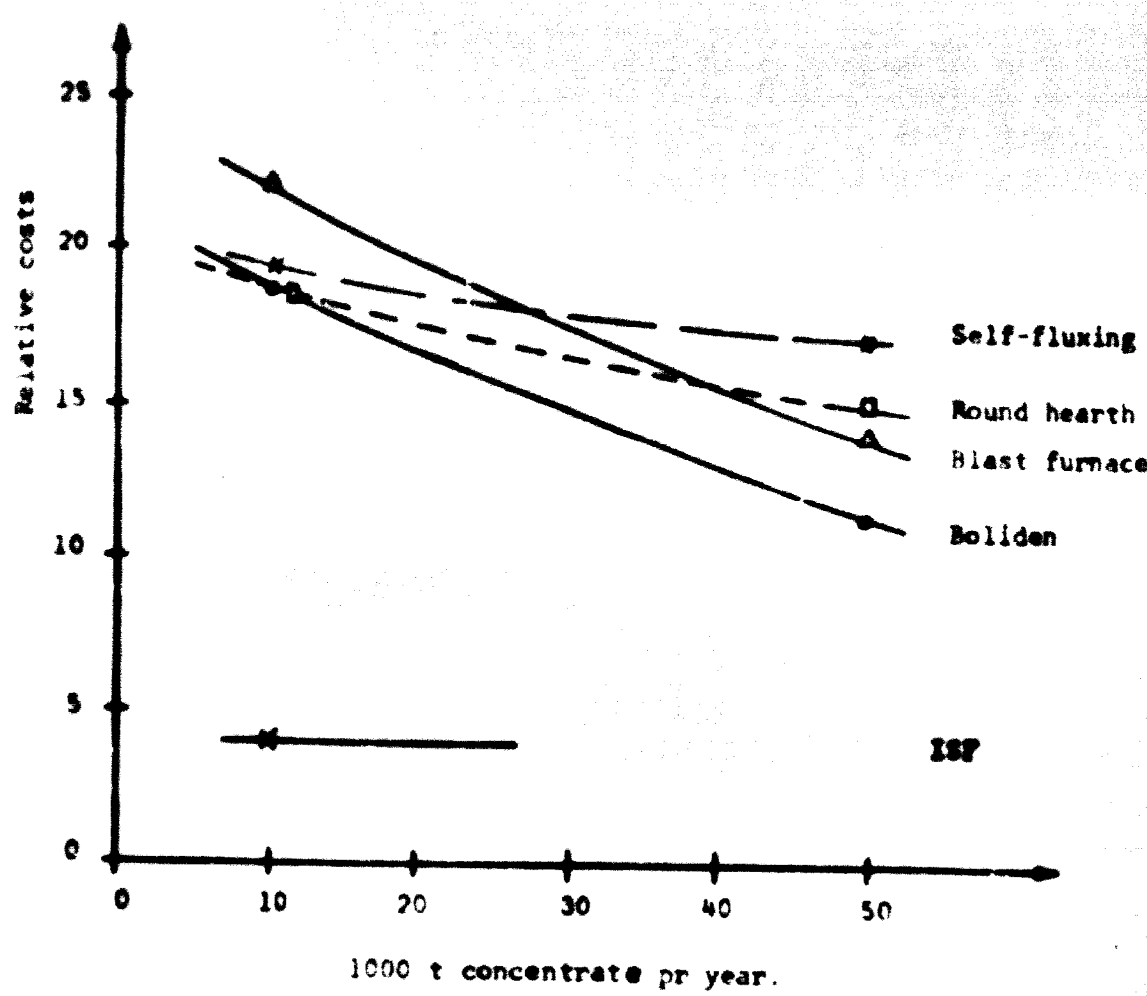

Fig. 42. Relative costs of different lead processes.

The paper "Sintering Techniques as applied to the Imperial Smelting Process" by C.J.G. Evans covered various aspects of the development and current practices in the process of converting zinc/lead non-sulphide ores or sulphide concentrates into a form suitable for charging into the Imperial Smelting Furnace. This process is generally termed sintering and is essentially a process combining agglomeration and desulphurisation. The amount of sulphur to be removed depends on the raw materials used since the desulphurised product should always contain less than 1% residual sulphur.

Sintering is by no means exclusive to the non-ferrous extraction industries being used widely in the ferrous industry as well. The broad objectives of sintering are:-

1. the drying, calcining and/or roasting of fine ores or concentrates
2. the agglomeration of fine ores or concentrates which could not be smelted economically otherwise and
3. increased blast furnace productivity

There are however some basic differences in the nature of operations the main one being the source of fuel for the sintering process. In general coke has to be used in iron sintering. This represents an added cost and therefore considerably less selectivity is exercised on the output sinter and the returns to raw materials ratio is kept much lower. Some other basic differences are outlined.

The fuel for most non-ferrous sintering operations is the sulphur contained in the metal bearing concentrates. This must be carefully controlled by the use of undersize sintered product in order to obtain a mixture which will combine high sulphur elimination with the requisite degree of fusion to give a good quality cellular structured product. Downdraught or updraught draughting techniques can be employed but in either case the gas leaving the sinter machine contains up to 7% SO_2 which is usually converted into sulphuric acid.

The development of the blast furnace process for smelting zinc necessitated considerable change in the sintering practices used at the Avonmouth and Swansea Works of Imperial Smelting Corporation. Downdraught sintering had been used to produce a small sized sinter (-¼") for the Horizontal Distillation and Vertical Retort Plants. In order to increase the size to produce a sinter suitable for the blast furnace hardening agents were added, such as silica. Further understanding of the Imperial Smelting Process resulted in an increase in complexity of the demands made on the Sinter Plant and resulted in much investigational work on the plant. Two pass sintering was tried, using coke as the fuel for the second pass but severe mechanical difficulties with grate sealing eventually prompted the development of updraught sintering for zinc/lead materials initially on a two pass basis using some coke fuel and ultimately using a one pass system with only sulphur (in the form of sulphide) as the fuel. This method provides the basis for current operations at eleven plats associated with Imperial Smelting Furnaces.

Due to improvement in knowledge and technique the design requirements for a modern sinter plant are considerably more complex than the original Avonmouth plant as modified for updraught sulphide sintering. Much more attention must be paid to raw materials proportioning, mixing and conditioning and the feeding of feed to the sinter machine. Sinter machine operation is similar although at a higher intensity and more controlled, while much more attention is paid to the handling of output sinter so that the sinter charged to the furnace is the best possible to promote high smelting rates and good recoveries.

Over the years considerable investigational work into sintering has taken place both on a laboratory pallet scale and on a full plant trial basis and from this work has emerged considerable knowledge of how certain factors exert an influence on the sintering conditions. These factors are:-

1. Sulphur content of the sinter machine feed
2. Intensity of draughting
3. "Returns" sizing
4. Efficiency of Mixing
5. Moisture in sinter mix
6. Chemical composition of sinter

and their influence on the requirement for sinter is covered in some detail.

Although using the same process to perform the same function no two sinter plants are identical either in equipment or in precise method of operation. The main differences at the various Imperial Smelting Furnace complexes throughout the world are outlined and a table showing the analysis of the different sinters produced is included.

Naturally the ever increasing requirement for improved efficiency means that the sintering process is under constant review. Possible alternative methods are examined briefly, particularly fluid bed roasing and briquetting, however, it would appear that sintering provides the best means of simultaneous desulphurising and agglomerating. This is especially true with the high lead sinters (+ 15% Pb) which are normally smelted in Imperial Smelting Furnaces.

Some areas for improvement in existing technique are proposed and in fact investigational work is already in hand on some of these topics. There remains considerable room for improvement however since there is an ever increasing demand for sinter of an every improving quality.

• The "Metallurgy of the Zinc/Lead Blast Furnace" was described in a paper by R. Healey. Zinc reduction at normal pressures can be brought about by carbon only at a temperature above the boiling point of the metal, and production of zinc in a blast furnace, therefore, involves reduction to vapour followed by condensation. The high latent heat of vapourization also implies that reduction can occur only in the hottest zone near the bottom of the shaft. The chemical potential of the gases in the upper shaft can be utilized, however, by including lead bearing materials in the charge, since lead runs down and is tapped off at the bottom of the shaft, while the zinc vapour rises to the top of the furnace.

Reoxidation of the zinc would be caused by the high oxygen potential of the gases if they were cooled slowly. The gases are therefore passed to a separate chamber and scrubbed with molten lead, thrown up from a pool by rotating paddles, which serves both the "freeze" the reaction and to dissolve the zinc vapour. Note that this lead splash condenser is used solely for absorbing zinc and has no connection with lead production in the furnace shaft.

The cooled gas is scrubbed again with water and used to fire the coke and hot blast preheaters, while the condenser lead is pumped continuously through a water cooled launder, where the zinc is thrown out of solution as a separate liquid layer. An underflow baffle diverts the zinc to a holding bath, while the cooled lead returns to the condenser.

CHARGE PREPARATION

The materials to be handled are sinter, coke, lime flux and a little recycled dross. The sinter is screened before charging to remove minus half inch material which is deleterious to furnace operation as it causes uneven gas flow through the charge. The coke is not screened, being mostly between 2½ and 3½ inches as received, but it is preheated to about 750°C as a means of returning waste heat to the furnace.

Most of the lime included in the charge to correct the slag composition is incorporated in the sinter, but a proportion is added at the furnace to give closer control. This furnace addition is made as hard burnt lime to avoid charging fine material.

Careful control of the proportion of coke to sinter is necessary as the carbon/zinc ratio in the charge has a strong effect on the zinc loss to slag. Increasing this ratio reduces the zinc in slag but also reduces the zinc throughput of the furnace since the coke burning rate is roughly constant. As a result it is generally most profitable to run with a zinc loss in slag of about 5% of the input, though technologically it is possible to get to below 3% zinc in slag assay, with good control of the sinter composition.

FURNACE SHAFT

The standard furnace shaft has a rectangular cross section with semicircular ends approximately ten by twenty feet in dimension. The height is thirty feet, of which the lower third consists of water jackets sloping in to about six feet apart at the bottom. Charge enters through two sets of double bells, and hot air is blown in through sixteen water cooled tuyeres near the bottom of the jackets. The height of the charge column is about twenty feet. This elongated shape was chosen to keep the tuyeres on either side relatively close together and provide an intense smelting zone for zinc reduction, although it also results in less even charge distribution.

The hot blast is preheated by Cowper stoves (up to 850°C) or tubular heaters (up to 750°C) fired with blast furnace gas. At present there is no standard system for controlling the blast distribution among the tuyeres, but the development of methods to give the best distribution of charge and blast is proceeding.

There are basically three zones in the furnace, the tuyere zone, the equilibrium zone and the charge preheating zone. The tuyere zone is the region in which carbon combustion, zinc reduction and slag melting occur, the principal chemical reactions being:

$$2C + O_2 = 2\ CO$$
$$ZnO + CO = ZN + CO_2$$
$$C + CO_2 = 2\ CO.$$

The latter reaction absorbs heat and consumes carbon without reducing zinc and is therefore undesirable. Thus the most suitable coke for the zinc blast furnace has low chemical reactivity as well as sufficient strength to resist mechanical breakdown. Typical hardness of coke supplied to Avonmouth in 1968 was MICUM M40 = 7[illegible] to 80%, M10 - 8 to 10%. This is adequate for the Imperial Smelting Process

Heat transfer from gases to charge is virtually complete at a short distance above the tuyere zone, where the equilibrium zone commences. Physical and chemical equilibrium, at a temperature of about 1,000°C, then persists until the charge preheating zone is reached near the top of the charge column. Chemical reaction is not possible because the reduction of lead oxide (and ferric to ferrous oxide) is completed in the preheating zone, and the temperature is not yet high enough for zinc reduction to begin.

The charge preheating zone consists of the upper two or three feet of the charge column in which cold sinter and preheated coke are raised to furnace temperature and preliminary reduction occurs. The necessary heat is supplied mainly from the sensible heat of the gases but also partly by reoxidation of some of the zinc vapour by carbon dioxide.

The gases leaving the charge would precipitate zinc oxide on any cold surface they met, so to prevent this, the temperature is raised by injecting so-called top air into the open space below the shaft roof. This burns part of the carbon monoxide content of the gas and raises the temperature above the reoxidation point for zinc.

The gas finally passes via the furnace offtake to the inlet of the lead splash condenser.

SLAG AND BULLION HANDLING

Slag and lead bullion are tapped off at approximately hourly intervals. The lead is separated in a forehearth from which it is removed via a lead well or a taphole, while the slag overflows and is granulated in a jet of water. The copper content of the charge is largely collected in the lead, with a recovery rate of 70% to 80%. The copper is miscible with lead at tapping temperatures but is thrown out of solution as the lead cools and is recovered as a copper dross. The present limit of normal operation is about 12% copper in bullion, though 20% has been reached in trial runs.

CONDENSATION AND SEPARATION

The condenser contains a pool of lead from which eight rotors throw up a spray of droplets to fill the gas space between the pool and the roof. Cooled lead enters at about 450°C and flows against the direction of the gas stream, reaching a final temperature of about 550°C. It then passes through a submerged slot to a sump from which it is pumped continuously to the water cooled launders.

The furnace gas enters the condenser at about 1050°C and is rapidly cooled, eventually leaving at about 500°C, while the zinc vapour is absorbed by the lead droplets. The gas is finally scrubbed with water, after leaving the condenser, to remove such zinc (about 5% of the total) as escapes absorption in the lead. This zinc is returned to the sinter feed.

The hot lead flows through two cooling launders (narrow water jacketted channels working in parallel) on its way back to the condenser. As the lead cools the zinc is thrown out of solution and rises to the surface forming a separate liquid layer. When the lead is sufficiently cool it passes to a chamber containing an underflow weir which holds back the zinc while the lead goes on to re-enter the condenser. The zinc is diverted and over-flows into a holding bath from which it is periodically tapped off.

ZINC PURIFICATION

The principal impurities in holding bath zinc are lead and arsenic. The arsenic is removed by addition of metallic sodium, forming a sodium arsenide dross which is skimmed off. The method of lead removal depends on the grade of zinc which it is desired to produce.

Simple liquation is all that is necessary to make Grade 4 (98.5%) zinc. The metal is tapped from the holding bath, sodium treated in the ladle, and poured into one end of a large bath through which it moves slowly. Lead settles out at the bottom, while the purified zinc overflows into another holding bath from which it is tapped off and cast.

Vacuum dezincing can be used if it is desired to produce Grade 3 zinc (less than 0.1% lead). This method makes use of the heat content of the condenser lead. which is pumped from the sump to the inlet of a culindrical vacuum vessel. The lead flows down a spiral launder close to the wall of the vessel, leaving by a barometric seal near the bottom, and finally returns to the condenser via a short cooling launder. Zinc vapour is evolved from the lead under vacuuum and is deposited on a central water cooled condenser, at first as a solid layer. As the thickness increases the surface temperature of this layer rises until it reaches the melting point of zinc, after which the condensed metal runs off through another barometric seal to a holding bath.

This process produces an enhanced grade of zinc, but cannot remove its cadmium content, which, being more volative than zinc, distills over with it. This cadmium can be recovered however, by use of the cadmium column only of a refluxer plant, which, since it does not require total boiling of the zinc, is much less expensive to run than the lead columns.

Typical composition of vacuum distilled zinc, produced at the rate of four (4) tons per hour, is

Pb 0.06%, Cd 0.02% (after decadmiumisation)
Fe < 0.003%, As 0.001%, Sn - not detectable.

Zinc purification by refluxing is a two stage process in which the zinc is first boiled off from lead and other non-volatile impurities (in the lead column) after which cadmium is boiled off from the zinc (in the cadmium column). Because of the heavier load on the first stage, it is normal to feed one cadmium column from two lead columns. Molten zinc runs from a feed bath to the middle of the lead column which consists of a stack of carborundum trays luted together at the edges. The lower half of the column is externally fired with oil or gas while the upper half forms a reflux column from which the gases pass to a condenser. Zinc and cadmium vapour pass upwards while liquid zinc, enriched in lead, flows down.

To produce all Grade 1 zinc, the whole of the bottom product of the lead columns must be recirculated. The lead liquates in the feed bath is removed through a forewell. If it is desired to produce a proportion of Grade 4 metal, the bottom product is removed and liquated in the normal way to reduce the lead content to below 1.3%. By adjusting the firing of the columns it is possible to control the relative proportions of the zinc feed which appear as top and bottom products.

The top product of the lead columns is transferred to the cadmium column by feed launders. Grade 1 zinc now appears as the bottom product, while the top product is a zinc alloy containing 5 to 10 per cent cadmium. The cadmium is recovered from this alloy by distillation in a small separate column producting pure zinc and crude cadmium metal.

In the paper "The Imperial Smelting Furnace for the Simultaneous Recovery of Lead and Zinc in Developing Countries" by B. Barlin it was pointed out that of the eleven Imperial Smelting Furnaces operating in nine different countries throughout the world, only one is situated in the developing country of Zambia, and is operated by the Zambia Broken Hill Development Company.

Production of lead and zinc from this source represents less than one per cent of world production and less than one per cent (now 2.7 per cent) of this production is consumed in Zambia.

The problems of operating the Imperial Smelting Furnace complex in Zambia revolve around the skilled labour availability to operate the sophisticated plant, the supply of stores and equipment, and the disposal of finished products to overseas customers.

The Rhodesia Broken Hill Development Company was formed in 1904 after an Australian prospector, T.G. Davey discovered the outcrops in 1902. The existing mining and metallurgical complex was developed over the years to treat the ores, which consist of intimate mixtures of sulphide lead and zinc minerals with abundant silicates, carbonates and other oxides of these metals.

The irregularity that characterizes the shape of the orebodies applies equally to their mineral content, which makes ore reserve calculations and the maintenance of a balanced feed to the metallurgical plants problems of some magnitude.

The Flowsheet

The ore hoisted from the mine is conveyed to a crushing and washing plant.

All the -¼ inch fraction is screened out and transported to the Sinter Plant.

The +¼ inch portion is treated in a Heavy Media Drum Separator to remove dolomite waste rock. The sink product is crushed, ground and treated in a flotation plant for the recovery of the sulphide minerals. The sphalerite concentrate is roasted in the Flash Roaster and the gases are converted to sulphuric acid in a Lead Chamber Plant.

Both the roasted calcine and the flotation tailing which contains approximately 25 per cent of oxidized zinc are leached together for the production of electrolytic zinc.

The feed materials to the Sinter Plant of the Imperial Smelting Process consist of all the -¼ inch material from the ore hoisted, large tonnages of reclaimed dump materials, all the lead concentrate and such calculated tonnages of zinc concentrate to maintain a minimum of 21 per cent lead and 24 per cent zinc in the sinter fed to the furnace. Condenser and refinery drosses are also circulated to the sinter plant. The only flux material added to the charge is pulverised limerock.

Final Products include electrolytic zinc (99.95% zinc); Prime Western Grade zinc (98.5% zinc) and High Purity lead (99.99+% lead). Silver and Cadmium metals are also produced as by products and in earlier year Vanadium Pentoxide was also produced.

Imperial Smelting Furnace Operation

The feed material for the furnace are confined to those available from the Mine and are relatively low grade and of variable composition, by comparison with those available to the majority of Imperial Smelting Furnaces in other countries, where judicious purchase of suitable ores from a variety of sources is possible.

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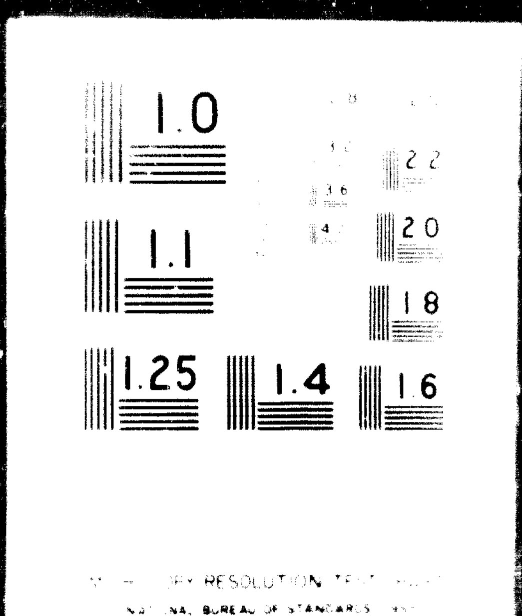

We regret that some of the pages in the microfiche copy of this report may not be up to the proper legibility standards, even though the best possible copy was used for preparing the master fiche.

As a result a high proportion of gangue must be handled, which limits the furnace zinc output rate to a level which compares unfavourably with that achieved elsewhere. All other performance indices are comparable.

Of major importance in the operation is the successful control of the slagging operation and of the condenser system for zinc vapour, in which some 2,000 tons per hour of molten lead is circulated. These functions are largely dependent on manual operations carried out by well trained operators.

Inattention to detail and slow response to deviation from target conditions cause immediate difficulties which rapidly escalate to halt production for long periods.

Manning and Training

The operation of a plant with a new process anywhere in the world brings in it's trade problems of manning and training. In a developing country these problems are compounded. At the time of the commissioning of the Imperial Smelting Furnace in [illegible], the [illegible] Development Company found itself with little own experienced labour, and all the skilled labour and professional managers were [illegible] Europeans.

Training for all the skilled levels required for the Imperial Smelting Furnace was provided by selecting men of [illegible] in similar [illegible] in existing plants and sending them to [illegible] and [illegible] for training.

[illegible]

In 1964 Zambia was granted independence and it was necessary to enhance the training programmes to satisfy the Government policy of Zambianisation in the industry.

Complete surveys of the existing labour force were carried out to determine the extent of the problem. This study revealed that of the 2,000 local workers employed, 1,200 were illiterate in English and their own language, and the remainder were literate only in their tribal language, and only two men at the time had a better than Form II (Standard VII) level of education.

Training therefore had to correct this condition in order to supply the future needs of the Company.

To resolve the situation in the metallurgical departments, job descriptions were prepared for all the jobs carried out and a Job Evaluation Manual for wage grading was drawn up.

From the job descriptions a breakdown of the components of each job was made; some components are common to all jobs, some common to certain jobs and so on. It was a fairly simple matter to [illegible] components into a series of modules, 'basic', '[illegible]' or [illegible] '[illegible]' for the most [illegible] and '[illegible]' for the individual [illegible] and operating jobs. This created a system [illegible] and the [illegible] personnel [illegible]. [illegible] the new [illegible] structure was [illegible] and the best man for each job was chosen and all were developed to the limit of their potential.

To [illegible] the Engineering [illegible] of the [illegible] [illegible]

It was then determined what part, and how much, of this could be taught in three months of intensive workshop classroom training followed by three months closely supervised "on Job" training. The skills acquired were formalised as being those of a mechanic grade III. Between this, the lowest level of tool using skill and full artisan skills, three further grades of mechanic were established, namely Mechanic II, Mechanic I and Leading Mechanic. Each grade in each trade being defined clearly with a job outline and standards set by trade tests.

The study enabled a revision of the establishment of the maintenance section to incorporate more mechanics and reduce artisans. By placing mechanics in crews under the supervision of an artisan it was possible to ensure adequate supervision of the mechanics and to further train him in acquiring greater skills.

The difficulties encountered are attributed to two main factors, language and environment. Language because of the difficulty in communications especially in the terminologies.

Environment because of the almost complete technical void in a society based on a simple agrarian economy.

Any training scheme, therefore, to be effective must be supported by a system of pure education to prepare a trainee mainly to understand the instruction he is about to undergo. Initially to provide literacy and ability in both English and arithmetic, adding other subjects as the student progresses at all basic principle levels. This education is provided in adult education classes.

Supply of Materials

The political implication of Zambia's position in relation to her Southern neighbours must be understood to realise Zambia's desire to divorce herself from dependence on these countries. In the transition period therefore it has become absolutely essential to realistically reset levels of stores held on the mine with a sufficient margin to cover emergencies. Stock holdings have therefore been increased by some 27 per cent to cover resultant longer delivery periods.

Metal Sales

Lead and Zinc

Metal is sold f.o.r. Kabwe for Central and South African customers and c.i.f. for overseas customers. Any divergence between sales in African and Overseas reflecting an increase in the latter does incur greater costs due to realisation charges on c.i.f. sales. South Africa withdrew orders in [illegible] and realisation charges will be increased considerably in [illegible].

The fact of Zambia being some 1,300 miles from the nearest ports of Beira and Lourenco Marques in Mozambique presents many problems particularly as all traffic has to pass through Rhodesia.

In travelling through three different countries three different railway companies are involved each presenting it's own problems of language, currency and difficulties with rolling stock.

Conclusion

The improvement in performance of the Imperial Smelting Furnace Plant over the past few years bears testimony to the success of the operation in Zambia.

A paper was tabled at the meeting on behalf of Mr. Fujimoni on "The Imperial Smelting Furnace Process for the Simultaneous Production of Zinc and Lead at the Karima Works of Somiko".

The Imperial Smelting Furnace operated by Sumiko I.S.P. Ltd., at Befu, Japan represented the first venture into zinc production by the parent organisation, the Sumitomo Metal Mining Company. The furnace, which has a shaft bricked to give an area of 165 square feet (15.3 square metres) as compared to the normal 185 square feet (17.2 square metres), was commissioned in May 1966. The plant acts as a custom smelter, utilising a variety of domestic and imported concentrates. Current weekly production averages over 1000 tons of zinc and 450 tons of lead.

In his paper Dr. Fujimoni considers the particular advantages of the I.S.F. to be as follows:

1) The process has a greater flexibility in the selection of raw materials to be treated compared with alternative processes such as vertical retorts or the electrolytic process.

2) The process has relatively low labour and capital costs. A table is given in the paper of unit comparisons of labour and materials required by the various zinc processes.

3) The process has the ability to recover copper and precious metals contained in concentrates in the furnace bullion without the additional costs of subsidiary processes.

<u>SLAG COMPOSITION</u>

Dr. Fujimoni considers that the desired characteristics of I.S.F. Slag are that it should be small in quantity, contain as little zinc as possible and be fluid.

The quantity of zinc in I.S.F. slag is governed by the activities

of zinc oxide and iron oxide in the slag and by the reducing conditions in the furnace. The object is to obtain good zinc elimination from the slag without reducing iron oxide to metallic iron.

Dr. Fujimoni calculates theoretically that under equilibrium conditions it is possible to decrease zinc in slag to 1.0 - 1.5% without reducing iron oxide.

In practice, since the furnace is not in equilibrium iron is made at higher levels of zinc in slag than the theoretical figures. Also the consumption of carbon required to obtain very low zinc in slag may not be economic.

At Befu with the prevailing high alumina (9-10%)

The slag made is of the melilite type (Feo.Cao.Sio_2. Al_2 O_3) as opposed to dicalcium silicate. Good zinc elimination is obtained from the slag without the need to add hard burnt lime as is practised on other I.S.F.s. The slag weight and association zinc loss in slag is therebye reduced.

Shaft Gas Analysis

The reducing conditions in the furnace shaft must be such that zinc oxide is reduced without iron oxide being reduced to metalic iron. The carbon in the coke is burnt to carbon monoxide at tuyere level and then the Co_2 ratio increases up to 1.0 at the reaction zone as carbon monoxide reduces zinc and is itslef oxidised to carbon dioxide. The Boudouard reaction between carbon and carbon dioxide subsequently reduces the Co_2/Co ratio. Dr. Fujimoni considers that by using a coke of relatively high reactivity the Co_2/Co at the top of the furnace before entering the condenser is lower than obtained on other I.S.F.'s. This is considered by him to be a main reason why the overall codensation and separation efficiency is as high as 90-91% at Befu since there is less tendency for the back reaction which forms zinc oxide from gaseous zinc

Blast Temperature

The importance of blast temperature in the I.S.F. is illustrated by a heat input summary prepared at Befu which indicates that nearly 20% of the total heat input to the furnace arises from the hot blast. A further increase in blast temperature would increase in output. However, Sumiko consider that additional cleaning of the low calorific value furnace exhaust gas, which is used to preheat the blast, would be necessary to protect the Cowper stoves refractories.

Recovery of Lead

Lead oxide in suiter charged to the furnace is easily reduced by carbon monoxide. The metallic lead formed acts as a collector for copper, silver, gold, antimony and bismuth. At Befu the total recovery of new lead in the form of bullion and copper dross is about 94%

An advantage of lead in suiter is that it gives satisfactory suiter hardness at lower silica contents. This means that a lower quantity of slag is made in the furnace with associated lower fuel consumption and lower zinc loss in the slag. The suiter currently used at Befu analyses 45% Zinc 19% Lead 2½% Silica and and 4% lime.

Behaviour of Sulphur and Copper

Sulphur input to the furnaces arises from suiter and coke which usually contain 0.8% and 0.7% sulphur respectively at Befu. The majority of the input Sulphur reports in slag and matte of speiss. It is considered that increased sulpher in Suiter has an adverse effect on operations by causing increased accretion formation in the furnace shaft.

In the I.S.F. copper is recovered in bullion rather than by formation of a copper rich matte. This is attributed to the reducing conditions in the furnace and the preferential formation of iron [illegible] is not present high and the sulphur capacity of the slag becomes exhausted.

IRON

As previously mentioned Befu have found a good correlation betwee zinc content in slag and Feo content in slag. A negative correl ation has been found to exist between zinc content in slag and th quantity of matter and speiss produced. This is explained by th fact that lower zinc in slag is associated with more strongly reduarg conditions and a higher iron oxide activity in the slag. Thus there is an increased tendency for the formation of iron sulphide and arsenide.

Mr. Fujimoni concludes his paper by detailing the florine and chlorine balances obtained at Befu.

The paper 'Some New Developments in Lead Refining and Treatment of Intermediate Products' by L.S. Getzkin examined the new processes for lead and zinc production and in particular the recent developments in the U.S.S.R.

Continuous decoppering of lead bullion

Since nineteen fifty six researches have been carried out in the USSR on a laboratory and industrial scale for improving the process of lead decoppering. The research was made in two directions:
firstly: transferring copper directly into matte,
secondly: transferring copper into dross.

In both cases a furnace with a deep bath of lead is used, with the temperature gradient from about one thousand degrees Centigrade in the upper layer to some four hundred degrees at the bottom.

Continuous transfer of copper into matte is carried out at one of the Soviet plants in an electric furnace, while another uses a flame furnace.

Decopperized lead is continuously discharged at the furnace bottom.

Lead concentrate and a small quantity of soda ash are used as reactants. Sodium sulphide thus formed reduces the melting point of the matte and its lead content.

Considerable advantages are offered by the electric furnace, as compared with flame heating:
an improved degree of copper removal,
improved temperature control,
reduced gas evolution, and
better working conditions.

The copper content in the purified lead is 0.I (point-one) to 0.4 (point-four) per cent.

The process was patented in the USSR. Later on it was modified at Port-Pirie : a device was made for cooling lead outside the furnace, which resulted in a higher degree of lead purification.

Electric smelting of copper drosses

The new process of copper dross treatment in a deep-bath electric furnace does not eliminate the drossing operation, but it has certain advantages. As only the drosses go to the electric smelting, the size of the furnace is greatly reduced.

The deep bath of molten metal yields the lead of sufficient purity, eliminating the circulation of metals which takes place when drosses are treated by other methods.

The copper dross is smelted with a reducing agent and some sodium sulphate added. As a result 96% (ninety six per cent) of the copper pass into the matte and the noble metals and stibium go into the metallic lead.

Sulphide-sodium phase systems pertaining to copper-sodium mattes have been studied to get a firm theoretical basis for these processes.

Removal of arsenic from lead smelter fume by sulphating roast

Many complex ores contain considerable amounts of arsenic. In the process of their benification this element finds its way into lead, zinc and copper concentrates. During blast furnace smelting about 60 per cent of arsenic go into the fume, other 20-30 per cent are removed in the form of sodium arsenate during the alkali softening of lead.

Thus, the fume and flue dust concentrate most of the arsenic, sometimes up to 120 kilograms of it per ton of fume. There are also copper, lead, cadmium, zinc as well as some rare elements in the fume, which is a valuable raw material for metal production.

Most of the lead smelters normally return their fume to the sinter charge, which leads to a build up or arsenic in the smelter products and greatly complicates lead reduction and refining.

In the Soviet Union a new method has been developed for the treatment of lead smelter fume, which provides for the elimination of arsenic from the process and brings about the complete recovery of valuable metals.

The process comprises in the main nodulising the fume with concentrated sulphuric acid on a balling pan with subsequent hot treatment of the nodulized fume in a fluid bed reactor. Under this set of conditions more than 80 per cent of arsenic are driven off and so are selenium, chlorine and fluorine. Non-ferrous metals and certain rare elements are converted into sulphates to be brought into solution by the following wet treatment.

Installations employing the new method of fume treatment have been built and put into operation at a number of smelters in the Soviet Union.

Electrothermic treatment of zinc crust

The conventional Faber-du-Faur retort furnace has low efficiency, gives low direct recovery of precious metals in the bullion, low recovery of zinc and entails hard labour conditions.

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[illegible] in [illegible] bottles, production of [illegible] by [illegible] of [illegible] gas in [illegible] bottles, distillation of Ag-Pb-Zn dross [illegible] [illegible] silver, [illegible] of fine silver and gold. [illegible] [illegible] [illegible] [illegible] to produce [illegible] lead. [illegible] [illegible] [illegible] to produce [illegible] and lead [illegible].

[illegible] "Short Bag" [illegible]

[illegible]

[illegible]

[illegible]

[illegible]

The existing bag filterhouse used in conjunction with the old hearth furnaces was utilised for effecting ventilation of the blast furnace building and the equipment of the sinter plant. Gases leaving the sinter plant pass through an electrostatic precipitator.

During short periods of operation on the sinter plant it has been possible to achieve sulphur elimination rates of 1.3 t/m^2 day and during a run of ten days on the blast furnace an average production of [illegible] t/day of lead bullion was obtained which corresponded to [illegible] tons sinter per square metre of blast area at tuyere level. However, over longer [illegible]

[illegible]

lytic zinc plant and slag from the blast furnaces. As yet no work has started on this new development.

Little change is foreseen in modernising the Pb refinery. The complete "Harris" method for lead softening will be introduced and the dezincing of lead by vacuum dezincing after desilverisation will also be introduced. The treatment of zinc-silver lead crusts will be by an electrical process. Two short rotary furnaces will be added for the treatment of refining by products. A new bag filter house will be provided [illegible] the reverberatory furnaces and cupels.

Now to come back to the aim of our meeting. We trust we [illegible] contribute some thoughts and guidance to underdeveloped [illegible] in the development of their zinc and lead industries [illegible] in turn will promote further industrial development. You [illegible] heard how we at Trepca have proceeded [illegible] can anything [illegible] from this? [illegible] another question! There are no [illegible] some general suggestions that may be proposed which [illegible] find useful.

[illegible]

[illegible]

[illegible]

[illegible]

3- The Lead and Zinc Statistical Group which met in Geneva last year found that there existed a surplus of smelting capacity in the world and this was expressed in the form of an insufficiency of lead and zinc ore and concentrates available.

4- The underdeveloped nations which want to develope their own lead and zinc industries must try to obtain the most modern and efficient processes and equipment. In this way, this industry will become richer but it can only happen if they choose the correct process regarding production economy to make them competitive.

5- How can we be helpful to these countries which want to develop their own lead and zinc industries?
I believe it is possible to do so if the nations which have developed their lead and zinc industries give assistance in the form of education on modern practices to both technicians and process operators.

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