中に行われた塊鉱装入試験によつて確認され，その実施の必要性は戦後早く再度にわたつて強調されていた[5)6)]．粉鉱の塊成法としての焼結についても，早くからその能力の増強につとめ，ジョセフ報告でも焼結鉱使用率はアメリカより高いとみとめられる状況にあつた．ただわが国の事前処理論では，それがまず高炉装入物としての通気性の改善をめざすものであり，伝熱・還元過程の改善はその間接的効果としてえられるものとする考え方が支配的であつた．それ故ジョセフ報告の意義は，なすべくしてなされなかつた整粒を実施させる強力な挺子となつたというにとどまらず，事前処理における被還元性重視の思想をうちだし，それによつて自溶性焼結鉱への転換にいたる道に導いたことにあつたというべきであろう．

ジョセフ報告は整粒のさいの下限粒度を 5/8″，上限粒度は緻密な鉱石では約 2″，マグネタイトでは 3/4″ としたが，わが国で最終的に採用された粒度範囲は下限 8～10 mm，上限 25～30 mm と著しく小さくかつ狭くなつている．焼結鉱の品質についても，報告が被還元性の向上のためにはソフト化，すなわち強度の低下がさけられないとしたのに対し，被還元性と強度とを両立させることをめざし，さらには高塩基度化などによる軟化・溶融性状の改善という新しい考え方をうちだしている．すなわちわが国の原料事前処理技術はジョセフ報告の域をこえることによつて「恩返し」をしたのである．

原料炭，鉱石のいずれについても，国内資源の積極的活用をはかるべきものとしたジョセフ報告の見解の背後には，当時海上輸送費が高かつたという事情のほかに，それが安全保障の見地から当然だという考え方があり，また当時の GHQ の方針の反映もあつたと考えられる．いずれにしてもわが国の鉄鋼業はこの路線ではなく，高品位の輸入鉱石と高品質の輸入原料炭に依存するという路線を歩んだ．とくに高品質の輸入原料炭の多量配合によつてつくられる高品質のコークスは，自溶性焼結鉱とともに，大型高炉の高能率操業の大前提であつた．そして高い海上輸送費は大型専用船による大量輸送で引き下げようというのが，わが国鉄鋼業の答だつたのである．これも「恩返し」の一つのあり方であつたといえよう．

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Iron Ore Preparation and Blast Furnace Practice in Japan

By *T. L.* Joseph[*]

Introduction

This report deals with a study of the production of pig iron in Japan and of ways and means of improving the size preparation of iron ore so as to offset the limitations which weak coke places upon output and efficient blast furnace practice. Because of its low bulk density, coke occupies about 65 percent of the total volume of the blast furnace charge. The absolute size and the uniformity of size of coke are accordingly major factors that govern the overall permeability of the stock column and the volume of furnace gases that can be forced through the charge without building up excessive pressures and disturbing regularity of operation.

Pieces of coke smaller than 0.75 to 1.0 inches are normally screened out before it is charged but some breakage occurs during handling. When rather weak coke, which is subject to size degradation during handling, is the most economical fuel available because of a price differential in physical character of the ore burden so that a permeable charge can be obtained notwithstanding the use of small coke[†]. Ore particles smaller than about 3/8 of an inch in diameter are most detrimental from the standpoint of maintaining a permeable charge and should therefore be sintered.

Adjustments must also be made in the size of hard dense ore to assure metallization of such ore before it reaches the hearth and to provide more surface for heat transfer from the rising gases to the descending ore. The ore is a major constituent of the charge by weight and its size should accordingly be adjusted to absorb the maximum amount of heat from the gas stream. If insufficient ore surface is exposed to the gas, heat transfer is restricted with the result that a large amount of heat is carried off as sensible heat of the exit gases.

History of Size Preparation of Iron Ore in the United States

Differences in the smelting characteristics of iron

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[†] 文章の脱落があると思われる．

ores were recognized in the operation of primitive blast furnaces only a few feet high. Limonitic ores were given preference over dense ores because of greater ease of smelting. With small furnaces, only a foot or so in diameter, size preparation was a necessity. Moreover the problem of ample air supply was critical thus necessitating a selection of small but uniform sizes of ore free from fine particles.

As furnace size was increased and more efficient blowing equipment became available these early smelting experiences were forgotten. Until the Mesabi range was discovered in 1890, the tendency was to use relatively coarse ores such as the magnetite ores of New York and New Jersey, the hard hematite ores of Alabama and the so-called "Old Range" ores of the Vermillion and Marquette ranges in Minnesota and upper Michigan.

From 1890 to about 1920, the chief objective in American blast furnace practice was to modify the shape and dimensions of the furnace and methods of charging to permit the use of the finely divided Mesabi ores. Bosh angles were steepened and the bosh height was lowered. Bell clearance was reduced in order to deposit a relatively thick layer of ore adjacent to the furnace walls with little if any ore in the center of the furnace. (See Figs. 10, 11, and 12, of attached report, "Blast Furnace Process and Means of Control"). This arrangement of the stock protected the brick walls of the furnace against high gas velocities, high temperatures and excessive wear. Moreover, the very permeable central area, filled largely with coke, provided for the escape of a sufficient amount of gas to maintain the pressure, resulting from the resistance of the stock-column, at such a level as to permit the charge to settle regularly. Smaller coke or smaller ore decreased efficiency because the central escape area had to be enlarged at a sacrifice of gas-solid contact, thus preventing proper preheating of all materials by the hot stream of ascending gases and the proper reduction of the ore by the gas

Blast Furnace Practice on Weak Coke and Well Prepared Ore

Throughout the period from 1890 to 1920, when furnace lines and methods of charging were being adjusted to permit the smelting of fine Mesabi ore, great emphasis was rightly placed upon the physical character of the coke; and especially upon its porosity and strength because both contribute to a low bulk density and high overall permeability. The basic philosophy was to obtain coke and furnace lines that would give efficient operation regardless of how much fine ore was charged.

Experience at Provo, Utah

This philosophy was appraised more critically in the early 1920's when a blast furnace was erected by the Columbia Steel Corporation at Provo, Utah, to operate on weak coke made from high volatile coal without blending with low-volatile material. The use of a set of untried raw materials posed a number of problems including the proper use of coarse ore with small coke. Coke consumption, up to 2 800 lb per gross ton iron was much higher than in the normal American practice on the comparatively fine Lake Superior ore and coke of normal strength made from blends of high and medium or low volatile coal.

A sharp reduction in coke consumption obtained by crushing the ore to minus two inches demonstrated the value of proper crushing notwithstanding an ore porosity of about 24 percent and fairly good reducibility. Screening into three sizes, 2 inches by 1 inch, 1 inch by 3/8 inches and minus 3/8 inches, and charging the 3 sized in separate layers, affected another substantial reduction in coke consumption thus demonstrating the principle of sizing which eliminates intermediate sizes that nest between larger particles and reduce the percentage of voids or interstitial space available for gas flow. Finally, sintering of particles smaller than about 3/8 of an inch demonstrated the value of eliminating fines because small particles offer high resistance to gas flow. This development is cited because a total saving of 950 pounds of coke per ton pig iron was made by utilizing the three cardinal principles of ore preparation; (1) crushing coarse ore to a size that will permit more efficient heat transfer and more complete reduction in the upper part of the furnace, (2) screening into separate sizes and charging each size separately and (3) sintering all pieces smaller than about 3/8 of an inch. Additional blast furnaces, built during World War II by the Government of the United States, at Geneva, Utah, are also operating satisfactorily on weak coke, sized iron ore and sinter.

Experiences at Fontana, California

Practice at the Fontana, California plant of the Kaiser Steel Corporation is directly applicable to conditions in Japan for a number of reasons. This practice demonstrates in a practical way that high sulphur ore can, after proper crushing and sintering , be smelted with a relatively low consumption of weak coke. Ore is crushed to aid the elimination of sulphur notwithstanding the fact that, except for high sulphur content, the crude ore is more satisfactory raw material than the sinter produced from the minus 5/8 inch pieces produced in

Table 1. Blast furnace performance and practice (DOBSCHA).

	Normal Ore Burden	Prepared Ore Burden	Difference	
			Amount	Percent
Production :				
Iron, Net Tons Per Day	1 324	1 605	+281	+21.2
Flue Dust and Sludge, Lb. per ton Iron	284	227	− 57	−20.1
Consumption :				
Net Coke, Lb. Per Ton Iron	1 782	1 510	−272	−15.3
Gross Coke, Lb. Per Ton Iron	1 859	1 574	−285	−15.3
Flux, Lb. Per Ton Iron	1 007	677	−330	−32.8
Unrecovered Metallics, Percent	1.5	0.8	−0.7	−46.7
Iron Analysis, Percent :				
Silicon	0.91	0.87	−0.04	− 4.4
Sulphur	0.030	0.030	0.0	0.0
Casts over 1.25 percent Silicon	5.3	1.7	−3.6	−67.9
Casts over 0.050 percent Sulphur	1.2	0.3	−0.9	−75.0
Slag :				
Analyses, percent :				
Silica	34.9	34.8		
Alumina	12.3	12.8		
Lime	46.0	45.6		
Magnesia	3.7	3.8		
Sulphur	2.0	2.1		
Ratio Bases to Acids	1.05	1.04		
Calculated Volume, Lb. Per ton Iron	1 264	968	−296	−23.4
Practice :				
Air Blown, Std. Cu. Ft. Per Min	83 651	85 651	+2 047	+ 2.4
Blast Pressure, Lb. Per Sq. Inches	20	22	+ 2	+10.0
Blast Temperature, Degrees F	969	916	− 53	− 5.5
Top Temperature, Degrees F	356	323	− 33	− 9.3
Added Water, Lb. Per Ton Iron	151	92	− 59	−39.1

crushing. In order to produce low sulphur sinter (about 0.06 percent) a relatively small amount of fuel is used and the sinter produced is of the soft oxidized and easily reduced type.

A special method of handling this type of sinter deserves attention. In order to minimize breakage, the hot sinter is given its roughest handling between the sintering machine (Dwight-Lloyd) and a special air cooler. After air cooling the product is transferred to the blast furnace by a conveyor belt to prevent breakage. This practice has received considerable attention in the States because fuel consumption of less than 1 400 pounds of coke per net ton of pig iron, or a coke ratio of 0.70, has been realized with a 27 foot hearth furnace operating on relatively weak coke and making 1 250 short tons (1 130 metric tons) per day.

Blast Furnace Performance on Normal Lake Superior Fine Iron Ore and upon Prepared Ore Burden

The most recent outstanding progress in blast furnace practice in the United States has resulted from the use of prepared ore burdens and from high top pressure. Several furnaces have produced more than a ton of iron per minute by the use of sinter and coarse ore from which fine sizes were removed and sintered. An outstanding example of what can be accomplished by ore preparation has been reported by *H. F.* DOBSCHA(1). Comparative tests were made with two modern identical blast furnaces with hearth diameters of 27 feet, 6 inches. A burden of 50.8 percent coarse ore, 29.2 percent of concentrates free of small sizes and 20.0 percent sinter was charged continuously on one furnace for one month and a normal burden of Lake Superior (fine) ore charged on the other. During a change over period of one month the burdens were reversed and the test was then continued for two months. Results of the tests are given in Table 1, taken from DOBSCHA's report.

Although the major part of the improvements reported in Table 1, were due to physical improvements in the ore burden, it should be noted that a reduction of 296 pounds of slag contributed substantially to the decrease in coke-consumption and to the increase in tonnage.

As a result of the improvement obtained with prepared ore burdens, the U. S. Steel Corporation began the operation of a new sintering plant and a new nodulizing kiln on the Mesabi range about April 1, 1951. The Dwight-Lloyd sintering Machine and the rotary kiln for nodulizing will each have a daily capacity of 1 000 tons. Other steel companies using Mesabi ore are expanding their sintering capacity as a means of increasing blast furnace capacity.

Ore preparation is also well advanced in the Alabama district where the Tennessee Coal and Iron Company crushes hard dense hematite to about one inch and sinters sizes smaller than 1/4 inch. The ore preparation plant is designed to

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(1) *H.F.*DOBSCHA, Effect of Sized and Sintered Mesabi Iron Ores on Blast Furnace Performance. Year Book American Iron and Steel Institute, 1948.

reduce the top size for more complete reduction, to eliminate small sizes that choke the furnace and, last but not least, to blend ores that vary widely in silica and lime content.

Size preparation of ore is making rapid advances in England where the Appleby-Frodingham plant is producing about 700 tons of basic iron per day in a furance with a heart diameter of 22 feet operating on ore with a percentage analysis as follows: Fe, 33.40; SiO_2, 10.50; Al_2O_3, 6.05; CaO, 14.05; MgO, 1.16; Moisture, 7–9. The slag volume averages 2 150 pounds and the coke 2 240 pounds per net ton of pig iron.

Preparation of Magnetite Iron Ore

The size preparation of magnetite ore deserves special consideration because such ore is normally difficult to reduce even in small sizes. Moreover, the magnetic properties permit concentration for partial elimination of silica and decrease in slag made and coke required per ton of iron.

Sweden has made outstanding progress in magnetic concentration and in sintering practice. These developments were undertaken to save coke, all of which is imported at a cost of about $20.00 per ton. Much of the saving has been realized by a decrease in silica and in turn in the amount of slag produced. An easily reduced, self-fluxing sinter made under carefully controlled sintering practice on the batch type of machines, has also contributed to a gradual decrease in coke during the last 20 years from about 2 250 pounds to a current level of about 1 500 pounds per net ton of pig iron. Daily output of coke blast furnaces averaged 175 tons in 1948. In other countries, fuel consumption has been rising because of the poorer quality of raw materials.

Although magnetite ore from the Adirondack deposits York and New Jersey were smelted extensively in the early days of iron production in the United States, their use declined with the discovery of the large deposits of Lake Superior hematite. Magnetite was used in several small furnaces producing foundry iron but its low reducibility and tendency to reach the furnace hearth unreduced have been generally recognized. Furnace operators are accordingly reluctant to use raw magnetite, a practice that has been discontinued in the United States and in Sweden. Some 4 to 5 million tons of magnetite concentrates, smaller than 20 mesh, are produced and sintered annually in the United States. The general practice is to produce a hard-burned sinter of approximately the following percentage composition: Fe, 64.0; SiO_2, 5.38; Al_2O_3, 2.71; CaO, 0.22; MgO, 0.24; TiO_2, 0.50; H_2O, 1.20.

Need for Improved Sinter Quality

Within the past few years there has been a growing worldwide awareness that sinter quality is irregular and generally rather inferior. Excellent furnace practice at Fontana, California, on relatively weak sinter has received considerable attention. More people are beginning to realize that while sinter is a very porous material, this does not make it an ideal material because the pores are large and surrounded by dense cell walls, thoroughly glazed, in many cases. These glazed cell walls are extremely difficult to reduce. The high but coarse porosity contributes in only a minor way towards reducibility but gives a product of low bulk density and low heat absorbing capacity. In operating on 90 percent of hard-burned sinter, blast volumes are reduced about 15 percent to allow more time in the furnace or a longer time for reduction. Even when this precaution is taken, high CO/CO_2 ratios indicate high solution loss.

$$CO_2+C=2CO-5.830\ \text{BTU/1b. C.} \quad (1)$$

High top temperatures indicate a low heat capacity of sinter, inherent in its low weight per cubic foot.

In most sintering plants the major concern is to provide a means of using fine iron bearing material, with only very limited attention to quality except for size and strength. Blast furnace sinter should be considered on the basis of its value to the blast furnace rather than on the tonnage of agglomerated product sent to the furnace without regard to its effect on blast furnace operation. This condition is not the fault of the sintering plant operator because most blast furnace operator can not make up their minds as to what constitutes good-sinter and on methods of testing for sinter quality.

Blending of Iron Ore

Regularity in the chemical composition of all raw materials is essential to good blast furnace practice. If the ores used do not maintain their respective analyses uniformly, but vary widely in the amount of sillica and alumina present, close control over the composition of the slag and over the analyses of the iron, and over furnace efficiency in general, is quite impossible.

Perhaps the most thorough blending of ore is done in the Lake Superior district where ore is graded to conform closely with a guaranteed season's analysis. This practice illustrates the care taken in well planned ore grading Underground mines operate the year around and the ore is stockpiled during the winter months when the shipping season over the Great Lakes is closed.

When Lake ore shipping is resumed in the Spring, ore is removed from the stockpile. Table 2 shows a comparison of the analyses taken going into and out of a stockpile containing 1.5 million tons. The analyses reported are based upon 193 000 pounds of samples representing some 772 000 sampling points.

Table 2. Ore moved from stockpiles on gogebic.

Range in 1949 (Thomas)	Percentage composition		
	Iron	Silica	Moisture
Going into stock	59.5	8.85	11.24
Shipped out of stock	59.9	8.36	10.83
Difference	0.4	0.49	0.41

Results of grading of a 10 000 ton typical Lake ore boat are illustrated by an analysis of the ores entering the boat, by an analysis of the ore deposited on the bottom, intermediate and top layers in the boat and by the analyses of ore deposited in three compartments of the boat.

Table 3. Cross section of ore in Steamer Joseph Sellwood, 10 428 B/L tons, year 1949 (Thomas).

Ores entering boat

Ore	Tons	%Fe	%SiO_2	%Moisture
A	5 613	53.68	8.38	10.83
B	839	54.05	7.05	11.83
C	2 929	54.17	7.46	12.14
D	1 047	50.25	9.61	11.50
Average	10 428	53.50	7.58	11.35
Guarantee		53.84	7.76	10.43

Bottom, intermediate, and top layers in boat

Ore	Tons	%Fe	%SiO_2	%Moisture
Bottom layer	4 278	53.73	7.81	11.03
Middle layer	3 904	53.45	7.26	11.67
Top layer	2 246	53.15	7.72	11.39
Average	10 428	53.50	7.58	11.35
Guarantee		53.84	7.76	10.43
Compartment #1	3 155	53.30	7.49	11.58
Compartment #2	3 529	53.61	7.58	11.27
Compartment #3	3 744	53.74	7.66	11.21
Average	10 428	53.50	7.58	11.35
Guarantee		53.84	7.76	10.43

Bedding of Iron Ore

When selective mining, careful sampling of cars or boat shipments and grading of iron ore at the mines is impractical, it becomes necessary to grade and blend ores at the furnaces. Although plants in Alabama and in Colorado operated for years on ore delivered in railroad cars to ore bins at the blast furnaces, irregularities in furnace performance were associated with variations in the analysis of the ore from ore car to another. Facilities for ore blending have been installed in Alabama and at plants in Utah, Colorado, and California. In the most widely used method, known as the-Robins-Messiter system, incoming ore is deposited as thin layers on stockpiles which are subsequently reclaimed in such a way as to get a vertical cross section of the layers. This system which has been used to blend ore forwarded from many small mines to so-called "custom" lead and copper smelters in the Western part of the United States, has recently been installed at the Appleby Frodingham plant in England. This movement towards uniform blast furnace feed, well established in other parts of the world, is badly needed in Japan. Japanese blast furnace practice can never be brought up to a high level of efficiency until better control can not be exercised over the composition of the ore burden.

Many factors such as freezing temperatures, number of ores used, variations in their character and the space available must be considered in selecting a blending system. A special study of this matter by American engineers who have had considerable experience with such problems should be made to determine the system best suited to Japanese conditions.

The Sintering Process Iron-bearing Materials

The sintering process was originally devised to agglomerate finely divided lead and copper sulphide concentrates produced by flotation. It was subsequently used to treat iron blast furnace flue dust, 90 percent of which is smaller than 14 mesh. The process is currently used to treat flue dust from dry dust catchers, filter cake from wet washers, iron sulphide concentrates, pyrite cinder, magnetite concentrates, and the small size screened from various types of iron ore. The average particle size of mixtures being sintered in the United States ranges from 0.0014 to 0.155 inches. This wide range in average particle size is due to the wide range in the size of material in the sinter feed. Iron bearing materials range from ore screened at 5/8 inches to minus 100 mesh concentrates. The gradual trend to sinter coarser sizes, with the advent of the size preparation of iron ores, is a major cause for much of the poor quality of sinter being produced today.

Nature of the Sintering Process

The process is based upon the combustion of carbon uniformly distributed between mineral particles, and the consequent attainment of temperatures that will produce mineralogical changes, grain growth and partial fusion sufficient to link the particles together into a continuous mass of high porosity.

Deficiencies in Sintering Practice and in the Quality of Sinter Produced

The presence of coarse particles in the mixture for sintering is detrimental because, in the short time available, it is impossible to transform 3/4 inches or 1 inch pieces of ore into a sintered mass. Moreover, great care must be exercised to prevent such coarse particles from segregating due to their greater inertia, flatter angle of repose, and tendency to collect in low spots of bins and charging hoppers. The inevitable result is wide variations in permeability, in carbon content, in the temperature attained in various parts of the bed and in character of the sinter produced. High percentages of fuel intended to attain temperatures that will sinter the carse ore particles do not lessen these irregularities but merely produce badly overburned sinter in some parts of the bed.

Since the sintering process depends upon the combustion of carbon by air drawn through the bed, the rate and uniformity with which it proceeds depends in large measure upon the absolute and relative permeability of various parts of the bed. This is necessarily true, because the amount of air drawn through the bed with fixed fan equipment is governed by the permeability of the bed. Beds of uniformly high permeability will sinter more rapidly and more uniformly, than otherwise, thus tending to increase production and uniformity of product.

Air leakage, normally large on Dwight-Lloyd machines, will increase as bed resistance increases, thus tending to lower the sintering rate. The whole purpose of sintering is to improve the permeability of the blast furnace stock to gas flow. Some of the principles that apply to the distribution of the gases in the blast furnace should be applied to the sintering process which for some reason has received little study. Most of the variations in the permeability of the sinter bed stem from the use of coarse ore particles and improperly screened returns. Depositing of the sinter mixture on the machine in such a way as to avoid packing and to segregate large pieces at the lower part of the bed improves permeability and lengthenes grate life.

Criteria of Sinter Quality

Sintering plant operators have not been supplied with definite measurable standards of sinter quality. They have accordingly not had definite objectives to work towards. In the writer's opinion, good sinter will have the following properties:

1. Particle size from 5/8 inches to 4 inches.
2. Absence of glazed surfaces thick cell walls and large pores that contribute neither to permeability of the stock nor to reducibility.
3. Highly oxidized with large percent of the total iron as hematite. (Low ferrous iron)
4. High reducibility.

Pig Iron Costs in Japan and in the United States

A detailed study of costs is beyond the scope of this report but a few comparisons are made in Table 4 to indicate the distribution of costs and the promising areas for reducing costs in Japan. Production costs in the States are not available for 1951, but except for an advance of \$1.00 per ton in the price of Lake Superior ore and an estimated advance of about \$1.00 per ton of coke, they are essentially the same as for 1950. Such an increase in the cost of these raw materials would add about \$ 2.50 to the raw material costs given in Table 4, for the United States. In passing, it is of interest to point out that the average cost of all raw materials for five typical plants in the States for 1950 was \$28.04, per net ton of pig iron. It appears therefore, that current raw materials costs in 1951 in the States will average about \$30.00 per net ton of pig iron or about one-half of similar current costs in Japan. Some differences between Japanese and Stateside figures are shown in Table 4 for total operating costs and for gas credit, but they are much smaller than differences in raw material costs. In round figures, the difference between Japanese and American costs of raw materials per net ton of pig iron is about \$30.00 of which \$16.00 applies to coke and \$14.00 applies to ore. Japanese pig iron is made from mixtures of domestic ore and imported ore and with coke made from blends of domestic coal and imported coal.

The current distribution of raw materials costs between domestic and imported materials appears to be approximately as follows:

Coke
Furnace coke from domestic coal; 0.65 N.T. at \$29.40=\$19.10
Furnace coke from imported coal; 0.30 N.T. at \$36.00=\$10.80
Total coke cost per N.T. pig=\$29.90

Ore
Domestic ore; 0.316 tons at \$11.20=\$ 3.54
Imported ore; 1.040 tons at \$24.10=\$25.10
Total ore cost per N.T. pig=\$28.64

Transportation costs make up a large part of these total costs. For example, ocean freight on 0.4 ton of coal from the States for the 0.3 ton coke is about \$8.00 out of the 10.80. In the case of the imported ore, freight on 1.04 tons at \$15.00 per ton is \$15.60 or about 62.0 percent of the total imported ore cost per net ton of pig. Considering the imported raw materials as a whole, the transportation costs will total about \$23.60 per net ton of pig iron. On this basis, an annual production

Table 4. Costs per ton pig iron in Japan and in the United States.

	Overall Japan Dec. 1950		Japan Co. No. 1 June 1951		Japan Co. No. 2 June 1951		U.S.A. Like Erie Pittsburgh 1950	
	¥/M.T.	$/N.T.	¥/M.T.	$/N.T.	¥/M.T.	$/N.T.	$/N.T.	$/N.T.
Raw material cost :								
Coke	8 500 1)	21.42			11 880 3)	29.94	14.15 4)	10.95 5)
Ore	8 710	21.95			11 360	28.64	12.15 6)	15.25 7)
Flux 10)	300	0.76			640	1.61	1.20 8)	1.20
Total	17 510	44.13	23 500 2)	59.22	23 880	60.19	27.50	27.40
Operation cost : 9)								
Item 1.								
Labor-overhead reserve for lining and depreciation	2 390	7.02			1 320	3.33		
Item 2.								
Supplies and service	1 020	2.57			1 600	4.03		
Total	3 410	8.59	4 400	11.09	2 920	7.36	4.70	4.70
Credit for gas	1 750	4.41	1 860	4.69	1 750	4.41	2.08	2.08
Total cost	19 140	48.31	26 000	65.62	25 050	63.14	30.12	30.02

Note : 1) Coke price M.T.—¥10 000
Coke price N.T.—$25.20
2) ¥14 800 or 74 percent of this cost is spent for importation
3) Coke price M.T.—¥14 000
Coke price N.T.—$35.30
4) Coke price N.T.—$14.40
5) Coke price N.T.—$11.60
6) Ore price L.T.—$7.25
7) Ore price L.T.—$9.10
8) Est. price stone L.T.—$2.40
9) Item No. 1, is supposed in Japanese practice to be inversely proportioned to pig iron production.
Item No. 2, is supposed to be independent of production.
10) Limestone price M.T.—¥800
Limestone price N.T.—$2.22

of 3 600 000 metric tons or about 4 000 000 net tons of pig iron, will require $94 400 000 to bring imported ore and imported coking coal to Japan. Such an expenditure implies transportation costs on imported ore and imported coal as follows:

3 950 000 N.T. ore at $ 15.00–$59 250 000
1 673 810 N.T. coal at $ 21.00–$35 150 000
Total cost of transportation–$94 400 000

It is evident that a reduction of these transportation costs offers the greatest opoortunity for reducing the cost of producing pig iron in Japan. Current freight rates are admittedly high, but if the transportation cost of imported materials were reduced 50 percent, the possibility of saving $ 47 200 000 a year or some considerable fraction of this sum offers a strong financial inducement to: (a) develop ways and means of using more domestic iron ore, (b) to utilize domestic iron pyrite in greatly increased amounts and (c) to prepare the ore burden by crushing screening, sizing and sintering to permit the use of coke made from much larger proportions of domestic coal.

The profitable use of more domestic ore will necessitate: (a) concentration of crude ore including pyrites wherever possible, (b) further exploration for material amenable to concentration, (c) the development of ways and means to eliminate such detrimental elements as sulphur, arsenic and copper, ahead of smelting.

The amount of carbon available over and above the amount needed to form, melt, and preheat the slag made from the ash in the coke drops rapidly with an increase in ash content. Efforts to produce ore burdens well prepared physically should be accompanied by an extension of effective washing of coal to remove ash. Although the reasons are not readily apparent to the writer, the current cost of producing coke from domestic coal is extremely high. It appears therefore that rigorous pursuit of any and all methods to reduce the consumption of very expensive furnace coke will be justified.

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