UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

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A REVIEW OF THE MAIN FACTORS INFLUENCING THE POSSIBILITIES OF DEVELOPING LEAD AND ZINC INDUSTRIES IN DEVELOPING COUNTRIES [1/]

by

V. V. Tchiganov
Ministry of Non-ferrous Metals
USSR

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A REVIEW OF THE MAIN FACTORS INFLUENCING THE POSSIBILITIES OF DEVELOPING LEAD AND ZINC INDUSTRIES IN DEVELOPING COUNTRIES

By Tsyganoff, V.V.
USSR

Introduction

(1) The creation and development of non-ferrous metallurgy--one of the mainstays of modern industry - is considered at present as one of the most important pre-requisites for the attaining by a country of a high economic potential and independance. The experience of establishment and development of non-ferrous metals industry in the USSR and the rapid pace of technological renovation of this industry in a number of industrially developed countries clearly demonstrate to what extent the pace of development of industry as a whole depends on the level of production and consumption of numerous non-ferrous metals. In a similar way the role and significance of non-ferrous metallurgy is determined also in developing countries. Furthermore, it should be borne in mind that non-ferrous metals are one of the stable items of imported and exported products, or, in other words, a stable source of obtaining a hard currency, which is an important consideration for developing countries.

(2) The lead and zinc industry belongs to the oldest branches of non-ferrous metallurgy. Variations (drops and rises) in the outputs of these metals in some countries are, as a rule, mutually compensated by corresponding variations in other countries, and , on the whole, this branch shows stable figures of the average annual rate of increase in consumption and production, as can be seen, for example, from Table I.

Table I. The average annual rate of increase in the mining of ore and in the production and consumption of lead and zinc over the period of 1955 to 1967, in %

	Indystrial countries		Developing countries	
	Lead	Zinc	Lead	Zinc
Mining of lead and zinc in ore	1.75	4.4	0.5	1.6
Production of primary metal	1.5	2.7	1.1	5
Consumption of primary metal	1.5	3.0	7.1	3.9

The rate of increase in the production of pig zinc over the period in question, for the industry as a whole, has been sufficiently steady showing no particular drops. While there were perceptible drops in the output of refined lead (from primary and secondary raw materials) in 1959 and later in 196[illegible], these drops were followed by a steady growth of 2 up 3 per cent, in the production of refined lead, and, on the whole, the output of this metal has also been stable.

In accordance with certain fluctwations in the production of lead and zinc in a number of countries, there have been also certain fluctwations of prices on the international market.

(3) As is known, the automobile industry is a big consumer of lead for the manufacture of storage batteries.

In industrial countries producing automobiles, the consumption of lead for storage batteries is on the average about 30 per cent of its overall consumption.

Taking into consideration, that, besides the consumption of lead for the manufacture of storage batteries, lead is also used for the production of anti-detinating agents such as lead tetraethyl and lead tetraethylene additions to petrol, it becomes quite obvious, that the automobile industry is at present the main consumer of lead.

Another considerable field of consumption of lead is for cable covers. Nearly 15 to 20 per cent in Western Europe and 5 to 8 per cent in the United States and Canada is used for these needs. A stable consumption of lead is maintained for the production of various alloys which amounts to 5 to 10 per cent of total lead consumption.

Among new applications for lead are making of organic--lead compounds, manufacture of sound-proof and anti-vibration sheets, and coating of steel.

(4) The consumption of zinc is characterized by its steady use for the oldest and biggest field of application-galvanizing. From 25 to 70 per cent is used for these needs in industrial countries (in Western Europe and Australia respectively).

Galvanizing, especially with subsequent painting, is one of the most reliable methods of protection of iron and steel against corrosion.

Another large field of consumption for zinc is making of zinc alloys, particularly those for die casting. Production of brass and bronze is one of the old fields of zinc consumption. Another one is zinc oxide production. Owing to the development of machine building industry the relative importance of this item of zinc consumption is continuously increasing.

Analysis of consumption of lead and zinc in the form of metal in industrial countries indicates, that lead and zinc consumption is directly related to the overall economic potential of a country; i.e. the degree of development of other industries, in particular iron and steel industry, automobile industry, engineering and chemical industry.

(5) The state of lead and zinc industry in developing countries - reserves of the metals in ore, mining of ores, production and consumption of lead and zinc, their export and import - is characterized by the data in Table II. The list of the developing countries which is given in this Table may be incomplete; it was compiled from the literary sources we have at our disposal.

Table II. Metal reserves, mining of ores, production and consumption, export and import of lead and zinc in developing countries, thousands of metric tons.

Country	Reserves of metal[1]		Mining of metal in ore	Production of primary metal	Consumption of primary metal	Export		Import	
	Total	Ascertained and probable				of raw materials (ore or concentrates converted into metal equivalents)	of metal	of raw materials (ore or concentrates converted into metal equivalents)	of metal
1	2	3	4	5	6	7	8	9	10
Lead									
Total amounts in the developing countries listed in this Table:									
1955	9285	3731	636.1	383	73	-	-	-	-
1967	20925	12237	647.15	434.4	166	-	-	-	-
Average annual rate of growth, %	-	-	0.3	1.1	7.1	-	-	-	-
Africa:									
Morocco									
1955	1000	500	89	27	-	96[2]	26	-	-
1967	1600	1200	75	20	-	62	20	-	-

1		2	3	4	5	6	7	8	9	10
Tunisia	1955	160	100	27	27	2 3)	-	25	-	-
	1967	160	160	15	15	3 3)	-	12	-	-
Zambia	1955	484	276	16	16	...	-	15	-	-
	1967	550	550	21	21	4	-	17	-	-
South West Africa	1955	854	854	74	-	-	78	-	-	-
	1967	1030	1030	75	70	-	5	63	-	-
Algeria	1955	-	-	10	-	-	13 2)	-	-	-
	1967	545	307	5	-	-	...	-	-	-
Congo (Brazzaville)	1955	-	-	-	-	-	-	-	-	-
	1967	500	460	4	-	-	4 3)	-	-	-
Tanzania	1955	-	-	4	-	-	4 3)	-	-	-
	1967	-	-	-	-	-	-	-	-	-
United Arab Republic	1955	-	-	-	-	-	-	-	-	-
	1967	30	...	-	-	-	-	-	-	-
America										
Mexico	1955	680	500	211	198	18	4 2)	180	-	-
	1967	6000	3000	168	164	63	...	86 3)	-	-
Argentine	1955	1170	440	23	18	25	-	-	-	-
	1967	1100	1100	31	36	30	...	-	-	-
Bolivia	1955	170	100	19	-	-	19	-	-	-
	1967	120	80	20	-	-	20	-	-	-
Brazil	1955	1145	40	4	4	14	-	-	-	13
	1967	3000	1100	19	16	26	-	-	-	...

1		2	3	4	5	6	7	8	9	10
Guatemala	1955	-	-	5	-	-	5	-	-	-
	1967	160[3]	80[3]	-	-	-	-	-	-	-
Honduras	1955	-	-	-	-	-	-	-	-	-
	1967	80[3]	80[3]	-	-	-	-	-	-	-
Peru	1955	1265	110	119	61	-	49	57	-	-
	1967	3000	2300	165	82	6	74	77	-	-
Equador	1955	-	-	0.1	-	-	0.2	-	-	-
	1967	20	10	0.1[1]	-	-	0.7[4]	-	-	-
Asia										
India	1955	230	230	2	2	14	-	-	-	12
	1967	500	110	5	2	34	-	-	-	34
Birma	1955	2000	498	14	14	-	2	16	-	-
	1967	2100	380	15	12	-	0.2[5]	12[5]	-	-
Iran	1955	-	-	14	14	-	-	-	-	-
	1967	600	150[3]	20	0.4[4]	-	45[2,4]	-	-	3[4]
Turkey	1955	70	70	3	2	-	-	-	-	0.6
	1967	40	40	2	1	-	1[4]	-	-	3[2]
Thailand	1955	48	4	5	-	-	...	-	-	-
	1967	50	50	7[4]	-	-	12[2,4]	-	-	1[4]
the Philippines	1955	9	9	2	-	-	-	-	...	-
	1967	10	10	0.05[4]	-	-	-	-	...	-

1		2	3	4	5	6	7	8	9	10
Zinc										
Total amounts in the developing countries:	1955	13893	4757	695	149	95				
	1967	38509	16683	844	269	150				
Average annual rate of growth, %				1.6	5.0	3.9				
Africa										
Algeria	1955	-	-	31	-	-	65[2]	-	-	-
	1967	1029	673	10	-	-	...	-	-	-
Morocco	1955	800	650	43	-	-	90[2]	-	-	-
	1967	800	680	46	-	-	45	-	-	-
Tunisia	1955	60	25	5	-	-	13	-	-	-
	1967	60	60	3	-	-	7	-	-	-
United Arab Republic	1955	-	-	-	-	-	-	-	-	-
	1967	860	...	-	-	-	-	-	-	-
Zambia	1955	776	423	31	28	-	-	26	-	-
	1967	1160	1160	53	45	-	-	40	-	-
Congo (Kinshassa)	1955	2000	-	68	34	-	103[2]	51	-	-
	1967	2000	1000	110	62	-	86[2]	30	-	-
South West Africa	1955	340	340	17	-	-	22	-	-	-
	1967	850	850	23	-	-	20	-	-	-

1		2	3	4	5	6	7	8	9	10
America										
Mexico	1955	950	890	269	56	13	371[2)]	49	-	-
	1967	12000	3600	235	66	35	160	38	-	-
Argentine	1955	1650	625	21	14	20	-	-	-	0.2
	1967	1500	1500	27	24	23	...	...	-	...
Bolivia	1955	1400	800	21	-	-	21	-	-	-
	1967	900	750	10	-	-	10	-	-	-
Brazil	1955	-	-	-	-	14	-	-	-	14
	1967	4000	1100	-	7[3)]	35	-	-	-	...
Guatemala	1955	-	-	9	-	-	-	-	-	-
	1967	120[3)]	60[3)]	-	-	-	-	-	-	-
Gonduras	1955	-	-	-	-	-	-	-	-	-
	1967	80[3)]	80[3)]	-	-	-	-	-	-	-
Peru	1955	3160	250	166	17	-	128	19	-	-
	1967	6000	4000	290	65	5	247	61	-	-
Asia										
India	1955	390	390	3	-	48	5[2)]	-	-	32
	1967	1000	270	6	-	52	...	-	20[4)]	57
Burma	1955	2275	308	8	-	-	41[2)]	-	-	-
	1967	2700	240	5	-	-	15[5)]	-	-	-
Iran	1955	-	-	6	-	-	-	-	-	-
	1967	2200	150	17[4)]	-	-	77[4)]	-	-	0.8[4)]

1		2	3	4	5	6	7	8	9	10
Turkey	1955	40	40	3	-	-	1 2)	-	-	-
	1967	40	40	6	-	-	17 2)	-	-	3 4)
Thailand	1955	40	4	3	-	-	-	-	-	6
	1967	1340	40	2 4)	-	-	-	-	-	12 4)
Philippines	1955	12	12	-	-	-	-	-	-	0.1
	1967	70	70	1 4)	-	-	...	-	-	...

1) Reserves indicated according to the data for 1958 and 1967

2) Full weight

3) Estimate

4) Data for 1966

5) Data for 1965

The data given in Table I and Table II have been borrowed from various publications and should therefore be regarded as approximate values.

(6) The character of the lead and zinc industry in many developing countries has considerably changed over the last 10 to 15 years. Whereas in the past these countries were mainly suppliers of raw materials (ore and concentrates) to the international market, in recent time trends towards the construction of metal works can be observed (in connection with the efforts of these countries to effect industrialization) so as to act on the international market as suppliers of metal. To that contributes also an increase in the consumption of lead and zinc in the developing countries themselves, which undoubtedly will steadily increase in the future in accordance with the development of iron and steel industry and engineering as well as other modern industries in these countries.

Altogether 636,000 tons of lead and 695,000 tons of zinc in ores has been mined in the developing countries in 1955, and 647,000 tons and 844,000 tons, respecticely, in 1967 - a growth of 1.7 per cent for lead and 21.4 per cent for zinc. The average annual rate of growth for lead has been 0.1 per cent and for zinc, 1.6 per cent.

The smelting of the metals in these countries in the same years was as follows:

in 1955 - 383,000 tons of lead and 149,000 tons of zinc,

in 1967 - 439,000 tons of lead and 269,000 tons of zinc - an increase in the production of metallic lead of 14.6 per cent and zinc 80.5 per cent, with the average annual rate of growth of 1.1 per cent and 5.0 per cent, respectively.

The consumption of lead and zinc in the developing countries listed in Table II has increased as follows:

	Lead, tons	1967, per cent of 1955 figure	Zinc, tons	1967, per cent of 1955 figure
1955	73,000		95,000	
1967	166,000	227,4	150,000	157,9

The average annual rate of increase has been 7.1 per cent for lead and 3.8 per cent for zinc.

The Main Factors of Development

(7) Factors influencing the possibilities of development of the lead and zinc industry in a country are very numerous. The main of these are:

(a) the procpects of the internal domestic market in connection with the objectives of development of other, consuming, industries in the country;
(b) possibilities of sale of lead and zinc for export determined by the situation on the international market;
(c) availability of raw materials, in other words the 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.

The development of the lead and zinc production is a complex integrated problem, technical, social and economic, and in solving it, all factors of development should be considered in their mutual relationships. Naturally, it has its own peculiarities for each particular country and should be solved taking them into consideration.

The decisive factors are raw material resources and availability of necessary technical means.

(8) 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. In the processing of zinc concentrates, for example, it is possible to obtain sulphuric acid in a quantity corresponding to that of the zinc produced. The cost of this sulphuric acid is one and a half to two times lower than in producing it at special sulphuric acid plants.

Factors of Product Selling

(9) An important pre-condition for the development of the lead and zinc industry in developing countries is a reliable and economically sound market for selling the products, which is determined by the existence of internal markets for sale and the possibility of export.

A large domestic merket for consumption of lead and zinc in developing countries is, in effect, still only being created, but it has great prospects, and there is every reason to believe that, on realization of the envisaged development programmes, it can absorb in some countries tens of thousands of tons of these metals.

The growing demands of these countries for cable products (in connection with the development of power transmission lines); increased production of crude and rolled steel which involves increased need for galvanizing, lead-plating, cadmium-plating etc.; construction on some countries of engineering plants consuming lead and zinc alloys; construction of oil refineries - all this will contribute to the enlargement of the domestic markets for lead and zinc. For a detailed estimate of the absorbing capacity of domestic markets we ought to consider the procpects of development in the countries concerned of all principal industries - consumers of lead and zinc, but this is beyond the scope of this paper.

The internal consumption of these metals in the developing countries has grown almost 2.3 times for lead and 1.6 times for zinc over the past 12 years, although the absolute values of the internal consumption are as yet relatively small. Considering, however, the existing of considerable reserves of lead and zinc in the developing countries, the factor of the internal consumption should be regarded as one which may determine serious shifts in the development of the lead and zinc industry in these countries.

(10) As mentioned previously, the domestic market is not the only consumer of lead and zinc in the developing countries. Analysis of the export-import situation at the present time indicates, that the developing countries have definite prospects for profitable sale of the metals.

The export-import operations for lead and zinc are being accomplished at present mainly according to the plans and intentions of industrially developed countries and are determined by their economic conditions. With the development of production and consumption of lead and zinc both in the form of concentrates , and in the form of metals in the developing countries, the overall picture of distribution of export and import of these products may substantially change, and some part of the export-import operations may be accomplished within the framework of the developing countries themselves. But however may change details in the distribution of export and import, the general tendency of prospective increase in the consumption of lead and zinc by the industry of all countries is sufficiently reliable and this determines the expedience of developing the lead and zinc industry for the developing countries.

(11) Present-day consumers set high demands on the quality of metals. Therefore, in cases where the smelting of metallic lead and zinc is to be developed, it is expedient to provide the use of flow sheets which will ensure the production of metals of higher grades at low costs.

(12) In some cases, where due to a number of conditions the mining of lead-and-zinc ores is organized in the developing countries before the organization of production of metallic lead and zinc, it may be possible to effect a direct export of these ores, provided their lead and zinc content is acceptable for the consumer. Thus, the trade organizations of the Soviet Union may consider offers of sale into the USSR of lead ores with Pb contents of 15 per cent and higher.

Availability of Raw Materials

(13) A most important factor enabling the development of lead and zinc industry in developing countries is the availability of raw materials, i.e. underground reserves of lead and zinc. These reserves, indicated in Table II in approximate and preliminary figures, permit us to believe that most of the developing countries have potential possibilities for developing lead and zinc industry.

The following countries have the greatest potentialities in terms of lead and zinc reserves:

in Asia - Burma, India and Iran. The underground reserves of lead in these countries vary from 0.5 to 2 millions tons, those of zinc, from 1.0 to 2.7 million tons;

in Africa - Algeria, Zambia, Rhodesia, Congo (Brazzaville - -lead, Kinshasa - zinc), Morocco, South-West Africa. The underground reserves of lead in these countries vary from 0.2 to

1.6 million tons, those of zinc, from 0.43 to 2.0 million tons;

in Latin America - Mexico, Argentina, Brazil, Peru, Bolivia (zinc). The underground reserves of lead in these countries vary from 1.1 to 3.0 million tons, those of zinc, from 1.5 to 12.0 million tons.

It is pleasant to point out that over a comparatively short period of time - twelve years (from 1955 to 1967 inclusive) there occurred a fairly large increase of established se. reserves in the developing countries:

total reserves of lead have increased 2.25 times over this period and industrial (ascertained) reserves, to an even greater degree - 3.2 times. The same is true for zinc - its total reserves have grown 2.75 times and industrial ones, 3.5 times.

(14) It is noteworthy that the ores of the Latin American countries have a fairly high total lead and zinc content - about 20-25%, with zinc content, as a rule, two to three times higher than lead content.

In the countries of Asia and Africa the total lead and zinc content of the ores is somewhat lower than that of the ores of Latin American countries, although the data for some deppsits indicate that in Asia and Africa there are also very rich deposits. In some deposits of Burma and Nigeria the Pb content amounts to 20% and the Zn content, 13.0%; in Iran there are deposits with the Pb contents up to 20% and the Zn content up to 30%. Among the countries of Africa stands out Zambia having deposits with the Pb content of 15% and the Zn content of 29%.

(15) The development of operations at new deposits and an increase of reserves at those being operated have made it possible to increase the mining of lead and zinc, though in relatively smaller proportions than the growth of their reserves: the mining of lead has increased approximately 2 per cent and of zinc, 20 per cent.

Noteworthy is a very slight growth in the mining of lead.

This is explained by the fact that deposits with poorer ores are involved into operations in some countries. This, in turn, causes the need for construction of concentrators with the use of the most up-to-date methods of ore dressing. Considering the fact that the lead-zinc ores contain, as a rule, very valuable by-metals (such as gold, silver, cadmium, selenium and other elements), this construction is justified. On this path has stepped Burma where previously only a rich ore at the Badwin deposit was mined which contained over 20 per cent of Pb and over 10 per cent of Zn. As a result of expansion and modernisation of mining and concentrating facilities and the utilization for processing of low grade ores this country is planning to increase the mining of lead and zinc twofold in the next few years.

(16) It should be pointed out that the existing estimates of geological reserves of lead and zinc show considerable differences, which are due mainly to the fact that the prospective lead and zinc deposits are not yet properly studied and that different methods are used in estimating their size. The difficulty of calculating the size of a deposit is further aggravated by a number of factors, among which the more impottant are: inconsistency of metal content in various parts of even the same ore field, irregular shapes of ore bodies, relatively great depths of ore deposits and the presence of other metals in the ore. The differences in estimates are also caused by the fact that the standard of geological exploration works and services in the developing countries is, as a rule, rather low.

(17) There can be no standard method of evaluation of an ore deposit with a minimum Pb and Zn content of the ore from the point of view of expedience of its working. Such evaluation can be made only individually by carrying out appropriate calculations for each particular case, taking into consideration,

primarily, the geological and mining conditions of the deposit, mineral composition of the ores, the scale of operations and current prices for lead and zinc on the world market.

(18) The chemical and mineralogical composition of the ore determines the choice of one of the following possible variants of the flow diagram of further processing of the mined ore: the use of ores for direct metallurgical processing or using them with preliminary dressing.

Availability of general technical means

(19) With favourable raw material conditions and the existence of internal demand or advantages export situation, the decisions to be taken on the development of lead and zinc industry and the kind of final commercial product to be obtained (ore, concentrate or metal) depend on the availability of general technical means such as fuel, power, water and various auxiliary materials and transport systems. In making the decisions it is, naturally, desirable to aim at the organization of manufacture with a flow diagram which would involve minimum expenditure of the above-mentioned resources and would be most suitable for the use of resources available on the spot.

(20) Determination of the minimum quantities of fuel, power, water and auxiliary materials, essential for the construction of a particular project of lead and zinc industry, can, naturally, be made only with due consideration of the geographic, climatic and other conditions in the country where the project is to be erected. To show, even if approximately, the order of magnitude of probable specific consumption figures, in the Tables (§§ 22-28) below are given the data of design developments carried out by the Soviet design organizations for several mining-and-concentrating and metallurgical lead-and-zinc projects of certain countries of Asia and Africa. In

the examples given in this paper, these projects are arbitrarily designated as 'A', 'B' and 'C' for mining-and-concentrating projects and 'D' and 'E' for metallurgical projects.

(21) For design development of the examples of mining-and-concentrating projects was selected the underground board-and-pillar method of mining, with pillars of minimum size and subsequent overhead caving. Preparation of ore for concentration was adopted, in the designs, by crushing and two-stage disintegration. Floatation of ore was adopted with a selective flow diagram with separation of lead and zinc concentrates. As the main reagents for carrying out the floatation process were selected butyl xanthate, potassium cyanide, calcinated soda, zinc vitriol and others. Under these conditions the following performance and consumption figures were found for the three mining-and-concentrating projects adopted as examples:

(22) Table III. The main consumption and output data as determined for mining-and-concentrating projects

	Units	Projects		
		'A'	'B'	'C'
1	2	3	4	5
Mining of ore	thousands of tons per year	250	165	165
Pb and Zn contents in the ore as-mined:				
Pb	%	6.5	3.5	11.0
Zn	%	6.5	14.6	11.0

Table III (continued)

1	2	3	4	5
Concentrate production:				
lead concentrates	thousands of tons per year	23	8	27
Pb content	%	61.5	59	60
Zn content	%	8	12	9
zinc concentrates	thousands of tons per year	24	39	28
Pb content	%	2.04	1.1	2.7
Zn content	%	51.5	54.0	51.5
Requirements:				
process water	thous.m^3 per year	485	330	330
	litres per second	18.4	12.7	12.7
welfare and drinking water	thous.m^3 per year	261	184	184
	litres per second	9.0	6.3	6.3
power	millions of kwhrs	18.5	14.0	14.2
required installed capacity of motors	kw	3250	2606	2700
Fuel	no fuel is required for technological processes for communal needs the heat of fuel gases of diesel-electric generators utilized.			

(23) The examples of lead-and-zinc plants were considered in two construction variants with the following annual capacities:

		'D' Projects	'E' Projects
lead	thous;tons	30	50
zinc	thous.tons	50	30

(24) Raw materials. Lead concentrate of the following analysis was arbitrarily adopted for lead manufacture: Pb 58%; Cu 0.1; Zn 8%; S 17.5%.

The flow diagram of lead manufacture is as follows:

Concentrates and lead cake, a by-product of zinc manufacture, are delivered by railway or trucks to a covered storage yard. If necessary concentrates are dried. Fluxing materials are crushed. The components of the charge are placed into storage bins. The charge is sintered on a band type sintering machine with undergrate blast. In the melting shop sinter, coke and return fines are melting in a shaft furnace. Refining of blast (rough) lead is provided by the pyrometallurgical method.

(25) Raw materials. Sulphide concentrates have been adopted for zinc manufacture. Along with these, it is planned to process zinciferous slags and dusts from lead manufacture. Zinc concentrate of the following analysis has been arbitrarily adopted for processing:

Zn 53%; Pb 1.5%; Cu 0.5%; S 33%.

The flow diagram of zinc manufacture (hydrometallurgical) is as follows:

Roasting of concentrates in fluidized bed kilns. The sinter is subjected to air separation. The learhing of the sinter is done in batch-type units in two stages-neutral and acid. The residue from leaching in the form of zinc cakes is subjected to wealz-processing. Electrolysis of purified zinc solution is done at current densities on the cathodes of 400 to 450 amp/sq.m.

The main consumption and output data in the examples given here have been determined for lead plants as shown in Table IV and for zinc plants as shown in Table V.

(26) **Table IV. The main consumption and output data as determined for lead plants**

Item	Units	'D' projects		'E' projects	
		per year	per ton of lead	per year	per ton of lead
1	2	3	4	5	6
Raw material requirements:					
Lead concentrates	tons	52370	1.74	89640	1.79
By-products of zinc manufacture:					
Lead cake containing 40% Pb and 7-8% Zn	tons	3000	0.1	1700	0.034
Output of commercial products					
Refined lead	tons	30000	1	50000	1
Flux consumption:					
Quartz ore	tons	2880	0.1	4930	0.1
Limestone	tons	2410	0.08	4120	0.08
Iron ore	tons	11260	0.4	19270	0.4
Fuel consumption:					
Coke	tons	10120	0.380	16860	0.338
Natural gas	thous. Nm^3	6800	0.227	10200	0.204
Utilities consumption:					
Fresh water	thous. m^3	1610	0.06	2680	0.06
Steam	tons	8000	0.27	13300	0.27
Power	thous. kwhrs	26000	0.86	35150	0.70

1	2	3	4	5	6
Metal extraction:					
Pb into refined lead	%	95	-	95	-

- -

(27) **Table V. The main consumption and output data as determined for zinc plants**

Item	Units	'D' projects		'E' projects	
		per year	per ton of zinc	per year	per ton of zinc
1	2	3	4	5	6
Raw material requirements:					
Zinc concentrate	tons	93500	1.87	48300	1.61
By-products of lead manufacture:					
Slag	tons	26200	0.52	44750	1.49
Dust	tons	2900	0.058	4880	0.16
Output of commercial products:					
Pig zinc	tons	50000	1	30000	1
Zinc in vitriol	tons	320	0.006	215	0.007
Fuel consumption:					
Fine coke	tons	20930	0.42	21690	0.72
Anthracite	tons	8970	0.18	9230	0.3
Natural gas	thous.Nm^3	5500	0.11	4400	0.46

1	2	3	4	5	6
Utilities consumption:					
Fresh water	thous. m^3	8000	0.20	4800	0.20
Steam	tons	70000	1.4	42000	1.4
Power:					
total (alternating current)	thous. of kwhrs	215370	4.3	136480	4.5
Including the amount of direct current (taking into consideration zinc dust manufacture for own needs)	"	160000	3.2	96000	3.2
Zinc extraction	%	93.3	-	92.2	-

(28) The main consumption and output data for sulphuric acid shops working on gases of zinc manufacture have been determined as shown in Table VI.

Table VI. The main process and output data as determined for sulphuric acid shops.

Item	Units	'D' projects		'E' projects	
		per year	per ton of sulphuric acid	per year	per ton of sulphuric acid
Raw material requirements:					
Sulphur in gas containing 5.7% SO_2	tons	28800	0.36	14400	0.36
Output of commercial product					
Sulphuric acid calculated into monohydrate equivalent	tons	80000	-	40000	-

1	2	3	4	5	6
Utilities consumption:					
Fresh water	thous.m^3	530	0.01	320	0.01
Power	thous.kwhrs	8130	0.1	4130	0.1

(29) The processes of mining ,concentration and metallurgical processing of lead-and-zinc raw materials require a wide range of reagents and auxiliary materials, the consumption of which may vary widely depending on the characteristics of raw materials and the parameters of manufacturing process.

An approximate list of the main materials essential for the operation of mining-and-concentrating and metallurgical facilities includes the following: explosives, detonators, rock-drill steel, hard alloys, steel for lining, steel balls, butyl xanthate, potassium cyanide, soda, zinc sulphate, copper sulphate, floatation oil, filtration fabric, lime, sulphur, sulphuric acid, caustic, ammonium chloride, saltpetre, pyrolusite, scotch glue, saponine.

(30) The above examples of the projects on determining general engineering conditions for ore dressing and metallurgical plants are considered in connection with the accepted flow sheets and can be used only as a guide for estimating some aspects of engineering conditions in organizing lead and zinc industry in developing countries.

(31) Any mining and metallurgical plant should have a good transport system for transporting materials and chemicals as well as for shipping the final commercial product. In view of the limited number of tracks and highways in developing countries transport problem deserves much attention in considering the

possibilities of developing lead and zinc industry. Transportation by water ways must be studied in the first place. It is obvious that transport problems which mainly depend on the plant location are connected with definite costs and must be considered on the basis of available estimates.

Personnel problem

(32) Morden mining methods, floatation and metallurgical processes of lead and zinc production require various equipment. Their efficiency is greatly affected by the skillfulness of personell maintaining this equipment.

General management is a function of professional engineers. It is necessary to note that due to the specific nature of raw materials metallurgical processes of lead and zinc production are considered to be the most complex in the sphere of metallurgy. Therefore the training of workers and engineers must be more effective. The problem of providing personnel for lead and zinc industry may be solved by the training of the required number of skilled workers and engineers at the plants of the same type in other countries.

Choice of typical flow sheets

(33) Alongside with the availability of raw materials and general engineering conditions (i.e. sufficient quantity of fuel, water, power and auxiliary materials) another important factor, affecting the efficiency of creating lead and zinc industry in some developing country is the choice of typical flow sheets and the main equipment for ore treatment.

(34) As far as this meeting is organized mainly to discuss metallurgical and general engineering aspects of lead and zinc industry in developing countries the problems of mining and ore dressing are not considered in detail in this report.

However it is necessary to underline some remarks, concerning these problems.

(35) According to the nature of mineralization and further treatment lead and zinc ores may be devided as follows:

a) oxidized polymetallic lead and zinc ores with lead and zinc content in the range of 6-7 per cent. Probably such ores can be most economically treated by waelz process without preliminary dressing by typical floatation methods; mixed lead and zinc sublimates produced by waelz process can be treated by one of the metallurgical methods described in the next part of this report;

b) oxidized or mixed sulphide monometallic lead ores containing 15 per cent lead probably can be most economically treated together with the standard lead concentrates by direct metallurgical methods (agglomeration + smelting in shaft furnaces and others); If a country with such ore deposits has not yet built a metallurgical plant, mined ore can be exported to other countries; in particular this problem can be considered by Soviet organizations, as mentioned above;

c) oxidized monometallic zinc ores, containing more than 6-7 per cent zinc. They may be treated by waelz process with further sublimation of oxidation products to produce commercial zinc white or these products can be shipped to zinc plants for further treatment;

d) monometallic and polymetallic sulphide ores. As a rule they are shipped for dressing by usual methods.

(36) The development of lead and zinc industry in any country may be most effective, if various aspects of mining, ore dressing and metallurgical treatment are connected by one general development scheme with the following considerations:

a) wherever possible it is necessary to use highly efficient mining systems, based on the usage of efficient mining equipment, which provides ore mining at the most low costs. When applying highly efficient mining systems there are cases of increased ore dilution due to gange inclusions.

In order to decrease the dilution effect in ore dressing it is necessary to use processes and equipment which allow to remove as more gange as possible at the initial stage by relatively cheap methods. This can be achieved by dressing in heavy suspensions and preliminary sorting by radiometric and photometric methods;

b) complex polymetallic ores are to be dressed by such methods, which allow the ultimate extraction of valuable metals as rich and clean concentrates, but those metals which can not be extracted as a rich clean product should be extracted as a bulk concentrate for further treatment by special metallurgical processes among which is a new process, sugested by Soviet engineers - the so called KIVCET process, described in the next parts of the report.

Choice of metallurgical processes of lead and zinc production

(37) Now lead is mainly produced by pyrometallurgical methods, which include:

- reduction smelting in shaft furnaces with preliminary agglomeration roasting of lead concentrates;
- "Imperial Smelting" process;
- hearth smelting of raw lead concentrate;
- reaction arc melting of lead agglomerate;
- agglomerate or rich partially calcined lead concentrate smelting in rotary furnaces;
- precipitation smelting in electric furnaces.

Compared with other methods agglomeration roasting of lead concentrates followed by reduction smelting of agglomerate in shaft furnaces is used on a very large scale.

About 87% of total lead output was produced by this method in 1966-1967.

During last two years about 8,5 per cent of the total lead output was produced by "Imperial Smelting" process.

- the amount of lead, produced by hearth smelting is about 3 per cent;
- lead production by precipitation smelting is less than 0,1 per cent.

(38) Lead extraction and the level of its production by reduction smelting in shaft furnaces are greatly affected by the quality of lead concentrates. In this connection a special attention is directed to the production of high quality lead concentrates containing 50-75 per cent lead, less than 2 per cent copper and not more than 5% zinc, because the high content of these metals may cause a number of difficulties and if copper content is above 2 per cent, considerable losses of lead are to be expected during smelting. The level of lead production by using this method is changing on a wide range both in relation to the efficiency of agglomeration machines and shaft furnaces, coke consumption per ton of melted change and to the lead extraction as a refined product and complex usage of raw materials, which greatly depends on charge composition.

(39) World lead production by using "Imperial Smelting" process is continued to grow.

(40) Lead melting in hearth furnaces requares clean rich concentrates and is not far promising.

(41) Reaction arc smelting is used for producing lead from rich lead concentrates mixed with limestone and dust, formed during agglomeration roasting.

(42) Precipitation smelting is worked only at Mukakami plant in Japan.

(43) Lead production by smelting agglomerate or rich

partially calcined concentrate in rotary furnaces, reaction arc melting of lead agglomerate and precipitation smelting in electric furnaces did not find wide application. Reaction smelting in electric furnaces with preliminary agglomeration of lead charge seemed to be more promising among these methods.

(44) In a number of countries extensive research and experimental work are being carried out with the aim to develop and introduce new processes of lead production.

(45) Now zinc in produced by pyrometallurgical and hydrometallurgical methods. Pyrometallurgical methods include:

- zinc distillation in furnaces with gorisontal retorts;
- zinc distillation in furnaces with vertical retorts;
- electrothermal method;
- "Imperial Smelting" process.

(46) Zinc distillation in furnaces with gorisontal retorts is the oldest method of zinc production (it was introduced in the beginning of XIX century). It has a number of disadvantages such as low labour productivity, low yield and metal quality, high operation costs and hard working conditions.

(47) Zinc distillation in furnaces with vertical retorts is more efficient and compared with the former has a number of advantages: higher labour productivity, higher yield and metal quality, better heat usage, the possibility of modernization, better working conditions dur to the sealing of equipment and besides that it can be worked on continuous basis. However this method requires additional capital investment due to expensive and complex charge preparation and consumption of such materials as carborundum used in muffle design.

(48) The electrothermal process of zinc production was introduced in 1936.

Now this process is being used in U.S.A., F.R.G., Peru, Argentina, Japan and U.S.S.R. The electrothermal process offers definite advantages: high metal yield, increased labour productivity, possibility of building large units, complex usage of raw materials. However it has some shortcomings: design difficulties in choicing appropriate materials for a furnace bath and condenser , sufficiently resistant to slag and zinc vapours. This process is definitely promising , especially in countries with considerable cheap power resources.

(49) In the pyrometallurgy of zinc a success was achieved by the Imperial Smelting Co which has developed a process providing within a single operation for the condensation of zinc vapours and the recovery of lead into the molten metal bath.

The advantages of the process is a theam of many reports presented at this conference.

(50) Hydrometallurgy is at present responsible for the greatest part of the world zinc production.

The advantages of hydrometallurgy include: high rate of zinc recovery (if the circulating material is also treated); high grade of metal recovered; efficient treatment of very complex ores and high rate of raw materials utilization (particularly in the combined production of zinc and lead); better working conditions. Disadvantages are the following: much worse results (both metallurgical and economical) in case the concentrates with high rate if impuruties (ferrum, silica, arsenic, antimony, cobalt, copper, magnesium, nickel, germanium chloride) are treated, which in turn involves the usuage of some additional equipment for the purification of solutions; low labour productivity in electrolitic recovery (manual cathods stripping operation); additional operation for the treatment of rich-in-zinc cakes.

Inspite of these disadvantages, hydrometallurgical method in the production of zinc will not apparently loose its significance for the treatment of rich zinc concentrates with low impurity rate in the countries where cheap electroenergy is available.

51. The choice of the production method for the recovery of zinc and lead depends on many circumstances and first of all on the constituents of the ore, electroenergy and coke resources and on the consumption pattern of the particular metal.

The choice should be decided by the way of technological and economical calculations in every particular case. For instance in case of developing countries the decisive factor is electroenergy and coke supply, without which it is virtually impossible to develop the lead-zinc production.

When coke resources are rich and the consumption pattern is not for the most high-grade metal, the preference may be given to the Imperial Smelting process; when on the contrary the coke resources are poor and high grades of metal are mostly consumed, then hydrometallurgical treatment of zinc may be preferred. The so called "KIVCET" process developed in the USSR provides for the production of middle grades of zinc with the comparatively low consumption of coke and mild electroenergy supply.

(52) On agenda of this meeting there are many interesting reports of various countries' representatives concerning the advances of the lead and zinc metallurgy in their countries. Allow me, please, to outline briefly some innovations in this field applied in the USSR.

(53) Trying to improve the existing flow sheets and to develop some new and more efficient methods of lead, zinc and other heavy non-ferrous metals recovery, the soviet specialists choose the way of wide application of industrial oxygen and of electrothermal processes.

More than 80% of primary lead is now recovered in the USSR with the aid of oxigen enrichment. At one of the plant the air blown into the blast furnace is enriched to 30% of oxigen, which results in a few per cent increase in the direct lead recovery, some 27-30% increase of the blast furnaces production and lower (by 10-15%) quantities of coke consumed.

The industrial-scale experiments of the enrichment of the blowing air to 25% of oxigen in the process of fuming slags of lead smelting furnaces have shown the increase of the specific production volume of the zinc fuming plant up to 40% and the rate of zinc recovery into fume sublimates - by 8-10% together with lower fuel consumption (by 10%).

Oxigen is also used in sintering to increase the productivity of the sintering plant and for greater concentration of sulphur dioxide in the fuel gases utilised for sulfuric acid production.

The oxigen enrichment is also used in the USSR in the hydrometallurgy of zinc in the process of the fluidised bed roasting of zinc concentrates.

The enrichment of the blowing air up to 28-30% of oxigen makes it possible to increase the specific productivity of fluidized bed roasters by 60-70%, to increase the solubility of zinc in sinter by 2-2,5% and also to increase sulfur dioxide concentration in the off-gases. Another application of the industrial oxigen is the separation of iron impurities from waelz-oxides leach solutions. This facilitâtes the filtration and pulp sedimentation procedures and reduces the quantities of manganese ore used.

The blowing air is also enriched with oxigen when processing zinc cakes in waelz furnaces. Under the conditions of the maximum oxigen consumption the recovery of zinc into the waelz-oxides is increased by 0,3%, cadmium- by 6,0%. The consistency of zinc in clinker is lowered by 0,7%.

The main advantages of the oxigen enrichment are : intensification of industrial processes, reduction of the specific fuel consumption, increase in quality and quantity of metals recovered, greater concentration of sulfur dioxide in the off-gases, lower costs of production.

(54) Much work has been done in the USSR in the course of development and application of electrothermal processes. In lead metallurgy electrothermal devices are used in the process of slag sedimentation after smelting in blast or fuming furnaces. Electrosmelting of copper dross at one of the plants made it possible to eliminate copper products circulation, to reduce quantities of lead lost with them and to produce the matte with 40-45% of copper and 10% of lead. The electrothermal process has been developed and applied for silver scum treatment with the resulting condensation of the liquid zinc.

Electric furnaces are also used for the continuous refining of lead.

Electrothermal processes are widly applied in zinc metallurgy. The Belovsk plant, for example, which is the only one still producing zinc in horizontal retort ovens is being reconstructed for electrothermal processes. Two big electrothermal furnaces with liquid zinc condensation have been already put into production at this plant.

This year electrothermal smelting furnace of 9000 kva with liquid zinc condensation is to start the operation at one of the lead smelters. The furnace will be used for the treatment of the previously granulated and calcined fume sublimates containing zinc and lead. Another smelter is equipped with the furnace of 9000 kVa for processing rich-in-zinc slags and zinc cakes.

A plant is being constructed for the treatment of sintered zinc cakes mixed with lead smelting slags in big 16500 kVa electrothermal furnaces with liquid zinc condensation.

(55) 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 abbriviation for the "oxigen-flash-cyclon-electrothermal process.

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

According to this method:

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

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

In case the sulfide material containing more than 20% of sulfur is treated, the sintering and smelting processes are autogeneous (without any fuel burning) and take place in the industrial oxigen atmosphere. The flue gases are rich in this case with sulfur dioxide.

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

The main components of the charge (zinc, lead, and copper) are distributed in the following way:

During the smelting process zinc enters the molten bath from which it is fumed in the electrothermal section of the plant and then con-densed in the condesator as liquid metal ready for use.

Lead is partially fumed and concentrated as fume sublimates but mainly it is condensed together with zinc as blast metal.

Copper, nickel and cobalt go to the rich matte withdrawn periodically from the accummulating pot in the electrothermal section of the plant.

The advantages of the KIVCET process are generally as follows:

granulation and sintering processes are eliminated;
high rate of desulfurisation is achieved;
small volumes leaving the equipment are rich with sulfur dioxide (70-90%), making recovery as cheap sulfuric acid, elementary sulfur or liquid sulfur dioxide economically attractive;
heat evolved from the oxidizing reaction taking place in the charge is utilised within the process itself for smelting and additional heating of the charge components (this reduces significantly the energy consumption during the whole process in comparison with many other methods);
the consumption of high-grade coke is eliminated;
the process provides for the treatment of lead-and-copper complex concentrates which in turn makes it possible to use the bulk floatation method, permitting higher rates of metals recovery from ores into concentrates;
the continuous processing of the material within a single plant is readily adaptable to automatisation of the main units of the system.

At the pilot stage of the development of the KIVCET process some 20 thousand tones of concentrates were treated.

The industrial plant with the capacity of 300 tones of concentrate per day is at present under completion. Another project now under construction is of the plant with the capacity of 1000 tones of charge per day.

Conclusions

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

This conclusion is confirmed by the following generalisations:

- The production and consumption of lead and zinc both in industrialised and developing countries for the last 12 years have been steadily but slowly increasing .
- Lead and zinc prices at the international market are keeping to be more or less stable.
- The inner lead and zinc market in the developing countries, being though in the stage of creation, is nevertheless promising and perspective.
- Raw materials conditions in the majority of the developing countries are favourable though not fully investigated yet.
- Due to the development of other industries in these countries the lead and zinc production development cannot be handicapped by the absence of general technical means

- Transport communications mainly depend on the economical and geographicul conditions of every particular country.
- The personnel supply problem can be solved by training specialists abroad.
- The existing and newly developed processes for the production of lead and zinc are highly efficient.
- When estimating the possibility and profitability of the development of lead and zinc industry in the developing countries, the interdependance of many factors should be considered. Therefore this problem should be solved for every country individually by the way of thorough technological and economical comparisons of the calculations made for different schemes of the material processing.

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