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Background paper

PROSPECTS FOR EXPORTS OF PROCESSED IRON ORE FROM DEVELOPING COUNTRIES

Presented by the secretariat of the United Nations Conference on Trade and Development

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CHAPTER I

INTRODUCTION AND SUMMARY

1. This study examines the state of the art of iron-ore processing and the location of iron-ore processing plants. A primary objective of the inquiry is to better understand the industrial potential of such operations in developing countries which are or which may be engaged in the mining and production of iron ores for the world market.

2. It is less than twenty years since iron ore has become prominent among the major commodities of international trade. Until 1950 iron for steel-making and foundry castings was produced mainly from domestic materials. When greater quantities of ore were needed for increased iron and steel production, most of the additional iron values were obtained from sources of home ore. This has not been the case since 1950. In that year, a total of 32.7 million metric tons1/ of iron ore were imported by the European Coal and Steel Community (ECSC), the United Kingdom, the United States and Japan. Ten years later, each of these four major steel-producing areas had serious domestic ore deficits and together they imported 130 million tons of iron ores in 1960. By 1965, that figure had grown to 178 million tons.2/

3. The increase in ore trade was reflected in a substantial change in the pattern of iron-ore origins based on the discovery and development of new sources of ore to replace long-used deposits that had been heavily depleted by the end of World War II. Such reserves were found in an intensive exploration effort, initiated in 1945 by the iron and steel industries. Since 1950, many new mines producing ores of impressively high iron content have been opened in Latin America, Africa, Asia and Australia. Practically the entire output from these operations is intended for export to industrially advanced countries.

1/ Throughout this study "tons" refers to metric tons of 2,204 lb.

2/ East Europe is the fifth primary iron and steel producing centre, comprising Bulgaria, Czechoslovakia, East Germany, Hungary, Poland, Romania and the USSR. Iron ore has been provided, in a more or less closed system, by the USSR, whose iron-ore shipments have gone almost exclusively to the six other countries. In 1950 such exports equalled 3.2 million tons; in 1960 that total rose to 15.2 millions and in 1965 to 24.1 million tons.

4. Parallel to this search for new ores, the industry undertook an equally concentrated inquiry into iron-making procedures. In a few years, these studies yielded several new practices that raised furnace outputs, reduced coke rates, and produced irons of better quality. The key to these improved techniques was the use of rich ores that were self-fluxing, strong, porous, of uniform size and consistency. These characteristics are available in but a few ores naturally, so that elaborate techniques of iron-ore beneficiation and concentration were developed. Simultaneously, the enriched ores were given desirable physical shape and form by sintering or by pelletizing.

5. At the iron plants these developments were manifested by a widespread use of high self-fluxing sinter burdens. Annual world production of sinter rolse as follows: 1937 - 5 million tons; 1955 - 100 million tons; 1960 - 185 millions tons; 1964 - 280 million tons. Because sinter tends to break up when shipped over long distances, most sinter is produced in facilities erected close to blast furnaces.

6. Sintered ore would have been used to an even greater extent except for the advent of a new form of processed ore: pellets. Introduced in 1950, total pellet production equalled 2 million tons in 1955, and 35 million tons in 1964. World pelletizing capacity has been increasing spectacularly since then, from 10 million tons in 1960 to ~~nearly 60~~ more than 50 million in 1965. It was recently estimated for 1975 a pellet capacity of 190 million tons compared with 52 millions in 1965.[3/] The latter allots to the United States the leading world position, with 58 per cent of the total installed facilities. By 1975, the United States' share is expected to drop to 37 per cent. The projection includes 35 million tons of pelletizing capacity in Asia, Africa, Latin America and Oceania in 1975. Stated another way, the estimate just cited expects that close to 20 per cent of the total world pelletizing plant of 1975 will be established at the ore source.

Scope and content of the study

7. The terms of reference for this study have already been explicitly stated.[4/] A study is requested "on the prospects for exports of processed iron ore from developing countries". The nature of the processing is not defined but an outline

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3/ "The Changing Iron Ore Industry", by H. Stuart Harrison, President of Cleveland-Cliffs Iron Co. (USA), and Chairman of the American Iron Ore Association - Address to American Mining Congress, October 1965.

4/ See introductory note by UNCTAD Secretariat.

guide for the study refers to a forecast "that should be made for the consumption of iron ore from 1970-75, as well as the extent to which iron ore is likely to be prepared, sintered, pelletized, or otherwise processed before use . . . .".

8. The analysis of processed iron ore begins with a consideration of the natural product. Chapter II reviews present and prospective demand in both developed and developing countries for iron ore, based on recent trends of iron and steel production, globally and for the world's main centres of steel-producing activity. It is shown that a world total of about 810 million tons of iron ore, concentrates and agglomerates may be consumed in 1975. This represents an estimated increase of 160 per cent in iron-ore tonnage over the 310 million ton consumption of 1954. Compared with these figures for a decade in the past and a decade in the future, total iron-ore consumption during 1964 equalled 565 million tons. Figures for iron-ore consumption and demand are also presented for selected countries and regions.

9. A similar set of analyses is made for iron-ore production, for the world as a whole and by countries of origin. The emergence of iron-ore producers in the developing countries is traced and the rising importance of these "foreign" sources of iron-bearing values for the advanced iron and steel-producing countries is noted. This leads to a consideration of past, present, and future patterns of iron-ore trade, with particular attention given to export movements from developing nations.

10. The technologies perfected for ore beneficiation, concentration, and controlled sizing are briefly described. Sintering and pelletizing procedures are also outlined, with reasons stated for their rapid acceptance and continued use by the iron and steel industries of the world. The effect that these technical advances have already had on the character of ores smelted to iron, and the impact they may have on the kinds of ores exported today and during the coming ten years are considered.

11. Finally, the trends of iron-ore processing developments are examined. The probable position of pre-reduction technology by 1975 is then assessed, and also the consequences these may have for existing pre-treatment operations and the opportunities they may present for new ones, in developing countries producing iron ores for export.

12. Chapter III directs attention to pellet installations at important iron-ore mines throughout the world. A selected number of ore-producing operations established in recent years in developing nations are described. These include Algorrobo (Chile), Vale do Rio Doce (Brazil), and Cerro Bolívar (Venezuela) in Latin America; Mont Nimba (Liberia), and Ouenza (Algeria) in Africa; Bailadilla (India) and the Philippine iron mines in Asia. In all cases, ore processing is a part of the over-all operation; in each but one instance, pelletizing is an immediate consideration.

13. Space limitations force the omission of other developing country iron-ore mines that are no less worthy of examination. Some of these are: Marcona (Peru), Fort Gouraud (Mauritania), Marampa (Sierra Leone), Mekambo (Gabon), Goa (India), and Malaysia. Also omitted are important ore-exporting countries which are not developing areas; among these are included Canada (Carol Lake and Quebec-Cartier), Sweden (Kiruna) and Western Australia (Hamersley, Scott River and Savage River).

14. The ore-treatment installations at the selected mines are described, including associated pellet processing units. The comparative importance of the different kinds of ore produced and shipped from these operations is discussed and related to plans for increasing processed ore outputs. The processing programmes are examined in terms of current practices and future developments, such as metallized pellets through pre-reduction.

15. Chapter III also is concerned with factors that may favour or impede increased ore processing at the mines or at their associated shipping points in developing areas. On the positive side are the possibilities for improvement in productivity and earnings that may accrue from larger scaled operations, reduction of production unit cost factors for the ore producer and lower freight charges for the consumer. Among the negative conditions are capital requirements for construction and equipment needed for expanded processing operations and for changes to infrastructure installations such as port areas, storage yards and shipping docks, roads, service lines, and community and housing development. In addition, there may be legal restraints in the form of tariff barriers and duties, limiting government policies, as well as staff and know-how deficiencies. The magnitude and applicability of these elements, favourable and unfavourable, are examined. Many of the obstacles may be expected to yield before the mutual interests and consequent joint efforts by the iron-ore consumer of the advanced country and the iron-ore producer in the developing nation.

16. Chapter IV deals with technical factors related to iron-ore processing at the source. The typical full range of iron-mine output is grouped into four main forms of ore: natural run-of-mine, selected run-of-mine, fines for sintering, and pellets. The practices used to process each of these is briefly discussed. The development of sinter and pellet practices at the iron plant is traced and the techniques shown to be thoroughly established. The consequent impact at the iron mines is also described. Each form of processed ore product offers advantages to iron-ore producer and consumer. These are reflected at many new iron-ore operations by close co-operative relationships between both parties. The chapter concludes with a commentary on the use of pre-reduced pellets, a development which is expected to come relatively slowly.

17. Chapter V, which considers economic considerations of iron-ore processing at the source, deals with costs. Capital investment requirements for new pellet-plant installations are estimated. Very little detailed information has been released for individual facilities so that the figures presented are drawn from analyses of published gross appraisals. Nevertheless, the estimate of $32 per ton of annual "natural" pellet capacity reached in this study is consistent with views expressed on the subject. The production costs per ton of pellets cited reflect appropriate modifications of calculations by Battelle Memorial Institute staff members in previous studies. The base estimates are generally accepted by the industry as typical for good pellet operations. Similar cost evaluations are given for pre-reduced ore.

18. The economic feasibility of the pellet operation is discussed, taking into account amortization and fixed charges. The added value component that accrues to the original iron ore as a result of pre-treatment, and the portion of this which may remain in the developing country, is evaluated.

19. Chapter VI examines several important aspects of the practical side of iron-ore processing at the source. It is recalled that by 1975 world trade in iron ore is expected to total 292 million tons. Of this, the developing nations of Latin America, Africa and Asia will provide almost half the tonnage, nearly all having been subjected to some pre-treatment. In approximate numbers the developing areas' iron-ore exports may reach some 45 million tons of run-of-mine and screened ore, 55 million tons of sinter fines, and 28 million tons of pellets. This provides opportunities for almost all mine operations of developing countries to participate in the shipment of processed ores. The level of such participation will depend on the type of local treatment facilities available to any particular mine.

20. The chapter also briefly discusses the mutual effects of processed ore exports and freight charges; and similarly the impact of tariff regulations. Finally, the relative position of ore processing at the source compared with treatment at the iron plant or some intermediate assembly and distribution area is reviewed. Although processing activities will undoubtedly develop at each of these points, there are sufficient advantages to be found to warrant support by industrialized iron and steel producing countries of a broad programme aimed at increasing the tonnages of processed ore exported from the developing nations.

Summary of conclusions

21. The conclusions of the study are brought together in chapter VII. In summary, the main findings are:

(a) By 1975, iron-ore exports are expected to reach a global total of 292 million tons, with an average Fe content of 62 per cent. Approximately 45 per cent, or 128 million tons, will originate in developing countries.

(b) The coming decade will witness a strong demand for increased quantities of processed ore, especially in pelletized form. An estimated pelletizing capacity of 180 million tons is foreseen for 1975. This figure includes only 9.5 million tons that are already planned for 1968, for iron mines located in developing countries; by 1975, the total pellet capability in those countries is expected to reach 28 million tons.

(c) From the point of view of the developed nations' iron and steel producers who will buy the ore, no less than from that of the developing country's iron-ore producer who will export it, an increase in the tonnage of all kinds of processed ores from the latter would be desirable and mutually beneficial. Iron-ore exports from the developing countries are estimated for 1975 at about 45 million tons of run-of-mine and screened product; 65 million tons of fines for sintering and 28 million tons of pellets.

(d) The use of highly metallized or pre-reduced ores by the iron and steel industry is expected to develop relatively slowly, and by 1975 the production and export of only token tonnages are anticipated. This does not alter the validity of the previous conclusion which refers to "regular" oxide pellets. Advances in iron-making technology for wider use of pre-reduced burdens will simply strengthen the case for increasing iron-ore processing operations in the developing countries.

CHAPTER II

DEMAND AND PROJECTIONS

22. Iron ore has become in recent years a significant commodity of international trade, ranking third behind only oil and grain. Since 1950, radical changes in the location and availability of iron ores have been accompanied by fast-changing market conditions. Concurrently, rapid strides have been made in ore production, its technology, its transport, and its utilization.

23. The main elements of change in the rise of iron ore to prominence among the commodities of world commerce are these:

- The acceleration in demand for iron ore to satisfy the steel-making needs of an expanding world economy;
- The development of large deposits of high-grade iron ore in areas remote from the world's centres of steel production;
- The construction of large ocean-going vessels that can transport iron ore economically over long distances;
- The widespread application of highly efficient new iron-making procedures that are dependent on high-quality processed ores;
- The development of economic processes for producing high-quality shipping products from low-grade iron ore;
- The substitution of high-grade concentrates and high-grade natural shipping ores for lower grade ores in the United States and Europe;
- The emergence of Japan as a major importer of iron ore;
- The advent of changes in steel-making practices that have resulted in increased consumption of iron ore per ton of steel produced and lessened dependence on scrap.

WORLD PRODUCTION OF STEEL

24. The increase in world steel production has been accompanied by a shifting relationship among the steel-producing areas of the world. Before 1950, nearly one-half of the world's steel was produced in the United States. By 1964, the United States share of world production had dropped to about 26 per cent, a position approached by both Western Europe and Eastern Europe (including the USSR).

25. The world production of steel for 1954 and 1964 and the estimated production for 1970 and 1975 are shown in Table II-1.

26. Sharp percentage increases in output in South America, Canada, Australia, Africa, and other Asian countries, although substantial, have had little effect on the over-all pattern of world steel production.

TABLE II-1

World production of crude steel for major areas

(millions of metric tons per year)

Country or area	1954		1964		1970		1975	
	Million metric tons	Per cent	Million metric tons	Per cent	Million metric tons	Per cent	Million metric tons	Per cent
United States	80	36	115	26	118	23	138	23
ECSC and UK	63	28	109	25	127	25	145	24
Other Western Europe	5	2	13	3	15	3	21	3
USSR	41	18	85	20	105	20	124	20
Other Eastern Europe	14	6	28	6	37	7	43	7
Japan	8	4	40	9	54	10	58	10
Other	14	6	46	11	60	12	78	13
Total	225	100	436	100	516	100	607	100

Source: Battelle Institute. Projections are based on anticipated annual rate of rise of 3.0 to 3.5 per cent over next ten years.

27. In the future, the United States' share of the world's production of steel will decline even further, to about 23 per cent in 1975. While little change is visualized for Europe's share of total production, increases will be registered by Japan, and by the developing countries. Moreover, the rate of increase in the share of production by many countries will be much less than has been experienced since World War II.

WORLD CONSUMPTION OF IRON ORE

28. With the rise in production of steel, world consumption of iron ore has risen from 127 million metric tons in 1915 to 310 million metric tons in 1954, and to 565 million metric tons in 1964. Especially significant has been the reduction of the weight of iron ore needed to produce a ton of steel. In 1915, an average of 1.8 tons of iron ore were used per ton of steel. Since then the ratio of ore to steel has been declining steadily to an average of about 1.38 tons of ore per ton of steel in 1950, after which it has remained approximately constant. The use of higher grade ores and improved smelting techniques and the increased use of scrap for steel-making have contributed to the reduction of the ratio of ore to steel.

29. The annual consumption of iron ore by major areas for 1954, 1964, and projected to 1970 and 1975 is shown in Table II-2. The United States, Western Europe, Eastern Europe and Japan used 86 per cent of the iron ore consumed in 1964; by 1975 the four areas are expected to consume about 83.3 per cent of the total.

PRODUCTION OF IRON ORE

30. The world is in the midst of a rapid expansion in iron-ore producing and processing capacity in response to this growth in steel production. Many of these iron-ore expansion programmes are based on long-term contracts with steel producers in Japan, the United States, and Europe. In other cases, steel producers who have participated in the development of mines in eastern and central Canada, the United States, Asia, the USSR, Latin America and Africa, provide an assured market for at least a part of the output from these ore sources.

31. The production of iron ore and iron-ore derivatives in 1954, 1964, and projected to 1970 and 1975 is shown in Table II-3. On the basis of projects now under way and production plans already announced, mine capacity will rise to over 700 million tons of iron ore in 1970 and about 850 million tons in 1975. For the estimated consumption of iron ore in Table II-2, the world supply of ore may exceed the market by nearly 60 million tons in 1970 and by about 50 million tons in 1975. The trend for producing beneficiated and agglomerated ore at the mine will also increase.

TABLE II-2

Annual consumption of iron ore by major areas

(millions of metric tons per year

Country or area	1954	1964	1970	1975
United States	95	122	129	153
ECSC and UK	99	157	168	192
Other Western Europe	7	11	21	29
USSR	64	121	152	174
Other Eastern Europe	18	43	52	62
Japan	7	32	60	65
Other	20	79	93	135
Total	310	565	675 a/	810 b/

Source: See Table II-1.

a/ Average Fe content: 53.5 per cent

b/ Average Fe content: 62 per cent

TABLE II-3

Production of iron ore by major countries or areas for 1954 and 1964 and projected production capacity for 1970 and 1975

(millions of metric tons per year)

Country or area	Actual production		Production capacity	
	1954	1964	1970	1975
North America				
United States	82	87	96	102
Canada	7	34	48	62
Other North America	1	2	3	5
South America	13	48	77	94
Africa	10	29	47	56
Western Europe				
ECSC and UK	78	96	90	84
Other Western Europe	23	39	52	61
Eastern Europe				
USSR	65	146	188	224
Other Eastern Europe	8	13	16	18
Asia - Oceania				
Japan	1	2	10	10
India	4	20	31	48
Australia	4	6	27	37
Other Asia	9	53	47	53
Total world	305	575	732	854

Source: See Table II-1

TRADE IN IRON ORE

32. World trade in iron ore in 1950 was 44 million tons, which equalled 17 per cent of the world output. In 1964, total exports were 168 million tons or about 30 per cent of the total production. In the same period, the number of producing countries rose from forty-three to sixty-five and the number producing over 5 million tons of iron ore increased from six to eighteen. The number of countries exporting over 5 million tons a year also increased from two to twelve.

33. The pattern of world trade in iron ore and iron-ore derivatives is given in Table II-4. The principal flows in 1964 were (a) from Canada and Latin America to the United States; (b) from Scandinavia, Africa, and Latin America to ECSC and UK; (c) from USSR to East European countries; and (d) from Asia, Latin America and India to Japan.

34. The pattern of future ore movement shown in Table II-5 anticipates a major transformation from the pattern that existed in 1964. The United States (which now imports about one-third of its iron-ore requirement) will increase its imports to 45 per cent with Canada outpacing Latin America as the major source of supply. For European Community and the United Kingdom together, imports will rise at an even faster rate than in the United States. Compared with 1964 figures, iron-ore tonnages imported into Western Europe from Africa in 1975 will have doubled and imports from Latin America and Scandinavia will have increased by 75 per cent and 25 per cent respectively.

35. The USSR will continue to meet its own requirements while also meeting most of Eastern Europe's import requirements. The Eastern European countries will probably continue to receive up to 20 per cent of imported iron ore from India, Africa and Latin America.

36. Japan's steel industry will continue to import from many sources in keeping with their policy of import diversification. It is foreseen that Australia will supply about one-third of the 1975 Japanese iron ore requirements while South America and India are each expected to provide about 15 per cent. The remaining part of Japan's ore supply will come from North America, Africa and South-East Asia.

PREPARATION OF IRON ORE

37. The optimum performance of a blast furnace depends upon (a) a physically and chemically uniform burden; (b) proper instrumentation and control of the furnace; (c) a smooth flow of materials to and from the furnace; and (d) knowledgeable supervision and operating personnel. Other things being equal, the most important element in blast-furnace production and performance is preparation of the burden, especially the

TABLE II-4.

Pattern of world trade in iron-ore, iron-ore concentrates and iron-ore agglomerates in 1964

(millions of metric tons)

Country or area	Production and consumption, imports and exports by country or area of origin				Exports by country or area of destination				
	Production	Consumption	Imports	Exports	United States	Canada	ECSC and UK	Other Eastern Europe	Japan
United States	86	122	43	7	--	5	--	--	2
Canada	34	9	5	30	25	--	3	--	2
ECSC and UK	94	157	63	--	--	--	--	--	--
Other Western Europe	37	11	--	26	--	--	25	1	--
USSR	144	121	--	23	--	--	1	22	--
Other Eastern Europe	16	43	27	--	--	--	--	--	--
Japan	2	32	30	--	--	--	--	--	--
India	20	11	--	9	--	--	1	2	6
Other Asia	50	41	--	9	--	--	--	--	9
Africa	29	5	--	24	3	--	18	1	2
Australia	6	6	--	--	--	--	--	--	--
Latin America	47	7	--	40	15	--	15	1	9
Total	565	565	168	168	43	5	63	27	30

Source: See Table II-1.

TABLE II-5

Pattern of world trade in iron ore, iron-ore concentrates and iron-ore agglomerates expected for 1970 and 1975

(millions of metric tons per year)

Country or area	Production, consumption, imports and exports by country or area of origin: Production		Consumption		Imports		Exports		Imports by country or area of destination: United States		Canada		ECSC and UK		Other Eastern Europe		Japan	
	1970	1975	1970	1975	1970	1975	1970	1975	1970	1975	1970	1975	1970	1975	1970	1975	1970	1975
United States	94	100	129	153	46	69	12	16	-	-	9	13	-	-	-	-	3	3
Canada	43	66	17	22	9	13	35	57	27	42	-	-	6	13	-	-	2	2
ECSC and UK	88	81	168	192	80	111	-	-	-	-	-	-	-	-	-	-	-	-
Other Western Europe	51	62	21	29	-	-	30	33	-	-	-	-	29	31	1	2	-	-
USSR	181-185	210-220	152	174	-	-	29-33	37-45	-	-	-	-	1-3	2-5	28-30	35-40	-	-
Other Eastern Europe	16	18	52	62	36	44	-	-	-	-	-	-	-	-	-	-	-	-
Japan	10	10	60	65	50	55	-	-	-	-	-	-	-	-	-	-	-	-
India	25-29	39-47	14	24	-	-	10-17	16-24	-	-	-	-	1-2	2-3	1-4	2-5	8-11	12-16
Other Asia	42	53	36	49	-	-	6	4	-	-	-	-	-	-	-	-	6	4
Africa	39	55	7	10	-	-	33	45	4	8	-	-	26	33	1	1	2	2
Australia	27	35-38	9	15	-	-	18	20-23	-	-	-	-	-	0-3	-	-	18	20
Latin America	52-54	71-76	10	15	-	-	42-44	56-61	15	19	-	-	15-17	23-26	2	2	10	12
Total	675	810	675	810	221	292	221	292	46	69	9	13	80	111	36	44	50	55

Source: See Table II-1.

Note: Table II-4 shows actual production and world pattern of trade. Table II-5 above does not show the actual amount of iron ore consumed in the furnace. Some iron ore listed in Table II-5 may be put in a stockpile for future use.

iron component of the burden. Production rates, cost of manufacture, and quality of the pig-iron produced are all improved when a properly prepared burden is charged to a blast furnace.

38. "Preparation" of an iron ore has the following purposes: (a) to remove gangue and increase the iron content of the ore; (b) to obtain a uniform size and a uniform chemical composition; and (c) to agglomerate iron-bearing units not suitable for blast-furnace feed in their existing physical form. There are several well-known commercial methods used to obtain these results for specific purposes. The methods need not be described, but some comments about the purposes follow.

COMMERCIAL PROCESSING OF IRON ORE

Crushing and screening

39. Crushing of iron ore may be either a basic or a preparatory process. At the mine site crushing is almost always needed to reduce the mined ore to a form that is suitable for handling. Screening is used to produce ore grade specifications for fines content and lump size.

40. Crushing and screening are also carried out at the plant site to bring ore sizes to that stipulated for the blast-furnace burden, and for blending with other ores. The crushing and screening operation is often needed at the plant site to separate and to prepare fines for sintering.

Blending

41. Iron ores are blended at the mine site to produce a single product of more or less uniform grade from several mines, or from a given mine, where the ore is mined from different benches or veins that vary in chemical composition. At the plant site, iron ore is blended to further reduce variations in the feed material for the blast furnace.

Sintering

42. Sintering is a method of agglomerating iron units by incipient fusion and controlled cooling. The process is based upon the combustion of carbon that has been uniformly mixed with iron-ore fines, mill scale, and blast-furnace dust. Limestone or dolomite, when added to the mixture, produces a self-fluxing sinter. The sintering process is generally carried out on a continuous travelling-grate machine (Dwight-Lloyd type) for a large-scale production and in batches (Greenawalt system, etc.) for small outputs.

43. The product from the sintering machine is a fused porous cake. The sinter cake may be cooled before crushing or crushed in the hot state. The maximum size of sinter is generally about 6" in diameter; pieces under 3/8" are designated as fines which are

too small for use in the furnace and these are recycled through the sintering process. A typical continuous sintering machine will be 60-72" wide and, depending on its length which may be as much as 170 feet, will produce 2.00 to 4.25 tons of sinter per square foot of grate in 24 hours.

44. Agglomeration of different ores by sintering was proposed initially in 1887. The first operations were batch processes that brought a bed of the mixture close to a molten state by exothermic combustion, and then cooled the mass by blowing air through the material. In 1905, it was suggested that a mixture of blast-furnace flue dust, ore fines, and fuel could be successfully sintered in a similar manner.

45. The travelling grate Dwight-Lloyd sintering machine was developed in Mexico for non-ferrous ores in 1906, and five years later a continuous-action strand-type sintering machine was placed in service for iron ore in the United States. The Dwight-Lloyd machine made possible the large-scale use of ore fines and highly efficient production of sinter at reasonable cost. Greenawalt developed a machine in 1912 which produced sinter in relatively small batches. Several versions of this system, well suited for minor scale production, were soon installed at many small plants. At large integrated steel plants, batch sinter units are used only to a limited extent, because of their limited outputs.

46. For many years the main purpose of the sintering machine was to "recover" blast-furnace flue dust, fine ores and coke breeze by agglomeration into a product that could be recharged to the blast furnace. As the sinter product improved with experience, and the performance in the blast furnace was better understood, it became evident that the qualities of sinter as a material for blast-furnace burden were just as good as those of natural lump ore. In many cases sinter burdens were found to reduce more readily than some lump ores. Increasing quantities were included in iron furnace feeds and by the mid-1930's inherent qualities of sinter were recognized to be very desirable for blast-furnace charging. Sweden was an early leader in the use of high sinter burdens in the blast furnace; in 1938, a blast furnace in that country was operating with a 100 per cent sinter burden.

47. The production of sinter in the major steel-producing countries of the world in 1940 was about 12 million tons per year. After World War II, sintering practice was adopted widely in the steel industry and plans were made by many companies to increase sinter capacity at the plant sites. By 1950, the global output of sinter equalled 41 million tons.

48. Sinter production of the major steel companies in the world from 1954 to 1964 is given in Table II-6. Output in 1964 was more than 3.5 times that of 1954.

TABLE II-6

Production of sinter in major steel-producing countries from 1954 to 1964

(millions of metric tons per year)

Country	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964
Austria	1.47	1.59	1.89	2.03	1.91	2.05	2.57	2.40	2.48	2.49	2.60
Belgium	0.67	0.71	0.74	0.69	0.93	1.66	2.23	3.21	4.87	5.16	6.59
Canada	--	--	--	--	--	3.54	3.29	3.22	3.16	3.25	3.54
Czechoslovakia	1.11	1.49	2.75	2.83	3.17	3.74	4.01	4.83	5.60	5.95	7.12
France	1.5	1.7	1.82	1.98	2.71	3.81	6.35	7.41	10.05	14.53	17.44
Italy	1.10	1.35	1.42	1.56	1.82	1.85	2.13	2.39	2.44	2.54	2.61
Japan	2.94	3.52	3.9	4.5	5.8	6.7	8.24	13.32	17.36	20.00	23.07
Luxembourg	--	1.21	1.65	1.84	2.0	2.4	2.93	2.9	3.21	4.47	4.78
Netherlands	--	--	0.025	0.60	0.69	0.81	0.97	1.8	1.99	2.35	2.79
Poland	--	2.04	2.98	4.05	4.45	5.15	5.49	6.37	7.04	6.99	7.01
Sweden a/	1.75	2.1	2.46	2.69	2.45	2.61	2.88	3.57	3.67	3.68	--
USSR	28.4	33.8	33.97	44.91	50.83	56.83	65.13	74.19	83.36	93.53	103.61
United Kingdom	6.04	7.89	7.83	9.39	9.56	11.64	15.02	14.84	15.94	18.05	21.36
United States of America	22.34	25.79	26.55	28.25	27.03	30.06	40.77	40.92	42.00	45.03	49.31
Western Germany (including the Saar)	11.26	13.96	14.83	16.08	17.19	18.79	22.90	24.39	25.83	24.93	28.71
Yugoslavia	--	0.3	0.46	0.48	0.75	0.93	1.0	1.05	1.06	1.02	1.00
Total	78.58	97.45	103.28	121.88	131.29	152.57	185.91	206.81	230.00	253.97	281.54

Source: The European Steel Market, ECE, Geneva, United Nations publication, several issues.

a/ Including pellets

Pelletizing of iron ore

49. Pelletizing is a method for agglomerating iron-ore fines; the process developed as an extension of the sinter experience at the iron-making plant. A typical pelletizing process consists of the following steps: (a) crushing and grinding of iron ore to 60 to 80 per cent minus 325 mesh; (b) beneficiaition of the ore fines to produce a concentrate, if required; (c) balling a humid iron-ore concentrate on a suitable disc or drum to produce a "green" pellet about 3/8" in diameter. Moisture content of the mixture is generally about 8 to 10 per cent and bentonite is often added as a binder; and (d) baking the green pellets which imparts to them high strength characteristics and a hard abrasive-resistant surface. The "burning" and hardening may be done in a shaft furnace or on a travelling grate or in a combination grate-kiln. At this point some pellet mixes tend to "swell" and require careful control.

50. Experiments with pelletizing iron-ore concentrates were started in Sweden in the early 1900's, but these did not lead to any industrial application. Modern pelletizing was developed in the United States after World War II when direct shipping ores of the Mesabi Range began to grow scarce. The pelletizing process was found to be effective for the treatment of low-grade taconite ore, and the pelletized product performed admirably in the blast furnace. This initiated an unusually rapid rise in pellet production in North America since 1956. In Japan, interest intensified in 1958, and the development of the use of pellets in Western Europe came five years later, in 1963.

51. The world production of pellets from 1954 to 1965 is given in Table II-7. The United States and Canada are the major producers, accounting for nearly 86 per cent of the production in 1965.

Relative consumption of run-of-mine and processed ores

52. The use of processed ore in the form of sinter and pellets has increased rapidly during the last ten or eleven years. Pellet production increased from a little over 2 million tons in 1955 to over 35 million tons in 1964 and 49 million tons in 1965, while the use of sinter in the burden of the blast furnace rose nearly threefold from 1955 to 1964. To maintain a proper perspective it is necessary to note that the 1955-1964 increase of 33 million tons of pellets hardly matches the 184 million tons of added sinter output during the same period.

53. Table II-8 gives the physical form of iron ore consumed in major areas in 1964 and projected for 1970 and 1975.

54. In 1964, about 56 per cent of the iron ore was consumed as pellets and sinter and 44 per cent as screened charge ore. The trend of pellet and sinter use combined is expected to continue upward and reach over 64 per cent in 1975. Screened run-of-mine ore

TABLE II-7

World production of pellets from 1954 to 1965
(millions of metric tons per year)

Country	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965
Canada	--	0.230	0.370	0.570	0.860	0.870	1.230	1.380	1.460	7.600 a/	8.000 a/	14.000 a/
Finland	--	--	--	--	--	0.150	0.150	0.150*	0.150*	0.150 a/	0.230	0.230 a/
France	--	--	--	--	--	--	--	0.040	0.040	0.050	0.050	--
Italy	--	--	--	--	--	--	--	--	--	0.330	--	--
Japan	0.600	0.500	0.600	0.600	1.500*	1.500*	--	--	--	1.500 a/	--	2.800 a/
Norway	--	--	--	--	--	--	--	--	--	0.400	0.600 a/	0.600 a/
Peru	--	--	--	--	--	--	--	--	--	0.400	0.800 a/	1.000 a/
Sweden	0.170	0.200	0.250	0.250	0.300	0.300	0.300	0.500	0.600	0.600 a/	1.000 a/	2.000 a/
United States of America	0.848	1.350	5.165	6.681	8.636	8.731	13.878	15.274	18.720	23.461	25.000 a/	28.000 a/
Yugoslavia	--	--	--	--	--	--	--	--	--	--	--	0.600 a/
Total	1.618	2.280	6.385	8.101	11.296	11.551	15.558	17.874	20.970	34.191	35.680	49.230

Source: Economic Aspects of Iron-Ore Preparation, ECE, Geneva, 1966, United Nations publication, Sales No. 66.II.E.6, Table 4.

a/ Rough estimate

TABLE II-8

Physical form of iron ore consumed in the world in 1964 and projected for 1970 and 1975

(millions of metric tons per year)

	1964		1970		1975	
	Tons	Per cent	Tons	Per cent	Tons	Per cent
Screened r.o.m. and direct-charge ore	247.9	43.9	252.0	37.3	288	35.6
Sinter fines	281.4	49.8	323.5	48.0	360	44.4
Pellets a/	35.7	6.3	99.5	14.7	162	20.0
Total	565.0	100.0	675.0 b/	100.0	810 c/	100.0

Source: See Table II-1.

a/ It is expected that about 10 million tons of pellets will be metallized by 1975

b/ Average Fe content: 53.5 per cent

c/ Average Fe content: 62 per cent

NOTE

In the context of the programme of work of the UNCTAD Committee on Manufactures, the UNCTAD secretariat has prepared studies on sectors of industry with a current or potential export interest to developing countries. The studies were to include, as far as possible, the consideration of the following points:

(a) Present and prospective demand in both developed and developing countries;

(b) Economic possibilities for the establishment or expansion of such industries in developing countries;

(c) Obstacles to exports from developing countreis, particularly to developed countries;

(d) Possibilities for industrial co-operation between developed and developing countries;

(e) Establishment of common markets and regional arrangements for facilitating economic integration and the establishment of regional or sub-regional industries in developing countries;

(f) Capital outlay required for the establishment of an efficient industrial enterprise and probable period of amortization;

(g) Possible need for and availability of assitance from developed countries for the production and export of products of developing countries.

The study on the prospects for exports of processed iron ore from developing countries has been prepared within the above terms of reference, at the request of the UNCTAD secretariat, by the Battelle Memorial Institute.

The description and classification of countries and territories and the arrangement of material should not be considered to imply any judgment by the secretariat of UNCTAD regarding the legal status of any country or territory, or in respect of the delineation of its boundaries, or regarding its economic system. Inclusion of a particular country or territory in any economic or geographical grouping (or its exclusion) has been dictated by considerations of availability of comparable data in statistics of the United Nations and other international agencies.

(Document TD/B/C.2/29/Corr.2 and a communication from the delegation of Australia - TD/B/C.2/Add.1 - are also attached. Document IT/B/C.2/29/Corr.1 has been incorporated in this Note.)

/...

consumption will increase modestly, from 248 million tons in 1964 to 262 million tons in 1970 to 288 million tons in 1975. In terms of per cent of total ore tonnage, there will be a steady drop from 43.9 per cent to 35.6 per cent between 1964 and 1975.

55. The use of sinter will also rise in absolute tonnage consumed while its percentage participation drops. The rise from 281 million tons to 360 millions between 1964 and 1975 will, in fact, represent a drop from 49.8 per cent to 44.4 per cent.

56. The difference will be made up by increased pellet use, absolutely and relatively. From 35.7 million tons and 6.3 per cent in 1964, oxide pellet production is expected to reach 100 million tons in 1970 and 162 million tons in 1975, corresponding to 15 per cent and 20 per cent of the total ore consumed in those years. In the 1975 figure is included some 10 million tons of pre-reduced pellets. With 90 per cent over-all pellet-plant utilization the 162 million ton output in 1975 indicates a total installed pelletizing capacity of 180 million tons annually.

Pre-reduced iron ore or pellets

57. Sponge iron or reduced ore is commercially produced on a small scale in the iron and steel industry; currently the total production is less than 500,000 tons per year.

58. There is great interest nevertheless among steel-makers in producing a "super" ore or sponge iron that may be used in the blast furnace, in electric-arc steel-making, and as a substitute for scrap in the oxygen converter. The product would enter the market place as a potential competitor to oxide pellets and to steel scrap. Production of a "super" or ~~"produced"~~ "pre-reduced" ore ("pre-reduced" before it is charged to an iron production unit) involves the extraction of some of the oxygen held chemically by the natural mineral. Since this may be done in conjunction with, or as a modification of an oxide pelletizing operation, the possibilities of pre-reduced pellets are of particular interest to developing countries. The added processing to upgrade their natural resources permits desirable new industrial activity at the source.

59. At the present time, the physical methods of concentration and agglomeration are well established and high-grade ore may be produced "artificially" by sintering and pelletizing. The best grade iron ore and pellets, however, contain over 28 per cent of oxygen that cannot be recovered by physical means. Further reduction of the iron oxide would be a step beyond the present maximum level of oxide pellet processing by the removal of oxygen in a preliminary "direct" reduction procedure.

60. A large number of "non-standard" (i.e., other than the blast furnace) methods have been developed since Sir William Siemens failed to prove one of the first attempts with direct reduction, a hundred years ago. Since then more than 2,000 patents have been granted relating to direct processes or equipment for them, but present liquid pig iron is produced commercially in only one small plant in Mexico. However, one group of non-conventional iron furnaces, electric-arc smelting units, produces more than 3 million tons annually.

61. The interest in pre-reduced ore, generally in pellet form, has stimulated a great deal of work to perfect some of the more promising direct reduction practices. At the Orinoco Mines in Venezuela, a gaseous reduction plant is now being designed and will be erected to convert 60 per cent run-of-mine ores to metallized pellets with 85 per cent Fe.

62. Although many technical and economic questions are still to be answered about pre-reduced pellets, the interest is so great that it is expected that by 1975 approximately 10 million tons of similar pre-reduced pellets will be produced and shipped into the world iron-ore market.

CHAPTER III

IRON-ORE PROCESSING IN THE DEVELOPING COUNTRIES: SUPPORTING FACTORS AND OBSTACLES

63. Chapter II has drawn attention to the substantial advances that have taken place since World War II in the production of iron ore and iron-ore derivatives. These developments moved from the installation of simple separation systems initially, to sophisticated sintering and pelletizing plants in recent years. This chapter discusses further expansion of pellet facilities throughout the world.

Pellet capacity - 1966 to 1975

64. In 1954, the global production of pellets was about 1.6 million tons; in 1966, the total pelletizing capacity approached 95 million tons. An additional 38 million tons of pellet-plant capacity are under construction, scheduled for completion in 1967 and 1968. The plants reported in operation in 1966 and their locations are tabulated in Table III-1. Installations expected to be completed in 1967 and 1968 are listed in Table III-2.

65. In North America (United States and Canada) pelletizing capacity in 1966 equalled nearly 77 million tons, and facilities for another 12 million tons were being built, for a total capacity of 89 million tons.

66. As of the end of 1966, the only active pellet plant in South America was the operation established in Peru by the Marcona Mining Company with a capacity of 1 million tons. Marcona is now adding a second plant to produce 2 25 tons of pellets annually. The Companhia Vale do Rio Doce is building a pelletizing plant with a capacity of 2 million tons a year at Vitoria, Brazil.

67. In Western Europe none of the steel producers in the European Coal and Steel Community have so far installed pellet plants. This follows partly from the nature of the ores mined by those countries of the continent but even more it is explained by the extensive use of sinter in French, West German, and British blast furnaces. By contrast, Sweden with high-grade ores for export sale, leads the area with an output of pellets of over 4 million tons a year. Norway, Finland, and Italy have a combined pelletizing capacity that totals a little over 1 million tons. Yugoslavia is building a small plant with about 150,000 ton capacity.

68. USSR pelletizing capacity is still relatively minor. Some 8 million tons are reported in operation, with twice that output under construction and scheduled for completion by the end of 1968.

69. Asia and Australia together account for pellet facilities that can produce 2.7 million tons a year and 3 million tons more are currently being erected.

70. Table III-3 summarizes by continent existing capacities of pellet plants in the world as of mid-year 1966, and the output potential of plants under construction. In practically all cases the pelletizing plants in the world have been erected at mine sites.

71. The pellet plants in developing countries as summarized in Tables III-1, III-2, and III-3 are, or will be, located in Brazil, Peru, India (Goa), and the Philippines. All other pellet plants are located in developed countries.

72. If one considers the facilities in the industrialized areas of North America, Europe and Australia, only 3 per cent of the total pellet capabilities are located in developing countries. By 1968, when all currently planned installations are in operation, the developing countries' share will still equal no more than 7 per cent of the total.

TABLE III-1

Iron ore pellet plants in operation as of 1966

Plant	Starting date	Output, million ton/yr	Ore feed	Pellets produced
NORTH AMERICA				
United States				
Silver Bay, Minnesota (Reserve Mining Co.) (G)	1955/60	9.4	Magnetite concentrates	9-12 mm 61-63.5% Fe
Hoyt Lake, Minnesota (Erie Mining Co.) (S)	1955/66	25.8	Magnetite concentrates	10-12 mm 63.1% Fe
Humboldt, Michigan (Cleveland Cliffs Iron Co.) (G-K)	1960	0.7	Hematite concentrates	10-16 mm
Grace Mine, Pennsylvania (Bethlehem Steel Co.) (S)	1961	2.0	Magnetite concentrates	64-66% Fe
Atlantic City, Wyoming (U.S. Steel Corporation) (G)	1962	1.3	Magnetite concentrates	64-66% Fe
Republic, Michigan (Cleveland Cliffs Iron Co.) (G-K)	1962	1.5	Hematite concentrates	
Eagle Mills, Michigan (Cleveland Cliffs Iron Co.) (G)	1962/65	1.9	Hematite concentrates	12 mm 61-66% Fe
Empire, Michigan (Empire Mining Co.) (G-K)	1963	1.2	Magnetite concentrates	63% Fe
Pea Ridge, Missouri (Meramec Mining Co.) (S)	1963	2.0	Magnetite concentrates	9-13 mm 65-68% Fe
Groveland, Michigan (Hanna Mining Co.) (G)	1963	1.3	Hematite and magnetite concentrates	10-14 mm 61-63% Fe
Eveleth, Minnesota (Eveleth Taconite Co.) (G-K)	1964	5.0	Magnetite concentrates	9-13 mm 65% Fe

TABLE III-1 (continued)

Plant	Starting date	Output, million ton/yr	Ore feed	Pellets produced
United States (contd.)				
Eagle Mountain, California (Kaiser Steel Co.) (G)	1965	2.2		9-13 mm 65% Fe
Mather Mine, Michigan (Cleveland Cliffs Iron Co.) (G-K)	1965/66	3.6		
Canada				
Marmora, Ontario (Bethlehem Steel Co.) (S)	1955/57	1.1	Magnetite concentrates	16 mm 64.4-65% Fe
Sudbury, Ontario (International Nickel Co.) (G)	1955/62	0.90	Pyrrhotine concentrates	25 mm (for steel making) 66-68% Fe
Hilton Mines, Quebec (Hilton Mines, Ltd.) (S)	1957/60	1.4	Magnetite concentrates	6-20 mm 63-66% Fe
Kinberly, British Columbia (Consolidated Mining and Smelting Co.) (G)	1961/63	0.30	Pyrrhotine concentrates (flotation)	65-67% Fe
Carol Lake, Newfoundland (Iron Ore Co. of Canada) (G)	1963	5.5	Specularite concentrates	10 mm 64-65% Fe
Moose Mountain, Ontario (National Steel Co.) (S)	1964	0.60	Magnetite concentrates	9-15 mm 63-63.7% Fe
Adams Mine, Ontario (Jones-Laughlin Steel Co.) (G-K)	1964	2.2	Magnetite concentrates	66% Fe
Pointe Noire, Quebec (Pickands Mather) (G)	1965	5.5	Specularite concentrates	10-12 mm 65% Fe
Boston Township (G-K)	1965	1.0		
Steep Rock, Ontario (Caland Ore Co.) (G)	1965	1.0	Hematite Hydrogoethite Ground ore	62% Fe

TABLE III-1 (continued)

Plant	Starting date	Output, million ton/yr	Ore feed	Pellets produced
SOUTH AMERICA				
Peru				
Marcona (Marcona Mining Co.)	1963	1.0	Magnetite concentrates	68% Fe
WESTERN EUROPE				
Sweden				
Bodas (Sandvikens Jernwerk) (S)	1952	0.06	Magnetite concentrates	
Persberg (Uddeholms AB) (S)	1954	0.04	Magnetite concentrates	64.5% Fe
Falun, Stora (Kopparbergs) (S)	1954	0.05	Magnetite concentrates	
Hofors (SKS) (S)	1955	0.05	Magnetite concentrates	
Malmberget (LKAB) (S)	1955/66	1.55	Magnetite concentrates	30 mm (for steel making 67-68.5% Fe
Kiruna (LKAB) (G)	1963/65	2.0	Magnetite concentrates	68% Fe
Strassa (Grangesberg) (S)	1963/66	0.83	Magnetite concentrates	(for steel making 67-68% Fe
Norway				
Mo-I-Rana (Norsk Jernwerk) (G)	1964	0.60	Magnetite concentrates	
Finland				
Otanmaki (Otanmaki Oy.) (S)	1959/60	0.25	Magnetite concentrates	25 mm 67% Fe
Italy				
Follonica (Montecatini) (G)	1963/65	0.30	Magnetite concentrates	63% Fe

TABLE III-1 (continued)

Plant	Starting date	Output, million ton/yr	Ore feed	Pellets produced
EASTERN EUROPE				
USSR				
Rudny (Sokolovsko-Sarbaisk Mining and Beneficiation Combine) (G)	1963	3.0	Magnetite concentrates	
Krivoi Rog (Central Mining and Beneficia-tion Combine) (G)	1964/65	3.0	Magnetite concentrates	12-16 mm 62.3% Fe
Sverdlovsk (Kachkanar Mining and Beneficiation Combine) (G)	1965	0.70	Magnetite concentrates	+10 mm 60.5% Fe
Krivoi Rog (Central Mining and Beneficiation Combine) (G)	1965	1.7	Magnetite concentrates	
ASIA				
India				
Goa Chowgule and Co. (G)	1966	0.50		65% Fe
Japan				
(Unlocated) (S)		0.40		
Chiba (Kawasaki Seitipu) (S)	1953/62	1.0		
Philippines				
Luzon (G)		0.75		
AUSTRALIA				
Scott River, Western Australia (Cleveland Cliffs - Mitsui)	1965	0.50		60% Fe

Source: Economic Aspects of Iron-Ore Preparation, ECE, Geneva, 1966, op. cit., Table 12.

(S) = Shaft furnace; (G) = Continuous grate; (G-K) = Grate and kiln.

TABLE III-2

Pellet plants under construction - as of 1966

Plant	Starting date	Designed capacity, million tons/yr	Feed ore	Pellet, Fe content
NORTH AMERICA				
United States				
Cooley, Minnesota (Hanna Mining Co.)	1967	2.00	Magnetite	62% Fe
Pilot Knob, Missouri (Hanna Mining Co.)	-	0.75	-	-
Keewatin, Minnesota (Hanna Mining Co.)	-	2.40	Magnetite	
Biwabik, Minnesota (Jones and Laughlin Steel Co.)	1967	1.50	Magnetite	65% Fe
Mountain Iron, Minnesota (U.S. Steel Corporation)	1967	4.50	Magnetite	65% Fe
Canada				
Tanagami, Ontario (Dominion Foundry and Steel Co.)	1968	1.0	Magnetite	63% Fe
SOUTH AMERICA				
Brazil				
Vitoria (Cia. Vale do Rio Doce)	1967	2.0	Hematite	68% Fe
Peru				
Marcona (Addition Marcona Mining Co.)	1967	2.25	Magnetite	66-68% Fe
WESTERN EUROPE				
Yugoslavia				
Skoplje (Zelezara Skoplje)	-	0.15	-	-
EASTERN EUROPE				
USSR				
Rudny (Addition) (Sokolovsko-Sarbaisk Mining and Beneficiation Combine)		9.0		
Sverdlovsk (Addition) (Kachkanar Mining and Beneficiation Combine)	1967	2.0	Magnetite	63.0% Fe

TABLE III-2 (continued)

Plant	Starting date	Designed capacity, million tons/yr	Feed ore	Pellet, Fe content
USSR (contd.)				
Krivoi Rog (Addition) (Central Mining and Beneficiation Combine)	1966	5.1	Magnetite	65.3% Fe
AUSTRALIA				
Robe River, Western Australia (Cleveland Cliffs - Mitsui)	1968	3.0		63% Fe
AFRICA				
Buchanan, Liberia (Lamco Mining Company)	1967	2.0	Hematite	65% Fe

Source: Economic Aspects of Iron-Ore Preparation, ECE, Geneva, 1966, op. cit., Table 13.

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Item 6 of the proposed revised provisional agenda

MEASURES FOR THE PROMOTION, EXPANSION AND DIVERSIFICATION OF EXPORTS OF MANUFACTURERS AND SEMI-MANUFACTURES FROM DEVELOPING COUNTRIES; CO-OPERATION WITH THE UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION (UNIDO) AIMED AT THE ESTABLISHMENT AND EXPANSION OF EXPORT-ORIENTED INDUSTRIES IN DEVELOPING COUNTRIES; OTHER FORMS OF ECONOMIC INDUSTRIAL AND TECHNICAL CO-OPERATION

Prospects for exports of processed iron ore from developing countries

Note by the UNCTAD secretariat

At its resumed first session, the Committee on Manufactures requested the secretariat to prepare, on the basis of item IV.5.(i) of the programme of work, for the second session of the Committee, in addition to the study on timber trends and prospects already presented, studies on other sectors of industry with a current or potential export interest to developing countries. The studies were to include, as far as possible, the consideration of the following points:

(i) present and prospective demand in both developed and developing countries;

(ii) economic possibilities for the establishment or expansion of such industries in developing countries;

(iii) obstacles to exports from developing countries, particularly to developed countries;

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TABLE III-3

Total capacity of iron-ore pellet plants in the world in 1966 and plants under construction

(millions of metric tons per year)

	1966	Under construction, to be completed 1967/68	Total
North America	76.95	12.15	89.10
South America	1.00	4.25	5.25
Western Europe	5.73	0.15	5.88
Eastern Europe	8.40	16.10	24.50
Asia	2.21	-	2.21
Africa	-	2.0	2.0
Australia	0.50	3.0	3.50
Total	94.79	37.65	132.44

73. For the 162 million tons of pellet consumption in 1975 forecast in Table II-8, global pelletizing facilities totalling 180 million tons are anticipated, an increase of 50 million tons over the 130 million tons of capacity now installed or in construction. It is expected that about 40 per cent of this increase, or 18 million tons, will be constructed in developing countries: 7 million tons in Latin America (1.0 million tons at San Isidro, Venezuela; 1.5 in North Chile; plus an addition of 4.5 million tons in Brazil); 6 million in Asia (mostly in India); and 5 million tons in Africa (Liberia, Mauritania and Sierra Leone). This would place approximately 16 per cent of the world's 1975 pelletizing facilities in the developing nations.

74. The establishment of an iron-ore operation anywhere is a major undertaking. Technical, economic, and financial problems of a highly sophisticated order must be solved before the venture becomes an effective and viable project. These problems notwithstanding, a number of successful iron-ore mining installations have been established in developing areas of Latin America, Asia, and Africa. In some instances, the stimulus for the activity has come from established iron-ore consumers. From the initial geological investigations through the period of construction, which involved the erection of ore mining and primary beneficiation facilities as well as the establishment of supporting installations (such as transport lines, power supplies, town sites, and shipping ports), there has been important assistance from the more experienced developed countries. In most of these co-operative undertakings, the joint effort has continued into the operating stage after the construction was completed. The more recent of these enterprises have required major capital outlays, up to $100 million and more.

75. In other cases, local government programmes have supported, wholly or partially, iron-ore mine constructions with modern preliminary ore processing and treatment adjuncts. Where there are ore export objectives, pelletizing installations are included, either in the immediate plans or in early expansion provisions.

76. A selected group of iron-ore producing installations in developing areas is described below. It will be seen that generally pellet processing is an immediate consideration in the over-all plans of the various operations.

AFRICA

Ouenza - Société de l'Ouenza (Algeria)

77. This ore mine on the Algerian-Tunisian border is an example of partial government support. The Djebels Ouenza Bou-Khardra deposits have been in production since 1921. Ownership is vested in the Société de l'Ouenza, with 50 per cent of the shares being privately owned. The remaining shares are divided between Algerian and French Governments, the latter holding 70 per cent of the balance, or 35 per cent of the total ownership.

78. Proved reserves of hematitic and sideritic and so-called "brown ores" in all the deposits are equal to about 140 million tons. The delivered ore assays 53 to 55 per cent iron, 1.7 to 1.8 per cent manganese, 0.001 to 0.01 per cent phosphorus, and 3 to 3.5 per cent SiO_2. In the future Ouenza expects to ship three qualities of ore, (a) run-of-mine, (b) screened 80 mm by 10 mm, and (c) fines below 10 mm. These fractions make up approximately 40, 35, and 25 per cent respectively of the production tonnage. Except for a small quantity of underground extraction, mining is simply "open cut" with negligible stripping. No concentration is carried on and the mineral is exported as a direct-shipping ore.

79. The ore is transported by rail a distance of 117 miles to the port of Annaba (Bône) where it is loaded into ships with draughts of up to 30 feet at a rate of 1,000 to 1,200 tons per hour.

80. Exports of Ouenza ore from Annaba were 2.2 million tons in 1964, up from 1.5 million tons in the previous year. About 50 per cent of 1964 shipments went to the United Kingdom, 13 per cent to West Germany, and 30 per cent to Italy. The balance was made up from amounts shipped to Belgium, France, Netherlands, United States, Poland, and Czechoslovakia. Future plans are based on a potential for export of 3 million tons annually. In addition, Ouenza has undertaken to supply annually a million tons of "brown ore", containing 45 to 49 per cent iron, to the new iron and steel plant at Annaba. This project, originally planned to go into operation in 1966, has not progressed as scheduled, and iron production may not begin until 1968.

81. The demand for Ouenza ore is largely the result of its desirable "self-fluxing" character. The mineral is readily saleable (but apparently only in limited quantities) without preliminary processing. The installations of a pellet plant at Ouenza has not received serious consideration.

Mont Nimba -
The Liberian-American-Swedish Mining Company (Liberia)

82. This mining operation, close to the Guinean border in the northern part of Liberia, is an instance of multi-national co-operation. The concession is owned 75 per cent by Liberian, American, and Swedish interests in a company designated as "LAMCO". One half-share interest is vested in the Liberian Government and the other one half share is divided equally between American-Canadian interests and a Swedish consortium. Bethlehem Steel Company owns the remaining 25 per cent of the concession.

83. The total investment for facilities producing 7.5 million metric tons of iron ore annually was about $220 million. The facilities include a mechanized mining operation on Mont Nimba close to the Liberia-Guinea border, a 165-mile railway from the mine to a new port at Port Buchanan, rolling stock, a deep water harbour, and a complete township.

84. The largest of the Nimba ore bodies is reported to contain at least 250 million tons of hematite ore averaging 66 per cent iron. Chemical analyses of the ore at Port Buchanan are expected to average 65.5 per cent iron, 0.11 per cent manganese, 0.05 per cent phosphorus, and 1.0 per cent SiO_2.

85. Physical specifications of the delivered ore calls for 30 to 50 per cent lump ore, sized from 10 mm to 100 mm. The minus 10-mm fraction will contain 25 to 30 per cent minus 200 mesh. Open-pit mining at several sites simultaneously is expected to produce a homogeneous product.

86. A $51.1 million pellet plant with a rated capacity of 2 million tons per year is being erected at Buchanan. It is expected to go into operation late in 1967. This plant, designed to handle large accumulations of fines, will permit LAMCO to raise its current rated capacity of 8 million tons per year to a new level of 10 million tons. The pellets will be 10 to 15 mm in diameter assaying about 65 per cent iron, 0.05 per cent phosphorus, and 2.0 per cent SiO_2. A washing plant is being installed in conjunction with the pelletizing unit to produce a direct shipping ore with sizes up to 40 mm and a sinter feed ranging from 1.2 to 4.0 mm.

87. Mine production began in 1963 and reached 7.2 million tons in 1964. Shipments were about 6.8 million tons in 1964 with 2.6 million tons going to the United States, and 4.2 million to Western Europe. Shipments to West Germany were also 2.6 million tons under a contract for the shipment of 2.5 million tons each year through 1979. Bethlehem Steel Company receives 25 per cent of the ore shipped, and when pellets are manufactured this company will take an equal percentage of pellet production.

ASIA

Bailadilla (Madhya Pradesh, India)

88. The Bailadilla deposits are being developed as a case of a mining installation established with full government support. It is located in the Bastar District, containing rich iron ores estimated at over 600 million tons. Fourteen separate deposits of the Bailadilla Range are being developed for iron-ore export to Japan. The iron content of the ore varies from 60 to 69 per cent and the deposit is described as one of the richest in the world.

89. The construction of a mechanized mine, Bailadilla No. 14, the laying of a new railway, and the improvement of the east coast port at Vishakhapatnam (Vizag) will cost about $250 million. It is being developed to produce about 4 million metric tons of lump ore from 5.5 million metric tons of run-of-the-mine product. The iron content of ore from Deposit No. 14 is about 65 per cent. Plans call for the development of other deposits so that production by 1975 for the entire Bailadilla deposit may approach 12 million tons per year. A pelletizing installation has been foreseen for 1969 or 1970, after a sufficient quantity of fines has been accumulated.

Philippines Iron Mines Inc. -
(Luzon Island, Philippines)

90. This operation, heavily government supported, has a capacity to produce about 1.3 million tons of magnetite concentrate annually from local reserves having an iron content averaging 39 per cent. A new concentration installation, rated at 4,500 tons daily, will increase production to about 2 million tons per year. With existing facilities, the concentrates contain about 55 per cent iron, 0.03 per cent phosphorus, and 19 per cent SiO_2 plus Al_2O_3. The output from the new concentrator is expected to contain about 65 per cent iron.

91. Screened ore and concentrates are transported to the north end of Colambayungon Island where they are stored before being loaded into 11,000-ton vessels.

92. Philippines Iron Mines, Inc. has nearly completed the construction of a pelletizing plant with an annual capacity of 750,000 tons, all of which is intended for export to Japan.

LATIN AMERICA

Cia. Vale do Rio Doce -
Itabira (Minas Gerais, Brazil)

93. The Brazilian government-controlled company, Companhia Vale do Rio Doce, has been exporting high-grade iron ores from various mines near Itabira in the State of Minas Gerais since 1942. Reserves are estimated to be about 1,000 million tons of ore containing 66 per cent iron. They constitute one of the world's richest deposits.

94. A broad variety of ores is shipped. Lump and rubble ores have iron contents over 68.5 per cent iron, with phosphorus about 0.02 per cent. Eighty-eight per cent of the lump (used as open-hearth charge ores) measures 2" by 8"; the same proportion of the rubble ore (for the blast furnace) falls in the range of 1/2" by 2". Substantial tonnages of fines, below 1/2" and analysing at about 65 per cent Fe, have also been shipped in recent years.

95. An extensive modernization programme at Itabira includes replacement of obsolete mining methods by fully mechanized techniques, improvement of transport lines, the addition of pellet capacity to produce 3 million tons annually, and a new loading facility at Porto do Tubarao, near the present shipping centre of Vitoria. The new port was completed and began operation in the spring of 1966. Tubarao can handle about 20 million tons of ore per year and accommodate carriers with capacities up to 100,000 tons compared with a previous top capacity of 45,000 tons at Vitoria. The new port alone cost nearly $25 million.

96. Since 1957, the Rio Doce Company has spent about $77 million on the iron-ore project, the largest portion was invested on the railway. The new rail facilities, designed to move 20 million tons of ore annually, carry the ore 335 miles to the coast. Export contracts have already been negotiated for current and future shipments to several European countries, including West Germany, Austria and Romania.

El Algarrobo - Compañía de
Acero del Pacífico (Chile)

97. This mine is wholly owned by the main Chilean steel producer, which itself has major government support. It ships high-grade iron ore at the rate of 3.5 million tons per year, from reserves that have an estimated life of over 50 years. The ore contains 66 per cent iron, 3.4 per cent SiO_2, and 0.11 per cent phosphorus for open-hearth lump; 62.8 per cent iron, 6.5 per cent SiO_2, and 0.13 per cent phosphorus for iron-making.

98. The ore is transported 7.5 miles by truck from open-pit operations to the railroad, and then railed 24 miles to Huasco where it is loaded into vessels having up to 50,000-ton capacity. Japanese steel producers have contracted for some 6 million tons of this ore to be delivered over a ten-year period.

99. The company is considering plans for an early installation of a large pelletizing facility.

Cerro Bolívar - Orinoco
Mining Company (Venezuela)

100. A wholly-owned subsidiary of United States Steel Corporation, the Orinoco Mining Company has been shipping high-grade iron ore from the Cerro Bolívar deposits of Venezuela since 1954. Proved reserves are estimated to be over 400 million tons of ore, containing between 45 and 62 per cent iron.

101. The ore, a mixture of hematite, limonite, and minor magnetites, is available in wide variety. It is relatively free of objectionable impurities, as indicated by a typical assay: 60 per cent iron, 1.5 per cent SiO_2, and 0.10 per cent phosphorus. The physical condition of the ore is variable. The high percentage of fines usually present are sintered at the iron and steel plant to which they are shipped.

102. The ore is extracted by open-pit mining and transported down steep grades by truck to a single-track, single-purpose railroad leading to Puerto Ordaz, 90 miles away on the Orinoco River. A 184-mile channel in the Orinoco River is kept open by continuous dredging to permit year-around operation of large ore carriers, drawing over 30 feet of water.

103. In recent years, shipments have averaged about 10.5 million tons annually. About 60 per cent of the ore is sold to the United States Steel Corporation in the United States. The balance is shipped to consumers in Europe, chiefly the United Kingdom, West Germany and Italy. Approximately 1 million tons of ore annually is sent to the Venezuelan national steel plant at Matanzas, less than 10 miles up-river from Puerto Ordaz.

104. The Orinoco Mining Company has no immediate plans to add regular or "oxide" pellet facilities at this mine. Instead it plans the development of a $40 million pre-reduced pellet plant that will raise the iron content of the run-of-mine Cerro Bolívar ores from 60 per cent to about 85 per cent. Designs for an initial capacity

of 1 million tons are nearly completed and construction is scheduled for 1967. Depending on the success achieved - at the direct-reduction processing plant and in the iron-producing furnace - the annual pre-reduced pellet capacity at Puerto Ordaz may ultimately be raised to 10 million tons.

IRON-ORE PROCESSING IN DEVELOPING COUNTRIES: SUPPORTING FACTORS

105. The preceding review presents only a representative picture of today's iron-ore mining operations in the developing regions. Omitted are such important installations as Marcona (Peru) and San Isidro (Venezuela) of South America; Goa and Bellary-Hospet (India) and the Malaysian iron-ore mines of Asia; and Marampa (Sierra Leone), Fort Gourand (Mauritania), and Mekambo (Gabon) of Africa.

106. An equally substantial group has been omitted because it includes mines of so-called industrially advanced countries. Accounted among these are Kiruna (Sweden), Hamersley Mining and Scott River (Australia), and various new mine developments (Canada). Finally, it is apparent that the major home ore operations of the United States, the United Kingdom, Western Europe, the USSR and South Africa are also removed from the scope of this report.

107. What remains is a typical cross-section of the iron-ore mining operations of the industrially limited areas of the world. In each case but one of the seven installations cited, large-capacity mines have been established in recent years around massive endowments of high-grade iron ores. The exception, Ouenza, is of limited size and relatively "old" as an operation, in contrast to the other later and more modern installations. Each of the seven mines offers for export a variety of products from run-of-mine ore to fines for sintering. All but two also are planning to instal pellets to their export product test; omitted are Ouenza which bases its sales effort on the self-fluxing characteristics of its output, and the Orinoco Mines operation in Venezuela. In the latter case, there is no underestimation of the importance of pelletization; the operators are looking one step ahead to pre-reduced pellets, instead.

108. The interest in pellets - oxide, self-fluxing, and pre-reduced - is hardly accidental. It follows from a build-up of competitive forces in the international world market, that are inherent in the figures of Tables II-2 and II-3. The spread

between iron-ore consumption and actual producing capacity of 1[illegible] million tons (565 million tons versus 575 million tons in 1964 is expected to rise to [illegible] million tons in 1970 and 44 millions in 1975. The excess availability will sustain a purchasers' market. Suppliers must be concerned with their ability to provide the highest grade and broadest variety of product including pellets.

109. For the modern iron-ore mine operator, pre-treatment capability thus appears to be a necessary adjunct for survival. The implied increase in the magnitude of his operation introduces possibilities for reduced unit production costs and, accordingly, a more competitive price position. Thus two factors, a wider product list to offer to the world market and a better base from which to meet price competition, favour especially processing plants at mine sites or their associated shipping ports. This is evident in the decisions that have already been taken by iron-ore producers and iron-ore consumers at mines - LAMCO and Western Australia are typical examples - where both have a joint interest.

IRON-ORE PROCESSING IN DEVELOPING COUNTRIES: OBSTACLES

110. There are also negative factors which may impede the development of iron-ore pellet production at the source. The more obvious of these are: (a) tariffs in importing countries, (b) high capital requirements for the processing facilities and associated services; and (c) limitations in the availability of experienced management staff forces from domestic personnel. The nature of these potential problems is briefly discussed below.

<u>Tariffs in importing countries</u>

111. Developed countries relying on imports for a significant portion of their iron-ore requirements are not likely to raise tariff barriers against this material. The United States, for example, has no duties on iron ore. The same considerations apply to iron oxide pellets. For example, no duties are paid by Japanese importers for iron-ore, sinter fines, or pellets.1/

1/ Information received from representatives of the Nippon Kokan K. K., after consultation with the Japanese Consul-General in New York, and several Japanese trading houses.

112. The future tariff status of pre-reduced material poses more of a question. The pre-reduction of iron ore to, say, 85 per cent iron content may ultimately offer definite advantages in product quality and lower shipping costs per ton of metallics. Furthermore, the value of the product will be increased by the additional work done on it. From the tariff viewpoint, importing countries might classify pre-reduced material in the same category as ore or oxide pellets, equate it to (synthetic) scrap, or consider it a semi-manufactured product.

113. To date, there has been virtually no trade in pre-reduced material, so that there is no precedent to go by. However, past experience shows that the more work done on an imported raw material outside the country of consumption, the more likely is it that affected parties (labour groups, competing producers, etc.) within that country will exert pressure for tariff protection. Just how pre-reduced material will be considered is presently unclear. In this connexion, however, it is useful to note that the first United Nations Conference on Trade and Development in 1964 adopted a recommendation that the developed countries should in international trade negotiations "make every effort to secure maximum reductions in and, wherever possible, the elimination of tariff differentials which differentiate unreasonably between products in their primary and their processed form".2/ This recommendation was adopted without dissent by representatives of over 100 countries, including every developed nation of the world. Its expressed intent, to encourage processing activities in the developing countries, would obviously be violated if tariffs were imposed on pre-reduced iron ores exported from those countries.

Capital requirements

114. Large amounts of capital funds will be needed for construction and equipment to build and operate iron-ore processing plants. Presumably, a large portion of these funds might be supplied by participating steel companies from the developed countries that would consume the processed material.

2/ Proceedings of the United Nations Conference on Trade and Development, Vol.I, Final Act and Report, Annex A.III.4 "Guidelines for tariff and non-tariff policies in respect of manufactures and semi-manufactures from developing countries", p.38, para.10.

(iv) possibilities for industrial co-operation between developed and developing countries;

(v) establishment of common markets and regional arrangements for facilitating economic integration and the establishment of regional or sub-regional industries in developing countries;

(vi) capital outlay required for the establishment of an efficient industrial enterprise and probable period of amortization;

(vii) possible need for and availability of assistance from developed countries for the production and export of products of developing countries (TD/B/69 - TD/B/C.2/14, paragraph 20).

It was further stated that each of these studies, when completed, would be considered by the Committee which might, if considered desirable, establish working parties similar to the one set up on forest and timber products (Ibid., paragraph 21). A study on the prospects for exports of processed iron ore from developing countries has been prepared within the above terms of reference, at the request of the secretariat, by the Battelle Memorial Institute. Chapters I and VII of the study gives a summary of the main findings and conclusions.

This study is herewith submitted to the Committee for its consideration.

The designations employed and the presentation of the material in this work do not imply the expression of any opinion whatsoever on the part of the Secretariat of the United Nations concerning the legal status of any country or territory or of its authorities, or concerning the delimitation of its frontiers.

115. Many developing countries, however, logically desire such activities to be at least partially owned by domestic interests. All too often, capital funds available in developing countries are far from ample and must be allocated on some sort of priority basis.

116. Equally important, capital funds also would be required in most instances for the infrastructure additions needed to support iron-ore processing operations. Such supporting requirements may include port, dock and stockyard facility enlargements; special handling installations; increased transport units, water, gas, electricity, sewage and other service lines; and also expanded community installations.

117. In developed countries, the availability of a sufficiency of most of these items is taken for granted. This may not be so in developing countries. In most instances, the national or local government within the developed country must take the major responsibility for the provision of adequate infrastructure support.

Requirements for adequate
management staff

118. The operation of an iron-ore mine and its associated facilities requires knowledgeable management, technical competence, and skilled operating personnel. A strong manager or management team is often lacking in developing countries unless the project is a joint venture between the developing country and the developed country. While this is generally the case for iron-ore projects, there is still an insufficiency of skills and managerial know-how among developing country nationals. This is equally true for skilled operation personnel.

119. For the most part, these conditions are generally "solved" for mining operations; for ore processing the situation is not likely to be very different. The same transfer of know-how that marked the transition from run-of-mine to upgraded ore outputs will be extended to include oxide and, later, metallized pellets. The challenge of funding exists for all industry efforts and, in this case, may be offset by favourable returns on investment that usually may be anticipated. Finally, the deficiencies of adequate management personnel and trained labour staff will generally be resolved by the benefits which both producer and consumer of iron ore may receive from processing at the source in developing countries. Closely related motivations provide the basis for wholly or partially joint activities that combine the experience and needs of the developed areas with the resources and enthusiasm of the developing countries.

CHAPTER IV

TECHNICAL CONSIDERATIONS OF IRON-ORE PROCESSING AT THE SITE

120. The increasing prominence of iron ore as an item of trade in the world market derives from factors which have been enumerated in Chapter II. Three of the more important of these are: (a) "the development of large deposits of high-grade iron ore in areas remote from the world's centres of steel production"; (b) an accelerated "demand for iron ore to satisfy the steel-making needs of an expanding world economy"; and (c) "the widespread application of highly efficient new iron-making procedures that are dependent on high-quality processed ores".

121. A superficial consideration would view the first of these developments as mainly the province of the iron-ore producer, the second as primarily that of the ore consumer, and only the third of equal concern to producer and purchaser. In actual fact all three situations are of direct interest to both parties. As regards the first point, most new iron mines in the developing areas exist today as a result of explorations by iron-makers from industrially advanced countries, seeking adequate ore supplies for their furnaces. Second, a rising level of iron and steel demand and production will almost always have a corresponding impact at the iron mine, imposing requirements for expanded plant facilities, enlarged handling and loading capabilities, and greater ship cargo capacities. The third factor places a premium on high-grade processed ores at the iron plant, and on a diverse product list at the iron-ore mine. This is especially true for ore operations in the developing country whose output is destined mainly for export sales to a highly competitive market.

<u>Classes of ore available for export</u>

122. Thus, LAMCO offers Liberia's Nimba ores as: (a) a run-of-mine product extracted by selective techniques from "as-mined" ore; (b) an improved grade of run-of-mine ore; (c) fines for sintering and also for use in direct-reduction fluidized-bed plants; (d) pellet feed; and (e) pellets. Currently only the run-of-mine product is shipped; by the end of 1967 when an ore-washing plant and pelletizing facilities are completed, all five grades will be available for export.

123. The same variety of iron-ore products, with one exception, is typical of the output that the iron-ore producer in many of the developing countries will offer for sale to the international market. The exception will eventuate with an anticipated

decline in shipments of pellet feed-ore grades.[1] In general, the specific demands of the iron-ore market will be met - currently and for the intermediate future term - by four classes of ore: natural run-of-mine; selected run-of-mine; fines for sintering; and pellets.

Relative importance of classes
of ore for export

124. The relative importance of each of these groups can be deduced from Table II-5 and Table II-8. Applying the percentage distribution of the latter to the anticipated tonnage of iron ore in international trade, a representative division by type of processing may be drawn. Within the projection of 292 million tons of iron ore, concentrates and agglomerates to be moved in the world market in 1975,[2] sinter ore shipments will equal about 130 million tons; run-of-mine ores, 100 million tons; and pellets, some 60 million.[3] Of these quantities, the developing countries of Latin America, Africa and Asia will provide nearly half.[4]

125. Dependent for so large a portion of their ore requirements on "foreign sources" in the developing areas, the iron and steel industries of the advanced nations can hardly be insensitive to the capabilities and scope of operations at these new points of supply. This is not an unexpected relationship. Iron-ore producers and consumers have always had to be concerned with each others' problems. This was the case when ore treatment involved only crushing and separation procedures, and it is even more true with the advent of sophisticated processing techniques - sintering and pelletization - on a broad scale. A brief review of iron-ore treatment practices will highlight the mutuality of interest of producer and consumer which underlies the technical basis of iron-ore processing at each stage of the development.

1/ As a mine's production of pellets reaches design levels, pellet feed-ore will be increasingly used up in the on-site pelletizing operation.

2/ See Table II-5. The figure of 292 million tons, averaging 62 per cent Fe (181 million tons of contained iron), compares with approximately 275 million tons (165 million tons of contained Fe) by T. Dennison ("Oil and Fuel: Some Economic Aspects and Potential Supplies" read before conference on "Iron-Making Tomorrow", British Iron and Steel Institute, London, November 1966). The higher figure used in the text takes partly into account the footnote to Table II-5: "Some of the ore may be put into a stockpile for future use".

3/ Based approximately on the relative percentages given in Table II-8.

4/ In Table II-8, Asia, Africa and South America account for about 45 per cent of the total iron-ore exports foreseen for 1975.

Simple ore treatments - crushing,
screening, sizing and blending

126. The earliest steps evolved from considerations of the producer's convenience. Screening made it possible to separate lumps of ore that were readily manageable from others that were not. Crushing reduced the quantity of the latter, and simple screening systems conveniently divided the product by size. Later, with the introduction of more advanced equipment and concepts, these procedures were used deliberately to break away iron values from gangue in the natural mineral.

127. By such means run-of-mine ores were converted into an enriched product that was more easily saleable. Materials that were too fine or too low in iron content were disregarded and set aside as economically uninteresting or technically difficult to process.5/ The immediate advantages of simple processing were enjoyed mainly by the ore producer. He gained a better yield in his operation and, often, an improved grade of product from this added effort at the mine.

128. The iron-maker, on his part, observed that his furnace ran smoother, and that specific output was increased when he charged uniform and richer burdens of a fixed size range. He accepted the treated ores as premium products. In the interest of uniformity, physical and chemical, he specified mixtures of several of these ores, and blending was thus added to the list of preliminary ore treatments. Better iron quality and, frequently, lower iron costs were achieved by the iron-maker as a result of the "simpler" treatment procedures.

Development of advanced
treatments - sintering

129. Selective improvement of the natural ore by "making little ones from big ones" and often, "better ones" also developed over a period of more than half a century, and by the mid-1930's was practiced widely in numerous well-established concentration and beneficiation procedures.

5/ This was true, of course, only when there were better alternative ores on hand. In Great Britain and in the Minette regions of eastern France and western Germany, ores no better than the Mesabi taconites have been the mainstays of important steel industry operation for more than a century.

130. During the same time a reverse problem developed, mainly at the iron plant. Iron-ore fines and coke breeze accumulated in increasing amounts in the stockyard; and rich flue dust from the blast furnace top was settled out in large piles. These products represented valuable credits to the iron-making process if they could be returned to the furnace burden. Otherwise, they were only the source of nuisance problems at nearly every iron plant. Around 1910, methods were perfected to fuse these wastes economically into a strong, rich sinter cake that made an excellent burden addition. Gradually, over the next twenty years, the larger integrated steel works added sintering units to make "big ones out of little ones".[6/]

131. Sintering provided advantages to the iron-maker that were very direct. Dust and fines that were usually held in inventory at token prices (as little as 10 cents per ton was a frequently used figure) assumed real values that were commensurate with those set for prime ores. At the mine, the ore producer also benefited. To meet a growing "demand for iron ore to satisfy the steel-making needs of an expanding world economy", he accelerated and mechanized his operation. This gave him an output with increasing amounts of fines. With these fines acceptable at the sinter units of the iron plants, he could export a previously unsaleable fraction of his production. Although he had to quote reduced prices for sinter fines, they, nevertheless, included adequate profit margins. In a real sense, the acceptance by the iron-maker of high sintered ore burden practice which improved the iron-production operation, also gave an added utility to run-of-mine fines that was a substantial boon for many long-established ore producers. Among these was included practically every supplier of home ores in the industrially advanced countries, as well as producers at the new (and older) mines of the developing areas.

132. The contribution of the sinter process to this "extension" of available domestic and foreign ores is apparent in Table II-6. The USSR, which in 1945 produced 4 million tons of sinter (after a previous high of 12 million tons in 1940), went from 12 million tons in 1940 to over 100 millions in 1965; and the countries of Western Europe[7/] rose from 5.6 million to 37.5 million tons during the same years.[8/] For

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6/ So did many smaller works which otherwise would not have been able to maintain reasonably economic production performance.

7/ The ECSC countries only are included in the figure. Sweden, which is not included, produced 1 million tons in 1950 and about 4 million tons in 1964.

8/ West Germany accounted for about two-thirds of the total in 1964, and practically all of the sinter tonnage in 1950.

the United Kingdom, the figures are 8 million tons (1950) and 21 millions (1964) respectively; for Japan, the corresponding sinter production was 2 million and 23 million tons; and for the United States, 17 million and 50 million tons. Sinter was produced almost exclusively from home ores, but after 1955 increasing quantities of fines were required. Since then, large amounts were imported. By 1960 the advantages enjoyed by the domestic ore producer from the increased demand for sinter-grade ores were fully shared by many foreign iron-ore suppliers.

133. The demand for sinter, plain or self-fluxing, followed from the iron-maker's skill to produce the material and then to use it with increasing success as an iron-furnace charge material. The improved economic and technical performance potential reflected by smoother furnace operations, higher tonnage outputs, lower coke rates and better iron quality was clearly summed up in reduced production costs. The magnitudes of these improvements have been thoroughly documented[9/] so that it will be sufficient to cite only one case here. Table IV-1 shows the rise in Japanese blast-furnace efficiency from 1954 to 1965, in terms of reduced coke consumption per ton of iron produced. With increasing agglomerated burden that is largely (90 per cent) sinter, coke rates fall impressively, by about 30 per cent. Similar experiences have been duplicated by iron-makers throughout the world.[10/]

Further advanced treatment - pelletizing

134. Sinter techniques were generally established in the industry by 1955. Notwithstanding the considerable advantages that were demonstrable for the practice, that year marked the introduction of a new agglomeration method, pelletization. The development grew out of efforts in the United States and Canada to convert massive taconite reserves in the Lake Superior region into a suitable substitute for depleted sources of direct shipping ores. To liberate the iron fractions from the gangue, it is necessary to grind the natural taconites to about minus 325 mesh. Such tiny granules cannot be kept from sifting through the grate bars of a sintering machine. The fine material was therefore moistened[11/] and "balled" into "green" pellets approximately 1/2" in diameter and baked. The resulting ball, when properly made, is strong, abrasion-resistant, readily reducible, and altogether an excellent feed for an iron furnace.

9/ See Chapter IV, Long-Term Trends and Problems of the European Steel Industry, ECE, Geneva, 1959, United Nations publication, Sales No. 60.II.E.3

10/ See documents of British Iron and Steel Institute meeting on "Iron-Making Tomorrow", London, 23-24 November 1966.

11/ Sometimes a binder, usually bentonite, is added.

TABLE IV-1

Trends in Japanese blast-furnace efficiency, 1954-65

Year	Agglomerated material in burden, per cent	Coke consumption, kilograms/metric ton of pig
1954	44.1	730
1955	44.7	710
1956	41.3	730
1957	44.4	715
1958	52.6	664
1959	48.6	632
1960	46.5	617
1961	55.6	598
1962	62.6	550
1963 a/	61.1	521
1964	61.2	500
1965	63.4	502

Source: Statistical Yearbook for 1965, Japan Iron and Steel Federation, 1966.

a/ Fuel-oil injection started in late 1962, figures from 1963 on also include the effect of fuel-oil injection.

135. Pelletization has been adopted by the iron and steel industry somewhat less rapidly than was sintering. For one thing, many steel plants have made recent sizable investments in sinter facilities. Furthermore, pellets as a charge material are not necessarily "better" than sinter. In actual fact, pellets are complementary to sinter rather than competitive. In some cases, one technique may be preferable: in others, the second may be desirable.

136. Nevertheless, pellets offer important positive effects at the blast furnace, and in 1956, with a global production of 6.3 million tons, the practice achieved a break-through in the iron-making industry. By 1964, world pellet output had reached 35.7 million tons, an increase of 29 million tons in ten years. Impressive as this may be, it is significant that during the same period sinter output for the world rose from 80 million tons to 280 millions.

137. The support for pellet practice has come strongly from steel-plant operators in the United States, Canada and, recently, from Japan. Thus, "pellets are now considered to be as effective as sinter with respect to production and coke rate ... Meanwhile, the intensification of crushing and screening of ore has caused a shortage in sintering capacity, and it is considered from such circumstances that the demand for pellets in Japan will gradually increase in the future".12/ This trend is reflected in the figures of Table II-8.

138. The anticipated increase in the future use of pellets will have an important impact at the iron mines. Unlike sinter that is generally produced at the iron and steel plant, pellets may readily be manufactured at the source. To date, practically all the pellets consumed are produced at iron-ore mines or near associated shipping points. The pattern is being followed closely at the new plants under construction and on the design boards. The iron-ore producer who exports the pellet and the iron-maker who imports it each derives benefits that are very much like those resulting from the use of sinter practices in the steel industries. In the future, it appears that these advantages will continue and, in the case of the ore producer, appreciate.

139. Two variations of the pelletizing process, nodulizing and fine ore briquetting, have been introduced during the past few years. Neither development has yet excited any considerable interest in the industry. Essentially, both variations may be grouped with pelletization, with regard to general features of the methods by which they are produced, level of iron content, and the manner in which they may be used for iron-making. The pre-treatment in each case lends itself to ready production at the source.

12/ S. Hayashi and K. Jizuka, "The Effects of Burden Preparation on Iron-Making"; "Iron-Making Tomorrow", British Iron and Steel Institute meeting, London, November 1966.

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PREFACE

This study of the prospects for export of processed iron ore from developing countries has been undertaken by the Battelle Memorial Institute, at the request of the United Nations Conference on Trade and Development. The study is one of several which the UNCTAD Committee on Manufactures requested the secretariat to prepare on sectors of industry of current or potential export interest to developing countries.

As indicated in its title, this study is concerned specifically with processed iron ore as a commodity of world trade, moving from primary producing countries to industrialized ones.

There is no question that an agglomerated iron-bearing mineral is favoured over the non-treated ore by the iron and steel industry. Indeed, the economics of today's advanced iron-making technology, no less than the requirements of the techniques themselves, demand processed ores with the highest iron content possible and consistently uniform physical and chemical characteristics. The development of such ores "artificially" by pre-treatment was suggested and sponsored by the iron-maker himself during the past two decades in an effort to improve and protect his operation. To attain the first of these objectives he has had to increase the output of his furnace to satisfy a rising demand for iron; for the second, he has searched for means to reduce the cost of his operation and raise the quality of his product. Among the steps taken to achieve these ends, the introduction of practices using better ores holds a prominent place.

Improved iron-bearing materials were obtained initially through selective grading of the natural product. Later, the character of the ore was altered by beneficiation procedures. The past ten years have seen these relatively simple practices augmented by sophisticated processes that produce sinter and pellets. As already noted, these developments were initiated by the iron-maker; the pre-treatment or processing concept therefore does not have to be "sold" to the iron-ore consumer. The points that are of concern today are "what kind of pre-treatment?" and "where may the processing best be done?" Part of the answers to such questions is already available. The iron-makers' preference for agglomerated ores - sinter and pellets - is clearly evident at most iron and steel-producing centres of the world. Moreover, a strong trend toward the use of increasing amounts of pellets is demonstrable. This has set the stage for the production of ever greater tonnages of iron-ore pellets in several developing countries.

At many iron sources in Africa, Latin America, Asia and the Far East, ore producers in developing countries and ore consumers from developed ones have worked together to plan large mining projects, which they are now operating jointly. Recently, several have decided to add pelletizing facilities. Some of these plants are still to be built, others are in construction and a few are already in production. Ultimately, such installations could provide a considerable part of all processed iron ores traded in the world market. The positive contribution that ore processing "at the source" may make to industrial advances in developing countries with good iron-ore endowments is generally apparent.

Although these effects are "obvious" they demand serious active attention, and the potential consequences require sharper definition. The addition of processing facilities to supplement iron-ore mining operations in developing countries introduces a long series of questions:

"How much ore - processed and otherwise - may be required to meet the current and future demand of the world's iron-making producers?"

"From what sources will these iron values come?"

"What are the economic implications of iron-ore processing activity in developing countries?"

"What conditions may operate in support of and in opposition to such operations?"

"What are the financial factors that apply?"

"What degree of co-operation is needed in the developing areas, and to what extent may assistance be forthcoming from developed countries?"

The replies to these inquiries support a general conclusion that the prospects for the export of iron ore in more processed forms, from developing countries, are quite favourable.

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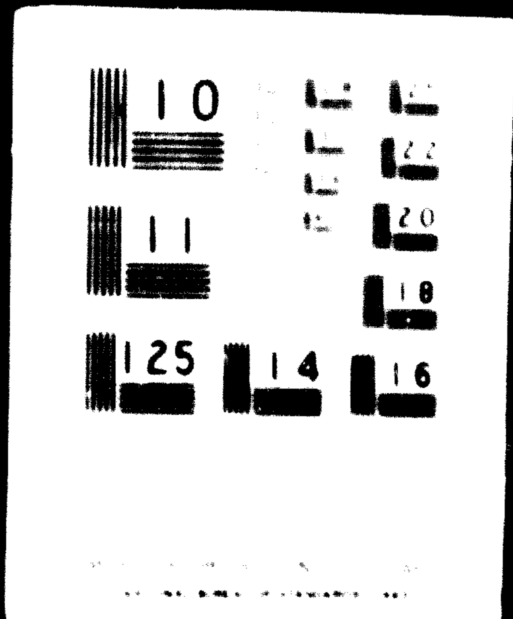

[illegible] per ton, can be [illegible] [illegible] If one assumes the natural ore and fines [illegible] per cent, that is [illegible] difference [illegible] per ton [illegible] [illegible] different [illegible] per [illegible]

[illegible] For [illegible] million ton [illegible] [illegible] million a year more [illegible] This [illegible] but even for the minimal figure of the [illegible] additional return. With [illegible] capital [illegible] for the pelletizing [illegible] approximately one-third the total [illegible] million investment, the return on the [illegible] million dollar expenditure needed for [illegible] between [illegible] and [illegible] per cent. This is equivalent [illegible] payout period of [illegible] years. Even if the entire [illegible] million capital outlay [illegible] considered, the [illegible] of the pellet processing operation [illegible] would pay out in [illegible] years, or at rates [illegible] per cent respectively.

__Retained added value__

165. Each ton of pellets produced at the source represents [illegible] ($1.[illegible] in pelletizing expenses plus $0.50 in overhead) per ton that would be [illegible] for industrial activity in the producing country. At the end of the payout period [illegible] years, the fixed expense component chargeable to the processing facility would [illegible] $0.[illegible] 17/ The retained added value for a 2 million ton a year operation can equal [illegible] per ton or $2.8 million annually. This may be compared with the $1.50 difference in mine margin indicated by Graff and Bouwer. 18/

__Pre-reduced pellet estimates__

166. Although only one iron-ore mining operation - U.S. Steel's Orinoco Iron Mines in Venezuela - has taken definite steps to add facilities to pre-reduce part of the output of the existing installation, the interest in procedures to raise iron-ore content "artifically" above maximum natural levels is widespread throughout the iron-ore and

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16/ __The Economic Times__ (India), 27 October 1966.

17/ The amortization charge over a 25-year life for the entire investment is $1.28 (out of the total $3.52 fixed charge). The pellet facility represents one-third of the entire investment, or $1.28/3 = $0.43.

18/ __Op.cit.__, footnote 15/, which assumes a mine margin of $1.50 per gross ton of natural ore and $3.00 per ton of pellets.

iron-making industries. Many questions remain to be answered [illegible] the iron [illegible] concerning the problems that may arise [illegible] theoretically [illegible] the [illegible] of metallized ores containing [illegible] per cent of iron and more. Nevertheless, the possible advantages for the iron-maker are so great and the development, from the viewpoint of the iron-ore producer, so logical, that investigations of applicable techniques [illegible] carried on with great urgency. It is too early to say when pre-reduction processing may become a standard practice in the iron plants, but five years hence may not be [illegible] an assumption. Since it will take nearly all that time to erect and put a pre-reduction facility on stream, a few preliminary remarks on applicable capital and operating cost estimates are appropriate now, even though no real production experience is available for reference.

167. The investment needed for a 1 million ton a year pre-reduced pellet plant is estimated in this study at $53 per annual ton, of which $18 is provided for reduction, $13 per ton for pelletizing, $9.50 per ton for preparation, and $12.50 per ton for mining facilities. This figure compares with an estimate of $50 per annual ton by Graff and Bouwer. The $18 per ton of annual capacity of pre-reduced pellet plant alone is somewhat higher than a $13 per ton estimate calculated by research metallurgists of the U.S. Bureau of Mines,[19] for a 2 million ton per year plant. Some of the difference is to be found in the assumed size of the pre-reduction installation under consideration.

168. As noted above, production cost evaluations must be largely based on untested assumptions. Graff and Bouwer have developed figures for hot-metal production for natural ore and five different types of processed material. A special case, comparing regular and pre-reduced pellets, estimates the capital investment for pellet production needed for a million tons of hot metal per year. In the first instance (1,335,000 tons of regular 62 per cent pellets annually), the cost for mining, preparation, and pelletizing installation is estimated at $40.6 million. In the second, (1,032,000 tons of pre-reduced 82 per cent pellets) the estimate is $51.6 million.

169. The additional investment of $11 million yields an estimated post-tax (48 per cent) savings of $860,000 or 7.9 per cent. Graff and Bouwer observe that this return on the additional investment for pre-reduced pellets may not be "sufficiently attractive". It should be noted, however, that the return calculated on a pre-tax "annual savings" of $1,650,000 would be a respectable 15 per cent on the additional capital expenditure.

19/ N. Bernstein, J.L. Reuss and P.L. Woolf, "A Cost Comparison: Production and Smelting of Prereduced vs. Iron Ore Pellets", Journal of Metals, May 1966 Table III, p.654.

CHAPTER VI

PRACTICAL CONSIDERATIONS OF IRON-ORE PROCESSING AT THE SITE

[illegible] In Chapter III some of the general conditions supporting and opposing iron-ore processing at the site were reviewed briefly. Chapters IV and V discussed more specifically relevant technical and economic functions. In this section, attention will be focused on some of the pragmatic factors. The more important of these centre on the degree of support that the main consumers of iron ore, i.e. the producers of iron and steel in the industrially developed nations, will continue to give to the spread of on-site processing capabilities at iron-ore mining operations in the developing countries.

Processing capability and export position

[illegible] At the outset, it will be useful to equate broadened iron-ore processing capability at the site with improved potential for export to the international iron-ore market. In support of this point it is necessary only to cite again the U. S. Bureau of Mines' estimation that by 1970, practically all iron ore consumed by the industrialized countries will be beneficiated.[1]

172. Increasingly, the iron ore that is expected to move in international trade (approximately 220 million tons in 1970 and 290 millions in 1975) will include larger quantities of graded ore, sinter fines, and pellets. Given the excess of anticipated ore-production capacity over expected consumption indicated in Tables II-3 and II-2, ore suppliers of the developed and the developing countries will both be faced by competitive price pressures on the one hand, and more stringent product specifications on the other. The effect of broadened processing capabilities in such a market development is illustrated by the limited potential and objectives of the Ouenza mine for the future, compared with those of the other six operations described in Chapter III.

173. It is also desirable to recall the tonnages of processed ores that are under consideration for 1975. With reference to paragraph 124 above, the iron-ore exporting countries of South America, Africa, and Asia are expected to export some 45 million tons of natural and graded run-of-mine ores, 55 million tons of sinter fines, and 28 million tons of pellets. The point needs to be made that fines and graded ores will equal more than three times the anticipated pellet shipments. For the developing country mining operation which may not be in a position to instal pelletising facilities, this means that there is nonetheless considerable latitude - up to 100 million tons of demand - in

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1/ H. T. Reno, "Iron Ore", U. S. Bureau of Mines, Minerals Yearbook (1964).

which to operate. But it must also be stressed that it will be desirable for such mines to extend as much as possible their capabilities to concentrate and otherwise beneficiate their outputs. This is necessary as an offset against the possibility that each of the developed countries, with the sole exception of Japan, may choose to process low-grade home ores rather than import equally poor or slightly better iron-bearing materials.

174. In the remainder of this chapter, some of the practical reasons why the iron-ore consumers of the developed countries should, or should not, do just that are considered.

Processing of imported ore at the plant versus at the site

175. There is some concern, especially among steel producers of Western Europe, with the effect of new practice patterns that favour the use of foreign iron ores. An authoritative expert of the European Coal and Steel Community notes[2/] that the first of the processing stages, which even today is invariably carried out close to the mines, is ore beneficiation; the different methods needed for different ores and the saving on transport costs have all along ruled out its inclusion in the cycle of the integrated plants. The next stage, the preparation of a high-grade burden for the blast furnace, in sinter or pelletized form, is nowadays almost always affected at the plants in the case of sinter, as sinter travels badly, but always at the mines in the case of pellets.

176. The impact of this development is of particular significance to the Western European steel industries. Dennison[3/] observes that, "it is already exerting an important effect on the location of the industry, away from proximity to the domestic low-grade home ore deposits to coastal sites, to take advantage of imported ore and coking coal". He continues, "traditionally, the economic competitiveness of the Western European steel industries has depended on cheap, but low-grade, home ore ... Economic trends, however, are rapidly eroding these traditional advantages". He then cites estimates that "in 1975 United Kingdom consumption of domestic ore will be less than 10 million tons a year compared with 15.5 million tons consumed in 1965". He also states that "the trend will be to import an increasing proportion of ore requirements as pre-reduced pellets ..." and he refers to a forecast[4/] that, "in the context of the UK the British steel industry may be importing almost one-quarter (nearly 5 million tons a year) of its imported ore requirements by the mid-1970's".

2/ Private communication (May 1966).

3/ T. Dennison, "Ore and Fuel: Some Economic Aspects and Potential Supplies", Iron-Making Today Conference, British Iron and Steel Institute, November 1966.

4/ The "Benson Committee" Report: Stage 1 Report of the Development Co-ordinating Committee of the British Iron and Steel Federation, July 1966.

177. Both authorities quoted above are clearly speaking of imported pellets produced at the source. The view, however, is not universal, as shown by a recent decision to build a 2 to 2.5 million tons a year pellet plant at the blast furnace division (Hoogovens, Netherlands) of the Royal Dutch Iron and Steel Works, near Amsterdam.5/ Construction is said to be scheduled to begin in 1967, and production is to start up in 1970. This will obviously be an operation based on imported ores (possibly distress cargo purchases), with some, if not all, of the beneficiation to be done at the plant.

178. The Hoogovens announcement represents a break away from the general pattern up until now. Whether it may set a new trend is still to be seen, although this would appear subject to some doubt. This view is held on the basis of an even later decision to put off a pellet plant project planned for the Europoort Centre at Rotterdam. It is reported6/ that "German interest in the pellet project is said to have waned ..." for several reasons, including a "renewed interest in the possibility of receiving ores prereduced by direct reduction from overseas". It would seem logical to conclude that if a large iron-ore assembly, storage, and trans-shipment centre cannot support a "local" pelletizing operation, a single works would have even greater difficulties, unless there are unusual ore purchase opportunities, as may be the case at Hoogovens.

Use of home ores versus imported ores

179. Whatever the implications of any special situations, the general consensus among iron-ore and steel men is well summarized by the view that "the likelihood is that even the countries which pelletize only a small proportion of their ore will mostly leave the pelletizing to be done at the mines".7/ For ores destined for sinter production, the confrontation between home and foreign mineral is no less unfavourable for the former. Aside from several important inherent technical disadvantages, the home ores have become more expensive than imports. While the price index of home ores in the United Kingdom has risen from a base of 100 in 1957 to 126 in 1965, the imported ore price index has fallen to 70 from the same 1957 base. The change "has been more rapid in the ECSC countries where home ore production has declined by nearly 18 per cent since 1961. There is no sign that this trend will be reversed".8/

5/ Metal Bulletin 11 November 1966, p.16.

6/ Metal Bulletin 25 November 1966, p.16.

7/ See footnote 2/ above.

8/ T. Dennison, op.cit., p.3.

180. Only in the United States and in the USSR are there practical possibilities of a change in the pattern of increasing dependence on foreign iron ores at the expense of domestic resources. In the case of the Soviet Union, pellets are to be used more extensively than in the past.9/ (Table III-3 indicates a probable capacity of no less than 30 million tons before 1970.) Unless the USSR decides to produce pellets for general export (which could occur notwithstanding the "normal" projection of only 2 to 5 million tons, shown in Table II-5), this would make no important difference among the developing country iron-ore producers. As the primary iron-ore supplier to a "closed" system, the USSR and its ore-processing practices have had little effect on the trade relationships outside that system. Now there are reports that the USSR "is planning to start large-scale export of pellets from Black Sea ports at a very low price. ... As far as the UK is concerned Russia has emerged recently as an important supplier. This year's 975,000 tons compares with 426,000 tons in 1965 when shipments started. Next year Russia is planning to ship 1.3 million tons".10/

181. In the United States, only token amounts of iron ore are exported (mainly to Canada). It has been suggested that United States ore producers might raise this amount to about 50 million tons annually, to offset a like amount of ore imports. Given "the solution of taconite conversion to quality pellets, and given established capabilities in high-capacity operations, it should be possible to effectively produce iron-ore values at competitive costs for export to many parts of the world".11/

182. For the period through 1975, it is unlikely that either of these countries will take steps that will seriously affect the tonnages of processed iron ore shipped from mining operations of developing countries. Both countries have shown concern for the new nations through their assistance programmes; furthermore, there is the practical consideration that much of the 50 million tons of imported iron ore will come from developing country mines in which United States steel producers have important ownership interest and operating responsibility.

9/ Economic Aspects of Iron-Ore Preparation, op. cit., p.246

10/ Metal Bulletin 1 November 1966, p.9.

11/ J. R. Miller, "The International Market for Iron Ore: 1975", paper presented at Annual Meeting of American Iron Ore Association, Cleveland, Ohio, June 1966.

Freight savings

183. It has been observed that pelletizing "at the mines affords a certain minor savings on transport costs ...".12/ The position is quite sound since freight rates for ore for shipping vessels of comparable size are functions of moisture content and iron content, the latter being the more important by far.

184. For oxide pellets, the difference in iron percentage of the beneficiated ore charged to the pelletizing unit and the finished pellet is only 1 or 2 per cent; in most cases, the end product is lower in iron than the feed ore.13/ The difference is generally made up by a comparable advantage that all good pellets have with regard to moisture absorption. Any balance that may remain in favour of pellets is offset by slightly greater handling difficulties. On balance, therefore, there is little differential in unit shipping charges between concentrated ore and pellets, for a given shipping vessel.

185. It might be thought possible to reduce the over-all shipping charges by raising the iron in the finished pellet, say, 5 per cent to a content of 68 or 69 per cent. But for regular blast furnace operations, 64 to 66 per cent pellets give optimum results. Thus, pellets with an Fe content over 67.5 per cent are avoided in Japanese blast-furnace practice and in their purchase of pellets no payment is made for Fe values over 67.5 per cent.14/

186. The economic feasibility of oxide pellets produced at the mine site as against concentrated ores of comparable iron value is thus generally independent of freight costs. This, of course, does not mean that transportation charges are not of great importance. They are. But if f.o.b. or c.i.f. prices are favourable (or unfavourable) for a pellet feed ore in a competitive situation, the comparable prices for a resultant oxide pellet will not greatly alter that situation one way or another.

187. The same thing is not true for a concentrate with, say, 65 per cent Fe made from a low-grade natural 35 to 40 per cent ore. Neither will it be the case for a pre-reduced pellet metallized to, say, 85 per cent Fe from a 60 per cent feed. In each instance, the rise in iron content will permit an almost comparable increase in the effective payload of a given ore carrier with a commensurate reduction in the specific transport charge.

12/ See footnote 2/ above.

13/ See Economic Aspects of Iron-Ore Preparation, op.cit. Table 12.

14/ Ibid., p.34.

188. The advantages of improving the elemental proportions of low and medium grades of run-of-mine ores are well known. Aside from the extension of available resources and their increased marketability which follow from regular concentration and beneficiation treatments, the resultant reduction in shipping costs can be decisive in establishing and maintaining an economically competitive position.15/ This is especially true for iron-ore mines of the developing countries, that are often several thousand miles distant from the furnaces in which their ore will be smelted. The current cost of ocean transport per ton of ore over 7,000 kilometres in a 50,000-ton ore vessel has been given as $2.75.16/ This figure is not wholly definitive in terms of contained iron, but it's significance may be judged from a comparison with the average mining cost of 57 cents per ton of 60 per cent crude ore, and 55 cents per ton for crushing and concentration indicated in Chapter V (paragraph 159).

189. Given a 1975 demand for approximately 100 million tons of run-of-mine and screened ore and fines; given the fact that after 1970 practically all ores consumed by iron producers in the developed countries will be beneficiated; and taking into account the advantages that ore-processing capabilities offer a mining operation, the prompt installation of at least some "regular" beneficiation facilities at any mines which do not have them would appear to be nothing less than an exercise in future survival. While in many cases it may be argued that the addition of pellet capacity at an iron-ore mine may be something of a luxury, this is seldom true for the proceeding stages of beneficiation and concentration. The savings in freight which such treatment practices make possible is one of the more important reasons for this.

15/ An incisive simulation model analysis of the effect of freight costs, taking into account such parameters as point of roigin, point of delivery, distance, size of ore carrier, iron content, moisture content, etc., is to be included in the forthcoming study of the "World Market for Iron Ore" by ECE. This work, by an ad hoc committee of experts, is scheduled for publication in mid-1967.

16/ Economic Aspects of Iron-Ore Preparation, op. cit., p.6

Developments following the use of pre-reduced pellets

190. The shipment of metallized pellets carrying some 20 to 25 per cent more iron than even the highest grade natural ores will produce unit freight savings similar to those described for run-of-mine ores which have received comparable enrichment. It is not quite possible to define these savings more precisely since full use of the pre-reduced pellet is still a matter of some ten years in the future. Nevertheless, there is no question among iron and steel men about the eventuality of pre-reduced burden techniques for iron-making. This has already been implied in the steps taken by the Orinoco Mining Company to build a pre-reduced pellet plant in Venezuela, and by the view of the Benson Committee, referred to earlier in this chapter, that the United Kingdom will be importing 5 million tons of pre-reduced pellets by the mid-1970's.17/

191. An even further step, involving pre-reduced ore, is foreseen. An authority18/ observes, "sooner or later the time will doubtless come when increasing tonnages of steel will enter the market from countries which produce in the neighbourhood of the raw material sources". Furthermore, "pre-reduced ore can be used not only as a blast-furnace burden material but also, as far as possible, in completely reduced form as a supplement to scrap. Since in a number of ore-producing countries gaseous and liquid fuels are cheaply obtainable, it should be possible to effect pre-reduction there very economically indeed, ... saving not only on transport costs but very probably on their own operating costs as well".

192. This concept was also formulated at Battelle as follows: "the limit of ore preparation activities by iron-ore suppliers is by no means exhausted with the production of regular pellets. Pre-reduced pellets represent more than insurance in a competitive market, apparently they are good business also ..... We may expect to reach the ultimate level of iron-ore enrichment by the ore producer (in the developing countries), where he becomes a manufacturer of pig iron and later steel".19/

193. E. Schneider (ECSC) considers this possible development sufficiently assured to suggest that "the object must now be to seek ways and means of keeping the steel industry in the consumer countries competitive under these new conditions".

17/ T. Dennison, op. cit., p.7.

18/ See footnote 2/ above.

19/ J. R. Miller, "The Geography of Iron Ore", presented at organisation meeting of Iron Ore and Ironmaking Group Study by Battelle Memorial Institute, Columbus, Ohio, January, 1966.

194. Obviously, the development should be considered by operators of the larger iron-ore mines in developing nations, such as Liberia, Brazil, Chile, Venezuela, and India, to name but a few countries. The apparent implications that pre-reduction capability can be a direct step to iron production followed by steel production in the future, cannot be easily overlooked. Yet, it would be incorrect to fail to underscore that this is a development of the future, possibly of the 1975-85 period, rather than the present decade. Schneider describes the situation well by noting that the development covers an extensive field that must be subjected to further research.

Tariffs and duties

195. Among some sections of the established steel-producing industry, another point of concern seems to be the future availability of adequate quantities of suitable ores. Thus, it is noted that "the world has produced more steel ..." and consequently more iron ore "... in the last 15 years than in the whole of recorded history. This situation involves the highly industrial countries in growing economic and political dependence on the less highly developed countries of the world ... when they are industrializing their own economies at an increasing rate and are beginning to realize the long-term need to conserve their own raw material resources for their own use".[20]

196. The concern would seem to be somewhat premature. Estimates made in 1962 concluded that the world is endowed with some 98 billion metric tons of iron ore in known exploitable deposits. Contained iron, or "iron-in-ore", was calculated to be 71 billion tons. It is further stated that "during the next 30 years, the steel industry will consume about 13 billion tons of iron-in-ore, or about one-fifth of the total estimated exploitable iron-ore reserves".[21]

197. Since the above estimate was made, four years ago, new iron-ore sources have come to attention, among which the notable Australian developments are perhaps the largest but not the only ones. An expert panel has been assembled by the Natural Resources and Transport Division at United Nations Headquarters, to update the United Nations appraisal of the world's iron-ore resources. In the judgement of one of the panel members,[22] the reappraisal will more than double the 71 billion tons mentioned above. Among the several factors which are responsible for the increased resources figure, enrichment of run-of-mine ores by pre-treatment is of more than minor importance.

20/ T. Dennison, op. cit., p.6.

21/ R. W. Hyde, B. M. Lane and W.W. Glaser, "Iron Ore Resources of the World", Engineering and Mining Journal, 163 (12), December 1962, pp.84-88.

22/ J. R. Miller, the author of the present study. The view concerning the expected resource figure is not wholly a personal opinion, but based on many discussions with other panel members.

Pre-reduced pellets

140. The use of pre-treated iron ore is thoroughly established throughout the iron and steel industry. Expert opinion forecasts that by 1970 practically all ores consumed in the iron plants of the advanced countries will be beneficiated, sintered, or pelletized. The average of all the iron-oxide materials charged to iron furnaces will average, globally, between 62 and 64 per cent Fe. This is a significantly high level; no less than 10 per cent above the average 53 per cent iron content ten years earlier.

141. Even so, the iron and steel industries of the world are in the midst of an intense activity to raise the proportion of metallic iron in the charge material to between 80 and 90 per cent. The intensity of this effort may be gauged from the recent published observation that, "ore producers cannot get together without the subject of pre-reduced pellets being discussed".13/

142. Pre-reduction has been described as a beneficiation step in which the oxygen content is decreased14/ and as "the best approach to obtain a further decrease in coke rates and a further increase in hot-metal production" and "a good process to exploit very high-grade iron ore or concentrates".15/ The most popular versions are based on reducing 65 per cent pellets to 85 per cent iron content by modified gaseous and direct-reduction techniques. The idea is very appealing and there is considerable but varying degree of support for it among iron and steel men. There is also a universal view that a great deal must still be done before pre-reduction is ready for commercial application. One of the most recent statements in support of pre-reduced pellets carefully conditions its conclusions, "for the time being, [oxide] pellets are the ultimate in 'prepared' ores from the mining industry to the ironmaking plant. The results of tests and theoretical calculations show clearly that prereduced materials could be the next step. Although such prepared materials have not yet been used, except for a few tests, in commercial blast furnaces ... pre-reduction appears to be

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13/ Mining Engineering, March 1966, p.51.

14/ N. Molchor and M.B. Fine, AIME Meeting, Duluth, Minn., January 1966.

15/ Astier, Kalling and Stahled, "The Use of Pre-reduced Materials on the Blast Furnace"; "Iron-Making Tomorrow", British Iron and Steel Institute meeting, London, November 1966.

198. But, the concern is not without some basis, for the movements of iron ore may be seriously inhibited if the countries where the mineral is produced impose restricting tariff burdens. Reno and Brantley, of the U. S. Bureau of Mines, have stressed the importance of free trade in stimulating commerce in all iron-ore products. They warn that tariff regulations that have permitted free trade will not apply to partially reduced ore and that this will inhibit commerce both in North America and elsewhere in the world. They urge that equitable, precisely drawn government regulations be established for all possible iron-ore products.23/

199. Far-sighted governments of countries with developing economies agree. In India, official policy decisions on a cabinet level have been taken to support iron-ore exports. The Economic Times (India) reported on 27 October 1966 that "it has been decided to give liberal excise concessions to the pelletisation industry to encourage the export of processed iron ore, which will increase exchange earnings from this item several-fold ... There is no export duty on iron-ore pellets". This is part of an official effort to change the pattern of ore movement in order "to encourage the export of ores in semi-finished and processed form".24/ Other iron-ore producing countries that have not taken similar steps will be well advised to do so. At the least, this may assure continued support from their ultimate customers for iron-ore treatment and processing at the source.

200. That such support may be forthcoming, given a reasonable tariff formula, is consistent with the attitudes of the main iron-ore consumers. The lack of any import duty on imported iron ores, even in pelletized form, by the United States and Japan has already been mentioned.

Concessions in support of iron-ore exports

201. The decision by the Indian Government to support the export of ores goes beyond the elimination of export duties on pellets. For example "excise duty on furnace oil used for pelletisation is not charged ..... Import duty on machinery and equipment needed for the pellet industry will be charged in instalments that commence from the date when the pelletisation plant is commissioned .... Studies are being made to determine if any more facilities or concessions should be given to this industry and the port facilities available for pellet exports".24/

23/ H. T. Reno and F. E. Brantley, "Problems Facing the North American Iron Mining Industry", as summarized in Mining Engineering, March 1966, p.52.

24/ The Economic Times (India), 27 October, 1966.

202. In the same category of government support must be added considerations for easing and encouraging financial involvement by local and foreign sources of capital. This might include tax relief, at least during the early years of operation. (It may be recalled that in the development of operating cost estimate in paragraphs 159-162 above no provision was made for taxes, "it being assumed that under the circumstances these would be waived".) Other steps to stimulate the required investments from local and foreign sources include favoured treatment in banking transactions (the Indian Government may issue directives to the nation's Industrial Development Bank and other financial institutions to treat the pelletisation industry on a priority basis), and a reasonable policy concerning the withdrawal of earned profits from the investment.

Mutual co-operation

203. Favoured treatment and concessions are hardly new ideas. Precedents have been cited and others are to be found in the producer-consumer arrangements established in West Africa with Franch and North American interest and support; in Latin America with United States and other involvement; in Australia with Japanese and North American participation. Such joint participation can facilitate the transfer of know-how, operating skills, and experienced management. Domestic financial burdens can be reduced and relieved. With a greater adequacy of funds, project capacities may more readily be conceived in magnitudes that will permit higher economic scales of operations. With "captive customers", long-term sales arrangements may more easily be reached. With greater assurance of continued high-level activity, a number of small nearby mines may more effectively work together at a single centralized processing complex (with or without pellet facilities) which all could support jointly, but none could justify alone.

204. The basis for close co-operation between the iron-maker of the developed country and the iron-ore producer in the developing nations is well established. Increasingly, both are now taking steps to add and broaden processing operations at, or close to, iron-ore mines in the developing countries. These decisions are supported by technical and economic facts that have emerged from studies which ore suppliers and ore consumers have made themselves, separately and jointly. Not the least consideration entering into these analyses is the evident conviction that the mutual benefits that have stimulated the initial decisions to seek and develop iron-ore resources in the developing countries, will be greatly enhanced by continued co-operative actions.

CHAPTER VII

CONCLUSIONS

205. The terms of reference for this study of the prospects for export of processed iron ore from developing countries, suggest seven points of inquiry. Replies to these questions based on the considerations developed in the preceding chapters are formulated below. The responses will also serve to answer the six additional questions at the end of the preface to this report, since there are, in fact, re-statements of the inquiries under the terms of reference.

(1) Present and prospective demand for processed iron ore in both developed and developing countries

Battelle estimates that the annual world consumption of iron ore in 1970 will reach 675 million metric tons with an average iron content of 53.5 per cent; by 1975, that figure is expected to rise to 810 million tons of ore, concentrates, and agglomerates containing an average of 62 per cent Fe.

The share of the developing areas (Latin America, Africa, and Asia) in the world total of iron-ore production will not change appreciably in percentage terms. 1975's 27.7 per cent will compare with the 25.8 per cent of 1964. In terms of ore-producing capacity, the developing areas are expected to account for about 27.5 per cent and 30 per cent of the world total in 1970 and 1975 respectively.

By 1970, practically all the iron ores consumed by iron and steel producers in the developed countries will be subjected to some previous beneficiation. The demand for "as-mined" ores will continue to decline and even screened ores will represent a decreasing fraction of the total. The proportion of screened run-of-mine and direct-charge ores will fall from approximately 44 per cent of all the iron ore consumed in 1964 to 35.6 per cent in 1975. The use of sinter fines is expected to decrease also, from 50 per cent in 1964 to 44.4 per cent in 1975. The reductions will be offset by an increase in pellet consumption from 6 to 20 per cent of the world total.

The global iron-ore consumption of 810 million tons (500 million tons of contained iron) in 1975 will include 288 million tons of direct-charging and screened run-of-mine ores, 360 million tons of sinter fines, and 162 million tons of pellets. Approximately 35 per cent, or 292 million tons, will be imported ore, concentrates, and agglomerates from foreign sources. The developing areas are expected to provide 128 million tons, or 44 per cent of the total tonnage imported by the iron and steel-makers of the industrially developed countries in 1975. (In 1970, iron-ore shipments by the developing countries are estimated at 96 million tons out of a total world export tonnage of 221 millions.)

The 1975 demand for iron ore, concentrates, and agglomerates from the developing countries is foreseen as being divided into 45 million tons of natural and graded lump ores, 55 million tons of fines for sintering and 28 million tons of pellets. Current demand for iron-ore products from the developing regions, taken as the average of known export tonnages for 1964 and those estimated for 1970, is estimated at 36 million tons for lump ores, 43 million tons of sinter fines, and 9.5 million tons of pellets.

Demand for pre-reduced pellets is expected to grow. Technical problems, however, must still be solved before this product will be ready for wide use. These solutions will probably not be fully developed until about 1975. By that time, total world pre-reduced consumption is estimated at 10 million tons annually, after which a rapid increase is likely.

(2) Economic possibilities for the establishment or expansion of such industries in developing countries

The installation of new or additional processing facilities at iron-ore mines in the developing countries will generally be found economically sound. This has been definitely shown for the simpler forms of beneficiation operations at many established mines, in both developed and developing areas. For the more sophisticated process procedures; the upgrading and segregation of fines for sintering, and the production of pellets; the study estimates an investment cost of $10.50 per annual ton of oxide pellet output for a 2 million ton a year operation. The differential between added production costs and increased sales price is favourable for the operation, and a payout period of about five years - or a return of 20 per cent on the investment - is indicated.

For pre-reduced pellet production there are no actual data available. Theoretical analysis indicates investment requirements of about $40 per annual ton of product (excluding mining facilities) and a return on investment of about 8 per cent, or a 12½ year payout, after taxes.

The study judges that an economic basis already exists for the establishment of close to 20 million tons of new or additional oxide pellet capacity in the developing countries.

Furthermore, it finds (paragraph 173) that "fines and graded ores will equal more than three times the anticipated pellet shipments. For the developing country mining operation which may not be in a position to instal pelletizing facilities, . . . there is considerable latitude . . . in which to operate".

(3) Obstacles to exports from developing countries, particularly to developed countries

Given a generally favourable technical and economic position, the prospects for increased exports of processed iron ore from the developing countries could nevertheless be compromised by pragmatic obstacles. Some restraints may originate in the developing areas. These can, in fact, stem from a lack of official government steps to support the improvement of existing iron-ore mining and processing establishments, and to encourage the export of ores in semi-finished and processed forms, as discussed in Chapter VI (paragraphs 198-204).

Equally, if not more, significant are the obstacles that may arise in the developed countries. The most important of these is the possible imposition of tariffs and duties. The study finds (paragraph 111) that for lump ores, fines and oxide pellets no tariffs apply in the two largest importers of these products, Japan and the United States.

For pre-reduced ore values no direct precedents are yet available. The study notes (paragraph 113), however, that the iron-ore consumers have taken a position that indicates a disposition not to impose tariffs or duties on pre-reduced ores from developed nations.

Other possible obstacles of importance are problems in major fund obligations that may have to be assumed for the new facilities. The lack of local management and operating staff personnel may also be a limiting factor. The study judges that these deficiencies fall before existing co-operative relationships that already exist in many instances, between iron-ore producers and consumers of the developing and developed areas.

(4) <u>Possibilities for industrial co-operation between developed and developing countries</u>

The study indicates that such industrial co-operation is already in force in many instances. It notes (paragraph 119) that "closely related motivations provide the basis for joint activities that combine the experience and needs of the developed areas with the resources and enthusiasm of the developing countries".

(5) <u>Establishment of common markets and regional agreements for facilitating the economic integration and the establishment of regional and sub-regional industries in developing countries</u>

In general, there appears to be little scope for common agreements on regional and sub-regional lines, involving iron-ore production or iron-ore processing in the developing areas. The difficulty would seem to lie in the lack of any equitable <u>quid pro quo</u>. The study judges the established close relationships between iron-ore consumers and producers as key factors for improving the prospects of processed iron-ore exports from the developing countries. These ties might easily be strained by conflicting stresses that frequently arise in regional and sub-regional agreements.

Such a development appears more likely in the case of large-scale operations than of smaller ones. The study notes (paragraph 178) that interest in a centralized pelletizing project for West European consumption has waned for several reasons including a renewed interest in the possibility of receiving ores from overseas.

On the other hand, it is observed (paragraph 203) that "with greater assurance of continued high-level activity, a number of small nearby mines may more effectively work at a single centralized complex (with or without pellet facilities) which all could support jointly, but none could justify alone". It needs to be added that, notwithstanding a considerable effort, no example of such local co-operation among iron-ore miners in the developing countries could be found.

(6) <u>Capital outlay required for the establishment of an efficient industrial enterprise and probable period of amortization</u>

The reply to this inquiry has been partially indicated in the comments on point (2). In Chapter V, the investment cost for simple crushing plants is cited at 54 - 97 cents per ton of annual output; primary beneficiation units at about $2.00 per annual ton; and secondary treatment installations at $8.00 to $8.85 per annual ton.

The capital outlay estimate established by Battelle per annual ton of pelletizing capacity, for a plant producing approximately 2 million tons a year, is $7.75 for the pellet plant plus $2.75 for supporting auxiliaries.

The capital outlay required for a 2 million ton a year pelletizing plant of the latest design, when added to an existing mining operation, is estimated to be $21 millions. If the mine development must be included, the necessary investment will rise to $64 millions.

Operated efficiently and effectively, the earnings of the plant have been calculated to be sufficient for a pay-out of no longer than five years, or 20 per cent on the investment for the pelletizing facilities. If the total outlay, i.e., including the cost of the mine development, the period of amortization is found to be 10 to 15 years; an estimated return on investment of 10 to 7 per cent.

Comparable figures are indicated for pre-reduced operations in Chapter V.

(7) <u>Possible need for, and availability of, assistance from developing countries for the production and export of products of developing countries</u>

This subject has already been discussed under point (4). The aid referred to will undoubtedly be needed; as noted, the study finds that such assistance is, in fact, already available. It is now necessary that steps be taken to strengthen and broaden the existing co-operative ties between iron-ore producers of the developing area and iron-ore consumers of the developed country. It is judged in the study that increased on-site processing activities will do just that.

Chapter VI concludes (paragraph 204) that not the least consideration entering the decisions taken separately and jointly, "to add and broaden processing capabilities, at, or close to, iron-ore mines in the developing countries . . . is the evident conviction that the mutual benefits that have stimulated the initial decisions to seek and develop iron-ore resources in the developing countries, will be greatly enhanced by continued co-operative actions".

206. The preface also raises two other questions: "what kind of pre-treatment (shall be installed)?, and "where may the processing best be done"? The study indicates that the responses are: "every kind of pre-treatment, wherever such activities may be carried out economically". Opportunities for this are widespread in the developing areas, and it has been shown (paragraph 171) that broadened iron-ore processing capability at the site is tantamount to improved prospects for export to the international iron-ore market.

207. For the iron-ore consumer of the developed nation this presents important advantages that support and improve his iron-making and steel-making functions. For the iron-ore producer in the developing country the study notes (paragraph 189) that, "given a 1975 demand for approximately 100 million tons of run-of-mine and screened ore and fines; given the fact that after 1970 practically all ores consumed by iron producers in the developed countries will be beneficiated; and taking into account the advantages that ore-processing capabilities offer a mining operation, the prompt installation of at least some 'regular' beneficiation facilities at any mines which do not have them, would appear to be nothing less than an exercise in future survival".

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MEASURES FOR THE PROMOTION, EXPANSION AND DIVERSIFICATION OF EXPORTS OF MANUFACTURES AND SEMI-MANUFACTURES FROM DEVELOPING COUNTRIES; CO-OPERATION WITH THE UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION (UNIDO) AIMED AT THE ESTABLISHMENT AND EXPANSION OF EXPORT-ORIENTED INDUSTRIES IN DEVELOPING COUNTRIES; OTHER FORMS OF ECONOMIC INDUSTRIAL AND TECHNICAL CO-OPERATION

Prospects for exports of processed iron ore from developing countries

Communication from the Delegation of Australia

The following factual comments have been submitted by the Government of Australia for the information of the Committee in connexion with its consideration of document TD/B/C.2/29 and Corr.1 "Prospects for exports of processed iron ore from developing countries".

Page 14, Table II - 5

Exports to Japan 1970

Contracts already signed call for the export of 20 million metric tons of iron ore to Japan in 1970.

Exports - total - 1970

On information currently available, total exports of iron ore in 1970 will be at least 20 to 22 million metric tons.

Exports - 1975

Because of possible radical changes in Australian iron ore exports from 1970 onwards the Australian authorities consider that no estimate for exports during 1975 can be attempted, whether for total exports or for exports by destination.

GE.67-12326

Production and consumption

On the basis of the above estimates and allowing for domestic consumption, production of iron ore in Australia in 1970 will be of the order of 30 million metric tons.

Estimates of production or consumption of iron ore for 1975 are not attempted.

Page 31, Table III - 3

1966 pelletizing capacity is stated as 0.50 million metric tons.

Australia had no pelletizing capacity in 1966.

Plants under construction at Brickmaker's Bay, Tasmania (2.3 million metric tons) and Dampier (2.4 million metric tons) will bring capacity in 1967/68 to 4.7 million metric tons per annum.

The Whyalla pelletizing plant of Broken Hill Proprietary Co. will be completed in 1969 and will have a capacity of 1.5 million metric tons of pellets per annum.

Page 38

"... Hammersley Mining and Scott River (Australia) ..."

This statement should read:

"... the Hammersley, Mt. Newman, Robe River and Savage River deposits (Australia) ..."

Page 56

"Thus long-term contracts for Australia 62 per cent lump ore to be shipped to Japan stipulate an f.o.b. price of 14.4 cents per iron unit as against 18.3 cents for 63 per cent pellets; another contract calls for 15.5 cents and 19.1 cents for lump ore and pellets of comparable iron content (64 per cent)".

This passage should read:

"Thus long-term contracts for Australian (64 per cent) lump ore to be shipped to Japan stipulate a c. and f. price of 19 cents per iron unit as against 22.0 cents for 64 per cent pellets; one company has contracts for 15.5 cents per unit f.o.b. for lump ore (64 per cent Fe) and 18.5 cents per unit f.o.b. for pellets (63 per cent Fe)".

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MEASURES FOR THE PROMOTION, EXPANSION AND DIVERSIFICATION OF EXPORTS OF MANUFACTURERS AND SEMI-MANUFACTURES FROM DEVELOPING COUNTRIES; CO-OPERATION WITH THE UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION (UNIDO) AIMED AT THE ESTABLISHMENT AND EXPANSION OF EXPORT-ORIENTED INDUSTRIES IN DEVELOPING COUNTRIES; OTHER FORMS OF ECONOMIC INDUSTRIAL AND TECHNICAL CO-OPERATION

Prospects for exports of processed iron ore from developing countries

Note by the UNCTAD Secretariat

Corrigendum

Page 2, paragraph 6, line 5 : Substitute "more than 50 million" for "nearly 60 million".

Page 15, paragraph 38, line 2 : Substitute "content of the ore" for "content of the iron".

Page 21, paragraph 58, line 5 : Substitute "pre-reduced" for "preduced".

Page 45, paragraph 132, line 3 : Substitute "12 million tons" for "6 million tons".

Page 52, foot-note 5/, line 2 : Substitute "$ 4.85 : 0.55 = $ 8.85" for "$ 4.85 + 0.55 = $ 8.85".

Page 57, paragraph 163, last line : Substitute "$ 4.00" for "$ 5.00".

Substitute "Federal Republic of Germany" for "Western Germany" on the following pages :

- page 17, Table II-6.
- page 33, paragraph 80, line 3.
- page 34, paragraph 87, line 3.
- page 36, paragraph 96, last line.
- page 37, paragraph 103, line 4.
- page 44, footnote 5/, line 2.
- page 45, footnote 8/, first line.

GE.67-11933

23. 9. 71

the best approach ...".16/ A similar limited optimism is apparent in a January 1966 report that, "the oxide pellet does not yet seem to be the one (as the optimum feed for the blast furnace) as partially or pre-reduced pellets are closer at hand".17/

143. This report maintains an equally limited position in assuring that pre-reduction will develop relatively slowly, mainly because the techniques for using large quantities of the product in the blast furnace are still to be perfected. To a lesser degree, the details of the pre-reduction procedures also have not yet been fully solved. The estimate in Chapter II that a total of 10 million tons of pre-reduced pellets will be consumed globally in 1975 is based on the indicated programme of the Orinoco Mining Company in Venezuela. These plans have been formulated closely with engineers and the production staff of the U.S. Steel Corporation.

144. For the Orinoco operation, such a joint effort may easily be achieved since the same entity is both supplier and purchaser, both iron-ore producer and iron-maker. In the more typical situation in developing countries with producing iron-ore mines, one or more ore consumers may hold only a partial interest in the operation. However, this is usually sufficient to fix a mutuality of interest in installing advanced iron-ore treatment facilities. Even when no direct captive ties exist, long-term contracts with iron-makers in industrially advanced nations are generally contingent on the mine's competence in the most highly sophisticated ore-processing techniques.

145. Except for pre-reduced pellets, the technical and economic parameters of the various forms of iron-ore pre-treatment are all thoroughly understood by the iron-ore producing and consuming industries. For pre-reduction, the widespread interest in both fields assures an ultimate effective solution. In reaching that end, co-operative relationships already established through joint efforts by iron-ore producers and users will be continued and extended.

16/ Idem, italics by author of present study.

17/ Mining Engineering, March 1966, p.48. Article entitled "Iron Ore in Quiet Revolution", reporting on the discussions of the AIME meeting in Duluth, Minn., January 1966.

CHAPTER 7

ECONOMIC CONSIDERATIONS OF IRON ORE PROCESSING AT THE SITE

147. In "Economic Aspects of Iron Ore Preparation"1/ the Cogne mining operation in Aosta, Italy, is described. The deposit contains some 8 million tons of measured reserves (12 million tons indicated) of magnetites with 38 to 42 per cent iron content. The operation is a small one and over the ten-year period ending 1962 annual ore production averaged around 150,000 tons. The raw output is subjected to several processing treatments. The initial ore extraction, mined at an elevation of 2,500 metres, is reduced to 60-mm size in a crushing plant with a capacity of 200 tons per hour. The crushed ore is divided according to size by dry and wet separators installed close to the mine mouth. These produce four fractions of ore at a rate of 150 tons per hour. The output includes 25 per cent (of the crude ore) of rich (50 per cent Fe) lump (+17 to 50 mm) ore; 40 per cent intermediate (32 per cent Fe and +8 to 17 mm) lump; 20 per cent fines (42 per cent Fe and 0 to 8 mm); and 15 per cent tailings which are discarded.

147a. The usable output is moved 12 km by rail and cableway to Aosta where the rich lump is charged to a blast furnace. The two intermediate fractions are further processed in a second treatment plant that can produce 40 tons per hour of 200 to 300 mesh concentrate with 61 to 62 per cent iron content, by fine grinding and wet magnetic separation. The concentrate is then pelletised in a plant with an annual capacity of some 140,000 tons of 18–21 mm pellets.

147b. The observation is made2/ that it would seem "more economic if all three plants were located near the deposit ...". In addition the following capital cost figures are presented: crushing plants - 54 cents per ton of annual output; primary beneficiation plant - $2.00 per ton of annual output; secondary beneficiation plant - $8.00 per ton of annual output; pelletising plant - $12.00 per ton annual output. The discussion indicates that the mine site crusher and the first beneficiation plant were established over thirty years ago and that the second beneficiation unit and pelletising installations were built around 1958.

1/ Op.cit., pp. 171 et seq.

2/ Idem, p. 171.

[illegible] from data [illegible] in the same study[3] for similar facilities in Sweden give results that are a little higher than the above capital investment figures. For example, it is stated that "the cost of installing an iron-ore beneficiation plant varies between 5 and 25 Swedish crowns ($0.97 and $4.85) per ton of feed per year". The lower figure applies to "plants with no grinding mills and the higher one to multiprocess plants producing fine concentrates for pelletising on a small scale". In terms of annual output, these estimates equate to $0.97[4] for crushing plants with simple primary beneficiation units (the Italian "average" is $1.27), and $8.85[5] for installations producing secondary concentrate (the comparable figure is $8.00).

[illegible] On the other hand, the Swedish estimates for pelletising plants, $5.00 to $7.75 per ton of pellets produced per year, appear to be considerably below the $12.00 expenditure reported in the Italian data.

150. The spread in the figures can, in large measure, be explained by differences in date of purchase and erection of the facilities, vagueness of definition of what constitutes an "average" plant, and changes in unit investment costs that vary with the size of an installation. Under such conditions, any general capital cost estimate can, at best, offer only a knowledgeable judgement that represents a cross-section of published (and, just as often, unpublished) data. The reliability of such estimates rises with the increased quantity of accessible related cost information. For crushing, beneficiation and even sintering installations which have been part of the pre-treatment process for many years, the available data are well established. Pellet plants are of much more recent date and investment estimates are more difficult to fix firmly. An attempt will nevertheless be made in the chapter to indicate the current magnitude of pellet-plant capital requirements, and also to consider the corresponding operating and financial relationships.

<u>Capital cost estimates</u>

151. Because firm patterns and bases for generalised estimates of sintering plant capital costs have not yet evolved, the investment requirements discussed below are the result of the composite evaluations by Battelle staff experienced in the fields of iron-ore and iron-making, after discussions with pelletising facility suppliers and pellet-plant operators and engineers. The unit costs of $7.75 per ton of annual pelletising

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3/ Idem, p.226

4/ In the Italian example, weight recovery at the mine crusher is 100 per cent. The capital investment required per ton of feed and per ton of output are therefore the same.

5/ However, the second beneficiation plant has a weight recovery of 55 per cent; hence, $4.85 ÷ 0.55 = $8.85.

capacity plus $[illegible] per [illegible] auxiliaries [illegible] output of approximately [illegible] based on the Battelle staff determination. They [illegible] with published figures.

15[illegible]. For example, a recent Battelle report[6/] [illegible] pellet plants in the U.S. cost from about [illegible] per annual ton, exclusive of accessory mining and concentrating facilities" [illegible] higher figure [illegible] increases in more recent quotations and an effort to offset a bias introduced by the fact that most United States installations have been equipped with continuous grates. These are generally less costly than either shaft or grate-kiln plants because the former usually have larger individual outputs.[7/]

153. "Economic Aspects of Iron Ore Preparation" also refers to industry figures and calculations that spread from $5.40 to $6.80 per ton for facilities producing 1.75 million tons a year.[8/] For a plant with half that output (i.e. 2,500 tons of pellets a day), a second estimate of $6.50 to $[illegible].50 per annual ton is presented.[9/] A quotation from a third source states that "the capital outlay for a pelletizing plant alone amounts to $6 to $8 per ton of annual product, and the investment cost for a complete pelletizing plant, including all auxiliary equipment, will amount to $9 to $11 per ton of annual production. These figures apply to the pelletizing of finely ground concentrates, and with increased production capacity the specific investment cost will decrease".[9/] These estimates are said to be "close to one another" and can therefore be considered to describe the cost of pellet production objectively.[9/] They are also consistent with the Battelle estimates of $7.75 per annual ton of pellet output, plus $2.75 per ton of supporting auxiliaries, given at the beginning of this section.

154. It is desirable also to consider the investment requirements for a full mining operation. Because of the present-day demand for ores of the highest possible iron content such an installation, when properly designed, will include concentration and beneficiation components. Together, mining, preparation, and pelletizing facilities to handle 1.5 to 3.0 million tons of ore per year may involve an investment of $30 per ton of annual production of oxide or self-fluxed pellets.[10/] These figures may be checked against data for several plants built in the United States and Canada in the past few years, shown in Table V-1.

6/ For a private sponsor, and therefore not available for reference at this time.

7/ See Graff and Bouwer, "Economics of Raw Materials Preparation for the Blast Furnace", Journal of Metals, April 1965. For regular pellets, the pelletizing plant portion is given as $8.00.

8/ Table 36, p.69.

9/ Idem, p.70.

10/ Graff and Bouwer, op.cit.

TABLE V-1

Estimated investment requirements for iron-ore operations including mining, preparation, and pelletizing

Plant	Capital cost, million $	Annual capacity, million tons	Investment per annual ton of pellets produced, $
A	37	1.3	28.50
B	75	2.4	31.25
C	100	3.6	27.75
D	255	5.5	46.40
E	450	9.0	50.00
F	438	10.3	42.50
G	337	10.7	31.50

155. The investment requirements shown in Table V-1 present several features that need explanation. For example, the unit capital costs fall into two categories: $30 per annual ton of pellets for the smaller plants (A, B, C) and about $45 for the larger ones (D, E, F), with the largest installation (G) an exception that belongs in the first group. A probable reason that the economy-of-scale principle does not seem to apply to these data may lie in the fact that these plants were built during the early phases of the pelletizing development. Initial designs, for the larger units especially, are likely to have included a variety of "ideas" and tentative features that added substantially to the project cost. Furthermore, the related, and frequently sizeable supporting infrastructure component costs were not necessarily proportional to the designed output size of the various plants.

156. Many of the tentative features have been shaken down, and Battelle judges that a total "consensus" estimate of $32 per ton of pellets per year is indicated for a total new mining, preparation, and pelletizing operation producing 2 million tons of oxide pellets annually. Of this, the estimated $10.50 for a pelletizing and auxiliary facility represents approximately one-third of the necessary capital cost.

157. For pre-reduced pellets, the total capital cost rises increased to $55 per annual ton, the $23 difference being accounted for mainly by the inclusion of a reduction facility. =/

The pelletizing installation will cost about $13.00 per ton,[11/] equal to one-quarter of the required expenditure. Together, the reduction and pellet units, which provide the pre-reduction phase of the processing, account for about [illegible]0 per cent of the cost.

Operating costs estimates

158. Even more than capital cost figures, access to actual production costs for processing iron ore to pellets is severely restricted. Again estimates have been reached on the basis of opinions obtained from experts who are currently active in the design and operation of pellet plants. An average figure of $7.20 per metric ton is established for a yearly output of 2 million tons of 64 per cent Fe pellets produced from raw ore with an average iron content of 60 per cent. For an efficient modern mining practice, this estimate established by the Battelle staff is arrived at as set out below.

159. The cost of one ton of 60 per cent crude ore as mined, is established at $0.57, based on North American mining operations varying in annual output from 1.3 to 3.6 million tons. For an "enrichment" to 64 per cent Fe, a relatively simple beneficiation procedure with a concentration ratio of 1.3 is employed. The mining cost for a ton of pellets will, on this basis, equal $0.57 x 1.3 = $0.74. The beneficiation costs per ton of crude ore include $0.55 for the crushing and concentrating operations; this equals $0.72 per ton of pellets. The feed brought to the processing unit for one ton of pellets is therefore worth $1.46. The pelletizing operation itself is estimated to cost $1.32 plus $0.90 for movement, handling, storage, general overhead, and process royalties. The estimated operating cost to produce one ton of 64 per cent pellets is thus equal to $3.68. To this amount must be added provision for fixed financial charges; i.e. interest and amortization.

160. For the full 2 million tons a year operation assumed, the capital investment at $32 per annual ton equals $64 million. The fixed charges include the cost of capital, taken at 7 per cent on the full amount, plus an amortization expense of 4 per cent for a 25-year life. The annual financial expense is $7,040,000 or, for 2 million tons of product, $3.52 per ton.

11/ The increase over the $10.50 unit capital cost for a conventional pellet plant is largely due to additional and more complicated materials handling and heat-reaction control. See Bernstein, Reuss and Woolf: "A Cost Comparison: Production and Smelting of Prereduced vs. Iron Ore Pellets"; Journal of Metals, May 1966, p.653. The authors estimate the cost of a complete pre-reduced pellet plant for 2 million tons annually (using lignite) at about $3.40 higher than conventional pellet plants. The lower Battelle estimated difference of $2.50 per ton is judged more applicable, based on current views of conventional equipment suppliers.

[illegible] provision is made for [illegible], it being assumed that under the circumstances these would be waived. The sum of the two components, $1.64 operational expenses and $1.[illegible] fixed charges, gives an estimate per ton of [illegible] per cent oxide pellets of $[illegible], f.o.b. down [illegible] the point of shipping and ready for loading.

[illegible] Within the operational component, $1.6[illegible] for mining, preparation and pellet processing operations, the mining and beneficiation steps are quite well known. There is little question about the acceptability of the costs estimated for these operations. The experience on the pelletizing activity is less firmly established, but the $1.12 estimate corresponds almost exactly with a recently published breakdown.12/ With its proportionate share of fixed charges and royalty payments added the pelletising cost estimate becomes $2.95. This compares with a $2.50 per ton estimate in a Battelle study of May 1966 13/ and $2.40 cited in "Economic Aspects of Iron-Ore Preparation". 14/

"Payout"

163. It is now possible to consider the earnings potential of pelletising at the source. For comparable high iron contents, natural pellets are worth about $3.25 per ton more than unprocessed ore. Thus, long-term contracts for Australian 62 per cent lump ore to be shipped to Japan stipulate an f.o.b. price of 14.4 cents per iron unit as against 18.3 cents for 63 per cent pellets; another contract calls for 15.5 cents and 19.1 cents for lump ore and pellets of comparable iron content (6[illegible] per cent). 11/ From the Marcona Mines of Peru a price of 22.2 cents for lump ore compares with 26.5 cents for pellets in 1964/65 which is estimated to drop to 24.5 cents for the period 1966-70. 11/ These three cases indicate differences in the f.o.b. price of $3.65 per ton for Australia, and an average of $3.30 for Marcona ($4.30 to $2.30). Estimates by Graff and Bouwer give a price differential of $3.66 per metric ton, assuming Lake Erie ore prices plus depreciation of $8.94 per gross ton and $12.60 for pellets. 15/ Finally, a somewhat optimistic differential between natural ore and pellets may be quoted from an Indian news release that "it has been estimated that low-grade iron ore and fines, which normally

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12/ L.W. Smith, D.Beggs and F.G. Rinker, "A New Process for Oxide Pellets", Journal of Metals. "Process additions = $0.162; electric power = $0.259; Natural gas = $0.220; labor = $0.270; supplies = $0.300; Miscellaneous = $0.066; total = $1.28 per [metric] ton". (Note: The figures cited have been converted from a long to a metric ton base).

13/ See footnote 6/ above.

14/ p.78.

15/ Graff and Bouwer, "Economics of Raw Materials Preparation for the Blast Furnace", Journal of Metals, April 1965, Table III, p.391.