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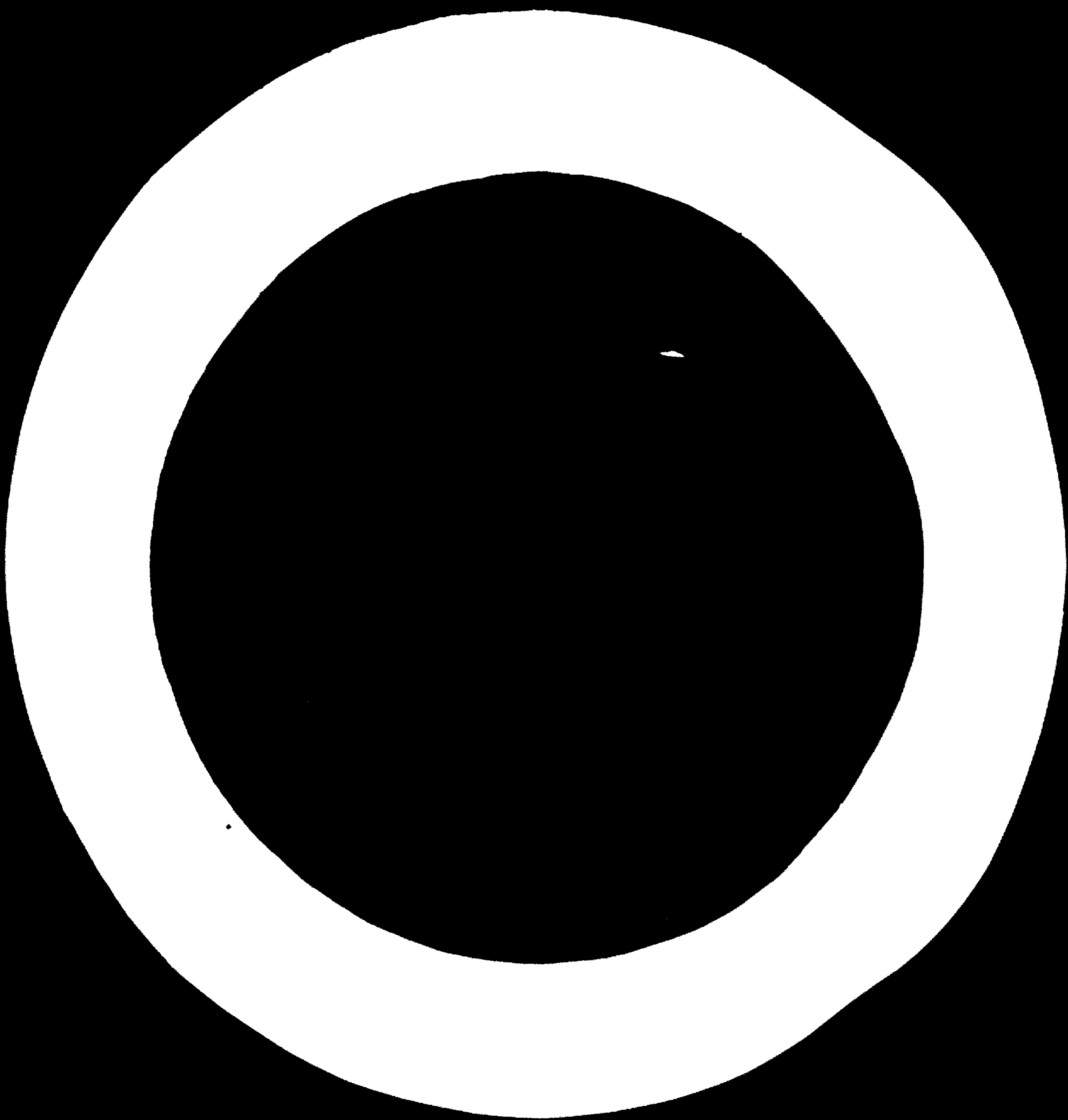
TECHNOLOGICAL DEVELOPMENTS IN LEAD AND ZINC PRODUCTION AND THEIR SIGNIFICANCE TO DEVELOPING COUNTRIES

Report of the Expert Group Meeting on Lead and Zinc Industries

London, 28 April - 2 May 1969

UNITED NATIONS



UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

VIENNA

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Explanatory notes

Reference to "dollars" ($) is to United States dollars unless otherwise stated.

Reference to "pounds" (£) is to British pounds unless otherwise stated.

A = ampere

GNP = gross national product

ppm = parts per million

tr = trace

Preface

1. Since its inception at the beginning of 1967, the United Nations Industrial Development Organization (UNIDO) has paid particular attention to the development of non-ferrous metal industries. This report covers the Expert Group Meeting on Lead and Zinc Industries held in the Conference Hall of the Rio Tinto Zinc Corporation, London, 28 April - 2 May 1969.

Purpose and theme

2. The purpose of the meeting was to assist in expanding the local processing of non-ferrous metals in developing countries so as to increase, as far as possible, the value added within the domestic economy, as well as to examine the technological developments in lead and zinc production and their significance to developing countries. The meeting had as its main aim, the review of recent technological developments in lead and zinc production and their possible application in developing countries. It is hoped that as a long-term result of these considerations, production of these metals will be initiated or expanded in developing countries.

3. The conclusions and recommendations of the Group are presented in Chapter 1, which includes also brief summaries of the information presented in the various papers as well as the points raised during discussion.

4. In addition to the main technical theme of the meeting, an economic assessment of the lead and zinc industries in developing countries was made. With regard to the latter, UNIDO is carrying out assessments of the potential growth of certain branches of industry, including that of lead and zinc, in developing countries during the Second Development Decade (1970-1980).

Organization of the report

5. An economic assessment of possibilities for the Second Development Decade is presented in Chapter 1. Chapter 2 examines the present state and recent technical developments in lead and zinc production. Chapter 3 assesses the

Imperial Smelting Process which has been developed for the simultaneous recovery of lead and zinc from complex ores. Chapter 4 examines the operation of an Imperial Smelting plant in Zambia. The application of the electrolytic process for zinc production in a developing country is described in Chapter 5, based on India's experience with this process. Chapter 6 examines the electrolytic refining of lead, and a comparison is made of the advantages and disadvantages of this process as compared with those of a thermal plant for refining the same quantity of lead bullion.

6. The discussion was based on documentation presented by UNIDO. A list of documents is presented in Annex 1.

Participants

7. The meeting was attended by members of the Expert Group, observers, and by members of UNIDO secretariat and of the International Lead and Zinc Study Group. A list of participants is presented in Annex 2.

Organization of the meeting

8. The Group elected Mr. B. Barlin, Manager, Zambia Broken Hill Development Company Limited, Zambia, as its Chairman and Mr. G. E. Bjorling, Professor of non-ferrous metallurgy, Royal Institute of Technology, Sweden, as its Vice-Chairman.

9. Mr. Barry Crowston and Mr. Sergei Glebov, of the UNIDO secretariat, served as technical secretaries to assist in the work of the Group.

10. The experts attended the meetings in a personal capacity, not as official representatives of their organizations and Governments.

11. The present report was drafted during the meetings and has been reproduced without the usual formal editing by UNIDO.

CHAPTER 1

CONCLUSIONS AND RECOMMENDATIONS

Conclusions of discussion

12. During the last eight years, the share of the developing countries in the world's apparent consumption of lead and zinc has grown from approximately 6 to 10 per cent and from 7 to 10 per cent respectively. The production of lead in developing countries has increased by 25 per cent during the period 1960-1968. The increase in the production of zinc metal in developing countries during the last eight years was 61 per cent.

13. An examination of lead and zinc industries in developing countries shows four main groups of countries, each group characterized by the present state of development of their lead and zinc industries:

- The first group has a combined lead and zinc apparent consumption of more than 10,000 tons per year. Most of the developing countries in this group have not developed their metal production to meet the local demand, and therefore must import these metals to meet their needs;
- The second group consists of exporters of lead and zinc metal and concentrates. These countries are smelting lead and zinc without considerable home consumption, making these industries largely dependent on the world market situation;
- The third group is exporting lead and zinc ores and concentrates, making the production of the metals a possible future development;
- The fourth group comprises all developing countries not included in the first three groups, where the influence of the lead and zinc industries on the economy is slight.

14. The identification of these four groups will assist UNIDO in planning its technical assistance programme in the lead and zinc industries of developing countries.

15. The projections for lead and zinc consumption in the world up to 1980 indicate the average rate of growth as:

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

The total world consumption, excluding centrally planned economies, will then reach:

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

To meet that new demand, the following new mine capacities and smelter facilities will be required:

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

16. The following efforts on the part of United Nations organizations and governments of both developing and developed countries are required in order to ensure that developing countries secure a share in the expansion of the world's lead and zinc industries during the Second Development Decade:

(a) Stabilization of metal consumption/production and metal prices;

(b) Further liberalization of trade; removal of quota systems and lowering of import duties;

(c) The assistance of United Nations experts in preparing the best economic and technical programme for lead and zinc industry expansion;

(d) The objective evaluation of foreign offers for construction of complete mines or smelters;

(e) The assistance of United Nations experts in training local staff, in consigning temporary management posts in industry and foreign trade enterprises.

17. The development of lead and zinc industries in developing countries during the Second Development Decade appears favourable for the following reasons:

- The production and consumption of lead and zinc both in industrialised and developing countries has been steadily increasing during the last decade;
- Lead and zinc prices on the international market have kept more or less stable. An internal lead and zinc market in the developing countries is being created and this appears promising;
- A number of developing countries have the necessary raw materials for the production of lead and zinc although they are not yet fully investigated;
- The existing and newly developed processes for the production of lead and zinc are highly efficient;
- In addition to lead and zinc, by-product metals, such as gold, silver, cadmium, bismuth or selenium, together with other valuable by-products, such as sulphuric acid and sodium antimonite may be produced.

18. An examination of the lead and zinc industry in Peru shows the potential benefit to the economy of a developing country. For example:

- The Peruvian mining industry is an export industry, and in 1968 it accounted for 51.1 per cent of the country's foreign currency earnings - $442.3 millions. (From this total 7.5 per cent corresponds to zinc and 6.6 per cent to lead.)
- It is estimated that 65.3 per cent of the total foreign currency mining earnings ($288.8 millions) is used in the country to pay salaries, service supplies, taxes and reimbursements;
- Lead/zinc production derives 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 $50 millions (702,000 kg); zinc accounts for $33 millions and lead, for $29 millions;
- 83.5 per cent of Peruvian lead production, which was 157,627 metric tons in 1967, is mined in the Central Andes; 89 per cent of total lead production comes from twenty-one mines;
- Peruvian zinc production, in 1967, was 328,904 metric tons; 89 per cent came from the Central Andes; twenty-three mines produced 96 per cent of the total zinc;
- 52 per cent of the lead production and 19 per cent of the zinc are refined in the country; the rest is exported as concentrates;
- During the period 1959 to 1968 zinc production in Peru had an actual growth rate of 10.7 per cent. It is estimated that this rate will be maintained through 1972, mainly due to the expected production from the mines Madrigal, Farallon and San Vicente, the reopening of the Gran Bretana mine at a large production scale and the planned expansion by Cerro de Pasco, Minera Atacocha and Milpo;
- In the decade 1959-1968, Peruvian lead production grew at the rate of 2.1 per cent per year. It is estimated that the rate will rise to 8 per cent during the period 1969-1972, due to expansion of operations of the companies mentioned above;
- Foreign companies established in Peru produce 50 per cent of the lead, 71.8 per cent of zinc and 49.5 per cent of the silver contained in the lead/zinc ores;
- Foreign investments in Peruvian mining industry are indispensable for the development of the country;
- Exports of refined lead and zinc are marketed fundamentally to the United States (96 per cent of the lead and 87 per cent of the zinc). Zinc concentrates are exported mainly to Japan (60 per cent); whilst lead concentrates go to the United States, European Common Market and Japan.

19. For the production of lead, conventional sintering and blast furnace smelting practice is still prevalent. If large lead smelters are built in the immediate future they will probably be based on this technology incorporating modern materials handling and control methods.

20. Oxygen enrichment may be used in future blast furnace plants, and added to existing plants to increase output and reduce coke consumption. The lead blast furnace has the greatest adaptiveness of all processes and is suitable for oxidic minerals like cerrusite $PbCO_3$ and anglesite $PbSO_4$. It requires coke, and is relatively high in costs for labour, repairs and construction; but like the blast furnace for pig-iron, it has proved very reliable. If existing lead plants were to be rebuilt today most of them would still use the blast furnace method.

21. There is one important aspect and that is, if the lead concentrate can be treated together with sufficient quantities of zinc concentrates, the Imperial Smelting Process can be used to produce lead at a cost below that of every other lead producing process.

22. A modern lead sinter plant requires a substantial investment which is economically justifiable only for a reasonably large output. New lead-making 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.

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

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

Process	1959 (percentage)	1968 (percentage)
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

25. During the last decade the growth of the Imperial Smelting Process has been spectacular. This process will continue to be widely applied in the immediate future, and several Imperial Smelters are now in the construction and planning stages.

26. A large share of the future lead and zinc plant expansion, however, will be based on the electrolytic process, particularly in the developing countries, for the following reasons:

(a) 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;

(b) The electrolytic process is suitable for comparatively small productions and an electrolytic plant can be gradually expanded as required;

(c) New residue treatment processes, in particular the Jarosite process, will result in the highest obtainable over-all recoveries for zinc and other values in zinc concentrates;

(d) The extraction of zinc from its ores is not a simple process, but the electrolytic process is still probably the easiest to operate well in developing countries with limited technically qualified personnel;

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

27. On the other hand, 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. The fact that the Imperial Smelting Furnace is the largest zinc production unit available can be an advantage in developed and developing countries with large zinc markets and access to investment capital. The Imperial Smelting Process will probably have an important share of future zinc capacity in industrially developed countries and especially in cases where both lead and zinc raw materials are available in a suitable ratio. There is still room for improvement in the Imperial Smelting Process, and its performance will undoubtedly be further developed in the near future.

28. The horizontal retort process is doomed to gradual extinction but existing vertical retort and electrothermic zinc plants appear still to be competitive. However, it is believed that little new capacity will be based on these processes, and that this capacity will be mostly expansion of existing plants. 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. Usually one of these energy sources is more advantageous; for example, the Imperial Smelting Process becomes a natural selection where coke is cheap, and the electrolytic process where electric power is cheaper.

29. Pressure leaching of zinc concentrates, with elemental sulphur recovery, offers interesting possibilities. The process is not, however, ready for commercial use, and would not be particularly well suited for developing

countries because of the sophisticated high-pressure equipment and expensive construction materials required.

30. A promising and significant process for the treatment of complex sulphide concentrates containing zinc, lead and copper is the KIVCET method developed in the USSR. The word "KIVCET" is the Russian abbreviation for "oxygen-flash-cyclone-electrothermal" process. The process consists of the smelting of fine materials, in a stream containing oxygen in amounts varying from the usual percentage in air up to 100 per cent. The product obtained is then treated electrically under a reducing atmosphere in the same vessel. The advantages of the KIVCET process are that sintering is eliminated; a high rate of desulphurization is achieved; the small volumes of gas leaving the vessel are rich in sulphur dioxide (70 to 90 per cent), making recovery of cheap sulphuric acid possible; and finally, the heat evolved from the oxidizing reaction is utilized within the process itself for smelting, thus significantly decreasing the energy required. The use of high grade coke is not necessary but high recovery of the final products can be achieved.

31. In spite of their simplicity and apparent ability to extract lead at low production costs, roast reaction processes have definite limitations in their adaptability. The most important is their exclusiveness to sulfidic concentrates and especially to high grade ones. A further disadvantage of the roast reaction processes with excess oxygen as well as of the round hearth process and the self-fluxing smelting, is that they operate in small furnaces. It is not clear that production can be carried out in larger units; thus an enlarged number of units is necessary, which increases the costs of both labour and equipment. Finally, these processes seem to be suitable only for concentrates with basic gangue.

32. The Boliden process (and eventually also the Outokumpu method) should be competitive for medium and big smelters. It requires medium-grade concentrate, and the capital costs are relatively high, but the need for 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 is highly applicable for the treatment of good concentrates. One drawback is the handling of large quantities of flue dust; this, however, can be mechanized to a large extent.

33. The increasing demands for both lead and zinc have resulted in the need to exploit ores containing a large variety of impurities, often in large amounts.

At the same time, consumers have been increasingly demanding with respect to metal purity. For example, the United States specification for the purest grade refined lead calls for a maximum bismuth of 0.05 per cent but some large consumers now specify 0.0025 per cent. In the case of zinc, the galvanizing industry, because of the development of continuous galvanizing, now demands large tonnages of zinc with 0.1 per cent of lead, whereas a few years ago this section of the market was satisfied with metal containing 0.2 per cent to 0.4 per cent of 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 United Kingdom and the United States.

34. A total of eleven Imperial Smelting units has been built in nine countries for the simultaneous recovery of lead and zinc. During 1968, the Imperial Smelting Furnaces yielded about 10 per cent of the total world production of zinc, and it was anticipated that by the mid 1970s this would reach about 25 per cent, in addition to approximately 18 per cent of the world's lead production. At the beginning of May 1969 the process had produced a total of 2 million tons of slab zinc and almost 1 million tons of lead bullion.

35. The first Imperial Smelting Furnace at Swansea, in the United Kingdom, was designed in 1960 to produce 30,000 tons of zinc per year. This unit is now capable of producing 70,000 tons of zinc per year from high grade concentrates. It has been estimated that a further 50 per cent increase is possible in the future. Campaign lives have been improved, from fifteen weeks in 1960 to the present level, 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 operational or metallurgical aspects, but rather in the need to make design improvements or modifications.

36. The sintering process, as applied to the Imperial Smelting Furnace, embraces both desulphurization and agglomeration, and it is difficult to envisage an alternate process which achieves both of these functions at the same time. One of the prime advantages of the Imperial Smelting Process is its ability to handle charges with up to 25 per cent of lead, and to date it has been extremely difficult to roast metals containing more than 10 to 12 per cent, except on a sinter machine. Hence, roasting and pelletizing, as an alternative to sintering, would certainly be less flexible and would probably require more capital expenditure. It appears, therefore, that the Imperial Smelting Furnace

will always have to be associated with a sinter plant if the flexibility of the furnace process is to be fully exploited.

37. The improvement in sintering must be aimed at producing a better quality sinter for the furnace in order to enable higher production rates to be achieved with more efficient utilization of coke. Coupled with this, the sinter plant must achieve higher production rates to match the increasing demand of the furnace.

38. Only one developing country possesses an Imperial Smelting Furnace, and this is Zambia. Production of lead and zinc from this source represents less than 1 per cent of world production; and 2.7 per cent of the lead and zinc produced is consumed in Zambia itself. The problems of operating the Imperial Smelting Furnace complex in Zambia revolve around the availability of skilled labour to operate the sophisticated plant, the supply of stores and equipment, the success of training local personnel and the disposal of the finished products to overseas customers. The performance of the Imperial Smelting Furnace in Zambia has steadily improved, and this is an indication of the success in training local operating personnel.

39. Over half the world's zinc is produced by the electrolytic process. Although the process is well established, it is still being improved. The main areas of development have been in roasting, with the application of fluidized beds; improvements in the calcine classification process; in purification of solutions from impurities; and finally in the operating characteristics of the electrolytic cells.

40. Commercial grades of zinc produced in the electrolytic zinc cells contain 99.975 per cent zinc. The quality of zinc deposited on the cathode is largely dependent on the rate of electrolysis. Higher grades of zinc can be obtained by the addition of such substances as barium hydroxide or strontium carborate.

41. There are two electrolytic zinc plants in India with rated capacities of 18,000 to 20,000 tons per year. Production at the newest plant started in January 1968 and reached its full rated capacity in March 1968. The process consists of fluo-solid roasting, followed by leaching and electrolysis. The efficiencies achieved were better than performance guarantees anticipated in the agreement with the technical collaborators concerned with the project. Certain basic defects in the original equipment and layout required expensive changes and possibly loss of time, but these were resolved by changes of materials of construction. The efficiency of cadmium recovery was also improved

considerably by modifying the process. The capital outlay required for installing this electrolytic plant was approximately £3 million. The electrolytic plant was built almost entirely in India, inclusive of rectifiers, and will eventually be expanded to a capacity of 50,000 to 60,000 tons of zinc per year.

42. The first electrolytic refining plant for lead was built in Canada and has been in operation since 1903. There are at present ten electrolytic lead refining plants in the world. These treat lead bullion from the blast furnace which contains silver, bismuth, copper and antimony. The electrolytic process permits refining of impure lead in a single stage. The purity of the refined metal remains consistently above 99.995 per cent. When extracting bismuth, and when subsequent recovery of this metal is to be carried out, the electrolytic method shows clearly its efficiency, elasticity and convenience. A final characteristic of the electrolytic process is the hygienic nature of the work premises.

43. A comparison between electrolytic refining and thermal refining of lead showed the following advantages of the electrolytic method:

(a) Higher recovery of lead, silver and bismuth:

(b) Lower consumption of reagents, fuel and other metals;

(c) Utilization of half the manpower required for thermal refining;

(d) Better quality of the refined lead;

(e) Possibility of treating bullion containing varying amounts of impurities, without increase in operating costs;

(f) Better hygienic conditions;

(g) Wider market outlets for the lead produced.

44. The disadvantage of the electrolytic method on the other hand is that the investment costs are 1.36 times higher than for a thermal plant with the same capacity.

45. New developments in fire refining include vacuum dezincing and continuous decopperizing, if of sufficient capacity.

Recommendations of the Expert Group

46. At the conclusion of the discussion, the Expert Group recommended that UNIDO, or other United Nations organizations, as appropriate, should:

(1) Continue to provide experts to developing countries to assess the metallurgical raw materials available and arrange for pilot plant testing to be carried out on ores and concentrates from developing countries. (In addition to the experts and consultants normally

provided for lead and zinc industries in developing countries, UNIDO is now in a position to arrange on the basis of an official request from Governments, for pilot plant testing of lead and zinc concentrates in the Imperial Smelting Process, the electrolytic method and the KIVCET process recently developed in the Union of Soviet Socialist Republics);

(2) Endeavour to further liberalize trade, remove quota systems and lower import duties, so as to encourage the production of lead and zinc in developing countries;

(3) Evaluate quotations to supply lead and zinc mines and smelters;

(4) Assist in the training of local staff towards mastering the technology of lead and zinc production before, as well as during, the operation of the plant;

(5) Provide management and experts in exporting, until local specialists acquire appropriate technical experience and qualifications;

(6) Examine means to increase the production of lead and zinc concentrates in developing countries in view of the international surplus of smelter capacity brought about by the shortage in the supply of concentrates;

(7) Undertake a market research study for semi-finished lead and zinc products;

(8) Encourage small consulting firms to examine the possibilities of developing small lead and zinc industrial projects in developing countries;

(9) Assist developing countries in assessing the extent and analysis of their complex lead and zinc ore deposits;

(10) Examine the feasibility of treating the complex oxide ores found in Turkey and Iran and other developing countries, to produce zinc, lead and other valuable components;

(11) Continue and increase co-operation with other United Nations organizations primarily concerned with the world's lead and zinc industry, particularly the International Lead and Zinc Group, with international organizations such as the Lead and Zinc Development Association and also institutes, federations, private companies and governmental organizations.

47. It was recommended that developing countries should:

(1) Before developing a lead and zinc industry, request UNIDO's assistance, or arrange for other organizations to undertake a detailed technical and economic assessment of the possible methods of concentrating, smelting or refining of lead and zinc. Such studies should show the importance of market requirements, availability and cost of materials on a continuing basis, possible changes in the mixture of products required in the future and other factors affecting the reliability of the new operation;

(2) Select key personnel for training in similar plants overseas before new smelters are built and operated;

(3) Once a concentration plant or a smelter is built, request UNIDO to supply any key personnel required to assist in the management and operation and any subsequent expansion of the plant;

(4) Take advantage of scale of operation by building plants in excess of local requirements and temporarily export concentrates or semi-finished lead and zinc or refined metals. In this way developing countries can use the most modern and efficient techniques with additional advantages of economy of scale and thereby successfully compete in international markets;

(5) Study the scheme used for training local labour for manual semi-skilled and skilled workers for the Imperial Smelting Furnace erected in Zambia where a system of layered training was adopted. This enabled a manning structure to be evolved which aimed at ensuring that the best man was chosen for each job and that all personnel were developed to their full potential;

(6) Combine in joint financial ventures to develop lead and zinc mines in one country and to export concentrates to the other participating developing countries;

(7) Exchange expertise in human resources and mining and beneficiation machinery for lead and zinc production.

48. It was recommended that developed countries should:

(1) Increase the amount of research on the separation of lead and zinc concentrates from complex ores by floatation;

(2) Eliminate tariffs and quotas for the importation of these metals or concentrates from developing countries;

(3) Co-operate with UNIDO in making available experts in lead and zinc production to assist developing countries and offer training opportunities for technicians and process operators from developing countries in modern lead and zinc smelting plants.

CHAPTER 2

PRESENT STATE OF LEAD AND ZINC INDUSTRIES IN DEVELOPING COUNTRIES AND PERSPECTIVES FOR THE SECOND DEVELOPMENT DECADE

49. The paper presented by the UNIDO secretariat examines The Present State of Lead and Zinc Industry in Developing Countries. An analysis of the production and consumption of lead and zinc in developing countries showed that these industries fall into four groups according to the different status of lead and zinc consumption and production in the various countries. An assessment was therefore made of the prospects of the lead and zinc industries in these countries during the Second Development Decade (1970-1980).

50. The first group is composed of consumer countries where lead and zinc apparent consumption is more than 10,000 tons a year. The members of this group are Argentina, Brazil, China (Mainland), China (Taiwan), India, Mexico, North and South Korea, Pakistan, Philippines and Thailand. Most of the countries in this group have not developed the metal production to meet the whole local demand and are therefore importing the metals for internal needs.

51. The second group contains exporters of lead and zinc metal and concentrates. These countries are smelting lead and zinc without substantial home consumption, and their industry is therefore largely dependent on the world market situation. They are Burma, the Democratic Republic of the Congo, Morocco, Peru, Tunisia and Zambia.

52. The third group exports only the ores and concentrates. The production of these metals is a task for future development. At present only four countries mine lead and zinc: Algeria, Bolivia, Honduras and Iran.

53. The fourth group includes all the developing countries producing lead and zinc metal or concentrates not included in the first three groups. 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 small.

54. Each group of the developing countries has its specific problems and naturally these are different for consumers and exporters of the metals. Analysis of the groups showed that the number of developing countries where the local demand for lead and zinc is higher than home production is greater than the number of countries supplying these products.

55. Only six countries of the second group, and 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.

56. The high tonnage of ingots, concentrates and ores exported by these twelve to the world market has given rise to the impression that developing countries are lead and zinc suppliers. Up to now the quantity of metals consumed by the developing countries has been 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 will be increased greatly during the 1970s. Only Turkey has a firm intention of joining this group of exporters of lead and zinc products.

57. 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, the number of countries in this group should increase together with the lead and zinc consumption of the developing world. If the rate of ingot metals production remains the same as it was during the 1960s, the developing countries will be net importers for both zinc and lead metal.

58. Practically all of the developing countries of the above group need to think about new smelting installations for lead and zinc utilizing the ores and concentrates which are now exported to meet local demand which cannot be covered only by import. There are many technological problems associated with the production of these metals. Technical assistance to the developing countries should therefore deal with the problems of lead and zinc production under specific conditions in different countries.

59. Some projects have already been implemented by various bodies of the United Nations. In 1966 the completion of the "Survey of Lead and Zinc Mining and Smelting in Burma" helped the country in planning some measures to develop resources for lead and zinc production.

60. The example of this meeting presents another form of assistance to the developing countries. It is aimed at providing a collection of experience and technological achievements in the lead and zinc industry of the developed countries on which can be based a consideration of their possible application under specific conditions in the developing world.

61. During the discussion the participants agreed with the UNIDO approach to the problems which exist in the lead and zinc industry of the developing countries.

62. In the paper A Review of the Main Factors Influencing the Possibilities of Developing Lead and Zinc Industries in Developing Countries, V. V. Tsyganoff examined the very numerous factors influencing the possibilities of development of the lead and zinc industry in a developing country. These are mainly:

(a) The prospects of the internal domestic market in connexion 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 existence 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.

63. Summing up the results of the analysis (made in the paper 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.

64. This conclusion is confirmed by the following generalizations:

- The production and consumption of lead and zinc both in industrialized and developing countries for the last twelve 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, though in the stage of creation, is nevertheless promising for the future.
- The necessary raw materials exist in the majority of the developing countries, though they are not yet fully investigated.

- Due to the development of other industries in these countries, lead and zinc production should not be handicapped by the absence of technical know-how.
- Transport communications depend mainly on the economic and geographical conditions of each 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 as gold, silver, cadmium, bismuth or selenium - and especially the need for sulphuric acid, zinc vitriol, sodium antimonate and other chemical by-products.
- When estimating the possibility and profitability of the development of the lead and zinc industry in a developing country, the interdependance of many factors should be considered. Therefore this problem should be solved for each country individually through 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, from our point of view, the so-called KIVCET method, developed by the Soviet specialists. The word "KIVCET" is the Russian abbreviation for the "oxygen-flash-cyclon-electrothermal" process.
- This process provides for the smelting of fine materials in a stream containing oxygen in amounts varying from the usual percentage in air, up to 100 per cent. The product obtained is then treated under electric arcs.

65. According to this method:

(a) Smelting fine materials in the blowing stream can be either flash, as a straight flame, or as a flame blown by a cyclone action;

(b) Further treatment of the molten charge takes place in an electrothermal device directly connected with the smelting equipment.

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

67. The advantages of the KIVCET process are as follows. Granulation and sintering processes are eliminated and a high rate of desulphurization is achieved. The gases leaving the equipment are rich with sulphur dioxide (70 - 90 per cent), making recovery of cheap sulphuric acid, elementary sulphur, or liquid sulphur dioxide economically attractive. The 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 (this reduces significantly the energy consumption during the whole process in comparison with many

other methods). The consumption of high-grade coke is eliminated and 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. Finally, the continuous processing of the material within a single plant is readily adaptable to automatization of the main units of the system.

68. In the paper Perspectives of Lead and Zinc Industry for the Next Ten Years by J. R. Carlson it was stated that the prospects for the lead and zinc industries in developing countries were closely tied up with the forward estimates on the consumption of these metals in world economy. Most developing countries enjoying deposits of lead and zinc ores, and producing both metals. are exporters of concentrates or metals.

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

70. Another method, based on correlation of consumption and expansion of industrial production or production of durables, can be valuable in assessing lead/zinc consumption in world economy. The above methods however are unrealistic 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, however, such a relationship has not been established. No doubt a projection of metal consumption can be made for any developing country, taking into consideration the specific conditions of its economy. It would be advisable therefore to make respective studies in countries intending to start lead/zinc production to meet domestic demand.

71. Independent of the methods of projecting the demand for lead and zinc in world economy, and the average annual rate of growth in consumption of these metals, a forecast in a number of recent papers shows a notable convergence, and falls within the limits:

2.0 - 3.5 per cent for lead
3.0 - 5.0 per cent for zinc.

72. The last eight-year period indicates that these projections are correct in principle, as the average annual rate of growth in consumption of lead in world economy in the 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.

73. The characteristic feature of those eight years was a relatively sharp increase in lead and zinc consumption in developing countries, surpassing by far the developed ones in that respect. The average annual growth rate in consumption in developing countries amounted to 9.2 per cent in the case of lead and 9.7 per cent in the case of zinc. There is reason to believe that some stabilization of the world market in lead and zinc during the period in question, and the growth in consumption of these metals, is not accidental but is brought about by a planned action.

74. The activity of the International Lead and Zinc Study Group set up in 1960 and presently comprising 30 member countries, among which are the foremost producers and consumers of these metals, seems to have a definite influence on the stabilization of the lead and zinc market. The growth in lead/zinc consumption is being influenced also by research into new applications for those metals and improvement of the methods of processing zinc semi-products. The co-ordination of this research carried on by the International Lead and Zinc Research Organisation is not without significance. The initial stages of industrialization have given rise to a rapid growth in lead/zinc consumption in developing countries considering the <u>per capita</u> lead/zinc consumption in developing countries which in Latin America amounts only to 10 per cent, in Asia and Africa only to about 1 per cent of the consumption in developed countries, one can easily see the potential possibilities of growth in consumption of these metals in developing countries.

75. In that case also the activities of the Zinc Development Association and Lead Development Association, initiated a few years ago, can be expected to have good results. The Indian Lead/Zinc Information Centre in Calcutta, established in 1962, the Overseas Developing Fund, and similar programmes for providing technical assistance in view of processing lead and zinc in developing countries, are and will certainly in the future stimulate growth in consumption of lead and zinc in those countries.

76. 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

organizations, it can be assumed that the average annual rate of growth in consumption over 1970-1980 will 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.

77. The consumption of lead/zinc in developing countries during the last eight years rose more sharply, yet the production of both concentrates and metals expanded at a considerably lower rate than in developed countries. During that period the production of lead concentrates in developed countries rose 32 per cent and in developing countries only 2.3 per cent. The production of zinc concentrates increased in developed countries by 64 per cent and in the developing world by only 38 per cent. The production of lead rose 31 per cent in developed countries while in developing Asiatic and African countries it dropped, and in Latin America rose by only 4.3 per cent. In developing countries the growth in zinc production was more rapid (61 per cent) than in developed countries (40 per cent).

78. The approximate forward estimates of new production capacities in individual countries for the next two to three years indicate that mine and smelter production will 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 Argentina, Bolivia and Iran, and a slight increase of existing capacities is expected in North Korea and Peru. No new production capacities were reported in lead smelters; in zinc smelters new capacities were reported in Algeria and India, with only slight increases in Mexico.

79. To estimate the expansion of lead/zinc production in the world, and in developing countries in particular, in order to meet the demand for consumption forecast over the period 1970-1980, the proven ore reserves and new mine/smelter capacities must be assessed. The world reserves measured and indicated in lead and zinc can be assessed approximately to 50 million tons of lead and 75 million tons of zinc, enough to meet the demands in 1970-1980. An analysis should be made of the lead/zinc consumption balance over these years, allowing for net import from centrally planned economies, in order to assess new production capacities required for 1970-1980.

80. Considering the balances of production/consumption over the years 1960/1968, and the fact that the rapid expansion of production of lead and zinc

in countries with centrally planned economies is matching the equally rapid growth in consumption in these countries, it can be assumed that in 1970-1980 the net import from centrally planned economies will be maintained at the level of about 30,000 tons for lead and 100,000 tons for zinc.

81. Assuming full equilibrium of the consumption/production balances and no essential changes in non-commercial stocks, it can be forecast that, depending on the adopted projection of metal consumption, new lead smelter facilities will be required within the limits of 627 to 1,087 thousand tons, and zinc smelter facilities within the limits of 1,560 to 2,260 thousand tons. Respective figures for new mine capacities amount to from 440,000 to 800,000 tons of lead and to from 1,780 to 2,530 thousand tons of zinc. The expansion of new lead/zinc capacities in world economy gives a favourable outlook for stimulating the production of these metals in developing countries. It would help to increase the rate of consumption of these metals in countries like Argentina, India and North Korea. In countries now exporting mainly metal concentrates, the expansion of smelter facilities would help to improve the foreign trade balance. Among these countries are Algeria, Bolivia, Burma, Honduras, Iran, Mexico, Morocco, Peru and Tunisia.

82. 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 industrialization would be possible and the development of applications of these metals would be stimulated.

83. As suggested by the above considerations, there is a favourable outlook for rapid expansion of the lead/zinc industry for the years 1970-1980.

84. To secure a reasonable share for the developing countries within that expansion framework, in conformity with their ore reserves and with their need for industrial and social progress, some efforts will be required from the organizations of United Nations devoted to that aim, and from Governments of both developing and developed countries.

85. The basic condition of lead/zinc expansion throughout the world, and above all in the developing countries, is the stabilization of the metals consumption/production balance and of metals prices at a level which will be adequate yet competitive with the substitutes. This is the main target of the International Lead and Zinc Study Group, whose activity, along with the co-operation of the member Governments - particularly of the United States in

respect of non-commercial stocks releases policy - is likely to secure such stabilization within suitable limits.

86. Further liberalization of trade, removal of quota systems, 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 organizations are dealing with.

87. In developing countries, specialists in lead/zinc industry are generally not available. Due to their absence, the best economic and technical programmes for 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. A "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 occasionally faced by the governments of developing countries. An objective evaluation of these offers by United Nations independent advisers could suggest the best choice.

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

89. To some management posts in enterprises taken over by developing countries, or in newly commissioned ones, local specialists are not immediately available. Experienced administration officers to supervise lead and zinc industry enterprises, and other forms of management are often lacking in developing countries. Until local specialists can acquire the appropriate professional qualifications there is need for United Nations advisory services in assigning these posts to their experts.

90. Technical schools and universities in those countries which enjoy opportunities for the expansion of lead/zinc industries should ensure suitable education to the future specialists in these fields. An essential form of United Nations assistance to developing countries is providing, where needed, lecturers possessing the necessary educational qualifications.

91. In many developing countries the expansion of the lead/zinc industry is closely linked with problems concerning foreign trade policy. The specific feature of foreign trade in lead/zinc concentrates and metals requires special experience. Until foreign trade officers in the developing countries acquire the necessary routine, the assistance of United Nations experts sent there at request of the interested Governments seems advisable.

92. In all the above mentioned cases the services of the United Nations experts should be temporary. Education and training of local specialists involves long-term residence in highly developed countries in order to gain practical experience. Training of the sort sponsored by the United Nations could help the developing countries to complete their own teams of experts.

93. In the paper Lead and Zinc Industry in Peru by A. Labarthe, the Peruvian position as related to world lead zinc production is described, as well as its character, its structure, its possibilities and its problems. The paper submitted contains information not generally available concerning distribution of ore reserves and describes the technology of mining, concentration and reduction in Peru. 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.

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

95. The country's present and future economic dependance on the mining industry can be illustrated by the following figures: In 1950 mineral exports represented 24.5 per cent of its total exports, while in 1968 this percentage had grown to 51.1 per cent. In terms of dollars, this means an increase from $46 to $442 million.

96. To the latter figure, lead exports contribute \$30 million, zinc \$33 million, but silver contained in the lead/zinc exports amounts to \$50 million, which makes the total value of lead/zinc products \$113 million or roughly 25 per cent of total mining exports.

97. Peruvian lead/zinc exports account for about 11 to 12 per cent of the total international trade of these metals.

98. Peruvian production growth of lead in the last ten years has been equivalent to the world production increase percentagewise, i.e. about 2.1 per cent. Zinc production has increased at twice the world rate, i.e. 10.7 per cent versus 4.9 per cent.

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

100. Lead/zinc ores exploited in Peru consist as a rule of complex minerals associated with copper and silver. As was already mentioned, silver is the most important in value. As exoeptions to the rule, in the last few years two important deposits have been developed in which zinc is the only valuable metal.

101. As to the geographical distribution, lead and zinc production is located in the Central Andean region, most of the mines being situated at altitudes in exoess of 4,000 metres above sea level. This region is oonnected to the port of Callao by good year-round roads as well as by railroad. This will no doubt always be the most important mining zone for lead/zinc, but other areas laoking transportation faoilities in the past will become important oontributors to produotion.

102. It should be pointed out that 23 mines produoe 90 per oent of the total lead/zino exports.

103. By recent oalculations ore reserves are estimated at 2 million metric tons of reooverable lead and 4 million tons of zino. At the present rate of extraction this means a 12-year supply of lead and a 13-year supply of zinc. If prospective reserves are added Peru should have lead for 35 years and zino for 50. The important point, however, is that reserves are being inoreased every year, and exploration in Peru is still far from oomplete.

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

105. Practically all mine production of lead/zinc ores is concentrated by floatation. Machinery for small plants up to a capacity of 300 tons per day is manufactured locally. Larger plants are mostly imported. Differential floatation 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 sulphide minerals and in other instances, sodium cyanide is used to float the galena concentrates from copper. There are a number of difficulties encountered in producing bulk lead/zinc concentrates from Peruvian ores for their further treatment at an Imperial Smelting Furnace. Most lead/zinc ores that present difficulties for differential floatation contain also pyrite and chalcopyrite. The idea of making a bulk concentrate is a very attractive proposition but difficult to attain. At least the Banco Minero laboratories have not obtained good results. The main reason is that the valuable portion of the concentrates is lowered by the pyrites and even the recoveries for lead and zinc are lower than with standard practice. Since the idea is convenient, and the development of successful procedures may be possible, and since an important source of concentrates for the process can be assured, it is justified to plan an intensive research programme.

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

107. 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, selenium and tellurium.

108. The zinc plant produces 60,000 tons per year of electrolytic 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 electrolysis. Total zinc recovery at the plant is 77 per cent. Treatment of residues which has been recently started will probably bring this figure closer to 90 per cent. 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 90,000 tons per year are being considered.

109. 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 programme announced by the Government for the mining industry may cause considerable changes in 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.

110. The projections presented give an increase of lead growth rate of 7 to 8 per cent and the past growth rate of zinc production is maintained at 10.7 per cent. Lead expansion comes mainly from operating units that have enlargement plans under way while zinc production figures will benefit both from the expansion of operating units and from new mines coming into operation. According to these figures zinc production will be 500,000 tons of pure metal content, which will mean almost 1 million tons of material to be shipped if no additional facilities are installed for metal reduction.

Marketing of Peruvian lead/zinc production

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

112. For simplicity, three markets have been considered, namely, Europe, the United States and Japan.

113. In the metal export picture Japan, who started imports in 1963, discontinued them in 1965 for zinc, and in 1967 for lead. Europe has maintained imports of zinc slabs of between 10,000 and 20,000 tons per year. On the lead picture, after maintaining imports of over 20,000 tons a year, Europe declined sharply after 1965 to less than 5,000 tons in 1967.

114. The United States, which from 1958 to 1965 imported around 10,000 tons a year, increased its zinc imports to 32,000 tons in 1967 and its lead imports from 20,000 to almost 65,000 tons a year.

115. On the concentrate picture the pattern is quite different. While lead concentrates have been exported without important changes to the United States, Europe and Japan, the zinc graph shows Japan as by far the largest importer, from a mere 20,000 tons in 1963 to almost 140,000 tons in 1967.

Role of foreign capital in lead/zinc production

116. That the role of foreign capital is fundamental in Peru can be easily understood if we consider that of $442 million of mining exports in 1968, 80 per cent proceeds from foreign companies, while only 20 per cent derives from national companies. Its preponderance is larger in copper and iron production than in lead and zinc. Foreign participation is 50 per cent in lead and 71 per cent in zinc.

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

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

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

120. 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 40,000 tons per year of electrolytic zinc, 70,000 tons of sulphuric acid and 90,000 tons of ammonium sulphate. Sulphuric acid will be totally absorbed by the fertilizer plant. Basic objectives are:

- To export natural resources at a higher stage of elaboration, thus increasing the aggregate value;
- To provide urgently needed fertilizers at a low price.

121. 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.

122. The last process 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 hydroelectric power, not depending on imported coke, and in general the process uses a larger proportion of local insumes. The initial investment is lower as well, which is important when financial capacity is limited.

123. Total investment is estimated at $30 million, working capital included. Ten 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 ten years.

124. From the first year of operation there will be a gain of foreign exchange revenue to the extent of $4 million and after amortization the annual gain will be $10 million. It is hoped that the presentation of this paper will help to clarify the problems of a developing producing nation. An awareness of the problems and possibilities of producers and consumers will contribute toward the most rational production of lead and zinc, and will help these nations to attain the stability of the industry that will be of benefit to everyone.

CHAPTER 3

RECENT TECHNICAL DEVELOPMENTS IN LEAD AND ZINC PRODUCTION

125. The paper Recent Improvements and Trends in Lead-Zinc Extraction Metallurgy by Jan H. Reimers does not deal at length with lead and zinc extraction processes, 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.

126. 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 US specification for the purest grade refined lead calls for a maximum bismuth of 0.05 per cent, but some large customers now specify 0.0025 per cent. In the case of zinc, the galvanizing industry - because of the development of continuous galvanizing - now demands large tonnages of 0.1 per cent lead grade, whereas a few years ago this section of the market was satisfied with metal containing 0.2 to 0.4 per cent 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 United Kingdom and the United States.

127. 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, though they will of course include modern materials handling and control methods. Oxygen enrichment may possibly be used in future blast furnace plants, and also added to existing plants to increase output and reduce coke consumption.

128. 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.

129. 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 decopperizing, if of sufficient capacity.

130. 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 percentages of total world zinc production capacity):

Process	1959 (percentage)	1968 (percentage)
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

131. During the last decade the growth of the Imperial Smelting Process has been spectacular. From a new process used only in a couple of plants belonging to Consolidated Zinc Corporation (now Rio Tinto Zinc) - the organization 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 produced, with the notable exceptions of the United States and the USSR. The Imperial Smelting Process will continue to grow in the immediate future as several Imperial Smelters are now in the construction and planning stages.

132. However, the author 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 are as follows:

(a) 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;

(b) The electrolytic process is suitable for comparatively small productions and an electrolytic plant can be gradually expanded as required;

(c) New residue treatment processes, in particular the Jarosite process, will result in the highest obtainable over-all recoveries for zinc and other values in zinc concentrates;

(d) 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;

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

133. On the other hand, 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 start out with a plant of a 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.

134. 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 connexion one must remember that there is still room for improvement in the Imperial Smelting Process and that its performance will undoubtedly be further developed in the near future.

135. The horizontal retort process is doomed to gradual extinction but existing vertical retort and electrothermic zinc plants appear still to 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.

136. 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.

137. In the paper New Lead Smelting Processes by G. Björling, it was indicated that in spite of the relative nobility of the metal, the metallurgy of lead is not so simple as one would presume. This is due both to its occurrence as sulphide and to the low melting points and high volatility of the metal and its compounds.

138. 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 one used around 1950.

139. The benefits of the hearth process were not forgotten, and since the supply of rich galena concentrates has become more abundant there have 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:

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

140. Of the new processes, the round hearth process is a direct conversion of the old straight hearth process, whereas the self-fluxing smelting has some new features. Both of these processes are 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.

141. Another type of process works with deficit oxygen in the basic reaction and therefore sulphur must be eliminated 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.

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

143. 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 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 of evaluating zinc and other minor metals in the raw material.

144. Table 1 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 under S refer to a small plant with a through-put of about 10,000 tons/year (30 tons a day) and under L to a larger plant of about 50,000 tons/year (150 tons a day).

145. In Table 2 each main item in Table 1 has 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 gives a relative estimation of the competitiveness of a process and how it varies with the size of the production. Finally, the Figure tries to illustrate these variations graphically.

146. 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 sulphidic concentrates and especially to high grade ones. For the round-hearth process and the self-fluxing smelting, described above as the roast reaction processes with oxide excess, there is the additional 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 a greater 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.

147. The Boliden process (and eventually also the Outokumpu method) should be competitive for medium and large smelters. It requires medium-grade concentrate and the capital costs are relatively high, but the need for 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 advantageously 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.

Table 1

Basis of cost calculations for smelting a ton of galena concentrate with 72 per cent Pb

Per ton of concentrate	Process: Blast furnace S	Blast furnace L	ISF S	Round hearth S	Round hearth L	Self-fluxing S	Self-fluxing L	Boliden S	Boliden L
Direct labour (man-hours)	9.7	3.2	1.5	11.6	3.4	7.1	3.3	4.0	1.5
Fuel in kg									
Oil	13.3	6.4	-	85.0	51.0	83.3	74.0	-	-
Coke	168.0	150.0	-	13.0	13.0	-	-	12.5	12.5
Coal	-	-	-	150.0	150.0	24.0	24.0	-	-
Electrical energy (kWh)	154	135	58	70	60	161	43	750	596
Materials									
Limestone	44.0	44.0	113.0	80.0	80.0	-	-	200.0	200.0
Soda ash	-	-	-	15.0	15.0	7.4	7.4	-	-
Maintenance (man-hours)	5.5	2.2	1.1	3.4	2.0	6.0	4.0	3.0	1.0
Capital costs (in dollars)	16.1	8.0	4.5	12.1	8.9	16.9	14.0	15.0	7.5

S = small plant.
L = large plant.

Note: ISF considered not fit for use for large tonnages of additonal lead burden.

Table 2

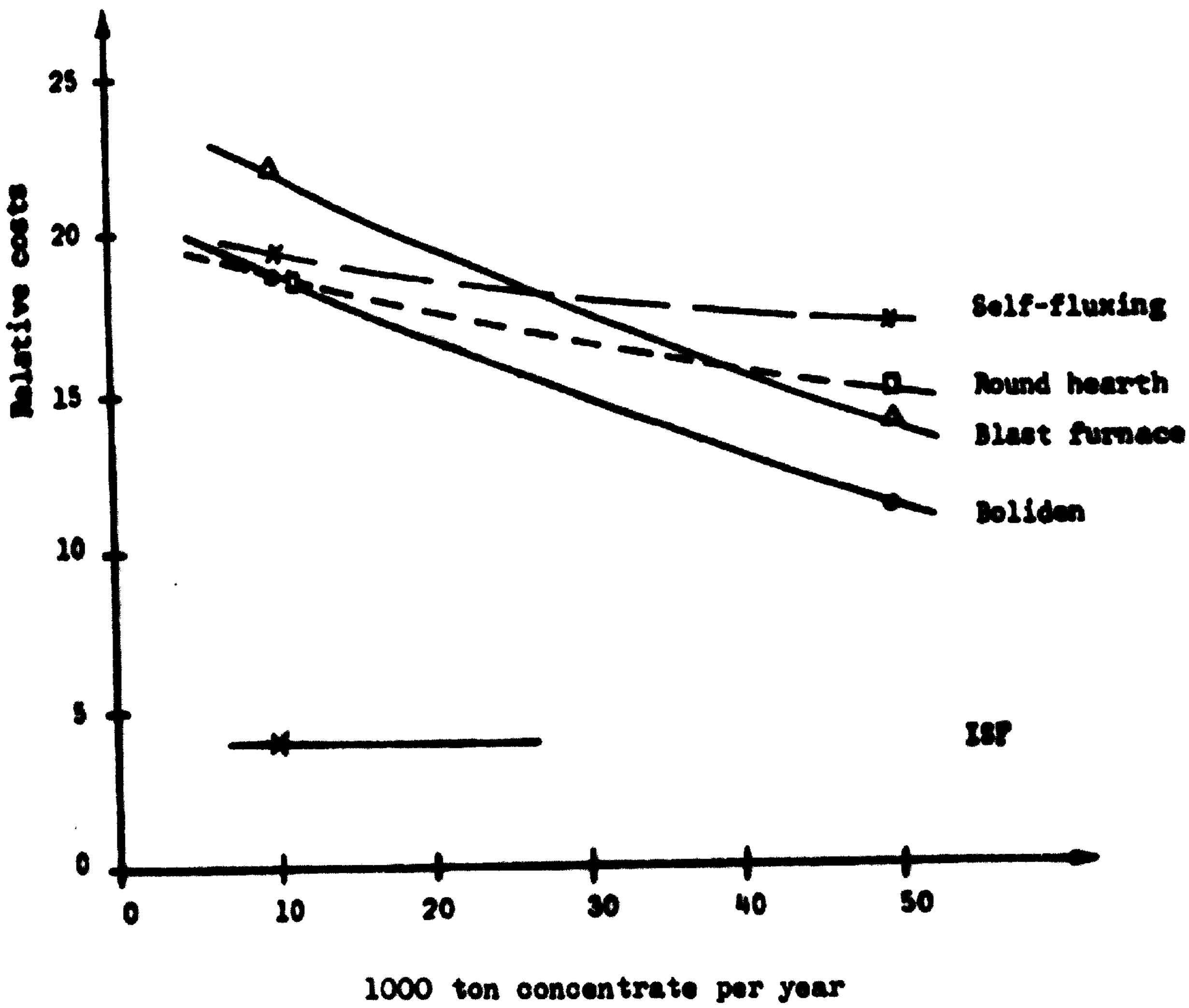
Relative characteristic cost of different processes

	Process: Blast furnace S	Blast furnace L	ISF S	Round hearth S	Round hearth L	Self-fluxing S	Self-fluxing L	Boliden S	Boliden L
Labour	5	2	1	5	3	4	3	3	1
Fuel	5	5	-	4	4	3	3	-	-
Electrical energy	1	1	-	1	1	1	1	5	5
Materials	1	1	1	1	1	1	1	2	2
Maintenance	5	2	1	3	2	5	4	3	1
Capital costs	5	3	1	4	4	5	5	5	3
Total	22	14	4	18	15	19	17	18	12

S = small plant.
L = large plant.

Figure

Relative costs of different lead processes



148. 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 has relatively high costs for labour, repairs and construction; but like the 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.

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

150. The paper Lead and Zinc Refining and Trends towards Purer Metals by L. S. Getzkin examines the new processes for lead and zinc production and in particular the recent developments in the USSR.

Continuous decoppering of lead bullion

151. Since 1956 research has 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:

(a) Transferring copper directly into matte;

(b) Transferring copper into dross.

152. In both cases a furnace with a deep bath of lead is used, with the temperature gradient from about 1,000°C in the upper layer to some 400°C at the bottom.

153. 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.

154. 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.

155. The copper content in the purified lead is 0.1 to 0.4 per cent.

156. The process was patented in the USSR. Later 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

157. 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.

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

159. The copper dross is smelted with a reducing agent and some sodium sulphate added. As a result, 96 per cent of the copper passes into the matte and the noble metals go into the metallic lead.

160. 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

161. Many complex ores contain considerable amounts of arsenic. In the process of their beneficiation this element finds its way into lead, zinc and copper concentrates. During blast furnace smelting, about 60 per cent of arsenic goes into the fume, and another 20 to 30 per cent is removed in the form of calcium arsenate during the alkali softening of lead.

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

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

164. In the USSR 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.

165. The process comprises, in the main, nodulizing 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 the arsenic is 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.

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

Electrothermic treatment of zinc crust

167. 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 difficult labour conditions.

168. In 1956-1957 an electrothermic method for working up zinc crust was developed and used throughout the USSR. The new process consists essentially in distilling the crust in an electric furnace where a slag is specially formed to constitute the resistor. The zinc distills and is condensed into liquid form. The noble metals are recovered in the silver-bearing lead.

169. The electrothermic unit consists of an electric furnace, a shower-action condenser, a dust catcher and a flue, delivering gases to the baghouse. Ordinary coke breeze is used as a reducing agent. The charging of the crust into the furnace is fully mechanized and is done continuously.

170. The distillation of zinc crust yields two products: silver-bearing lead and liquid zinc.

171. The typical operating data are given in the following paragraphs.

172. The daily capacity of the unit amounts to 4 to 5 tons of zinc crust treated, per square meter of the furnace hearth area. The direct recovery of metal values in the silver-bearing lead is as follows: noble metals - about 100 per cent, lead 99.5 per cent, zinc into liquid metal 95 per cent. Power consumption is 500-600 kWh per ton of crust, electrode 3 to 5 kg, coke breeze 20 kg. The construction and installation costs are repayed in two or three months.

173. The USSR is prepared to offer the design of the installation - with the technological instructions and experts' assistance for mastering the process - to any country.

Preparation of high purity lead

174. Metals of very high purity are produced in a relatively small quantity. In the USSR a new process for the preparation of lead of a very high purity has been developed and has proved a success on a commercial scale. This process includes a multistage amalgam electrolysis with selective separation and subsequent extraction of mercury by the vacuum distillation technique. The lead has a purity of from 99.9990 to 99.9999, calculated by difference, when analysed for 24 elements.

175. All the processes of lead refining and treatment of the intermediate products, which were reported here, have been patented in the USSR.

Pyrometallurgical and hydrometallurgical methods of zinc production and their relation to zinc purity

176. Further development of the Soviet zinc industry will be based on the two methods of production, namely hydrometallurgical and electrothermic.

177. Operating improvements in the electrolytic zinc process have been directed in the USSR towards the application of fluidized bed roasting and the perfecting of such operations as calcine classification, leaching, filtration, solution purification and electrolysis.

178. Progress attained in the pyrometallurgy of zinc, especially the advent of the electrothermic and Imperial Smelting Processes, has made it possible to process complex and low-grade raw materials. The general trend in the development of the world's non-ferrous industry shows that in a number of countries where cheap electric power is available, electrolytic zinc plants are being built and the existing ones are being expanded.

179. The problem of choice between the hydrometallurgical and pyrometallurgical methods can only be solved by taking into account the composition of raw materials, the availability of cheap electric power, the spheres of zinc consumption in the particular country and a number of other factors.

180. In the end, it should be said that both methods have prospects for future development, and the preference in the particular case should be based on an analysis of the economical and metallurgical aspects involved.

Control of impurities in zinc electrolyte mandatory to the production of pure zinc

181. The quality of the zinc produced depends mainly on the content of impurities such as iron, copper, cadmium, cobalt and chlorine in the solution fed to the electrolyzing step.

182. Removal of copper and cadmium from the zinc sulphate solution is carried out in the USSR on a continuous countercurrent basis. At the Soviet zinc plants, cobalt is removed from solution by precipitation with sodium ethyl xanthate.

183. A new method has also been developed which is essentially a simultaneous cementation of copper, cadmium and cobalt with zinc dust in the presence of antimony salts as an activating additive.

184. The Soviet practice is to remove chlorine by precipitation in the form of cupreous chloride. This method is very simple and cheap as compared with other methods. This purification, however, cannot reduce chlorine below 150 to 200 mg per litre.

185. In the USSR a new method for the removal of chlorine by solvent extraction technique has been developed and tested on a semi-commercial scale. This method has been patented in Austria, Belgium, the United States and the USSR.

Preparation of high purity zinc

186. The highest grade of zinc now produced according to the USSR standard specification requires to conform to a very limited amount of impurities - copper, lead and iron in particular being not more than one part per 10 million each.

187. High-purity zinc is usually prepared by one of three methods: purification by distillation, zone refining, or electrolysis; and purities of not less than 99.999 are obtained. The metal was analysed for 14 impurities and the zinc content was taken by the difference.

188. High purity metals are gaining more and more ground in science and technology, especially in the new techniques and developments.

189. The paper Modernisation of Lead Smelting and Refining at Trepča, by B. Vasijlevic, describes the operation of the lead smelter and refinery which is situated in the underdeveloped southern part of Yugoslavia. Evidence of smelting throughout the ages can be found in the area.

190. In the first stages of redevelopment of the Trepča lead smelter, two processes worked in parallel, one being the use of hearth furnaces (roast reaction type) from which the larger part of the lead bullion was produced from the rich and pure concentrates, and the second being the modern practice of sintering the poorer grades of lead concentrates together with grey slag from the hearth furnaces, with subsequent reduction of sinter in the blast furnace.

191. The hearth furnaces were of the Newnam type - 2.5 m long and 0.5 m wide. The sinter machine has an effective downdraft grate area of 22.5 m^2, and the blast furnace has a cross sectional area at tuyere level of 5.8 m^2. The gases leaving the hearth furnaces pass through a bag filter into the atmosphere, whereas the gases from the sinter machine and blast furnace pass through an electrostatic precipitator prior to entering the atmosphere.

192. The lead refinery is equipped with 300-ton capacity kettles which are gas fired. The refining process incorporates the following stages: decopperizing, softening with soda-saltpeter, desilvering with zinc, dezincing by Cl_2 gas or by $PbCl_2$ and debismuthizing by Ca-Pb alloy and Mg metal.

193. With very pure and rich concentrates from "Stari Trg", the hearth furnaces were able to maintain good production figures. It was not uncommon to have an output of 24 tons/day/furnace. It was found however, that by using lead concentrates containing 72 per cent, lead production fell to about 12 tons/day/furnace. The basis for enlarging the capacity of the Trepča smelter was by the use of lower grades of lead concentrates containing more impurities. In consideration of the process to be adopted, the hearth furnaces were found to be less attractive, since production costs would be higher and the hearth condition unsatisfactory. The alternative was to modernize the lead smelter.

194. The modernization of the smelter meant the end of the hearth furnaces, and, in their place, the erection of a modern sinter plant of an 80 m^2 up-draft effective grate area, together with a sulphuric acid plant, and the erection of two chair-type blast furnaces having double row tuyeres. The cross-sectional area at the lower row level of tuyeres is 9.7 m^2 and at the upper row level, 22 m^2.

195. Both the sinter and blast furnace plants are provided with central control rooms, from where it is possible to command the proportioning of the charge to the sinter machine and blast furnaces respectively. Instruments, switches and alarms are provided also to control the process both safely and accurately.

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

197. During short periods of operation on the sinter plant it has been possible to achieve sulphur elimination rates of 1.3 tons/m^2/day, and during a run of ten days on the blast furnace an average production of 250 tons/day of lead bullion was maintained, which corresponded to 60 tons sinter/m^2 of blast area at the lower tuyere level. However, over longer durations of operation, these encouraging figures have not been maintained and the yearly average is much lower to date. As yet, the ventilation of buildings and equipment is still

unsatisfactory, and much attention will have to be given to this problem to improve the ambient conditions. The contact sulphuric acid plant is now being erected and it is hoped that it will go into operation towards the end of this year. A short description of this plant is as follows: Sinter gases having passed through the horizontal hot gas electrostatic precipitator are further cooled and cleaned in a venturi scrubber. After this stage, the gases pass through four horizontal indirect gas coolers and on to two groups of wet electrostatic precipitators to remove mist formations. The gas is finally cooled to 35°C through a vertical indirect gas cooler. Drying and conversion of SO_2 to SO_3 follows. The converter has a vanadium ferrous catalyst, and heat exchangers are arranged between the catalyst layers. A conversion efficiency of at least 98 per cent SO_2 is expected. Finally, the gases pass through the absorbtion tower to produce sulphuric acid.

198. The third stage in the proposed modernization at Trepča is that of erecting a fuming plant to treat the residues from the electrolytic zinc plant and slag from the blast furnaces. As yet no work has started on this new development.

199. Little change is foreseen in modernizing the lead refinery. The complete "Harris" method for lead softening will be introduced and the dezincing of lead by vacuum dezincing after desilverization 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 for the reverberatory furnaces and cupels.

CHAPTER 4

THE IMPERIAL SMELTING PROCESS FOR THE SIMULTANEOUS PRODUCTION OF LEAD AND ZINC

200. The paper of D. A. Temple entitled Utilization of the Imperial Smelting Process, aims at supplementing the other papers submitted to the meeting, including that of Dr. Fujimori of Befu, Japan.

201. Dr. Temple considered that the present stage of application of the zinc/lead blast furnace could usefully be outlined, and he illustrated the location and general characteristics of the eleven units that were currently in operation. (See Table 3.) During 1968 the Imperial Smelting Furnaces had contributed about 10 per cent of the total world production of zinc and it was anticipated that by the mid 1970s this would amount to about 25 per cent, along with the simultaneous production of approximately 18 per cent of the world's lead production. It might be worthy of note that around the beginning of May 1969 the process had produced a total quantity of 2 million tons of slab zinc and almost 1 million of lead bullion.

202. Considering the increase in performance of the standard size of the Imperial Smelting Furnace (with a 17.2 m^2 shaft area) constructed at most of the smelter sites, it is interesting to note that the original unit at Swansea was first operated in 1960 to produce 30,000 tons of zinc per year, and the standard Imperial Smelting Furnace unit is now capable of producing 70,000 tons of zinc per year from high grade concentrates. It has recently been estimated that a further 50 per cent increase is possible in the future. Improvements in smelting efficiencies have also been proposed since 1960, i.e. carbon utilisation etc. One important improvement that should be noted is the prolongation of campaign length from fifteen weeks in 1960 to now over two years, due mainly to the development of blasting techniques for removal of accretion from the furnace shaft. The limit of campaign length now depends not on operational or metallurgical aspects but rather on the need to make design improvements or modifications. The Imperial Smelting Furnace is still in a stage of development.

Table 3

The Imperial Smelting Process

Continent	Company	Year of commissioning	Shaft area (m^2)	No. of condensers	Typical sinter Composition (%)		1968 Metals production ('000 M.T. per year)	
					Zinc	Lead	Slab zinc	Lead bullion
AUSTRALASIA								
Cockle Creek, New South Wales, Australia	Sulphide Corporation Pty. Ltd., (Conzinc Rio Tinto of Australia Limited)	1961	17.2	1	45	20	51	20
ASIA								
Befu, Japan	Sumiko I.S.P. Co. Ltd., (Sumitomo Metal Mining Co.)	1966	15.3	1	46	19	45	18
Hachinohe, Japan	Hachinohe Smelting Co. Ltd., (Japanese Smelters Consortium)	1969	17.2	1	42	20	-	-
AFRICA								
Kabwe, Zambia	Zambia Broken Hill Development Co. Ltd., (Anglo American Corporation)	1962	19.6	1	27	22	31	25
CANADA								
Belledune, New Brunswick	East Coast Smelting and Chemical Co. Ltd., (Noranda Group of Companies)	1966	17.2	1	26	19	22	19
EUROPE								
Avonmouth No. 1 England		1950-1959	5.1 9.3	2	-	-	-	-
No. 2	Imperial Smelting Corporation (N.S.C.) Limited	1952-1967	6.4 12.4	2	-	-	-	-
No. 4		1967	27.1	2	46	18	51	16
Swansea, Wales		1960	17.2	2	44	17	50	20
Noyelles-Godault, France	Societe Miniere et Metallurgique de Penarroya	1962	17.2 24.6	2	46	18	49	20
Duisburg, Germany (Fed. Rep.)	'Berzelius' Metalhutten G.m.b.H., (Metallgesellschaft A.G.)	1965	17.2	1	44	21	68	33
Copsa Mica, Romania	Uzina Chimico Zetalurgica	1966	17.2	2	40	17 Cu 2%	36	17
Miasteczko, Poland	Huta Cynku "Miasteczko Slaskie"	1968	17.2	1	42	19	4	2

203. A significant attribute of the process is its flexibility of treatment. S. W. K. Morgan and D. A. Greenwood have defined the metallurgical and economic advantages of increasing the amount of lead that can profitably be smelted. They have shown that as the lead production is increased, the additional lead is produced relatively cheaply and at high recovery. For a high grade charge, the Pb/Zn ratio in sinter is possible up to 0.75/1. The range of charge grade is appreciable. Slag/zinc ratios of between 0.7 and 3.0:1 are being operated. The ability of the process to treat increasing amounts of copper has made the Imperial Smelting Furnace into a useful process for smelting copper, which is so often associated with zinc and lead raw materials. As an example, the furnace at Copsa Mica in Rumania regularly produces lead bullion from the furnace hearth containing 9 to 10 per cent Cu; this has been increased to 13 per cent; on special tests at Avonmouth it has been demonstrated that 15 per cent copper and above in molten lead bullion is feasible. Both oxide and sulphide raw materials as either ores or concentrates may be fed to the sinter machine. In the case of oxide materials, coke fines need to be added as the sintering fuel. With sulphide materials, H_2SO_4 is produced from the sinter plant gases. The amount of H_2SO_4 produced from the complex can be varied according to the variation of the oxide formation of the sinter feed. Thus the Imperial Smelting Furnace can smelt satisfactory sinters made from oxide or sulphide raw materials, and from mixed or bulk Zn/Pb/Cu materials as well as from high grade separate zinc (55 per cent Zn) and lead (70 to 75 per cent Pb) concentrates.

204. Regarding the application of zinc and lead smelting in the developing countries, Imperial Smelting Processes Limited considers the minimum size of unit that is economically practical to be an 11 m^2 furnace, especially considering conditions in most countries. However, this is difficult to judge worldwide without making a detailed study. From high grade materials, this size of Imperial Smelting Furnace would produce annually 40,000 tons of zinc and 25,000 to 30,000 tons of lead. Some mention has been made in the earlier discussions of plants to produce 10,000 tons of zinc per year. However, there is the question of the economic viability of an installation of this size. The Imperial Smelting Furnace makes possible a "clear cut" separation of zinc and lead in a single unit, and this results in eliminating additional operations of removing zinc from lead blast furnace slags, by fuming or other methods, and also obviates the recovery of lead and other valuable materials from the leach plant residues formed in an electrolytic zinc plant.

205. The Imperial Smelting Process must be classified as a sophisticated one, as is indeed true of all modern techniques when one considers the use of automatic handling and control and, more recently, computer control. These tendencies make the process ideally suited to the industrialized countries. It has been shown, however, by B. Barlin in his paper at this meeting, that by means of suitable and adequate training, indigenous labour can be employed to operate the process satisfactorily. This tends to contradict the views expressed by J. W. Reimers in his papers. The aspect of training is considered by Imperial Smelting Processes Limited, and by the organizations which operate the process, to be of great importance. The normal minimum training programme of staff and operators in the United Nations amounts to 7 man-years, involving approximately 24 persons on a carefully planned schedule.

206. Mention has been made of the opportunity of the Imperial Smelting Furnace to provide better over-all recoveries of the metal values. For, if one considers the use of separate zinc and lead concentrates, the lead in zinc concentrates and the zinc in lead concentrates, as well as the copper silver in both, they are equally recovered at high efficiency. Very often if one considers the over-all recovery from ore to salable metals, the production of both Zn/Pb/Cu concentrates is most favourable for the over-all utilization of the metal values. When defining metal recoveries it is necessary to give attention to the grade of raw materials. But again using the example of high grade concentrates, the following recoveries are possible in the Imperial Smelting Furnace:

Zn	92 - 93 per cent	
Pb	90 - 96 per cent	(depending on the Pb content of the charge).

207. Massion, Maczek and Adami (3) have reported examples of metals recoveries from the Duisburg Imperial Smelting Furnace.

208. R. Healey in his paper deals with the question of zinc grade as produced directly from the Imperial Smelting Furnace condenser/separation system, as well as with the methods of vacuum de-zincing and reflecting towards the production of respectively high-grade and special high-grade metal.

209. The capital cost of installing a complete Imperial Smelting Furnace plant can best be summarized as follows: $375 per annual ton of zinc produced: this applies to a 17.2 m^2 furnace which is capable of producing (from high-grade materials fed to sinter plant):

Slab zinc	70,000 tons/year (including 35,000 tons special high-grade zinc)

Lead bullion	40,000 tons/year
Sulphuric acid	120,000 tons/year
Cadmium	100 - 200 tons/year
Copper in bullion	4,000 tons/year.

210. The figure $375 quoted above assumes a green field site, and includes the Imperial Smelting Furnace and following auxiliary plants: sinter-plant, acid plant, zinc refluxer, pyro-metallurgical lead refinery to recover all values, cadmium plant, effluent-treatment plant, ore storage, offices, workshops, laboratories, transport as well as general site development, but does not include working capital. This indicative price factor in dollars has been converted from pounds by using a factor of 2.4 and is based on United Kingdom conditions in January 1969. Naturally the size of the Imperial Smelting Furnace and its auxiliary plant as well as the site location, will effect modifications to this price factor.

211. An important factor that has emerged from the plants which use the process is the highly useful aspect of collaboration of members of the "I.S.P. Club". Regular exchanges of data and ideas on operating techniques and design components, as well as metallurgical data, is being enthusiastically carried out. Other activities are visits of personnel to each others' plants, as well as periodic visits by the technical staff of Imperial Smelting Processes Limited. Conferences of licensees are arranged at approximately 3-year intervals. Process development is now based on a co-ordinated programme, making a greatly accelerated progress possible. All these elements of collaboration have resulted in the appreciable development in the process which has taken place and is likely to do so in the future.

212. The paper Sintering Techniques as Applied to the Imperial Smelting Process by C. J. G. Evans covers 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 desulphurization. The amount of sulphur to be removed depends on the raw materials used since the desulphurized product should always contain less than 1 per cent residual sulphur.

213. 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:

(a) The drying, calcining and/or roasting of fine ores or concentrates;

(b) The agglomeration of fine ores or concentrates which could not be smelted economically otherwise; and

(c) Increased blast furnace productivity.

214. 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.

215. 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 products 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 per cent SO_2 which is usually converted into sulphuric acid.

216. 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 the Imperial Smelting Corporation. Downdraught sintering had been used to produce a small sized sinter ($-\frac{1}{2}$ in.) for the horizontal distillation or vertical retort plants. In order to increase the size to produce a sinter suitable for the blast furnace, hardening agents were added, notably 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 recurring mechanical difficulties with grate scaling 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 only with sulphur (in the form of sulphide) as the fuel. This method provides the basis for current operations at eleven plants associated with Imperial Smelting Furnaces.

217. 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 material 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.

218. 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:

- Sulphur content of the sinter machine feed
- Intensity of draughting
- "Returns" sizing
- Efficiency of mixing
- Moisture in sinter mix
- Chemical composition of sinter.

219. 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.

220. 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 roasting and briquetting. However, it would appear that sintering provides the best means of simultaneous desulphurizing and agglomerating. This is especially true with the high lead sinters (+15 per cent Pb) which are normally smelted in Imperial Smelting Furnaces.

221. Some areas for improvement within the 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 increasing demand for sinter of an ever improving quality.

213. 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:

(a) The drying, calcining and/or roasting of fine ores or concentrates;

(b) The agglomeration of fine ores or concentrates which could not be smelted economically otherwise; and

(c) Increased blast furnace productivity.

214. 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.

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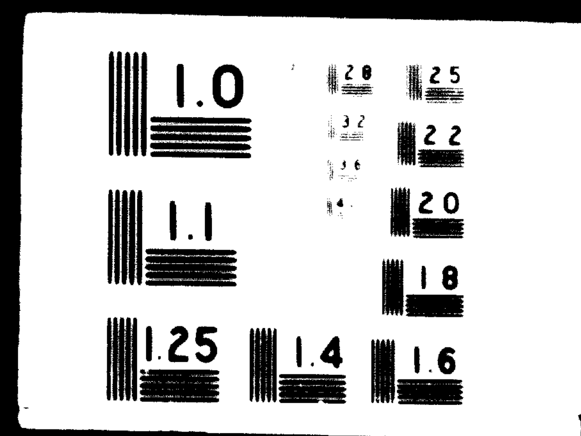

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222. The Metallurgy of the Zinc/Lead Blast Furnace is described in a paper by R. Healey. The paper pointed out that zinc reduction at normal pressures can be brought about by carbon only at a temperature above the boiling point of the metal. Production 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.

223. Re-oxidation 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 to "freeze" the reaction and to dissolve the zinc vapour. It should be noted that this lead splash condenser is used solely for absorbing zinc and has no connexion with lead production in the furnace shaft.

224. 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

225. The materials to be handled are sinter, coke, lime flux and a little recycled dross. The sinter is screened before charging in order to remove -½ 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 2.5 and 3.5 in. as received, but it is preheated to about 750°C as a means of returning waste heat to the furnace.

226. 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.

227. 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 through-put 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 per cent of the input, though technologically it is possible to get to below 3 per cent zinc in slag assay, with good control of the sinter composition.

Furnace shaft

228. The standard furnace shaft has a rectangular cross section with semi-circular ends of approximately 10 by 20 ft in dimension. The height is 30 ft, of which the lower third consists of water jackets sloping in to about 6 ft 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 20 ft. This elongated shape was chosen to keep the tuyeres on either side relatively close together and to provide an intense smelting zone for zinc reduction, although it also results in less even charge distribution.

229. 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.

230. Basically there are 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:

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

231. 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 = 76 to 80 per cent, M10 = 8 to 10 per cent. This is adequate for the Imperial Smelting Process.

232. 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.

233. 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 re-oxidation of some of the zinc vapour by carbon dioxide.

234. The gases leaving the charge would precipitate zinc oxide on any cold surface with which they come in contact, 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 re-oxidation point for zinc.

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

Slag and bullion handling

236. 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 per cent. 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 per cent copper in bullion, though 20 per cent has been reached in trial runs.

Condensation and separation

237. 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.

238. The furnace gas enters the condenser at about 1,050°C, is rapidly cooled, and eventually leaves the condenser 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 per cent of the total) as escapes absorption in the lead. This zinc is returned to the sinter feed.

239. The hot lead flows through two cooling launders (narrow water jacketed 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 overflows into a holding bath from which it is periodically tapped off.

Zinc purification

240. 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 is desired to be produced.

241. Simple liquation is all that is necessary to make Grade 4 (98.5 per cent) 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.

242. Vacuum dezincing can be used if it is desired to produce Grade 3 zinc (less than 0.1 per cent lead). This method makes use of the heat content of the condenser lead, which is pumped from the sump to the inlet of a cylindrical 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 vacuum and is deposited on a central water cooled condenser, 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.

243. This process produces an enhanced grade of zinc, but cannot remove its cadmium content, which, being more volatile 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.

244. Typical composition of vacuum-distilled zinc, produced at the rate of four tons per hour, is:

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

245. 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), and then the 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.

246. 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 and 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 1.5 per cent. 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.

247. 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 producing pure zinc and crude cadmium metal.

248. A paper was tabled at the meeting, on behalf of Mr. Fujimori, on The Imperial Smelting Furnace Process for the Simultaneous Production of Zinc and Lead at the Karima Works of Sumiko.

249. The Imperial Smelting Furnace operated by Sumiko I.S.P. Ltd., at Befu, Japan, represented the first venture into zinc production by the parent organization, the Sumitomo Metal Mining Company. The furnace, which has a shaft bricked to give an area of 165 ft^2 (15.3 m^2), as compared to the normal 185 ft^2 (17.2 m^2), was commissioned in May 1966. The plant acts as a custom smelter, utilizing a variety of domestic and imported concentrates. Current weekly production averages over 1,000 tons of zinc and 450 tons of lead.

250. In his paper, Dr. Fujimori considers that the particular advantages of the Imperial Smelting Furnace are as follows:

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

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

(c) 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.

Slag composition

251. Dr. Fujimori considers that the desired characteristics of Imperial Smelting Furnace slag are that it should be small in quantity, contain as little zinc as possible and be fluid.

252. The quantity of zinc in the furnace 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.

253. Dr. Fujimori calculates that theoretically, under equilibrium conditions, it is possible to decrease zinc in slag to 1.0 to 1.5 per cent without reducing iron oxide.

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

255. 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 Imperial Smelting Furnaces. The slag weight and association zinc loss in slag is thereby reduced.

Shaft gas analysis

256. The reducing conditions in the furnace shaft must be such that zinc oxide is reduced without the reduction of iron oxide to metallic 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 itself oxidized to carbon dioxide. The Boudouard reaction between carbon and carbon dioxide subsequently reduces the Co_2/Co ratio. Dr. Fujimori considers that by using a coke of relatively high reactivity, the amount of Co_2/Co at the top of the furnace - before it enters the condenser - is lower than that obtained on other Imperial Smelting Furnaces. This is considered by him to be a main reason why the over-all condensation and separation efficiency is as high as 90 to 91 per cent at Befu, since there is less tendency for the back reaction which forms zinc oxide from gaseous zinc.

Blast temperature

257. The importance of blast temperature in the Imperial Smelting Furnace is illustrated by a heat input summary, prepared at Befu, which indicates that nearly 20 per cent of the total heat input to the furnace arises from the hot blast. A further increase in blast temperature would result in an increase in output. However, Sumiko considers 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 stove refractories.

Recovery of lead

258. Lead oxide in sinter 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 per cent.

259. An advantage of lead in sinter is that it gives satisfactory sinter 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 sinter currently used at Befu analyses 45 per cent zinc, 19 per cent lead, 2.5 per cent silica and 4 per cent lime.

Behaviour of sulphur and copper

260. Sulphur input to the furnaces arises from sinter and coke which usually contain 0.8 per cent and 0.7 per cent sulphur respectively, at Befu. The majority of the input sulphur goes into the slag and matte of the speiss. It is considered that increased sulphur in sinter has an adverse effect on operations by causing increased accretion formation in the furnace shaft.

261. In the Imperial Smelting Furnace, 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 to the preferential formation of iron sulphide rather than copper sulphide. Copper is not present significantly in matte unless the sulphur content of the sinter is high and the sulphur capacity of the slag becomes exhausted.

Iron

262. As previously mentioned, Befu has found a good correlation between zinc content in slag and FeO content in slag. A negative correlation has been found to exist between zinc content in slag and the quantity of matte and speiss produced. This is explained by the fact that lower zinc in slag is associated with more strongly reducing conditions and a higher iron oxide activity in the slag. Thus there is an increased tendency for the formation of iron sulphide and arsenide.

263. Dr. Fujimori concludes his paper by detailing the flourine and chlorine balances obtained at Befu.

CHAPTER 5

THE OPERATION OF AN IMPERIAL SMELTING PROCESS PLANT IN A DEVELOPING COUNTRY

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

265. Production of lead and zinc from this source represents less than 1 per cent of world production and 2.7 per cent of this production is consumed in Zambia.

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

267. 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.

268. The irregularity that characterizes the shape of the ore bodies 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 flow-sheet

269. 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.

270. The $+\frac{1}{4}$ inch portion is treated in a heavy media drum separator to remove dolomite waste rock. The heavy product is crushed, ground and treated in a floatation 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.

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

272. The feed materials to the sinter plant of the Imperial Smelting Process consist of all the $-\frac{1}{4}$ inch material from the ore hoisted, large tonnages of reclaimed dump materials, all the lead concentrate and sufficient 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 lead refinery drosses are also circulated to the sinter plant. The only fluxing material added to the charge is pulverized limerock.

273. Final products include electrolytic zinc (99.95 per cent zinc), Prime Western Grade zinc (98.5 per cent zinc) and high purity lead (99.99+ per cent lead). Silver and cadmium metals are also produced as by-products, and in earlier years vanadium pentoxide was also produced.

Imperial smelting furnace operation

274. The feed materials for the furnace are confined to those available from the mine and are of relatively low grade and 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.

275. 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.

276. 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 are circulated. These functions are largely dependent on manual operations carried out by well trained operators.

277. 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

278. The operation of a plant with a new process anywhere in the world brings in its train 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 1962, the Zambia Broken Hill Development Company found itself with little even semi-skilled local labour and all the skilled labour and professional managers were provided by Europeans.

279. Training for all the skilled levels required for the Imperial Smelting Furnace was provided for through selecting men of known and proven ability in similar capacities in existing plants and sending them to Swansea and Avonmouth for training.

280. The local labour force was drafted across for lower level jobs on the new plant.

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

282. 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, 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.

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

284. 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.

285. From the job description, a breakdown of the components of each job was made; some components are common to all jobs, some common only to certain jobs, and so on. It was a fairly simple matter to group components into a series of courses: 'basic', 'secondary' or semi-skilled, 'tertiary' for the next scale up and 'specialist' for the individual sectional operating jobs. Thus evolved a system of layered training. Each course 'skimmed the cream' of the personnel for the next course. In this way the new manning structure was evolved and the best man for each job was chosen and all were developed to the limit of their potential.

286. To resolve the engineering maintenance problem, an analysis by trades of the component skills acquired by an artisan in the five years of his apprenticeship training was made.

287. 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 formalized 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 was defined clearly with a job outline and standards set by trade tests.

288. 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 them in acquiring greater skills.

289. The difficulties encountered are attributed to two main factors: language and environment - language because of the difficulty in communications, especially in the technologies; environment because of the almost complete technical void in a society based on a simple agrarian economy.

290. 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 it must 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

291. The political implication of Zambia's position in relation to its southern neighbours must be understood to realize Zambia's desire to divorce itself 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.

Lead and zinc metal sales

292. 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 Africa and overseas, reflecting an increase in the latter, does incur greater costs due to realization charges on c.i.f. sales. South Africa withdrew orders in 1968 and realization charges will be increased considerably in 1969.

293. The fact that Zambia is 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 Southern Rhodesia.

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

295. 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.

CHAPTER 6

THE OPERATION OF AN ELECTROLYTIC ZINC PLANT IN A DEVELOPING COUNTRY

296. In the paper Some Interesting Problems in the Start-up of the Electrolytic Zinc Plant in a Developing Country by J. D. Adhia, it is pointed out that India is one of the few developing countries that has large reserves of lead and zinc ores as well as having a market for these metals. Presently, India consumes approximately 75,000 tons of zinc per year and this demand is likely to increase to 141,000 tons by 1973-1974.

297. At present there are two plants in the country, namely, one at Debari, Udaipur, with a rated capacity of 18,000 tons of zinc per annum, and Cominco Binani Zinc Limited at Alwaye, with a rated capacity of 20,300 tons of zinc per annum.

298. Some interesting problems were encountered during the start-up of the Debari plant and these are discussed below.

299. The Debari factory uses the only fluo-solid roaster in India. As is known, the start-up of the fluo-solid roaster requires calcine for the initial charging and the creation of fluidized bed condition in the roaster. Some 40 tons of calcine were therefore obtained from the Cominco Binani Zinc Plant in the south of India, but this was found to be rather fine in particle size (about 70 per cent passing through 30 mesh) and material quantities were lost during initial start-up of the roaster. The roaster was finally started on a mixture of fine silica sand and the flash roaster calcine. The final starting was achieved without any foreign technicians and the initiative was entirely with the Indian personnel trained in the operation of fluo-solid roaster for a short period of three to four months. The fluo-solid roaster (capacity 120 metric tons/day) is of LURGI design and was found to be extremely simple in operation. During the capacity test run on this roaster from 24 to 26 January 1968, 152.5 tons of blend could be charged in 24 hours. The quantity

of acid recovered was 121.4 tons. The recovery of sulphur was 89.15 per cent as sulphuric acid. The roaster diameter is 4.85 metres at the bottom and 7.3 metres at the top (internal). Typical analysis of zinc concentrates fed and the calcine produced were as follows:

	Concentrate (percentage)	Calcine (percentage)
Total Zn	54.20	62.11
Acid solution Zn	-	57.40
Zn-solubility	-	92.57
Total Fe	5.67	6.26
Total S	30.17	3.87
So_4-S	-	3.50
H_2S-S	-	0.37
Pb	1.12	1.29
Cu	0.07	0.08
Cd	0.30	0.35
Ni	0.0004	0.0005
Co	0.0041	0.0050
Cl	0.0016	tr.
F	0.0060	0.0070

300. The gases from the roaster, along with a major part of calcine, pass through a waste-heat boiler followed by a series of dry cyclones. The gases are then scrubbed in a pea-body scrubber and the scrubbed clean gases are sucked by a PVC blower and pushed through an electrostatic precipitator in the sulphuric acid plant. A number of operating problems associated with the PVC blower are described together with the steps taken to overcome them.

301. In the Debari plant, leaching is carried out in two stages. The first stage is neutral leaching followed by the acid leaching of the underflow from Dorr thickeners. The two-stage purification is carried out cold and batchwise. The total volume of the neutral-leaching pachucas is 135 m^3 and that of the acid-leaching pachucas is 180 m^3. The total settling area of the Dorr thickeners is 555 m^2 for the neutral leaching and 370 m^2 for acid leaching. The acid underflow is filtered on Moore leaf filter having a total area of 360 m^2.

Typical analysis of neutral overflow and the leach residue (Moore cake) is as follows:

(a) Neutral overflow

Zn	Co	Ni	Cu	Cd	Fe	As	pH
g/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	
133.9	2.65	0.95	43	419	tr.	tr.	5.5

(b) Leach residue (Moore cake)

T-Zn	Acid sol. Zn	Water sol. Zn	T-S	T-Fe	Pb	Cu	Cd
%	%	%	%	%	%	%	%
20.67	2.71	1.24	5.31	26.3	5.14	0.08	0.23

302. The first and second stage purifications of the neutral leach are carried out by the addition of zinc powder and α-nitroso β-napthol respectively. Zinc dross, obtained in the low frequency induction furnace making zinc ingots, was also used successfully in place of a major part of the zinc powder. The composition of zinc dross which was found suitable for such use is given below:

Total zinc	- 89.2%
Metallic zinc	- 70.67%
Cl	- 0.30%
Screen analysis	- 64.0 passing through 100 mesh.

303. The typical analysis of solution after the first purification with zinc powder and zinc dross was found to be as follows:

	Co	Ni	Cu	Cd
	mg/l	mg/l	mg/l	mg/l
Zinc powder	2.84	tr.	tr.	1.95
Zinc dross	3.61	0.2	tr.	2.40

304. This helped in sparing some of the zinc powder for the market and also resulted in better over-all zinc recovery as there are certain losses during formation of zinc powder and also during retreatment of zinc dross from the induction furnace.

305. The zinc electrolytic cell plant at Debari consists of 240 cells of the standard Anaconda design. These are 10,000-ampere cells and the current

density is 300-350 A/m^2. The average analysis of cell feed solution and spent-electrolyte is as follows:

	Zn g/l	Acid g/l	Co mg/l	Ni mg/l	Cu mg/l	Cd mg/l	Fe mg/l	As mg/l	Mn g/l	Cl mg/l
Cell feed	134.0	1.39	0.5	tr.	tr.	2.6	tr.	tr.	0.37	21
Spent electrolyte	64.0	115		tr.					0.05	

306. The typical analysis of zinc cathodes produced is Pb-0.028 per cent, Cu-0.0010 per cent, Cd-0.0028 per cent, Fe-0.0005 per cent, Zn (by diff.-) 99.967 per cent.

307. The electrolysis plant not only reached its rated capacity in the very first months of its start-up, but also continues to give high recovery efficiency. The efficiency of recovery from zinc concentrates to cathodes, for example, during December 1968, i.e. at the end of the first year of start-up, was 88.7 per cent and from zinc concentrates to zinc ingots was 87.5 per cent. The efficiency guaranteed by the consultants of the plant suppliers was 86 per cent with the iron content in the zinc concentrates at 3 per cent. The above efficiencies were obtained with an actual iron content of about 6.0 per cent in the zinc concentrates. The average power consumption per ton of zinc cathodes was 3,142 kWh.

308. Cadmium metal is produced electrolytically at the Debari plant starting from copper-cadmium cake (obtained during zinc powder purification; Cd-13.1 per cent, Cu-1.27 per cent, Zn-69.5 per cent).

309. There are six 1,000-ampere cells with current density 30-35 A/m^2. The efficiency of recovery of cadmium is far superior to that which was envisaged by the consultants (72.0 per cent) and is even superior to that which is being obtained in many other plants in the world. The cadmium recovery efficiencies for the months of December 1968 and January 1969 were 87.5 per cent and 87.9 per cent respectively from zinc concentrates to cadmium cathodes. The recovery of cadmium ingot metal from cathodes has been 95 to 96 per cent consistently. The flow-sheet for cadmium recovery has recently been modified.

The typical analysis of cell feed and spent electrolyte, and the cadmium cathodes, as obtained with the old and modified schemes, are given below:

(a) Cell feed and spent electrolyte

	Old scheme		Modified scheme	
	Cell feed	Spent electrolyte	Cell feed	Spent electrolyte
Cd g/l	109.0	32.7	104.7	26.4
Acid g/l	-	66.5	-	62.0
Zn g/l	66.5	65.8	27.5	26.2
Mn g/l	12.8	12.0	18.10	11.65
Cu mg/l	26.7	-	6.60	4.40

(b) Cadmium cathodes

	Old scheme (percentage)	Modified scheme (percentage)
Pb	0.0276	0.0120
Cu	0.0095	0.0074
Zn	0.0029	0.0040
Fe	0.0026	0.308
Cd (By diff.)	99.9574	99.9758

310. Copper too has been recovered as pure metal by batch electrolysis, starting from the copper cement residue.

311. The cost of electricity at Debari is very high (12 units per rupee - 1 US$ = Rs. 7.5) and, therefore, it has not been possible to drain the electrolyte after reducing the zinc content. Attempts are being made to make high-grade zinc sulphate from the spent electrolyte and the plant is already in production. A small quantity of zincated superphosphate has also been made available to Agricultural Experimental Stations. A large tract of Indian soil is deficient in zinc and if it is possible to market this product, waste electrolyte will be used for manufacture of zincated superphosphate, thus providing an outlet for the impurities in the electrolyte and a cheaper source of zinc to the Indian farmers.

312. The paper concludes with a comparison of an electrolytic zinc plant and an Imperial Smelting Furnace for producing zinc and lead in India.

CHAPTER 7

THE REFINING OF LEAD BULLION BY THE ELECTROLYTIC METHOD AND COMPARISON WITH THERMAL REFINING

313. In the paper Electrolytic Lead Refining by Elio R. Freni it is reported that a very large number of electrolytes have been studied and suggested for lead electrolytic refining, but it was Anson G. Betts who came up with a really practical solution of the problem, by developing industrial application of the electrolyte based on lead fluosilicate. The first electrolytic refining plant built according to Betts' process - the Consolidated Smelting and Refining Co. of Trail in Canada, has been in continuous operation since 1903. At present there are about ten plants for electrolytic lead refining scattered throughout the world.

314. The paper describes the characteristics and technological and economic results of the San Gavino plant in Sardinia, operated by Monteponi and Montevecchio. This plant started production in 1957, initially using an electrolyte based on lead sulphamate. Subsequently, the sulphamate electrolyte was gradually and progressively changed into fluosilicate electrolyte. A peculiar characteristic of the plant is the high degree of automation which has limited operating costs to extremely convenient levels. Its productive capacity is 105 metric tons of refined lead daily, and it has replaced a thermal plant which had operated for 25 years according to the classic Parkes' process. The lead to be treated, containing large percentages of Ag, Bi, Cu, Sb and As, is skimmed and cast into anodes, by means of a completely automatic plant which supplies racks of anodes ready for introduction into the cells. The starting cathodes consist of thin sheets of lead which are also produced by means of a special automatic machine. The cathodes are extracted in complete racks from the cells, re-melted, and automatically cast into ingots. Power density for the operation varies from 140 to 210 A/mg according to the impurity content of the anodes, with a power efficiency of about 97 per cent. Refined lead

containing: Sb = 0.0001 + 0.0003 per cent; As = 0.0001 per cent; Cu = 0.0003 + 0.0007 per cent; Bi = 0.0001 + 0.0004 per cent; Ag = 0.0001 + 0.0003 per cent, is obtained from anodes containing Sb = 1.5 - 2.5 per cent; As = 0.2 - 0.5 per cent; Cu = 0.02 - 0.06 per cent; Bi = 0.1 - 0.3 per cent; Ag = 0.1 - 1 per cent.

315. With progressive dissolving of the anodes, the impurities associated with the lead form a compact spongy layer of sludge which, when subsequently treated, yields all the constituent metals. Treatment of the sludge is based on progressive oxidation of the more easily oxidized elements according to a sequence of reducing and oxidizing melting operations, which permits final separation of the noble metals in the form of oxides. These operations are performed in a rotary furnace, a converter and a Cupel furnace. The copper dross obtained from the skimming of bullion is processed in rotary furnaces to recover the lead which is returned to the refining cycle, while the copper is recovered in the form of matte and speiss. The electrolytic process permits refining of impure lead in a single stage, with a markedly lesser production of intermediate recycling by-products typical of heat processes. Large amounts of impurities are tolerated in the lead to be refined, while the purity of the refined metal remains consistently above 99.995 per cent. When refining of bismuth and subsequent recovery of this metal is to be performed, the electrolytic method especially reveals its efficiency, elasticity and convenience. Another characteristic of the electrolytic process is the hygienic nature of the work premises.

316. The paper gave a comparison of the electrolytic and thermal refining of lead for a plant treating 50,000 tons per year of bullion of composition: Cu = 1.7 per cent; Sb = 1 per cent; As = 0.15 per cent; Bi = 0.06 per cent; Ag = 0.07 per cent.

Flow-sheet

Thermal treatment	Electrolytic treatment
(1) Drossing by cooling and stirring	(1) Drossing by cooling and stirring
(2) Decoppering by sulphur addition	(2) Anode casting
(3) Arsenic removal by natrium hydroxide	(3) Electrolytic refining in the cells
(4) Antimony removal in kettle by air	(4) Cathode melting
(5) Desilverization by Parkes process	(5) Additional treatment with NaOH
(6) Dezincing by vacuum distillation	(6) Copper dross treatment in short rotary furnace.

Flow-sheet (cont'd.)

Thermal treatment

(7) Additional treatment with NaOH

(8) Debismuthizing by Kroll-Betterton process

(9) Final refining with blowing air

(10) Further NaOH treatment

(11) Copper dross treatment in short rotary furnace

(12) Arsenic dross treatment in short rotary furnace

(13) Antimony dross treatment in short rotary furnace

(14) Working up of rich dross:

(a) Liquation in kettle
(b) Zinc distillation in Faber du Four furnace
(c) Cupelation in Cupel furnace for silver recovery

(15) Working up of bismuth dross

Electrolytic treatment

(7) Slime treatment:

(a) Smelting in short rotary furnace
(b) Blowing in converter
(c) Cupelation in Cupel furnace for silver recovery
(d) Recovery of bismuth

317. Although two completely different treatments are being compared, nevertheless, some similar types of equipment are used.

318. In both treatments drossing and removal of copper is effected in two or three separate kettles.

319. In a thermal refinery, equipment for softening Cu removal, Zn removal, bismuth removal and final refining of lead to be cast into ingots corresponds to the equipment of electrolysis, for anode casting, electrolyte preparation, mud filtering and cathode smelting as well as for lead casting.

320. Equipment for by-product processing in the thermal refining corresponds to the equipment of anode mud processing and copper dross processing in electrolytic refining.

321. For copper dross processing, fuel fired furnaces or short rotary furnaces are envisaged for both treatments.

322. For anode mud processing in the electrolytic treatment the following basic equipment is required:

1 each short rotary furnace
1 each convertor
1 each cupelation furnace
5 each small kettles for Bi refining.

323. Processing of by-products in the thermal treatment is envisaged by the following equipment:

2 each furnaces Faber du Four
1 each cupelation furnace
1 each short drum type furnace
3 each kettle Bunker Hill for Bi-slag processing.

324. Both processes should produce the same product, but they will be slightly different in composition:

Product	Composition	
Refined lead	Thermal refinery	Electrolytic refinery
Pb	99,95%	99.99%
Cu		3 + 5 g/ton
As		traces
Sb		2 + 3 g/ton
Bi	100 g/ton	2-3 g/ton
Ag	-	2-3 g/ton
Hard lead	75% Pb, 25% Sb	75% Pb, 25% Sb
Lead-copper	40% Cu, 25-30% Pb	50-60% Cu, 14-15% Pb
Silver	Doré 99.2% Ag	Doré 99.2% Ag
Refined bismuth	99.99% Bi	99.995% Bi

325. It is noted that there is a difference in quality for refined lead. By electrolytic refining, a purer product is produced, particularly as to bismuth content.

326. The type and quantity of by-products produced in the aforesaid refineries are considerably different. The quantity of by-product in thermal refining is considerably larger than the quantity obtained in the electrolytic refining. The type and quantities of by-products for both refineries are shown below:

	Thermal refining	Electrolytic refining
Copper dross	10,600 tons/year	3,500 tons/year
Lead oxide (lead pumping and NaOH treatment)	500 tons/year	300 tons/year
Arsenic dross	450 tons/year	
Antimony dross	1,000 tons/year	
Ag rich dross	3,000 tons/year	
Liquated dross (Pb-Ag-Zn)	160 tons/year	
Ag rich lead	100 tons/year	
Enamel	100 tons/year	
Low Bi dross (0.4% Bi)	2,500 tons/year	

	Thermal refining	Electrolytic refining
High Bi dross (6% Bi)	170 tons/year	
Zinc oxide	400 tons/year	
Ca-Mg-Pb oxide and chloride	850 tons/year	
From anode slime	-	1,500 tons/year
(a) $PbO-Sb_2O_3$ slag		600 tons/year
(b) Alloy Pb-Ag-Bi-Cu		250 tons/year
(c) $PbO-BiO-Sb_2O_3$ slag		100 tons/year
(d) Flue dust		450 tons/year
Total	19,830 tons/year	6,700 tons/year

327. The total amount of by-products obtained in electrolytic refining is one third of that obtained in thermal refining.

328. Metal recovery in electrolytic process is slightly higher than in thermal process, partly due to the fact that, as a final product, a refined lead containing fewer impurities is produced, and partly, due to the fact that the quantity of by-products in electrolytic process is for the most part smaller, and the basic process of electrolysis is carried out at low temperatures. The following figures for metal recovery are generally accepted:

	Electrolytic refining	Thermal refining
Pb	99.5%	99.0%
Cu	95.0%	95.0%
Sb	90.0%	90.0%
Bi	95.0%	80.0%
Ag	99.0%	98.0%

329. Output of refined lead is larger in electrolytic refining due to the higher metal recovery.

330. Labour force is used as a base for comparison:

Electrolytic refining

Operation department head	1
Foreman	2
Drossing and anode casting	4
Starting sheets	2
Replacement of anodes and cathodes	4
Slime filtering	1
Cathode melting and ingot casting	1

Thermal refining

Operation department head	1
Main foreman	1
Foreman	6
Refining	18
Silver production	3
Bismuth production	3
Short rotary furnace	15
Crane operator	6

Electrolytic refining		Thermal refining	
Copper dross and anode slime processing	15	Casting machine	2
		Lift truck	1
		Cleaning machine	1
Total	30	Total	57

331. The labour force is almost the double in thermal process, due to the higher amounts of by-products to be treated.

332. The following consumption figures are related to one ton of refined lead:

	Thermal refining	Electrolytic refining
Sulphur (kg)	1.2	-
Zinc (kg)	3.2	-
NaOH (kg)	1.1	0.8
$NaNO_3$ (kg)	0.5	-
Ca (kg)	0.45	-
Mg (kg)	2.1	-
Glue (kg)	-	0.5
Goulac (kg)	-	0.5
Na_2SiF_6 (kg)	-	2.5
Oil (kg)	40.0	20.0
Electric power (kWh)	25.0	140.0
Maintenance (h/ton)	1.1	0.6
Manpower (h/ton)	1.8	0.85
Water (mc/ton)	3.5	3.0

333. The following investment figures are estimated:

	Thermal refining	Electrolytic refining
Operating equipment	$ 750,000	$ 950,000
Building	2,500 m^2	6,000 m^2
	$ 250,000	$ 400,000
Installation	$ 100,000	$ 150,000
Total	$1,100,000	$1,500,000

$$\frac{\text{Electrolytic plant} = \$1,500,000}{\text{Thermal plant} = \$1,100,000} = 1.36$$

334. Other factors - The quantity of lead required, or bound in, an electrolytic process is considerably higher than in the thermal one. Lead is bound in anodes, in cathodes, in electrolyte and in kettles for an amount of about

1,900 tons, which represents about 30 per cent of the quantity bound in an electrolytic plant.

335. The electrolytic process provides for better uniformity of operation and superior quality of lead.

336. Thermal refining may be advantageous as purification of lead could be adjusted as required. For instance, it is not necessary to remove bismuth from lead when there is the possibility of selling lead containing bismuth. But in electrolytic refining, debismuthizing is carried out always in the same way, without additional cost.

337. The same is true of silver and other impurities. The increasing of the content of all the impurities does not mean a higher amount of by-product as in the thermal refining.

338. Electrolytic refining assures better hygienic and sanitary requirements. The content of lead in the ambient of the cell room is currently less than 0.015 mg/m^3.

Annex 1

PAPERS PRESENTED TO THE EXPERT GROUP MEETING ON LEAD AND ZINC INDUSTRIES

ID/WG.33/2	Modernization of Trepča lead smelting and refining by B. Vasiljević, Yugoslavia
ID/WG.33/3	Electrolytic lead and zinc refining by I. Freni, Italy
ID/WG.33/4	New lead smelting processes by G. E. Björling, Sweden
ID/WG.33/5	The Imperial Smelting Furnace for the simultaneous recovery of lead and zinc in developing countries by B. Barlin, Zambia
ID/WG.33/6	Sintering techniques as applied to the Imperial Smelting Process by C. J. G. Evans, United Kingdom
ID/WG.33/7	Metallurgy of the zinc/lead blast furnace by R. Healey, United Kingdom
ID/WG.33/8	Lead and zinc refining and trends towards purer metals by L. S. Getzkin, USSR
ID/WG.33/9	A review of the main factors influencing the possibilities of developing lead and zinc industries in developing countries by V. V. Tchiganov, USSR
ID/WG.33/10	Present state of lead and zinc industries in developing countries by UNIDO secretariat
ID/WG.33/11	Perspectives of lead and zinc industry for the next ten years by J. Carlson, Poland
ID/WG.33/12	Recent improvements and trends in lead-zinc extraction metallurgy by J. H. Reimers, Canada
ID/WG.33/14	Lead and zinc industry in Peru. Present state and development during the next ten years by H. Labarthe, Peru
ID/WG.33/16	Utilization of the Imperial Smelting Process - A survey by D. A. Temple, United Kingdom
ID/WG.33/17	The Imperial Smelting Process for the simultaneous production of lead and zinc at the Harima works of Sumiko by M. Fujimori, Japan
ID/WG.33/18	Some interesting problems of the start-up of the electrolytic zinc plant in a developing country by J. D. Adhia, India

Annex 2

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