資料

ジョセフの報告(3)

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Iron Ore Preparation and Blast Furnace Practice in Japan

By *T. L.* JOSEPH

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The Utilization of Iron Sulphide Ore of Japan

The pyrite and pyrrhotite (iron sulphide) deposits of Japan constitute the largest source of domestic iron. Moreover, the judicious exploitation of this ore will stimulate home industry, and provide a greatly needed safeguard against the dislocation of the steel industry that would inevitably arise from curtailed water transportation in times of duress.

In a recent report[3] on the "Iron and Manganese Ore Potential Japan", Dr. *Charles F.* PARK, Jr. makes the following statement, "In 1947 the reserves of pyrite were estimated at 106 235 925 tons. Exploration since that time probably has increased this amount and the potential reserved are far greater. The pyrite and pyrrhotite ores of Japan probably contain as an average between 40-50 percent of iron. After roasting to remove sulphur, the residues contain 60 percent or more of iron. In Europe and in the United States such residues are fully used and they should be in Japan."

In 1925, the Tennessee Copper Company developed a selective flotation process for the treatment of ore containing the sulphides of copper, iron, and zinc. Early in this development the iron sulphide concentrate contained amounts of zinc that restricted the market for the pyrite cinder produced in the production of sulphuric acid. The flotation circuit was subsequently modified to separate the zinc sulphide and thus bring the zinc content of the iron sulphide within the limits set by steel companies. As the following table shows, the iron bearing product is also low enough in copper to permit wide use.

Details of the present flotation practice in Japan are not available, but the ease and reliability of small scale flotation tests leave little doubt as to the ability of the metallurgists, chemists and mining engineers of Japan to work out a process applicable to deposits such as Yanahara in Okayama Prefecture, Kawayama in Yamaguchi Prefecture, and Hitachi in Ibaraki Prefecture. This assurance is based upon the great similarity in the mineralogical make up of the Tennessee deposits and those cited for Japan. The Kawayama ore with an estimated reserve of 10 000 000 tons of massive sulphides is very similar to the Tennessee Copper Company ore as the following tabulation of percentage composition will show:

	Kawayama Ore	Tennessee Ore
Copper	0.83	0.80
Iron	38.52	36.00
Sulphur	27.34	27.60
Zinc	1.32	0.70
Chalcopyrite	2.40	2.76
Pyrrhotite	58.50	39.20
Pyrite	4.50	20.00
Spholerite	2.50	0.80

From memorandum Aug. 4, 1950 by *Joseph H.* HARRINGTON. N.R.S.

Details of the flotation practice of the Tennessee Copper Company are given in Technical Publication No. 1680 of the American Institute of Mining and Metallurgical Engineers. This company treats about 1 400 tons of ore per day, recovering 92 percent of the copper in a concentrate assaying 20 percent copper. Although the Kawayama deposit may differ in copper content and to a small extent in other ways from other pyrite deposits in Japan, there seems to be no serious obstacles to prevent much wider utilization of the pyrite ores of Japan as a source copper sulphuric acid and elemental sulphur and a very high grade sinter for iron smelting.

Fineness of grinding to mechanically unlock the various sulphide minerals will have to be determined by experimental work. The Tennessee con-

Constituent	Iron concentrate	Calcines	Sinter
Fe	52.90	64.40	68.80
S	43.00	10.00	0.05
SiO_2	0.90	1.10	1.20
CaO	0.40	0.50	0.50
MgO	0.28	0.36	0.38
Al_2O_3	0.25	0.33	0.33
Cu	0.10	0.11	0.12
Zn	0.17	0.19	0.20
Mn			0.07
P			0.006

Data by *R. B.* PURNS, Asst, Smelter Supt., Tennessee Copper Co., Copperhill, Tenn. Proceedings, Blast Furnace, Coke oven and Raw Materials Conf. AIME, 1949.

3) *Charles F.* PARK, Jr. Iron and Manganese Ore Potential of Japan, Preliminary Study No. 50, Natural Resources Section, May 1951.

centrate averages about 75 percent minus 200 mesh and 56 percent minus 325 mesh material. Typical percentage analyses of the iron concentrate produced in the Tennessee plant are as follows:

Sintering of Iron Sulphide Concentrate

The Tennessee iron concentrate is roasted to remove about 80 percent of the sulphur content as sulphur dioxide bearing gas for use in acid manufacture. As indicated in the foregoing tabulation, about 10 percent sulphur is left in the roasted product to supply heat for the sintering operation. Sulphur dioxide evolved during sintering is also recovered in the production of acid. In view of the fine size of the concentrate, special attention is given to charge porosity, the most important requirement of sintering fine material and the most difficult one to achieve. Reference has been made therefore to a paper by *R. R.* BURNS, on the sintering of fine flotation sulphide at Ducktown and at Copperhill, Tennessee.

Economic Aspects of Iron Pyrite Treatment in Japan

The utilization of the iron sulphide deposits of Japan will require the cooperation of the mining companies, the chemical companies and the steel companies. At present the extremely low price paid for pyrite cinder offers little incentive to produce a high grade product. Price incentive for quality would discourage the haphazard mixing of siliceous pyrite with material more suitable for the production of pig iron. It is hoped that the present committee on the utilization of pyrite cinder, on which representatives of the chemical, the mining and the steel companies are serving, will be instrumental in establishing more efficient and less wasteful methods of blending and handling pyrite ore.

Markets for the Sulphur from Iron Pyrite

Another large tonnage of high silica pyrite in Japan probably should be replaced at chemical and paper plants by low silica high iron pyrite which can be made into material suitable for making pig iron.

Elemental sulphur is the most convenient form for marketing sulphur for export because one ton of sulphur is equivalent to 2 tons of SO_2 and nearly three tons of 66° Bé acid. The production of elemental sulphur is therefore extremely important when markets must be found in remote consuming centers. A world wide shortage of elemental sulphur has recently developed. A greatly expanded production of iron pyrite might create a problem in marketing the sulphur. It is pertinent therefore to cite a statement from a recent article on Sulphur by *William L.* SWAGER and *John B.* SULLIVAN which appeared in the May, 1951, issue of The AIME Mining Journal. The statement follows†. "By proper treatment of pyrite and marcasite, it is possible to recover as much as 35 percent of the sulphur in elemental form, the remainder being recovered as sulphur dioxide. Byproduct Fe_2O_3 in the form of pyrite cinder is increasing in value as well as the sulphur constituents. Undoubtedly these economic factors will bring on the market increasing amounts of sulphur in one form or another."

It is significant to note that sulphides are being considered in the United States as a source of sulphur and iron. This is due to the increased value of iron ore and to the rapid depletion of the reserves of elemental sulphur.

Blast Furnace Practice in Japan

In order to obtain an overall picture of blast furnace practice in Japan, a study was made of raw materials consumed and the practice on the furnaces which were active during November and December of 1950, and January and February of 1951. This comparison has not taken into consideration certain details such as lining life, physical character of coke, and some other factors which affect furnace performance. It is not intended to be an accurate and complete survey of the performance of individual furnaces which vary from time to time in their behavior for reasons not always understood. The purpose of the comparison is to bring out important characteristics of the blast furnace practice in Japan as a basis for comment and suggestions.

Raw Materials

It is evident from the information on raw materials that relatively large amounts of sinter are being used in the blast furnaces of Japan. Omitting Kukioka No. 1 furnace from consideration, the percent of sinter in the mixture averages 36.57 percent which is about double the proportion used in average ore burdens in the States. (See Table 7). Except for the excellent sinter made at Kamaishi Plant of Fuji Iron and Steel Co. the quality of sinter can be greatly improved by overcoming the handicap imposed by the use of improperly screened ore (especially limonite) and by other means. However, the rather extensive use of sinter represents an important step in the preparation of iron ore which can be further improved by

† "follows" には疑問があるがそのままとした.

Table 7. Average blast furnace

Blast furnace	Hearth diameter (ft.)	Iron ore & sinter	Consumption of raw materials % Sinter	Scrap	Total	Limestone	Grand total	Coke rate (lbs)	Coke ash (%)	Pig iron output net ton/ day	Pig iron output net ton per sq.ft. act. ann. of hearth
		Net tons per net ton of pig iron									
Wanishimachi No.3	14.00	1.635	53.3	0.166	1.801	0.369	2.169	1 865	14.53	280	1.85
Nakamachi No.3	21.98	1.670	42.8	0.175	1.845	0.394	2.239	1 764	14.96	650	2.16
Kamaishi No.8	22.14	1.698	31.56	0.087	1.771	0.197	1.968	1 725	12.33	548	1.80
Kamaishi No.10	22.14	1.642	38.35	0.115	1.757	0.218	1.975	1 540	12.49	728	2.39
Hirohata No.1	23.62	1.641	34.36	0.114	1.784	0.413	2.197	1 756	14.72	960	2.88
Kawasaki No.4	21.98	1.754	22.61	0.167	1.921	0.207	2.128	1 847	14.2	639	2.12
Kawasaki No.5	22.96	1.389	25.31	0.294	1.683	0.401	2.084	1 745	14.5	675	2.39
Higashida No.1	15.74	1.573	44.9	0.152	1.725	0.442	2.167	2 053	15.90	323	1.76
Higashida No.4	17.06	1.698	36.2	0.176	1.874	0.479	2.353	2 070	15.73	378	1.92
Higashida No.5	19.68	1.608	33.5	0.181	1.789	0.476	2.265	1 926	15.57	469	1.82
Kukioka No.1	20.01	1.888	1.4	—	1.888	0.574	2.462	2 127	15.74	450	1.71
Kukioka No.2	22.96	1.636	39.4	0.222	1.858	0.346	2.204	1 759	15.73	713	2.23

crushing certain dense imported ores and by finer crushing of some ores which are not being crushed, and by the installation of sufficient equipment to sinter all material smaller than 5/8 of an inch. The use of porosity and reducibility data in determining which ores to crush and the maximum size for blast furnace use is given in exhibit A which contains a reference to a detailed published paper.

Screen analyses show that from 25 to 50 percent of many of the imported ores is in the minus 50 plus 10 mm fraction, (2 inches to 3/8 inches). This is a most favorable size range for heat transfer and for the indirect reduction of all ores except magnetite. Great improvements in furnace practice can accordingly be made by increasing the proportion of this favorable size range by crushing some of the denser imported ore to a smaller size. Moreover, it appears that the ultimate charge would then contain a high proportion of ore in this favorable size range. Due to higher bulk density, properly crushed and sized ore is a better raw material than sinter of comparable chemical composition. For example, the amount of plus 2 inch material in ores such as Goa, Calcutta, Hongkong, and Larap, ranges from about 10 to as high as 86 percent. (See Table 2 Appendix). It is possible to crush such hard material at 2 inches without producing an excessive amount of minus 5/8 inch material that requires sintering.

Iron Ore per Ton of Pig Iron

The amount of iron per net ton of pig iron ranges from 1.389 to 1.888 tons due to variations in the amount of scrap used. If the ore per ton of pig is adjusted for the scrap reported, the iron content of the burden ranges from 47.5 to 54.0 averaging 51.3 for all the furnaces listed in Table 7. Lake Superior ore averages about 54.5 percent on a dry basis. The generally higher slag volumes of Japan which range up to 1 500 lb. per net ton compared with an ayerage of about 1 000 lbs. for the United States, are therefore, partly due to the lower average iron contents of ore mixtures used in Japan.

The high ash coke of Japan contributes less than half the difference in the average amount of slag per ton of iron in the two countries. Sinter made from iron sulphide concentrates produced by improved selective flotation would contain up to 68 percent iron and only a few percent of gangue. The use of this high grade sinter would decrease the volume of slag per ton of pig iron and lower the amount of expensive coke required to produce a ton of pig iron in Japan.

Coke Rates, Slag Volume and Production Rates

In view of the high slag volume, an average fuel consumption of 1 826 pounds of high ash coke per ton of pig iron for the nine furnaces in Table 6 that are producing basic iron is a very creditable performance. Kamaishi No. 10 furnace with a coke consumption of 1 570 lb. per ton of pig reflects the use of comparatively low ash coke, a relatively low slag volume, excellent sinter, and generally good practice. In full justice to the operaters in other plants, it should be pointed out that they are shaping their practices to obtain the most effective operation within the limitations imposed by raw materials and the equipment available.

One is impressed with the opportunity to increase output by blowing more wind and by the use of higher blast temperatures which would reduce the aconsumption of coke.

Using the tons of iron per sq. ft. of active annulus (6ft. wide) in the hearth as an index of production in terms of furnace size, Table 7 shows the rates are rather low, except in the case of Hirohata No. 2 furnace and Kukioka No. 3. The latter furnace which was not in blast for the period selectpractice in Japan.

Slag volume per net ton (lbs)	Volume Cu. ft/min	Blast pressure lbs/sq.in	Temperature °F	Top gas temperature °F	Pig iron analysis			Slag analysis					
					Si (%)	S (%)	Mn (%)	SiO_2 (%)	Al_2O_3 (%)	CaO (%)	MgO (%)	FeO (%)	S (%)
1 135	26 300	10.8	932	307	1.60	0.031	0.73	35.37	18.20	40.29		0.42	1.00
1 415	50 850	12.9	1 234	426	1.14	0.034	1.32	34.55	17.64	41.22	3.86	0.51	0.93
1 077	32 400	10.9	1 029	538	2.24	0.039	0.62	34.20	16.52	39.27	4.06	1.42	1.88
1 149	38 730	11.3	924	510	1.03	0.036	1.34	33.92	14.81	40.58	5.23	0.94	1.47
1 203	52 570	15.8	926	372	1.07	0.036	1.15	33.02	17.08	41.83	5.65	0.39	1.38
1 562	42 300	11.0	924	441	0.67	0.071	1.16	30.36	15.30	42.06	5.55	1.47	1.39
1 184	41 400	10.4	1 067	428	1.26	0.036	1.03	30.93	14.81	43.35	5.20	1.06	1.17
1 306	31 000	8.8	1 066	535	1.71	0.049	0.64	32.08	15.01	44.68	5.37	0.69	1.59
1 526	31 950	10.4	1 018	500	1.00	0.052	1.22	32.20	14.64	43.11	5.24	0.74	1.47
1 495	41 400	11.3	1 009	396	0.99	0.048	1.18	31.95	14.83	43.39	5.02	0.73	1.47
1 559	37 470	10.7	900	582	1.23	0.040	1.21	30.24	17.14	45.02	2.806	0.97	1.678
1 360	56 370	13.7	972	490	1.20	0.040	1.28	31.04	16.83	44.20	3.207	0.836	1.532

ed for study will be discussed somewhat in detail later. The reason for using an active annulus 6 ft. wide in the crucible is that more consistent results are obtained when this portion of the hearth is used as a basis for comparing the production rates of furnaces varying widely in hearth diameter. It is well known that the combustion zones extend about 4 ft. inward from the tuyers, beyond which the temperature drops because the gases tend to move upward and do not carry heat to the inactive central core. Due to the rather constant size of the combustion zones, this inactive central core becomes proportionately larger as the hearth diameter increases. (See Fig. 19, attached report, "The Blast Furnace Process and Means of Control.") The effective or active hearth area does not, therefore, increase proportionately with increases in the diameter of the hearth.

Production Rates per Square Foot of Active Annulus for Japanese Blast Furnaces

When expressed in terms of net tons per day per sq. ft. of active annulus, the production rates of Japanese blast furnaces are much smaller than those of furnaces in the United States of comparable size. This is shown in the following tabulation of production rates of the basic iron furnaces listed in Table 7.

Furnace	Diameter of hearth in feet	Net tons per day per sq. ft. of active annulus
Higashida No.4	17.06	1.92
Higashida No.5	19.68	1.82
Kukioka No.1	20.01	1.71
Nakamachi No.3	21.98	2.16
Kawasaki No.4	21.98	2.12
Kamaishi No.10	22.14	2.39
Kawasaki No.5	22.96	2.39
Kukioka No.2	22.96	2.23
Hirohata No.2	23.61	2.88
Average	21.37	2.18

The production rates range from 1.71 to 2.88 tons of iron per day per sq. ft. of active annulus, averaging 2.18 for the 9 blast furnaces in operation during the period November, 1950 to 1 March, 1951. In the United States, the average basic iron furnace will, according to *Owen R.* RICE[4], consume about 5 418 lbs. of carbon charged per day per sq. ft. of active annulus. This is equivalent to a consumption of 6 300 lbs. of coke containing 86 percent fixed carbon, per day, per sq. ft. of active annulus.

Applying a fuel consumption of 1 800 lbs. of coke, per net ton, of pig iron, it follows that the production rate of basic pig iron furnaces in the United States averages 3.5 tons per day, per sq. ft. of active annulus. The writer believes that a value of 3.2 is a more representative figure for the smaller furnaces which are less favored in the use of prepared ore burdens. Using a figure of 3.2 as a basis of comparison, it appears that the basic iron furnaces of Japan are averaging about 68 percent as much pig iron per day per square foot of active annulus as furnaces of comparable size in the States. The underlying reasons for the lower production rates in Japan are not readily apparent. The use of hard dense ores that would reach the hearth unreduced, at faster blowing rates and therefore increase the consumption of coke may dictate the slow rates of furnace operation in Japan until ore preparation is improved. Generally high top temperatures, as shown in Table 7, indicate a rather poor heat transfer, which may be due to the relatively small surface area available for heat absorption by the coarse ore. An unfortunate combination of rather coarse ore and some very fine ore may be another factor contributing in some instances to low production rates in Japan. The low blast pressures do not, however, indicate a lack of permeability in the charge.

4) Some aspects of the Blast Furnace Situation in the United States, May 1951, Meeting, British Iron and Steel Institute.

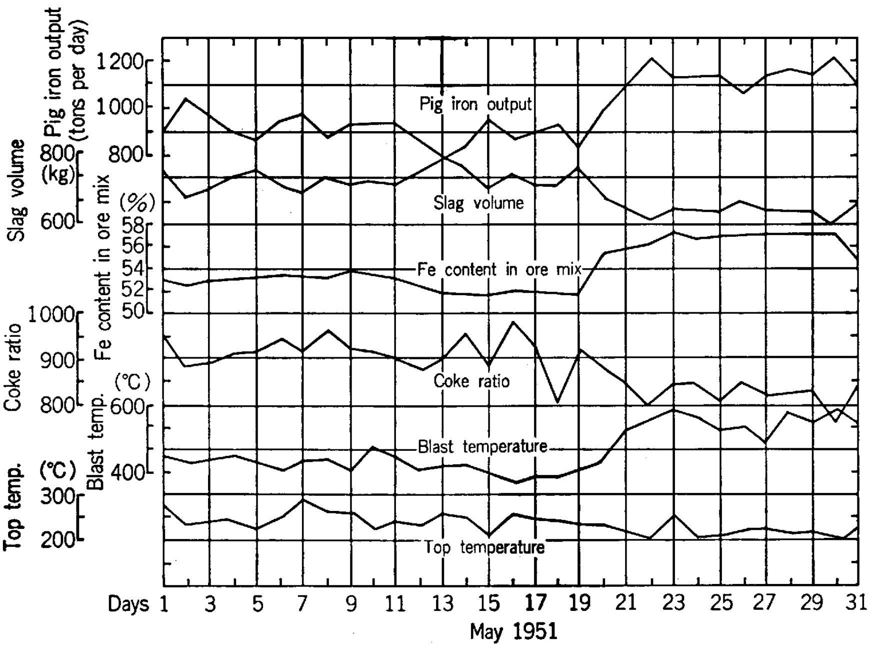

Fig. 2. Performance of Kukioka No. 3 blast furnace, May 1951.

Blast Pressure and Temperature

The blast pressures shown in Table 7 are much lower than those in the United States. They range from 10.4 to 15.8 averaging about 12.0 pounds per sq. inch. Basic iron furnaces in the United States operate at blast pressures of about 16 pounds per square inch for furnaces with hearth diameters up to 18 ft., and at an average pressure of 17.8 pounds per sq. inch., for furnaces with hearth diameters up to 24 ft. The larger and more modern furnaces with hearth diameters up to 28 ft. operate on blast pressures of about 22 pounds per sq. inch. In view of the low blast pressures shown in Table 7, it appears that the physical character of the stock including, of course, the coke will permit faster rates of blowing and somewhat higher blast temperatures. If stove facilities are not available to get more blast heat, which is true in some plants, additional stove capacity should be provided at the earliest opportunity since high blast temperature tends to save coke. The blast temperatures employed in Japan are comparable and in some cases higher than those possible without excessive blast pressure or irregular stock movement, when using fine Lake Superior ore. Alabama furnaces operate on very low grade coarse ores which are properly crushed and blended. These furnaces are driven with blast pressures of about 27 pounds per sq. inch and they produce about 2 200 lbs. of slag per ton of iron. The fast rates of blowing result in high blast pressures which are partly due to the resistance to gas flow in the fusion zone. It is necessary to check the blast at 20 minute intervals to get the stock to settle. The level to which the blast can be heated without causing irregular stock travel must be determined for every furnace and the raw material used. However, since a major effect of an increase in blast temperature is to increase blast pressure, the generally low blast pressures in Japan suggest the feasibility of higher blast temperatures.

Performance of Kukioka No. 3 Blast Furnace

Throughout this report, considerable emphasis has been placed on slag volume, upon fuel requirements per ton of pig and upon blast temperature. The importance of these features of blast furnace practice are demonstrated by the performance of Kukioka No. 3 Blast Furnace of the Yawata Iron & Steel Co. during the month of May, 1951. On May 19, the iron content of the ore mixture was gradually increased from an average of about 52 percent during the first part of the month to a little less than 57 percent for the last 11 days. This change was accompanied by a decrease in average slag volume from 690 kg per metric ton during the first 20 days of May to an average of 558 kg for the last 11 days of the month. (1 380 pounds to 1 116 pounds of slag per net ton of iron) the sharp response in tonnage and coke rate to this decrease in slag volume and to an average increase in blast temperature of 195°C (351°F) is shown in Fig. 2 and in the following tabulation.

Changes in the performance of Kukioka No. 3, blast furnace during May, 1951.

	May 1 to 20 incl.	May 21 to 31 incl.	Difference Amount	Difference Percent
Metric tons/day	912	1 146	+234	+26
Net tons/day	1 005	1 263	+258	+26
Kg slag per metric ton iron	690	558	−132	−19
Pounds slag per net ton iron	1 380	1 116	−264	−19
Pounds coke per net ton iron	1 824	1 652	−172	−9.4
Blast temp. °C	433	628	+195	+45
Top temp. °C	249	223	− 26	−10
Blast pressure, kg/cm²	1.166	1.213	+0.047	+ 4
Blast pressure, psi.	16.6	17.3	+0.7	+ 4
Air per minute, (m³)	2 098	2 180	+ 82	+ 4
Air per minute, (cu.ft.)	74 459	76 954	+ 2 895	+ 4
Kg scrap per metric ton iron	101	135	+ 34	+34
Pounds scrap per net ton iron	202	270	+ 68	+34

Only a minor part of the increase in tonnage and the decrease in coke rate from May 21 to the 31 inclusive, can be attributed to an increase of 68 pounds of scrap per net ton of pig produced. An increase of 258 net tons of pig iron per day and a decrease of 172 pounds of coke per net ton of pig, are of much greater magnitude than the increase in scrap. The performance of this furnace is cited because it demonstrates very clearly the pronounced effect which a reduction slag volume and an increase in blast temperature have upon the output and upon fuel consumption.

Furnace Volume

According to *Owen R.* RICE, a group of 75 American blast furnaces had an average hearth diameter of 22′3″ and an average volume between the iron notch and the large bell of 33,897 cu. ft. in 1944. By 1950, the hearth diameter of this same group of furnaces had increased to 23 ft. 3 inch, with an average volume of 36,043 cu. ft. The furnace volume for a given hearth diameter is about the same for Japanese and American blast furnaces, as the following tabulation will show.

Comparison of Hearth Diameters and Furnace Volumes in Japan and in the United States.

Furnace	Japan Hearth Dia.	Japan Vol. Cu. Ft.	United States Hearth Dia.	United States Vol. Cu. Ft.
1. Kukioka No. 2	22′11″	32 500		
2. Kamaishi No. 10	22′1″	32 500	22′3″	33 897
3. Kukioka No. 3	24′3″	40 143		
4. Hirohata No. 1	23′7″	40 500	23′3″	36 043
5. Hirohata No. 2	23′7″	42 500		
6. Average 1 & 2	22′6″	32 500	22′3″	33 897
7. Average 3, 4, & 5	23′9″	41 048	23′3″	36 043

The low coke rates obtained on American Furnaces during the depression of the 1930's furnished ample evidence that slow rates of operation (and consequent large volume of furnace per ton iron per day) tend to conserve fuel. The reduction in fuel was due to better distribution of the gas and to a longer time of residence of the ore in the furnace. Slow stock travel obtained by slower blowing or by relatively large working volumes is particularly desirable when dense ore of poor reducibility is charged in sizes larger than 2 inches, as is currently practiced in Japan. The question of whether a reduced fuel cost would offset the increase in costs above raw materials at slow operating rates would have to be determined for each furnace.

New Developments in Blast Furnace Practice
High Top Pressure Operation

The use of high top pressures obtained by placing a series of butterfly valves in the gas main beyond the wet washer has attracted universal attention because the underlying principle of this innovation in blast furnace practice is sound and straightforward. The principle involved is that the large increase in absolute pressure and the corresponding increase in the density of the gas near the top of the furnace greatly reduces the linear velocity at which it moves through the stock. Since the dust carrying capacity of the gas varies as the square or some higher power of the speed of travel, any reduction in velocity reduces dust production very sharply, particularly, since the gas velocities are highest near the top of the furnace due to the pressure being lowest there and the small area. Because high top pressures on the order of 10 pounds per sq. inch are very effective in reducing dust losses, blowing rates can be increased through the application of high top pressure with a reduction in the amount of dust produced. When the top pressure is increased to, say 10 pounds per square inch, blast pressure will increase by about 6 pounds per square inch if the blowing rate is constant. This is necessarily so, because the generally denser gas throughout the furnace moves through the charge without building up as much differential pressure, in addition to top pressure, at the base of the furnace.

Operators are universally agreed that furnaces operating at high top pressures work smoothly with less slipping and hanging.

The Republic Steel Corporation has poineered this development, which was undertaken in 1944 on a U.S. Government owned blast furnace operated by this company in Cleveland, Ohio. By the end of 1951, or shortly thereafter, 13 American blast furnaces and one British furnace, operated by Colvilles, Ltd., Glasgow, Scotland, will be capable of operating at high top pressures. Size of these furnaces are owned by Republic Steel Corporation and the other 7 are distributed among the major steel companies in the United States†. No new furnace should be built today without provision for high top pressure operation which adds about $ 200 000 to the cost of a furnace. This is a means of getting gases through the stock with smooth operation and is particularly important when fine ore or small coke increases the resistance of the stock column.

Mechanical difficulties of keeping the large bell tight have been a great factor in retarding wider use of high top pressure. In the early stages of this development, the pressure between the bells was not equalized except when the large bell was dumped. Any leaks quickly enlarged due to the great differential in pressure above and below the large bell. The new practice is to equalize the pressure between the bells except for the brief time when the small bell is lowered. The question of large bell maintenance is no longer considered an obstacle to high pressure operation. Companies who have been on the sidelines while Republic solved this and other mechanical problems associated with high top pressure are now taking an active interest in this new development.

Mechanical difficulties are now causing much less lost time. A pressure furnace that showed a 65 percent increase in lost time in 1948, due to the application of high top pressure showed only 40 percent more than average lost time in 1949. A further decrease in lost time was realized in 1950.

Another furnace showed an increase of 53 percent in lost time during its first year on high top pressure but the lost time in 1950 was only 11 percent above normal. As mechanical difficulties are overcome, the potentialities of high pressure operation will be more fully realized.

On the whole, furnace capacity has been increased from 6 to 8 percent, with a gratifying reduction in flue dust and with generally smoother operation. This development will not be complete until equipment is developed for recovering power by passing the top gas through suitable turbine equipment. It has been estimated by the Arthur D Little Co., Cambridge, Mass., that 2 200 HP can be produced by a single stage turbine placed in the wet gas stream after the wet washer. These calculations are based upon a furnace operating with a top pressure of 12 pounds per square inch and with 90 000 cu. ft. of blast per minute.

All of these developments should be followed closely by the Japanese steel industry and a test installation of high top pressure practice should be made on at least one furnace in Japan.

† この文章には語句または文の脱落があると思われる.

Oxygen Enriched Blast

In 1948, three large American companies conducted a cooperating investigation of the use of oxygen enriched air. Equioment was built to increase the oxygen content of the blast used on a modern basic iron blast furnace from about 21 percent in normal air to about 25 percent in the enriched blast. For a year, tests were conducted by alternating operating periods on normal air and enriched air. Typical Lake Superior ore was used throughout. Results were not encouraging with respect to tonnage, coke rates, or iron quality. Furnace behavior on enriched blast was similar to that on high blast temperatures (above about 925 °F). The furnace reacted to an increase of a few percent in the oxygen in the blast much in the same way as would be expected if attempts were made to raise the blast temperature by several hundred degrees. Because of this similarity in furnace behavior, it was concluded that higher blast temperatures can be secured more cheaply than enriched blast. The oxygen equipment is however, being used with good results on a furnace producing 80 percent ferro-manganese.

In conclusion, it can be stated that ore preparation and the use of high top pressures are the two new developments in the United States, that are pointing the way to increased production, more uniform operation and better fuel economy.

Carbon Linings

At the end of 1950, 86 blast furnaces in the United States were equipped with carbon hearth linings; 14 of these had a carbon pad only, 51 had double carbon walls, and the remaining 21 had single carbon walls.

Annual installations of carbon hearthlinings from 1945 to 1950 were as follows :

Year	Number of installations
1945	5
1946	10
1947	16
1948	35
1949	13
1950	7

In making these installations of carbon linings in the hearth, there were many varied engineering concepts, some of which were unsound because moisture. Some failures occured and inspections revealed soft spots in the carbon and intrusions of iron between the carbon blocks.

As a result, interest in carbon linings lessened and there followed a period of watchful waiting and hesitation to go further until a solution to the difficulties could be found. Orders were cancelled and some corporations froze all further moves toward carbon linings. After careful and more mature consideration of the entire problem and as further operating results became available, it was found that the majority of carbon hearth furnaces had given no trouble and many began to take a different attitude. In 1951, the trend away from carbon hearths reversed itself. It appears, therefore, that the steel companies of Japan should watch further developments, study the difficulties that caused failures, and await sound solutions to them.

Recommendations

Iron Ore Preparation

1. Electrically heated screens should be installed for sizing high moisture domestic limonites and wet, sticky imported ores such as Dungun. The high capacity and generally effective results of such equipment in screening ore containing up to 25% moisture at 5/8 inches was demonstrated last summer at the Portsmouth Mine of the M. A. Hanna Company, Crosby, Minnesota. A second electrically heated screen will be installed at the Portsmouth Mine this summer.

2. Information should be obtained on the pelletizing of domestic limonites as follows:

a. The feasibility of rolling minus 5/8 inch pieces of limonite into balls ranging in size from 0.75 to 1.25 inches.

b. Determine the compressive strength of such balls at temperature levels ranging from 200 to 1 300°C. The average result of the weight required to break 10 pellets of equal size when each of them is placed between two plates and a load is applied, is taken as the compressive strength.

c. If small scale tests made in a rotating steel drum about 30 inches in diameter and 5 feet long demonstrate the feasibility of forming the balls, and providing further that these balls develope a strength of 3 times their wet strength upon heating to 400°C, a pilot plant shaft furnace should be built to enlarge the scale of operations. This furnace should have a capacity of about 2 tons per hour. (See Page 8 of attached report "Agglomeration of Iron Ore by Pelletizing Process", for further details.)

d. If encouraging results are obtained from recommendations 2(a) and 2(b), special attention should be given to the feasibility of eliminating arsenic in the pelletizing treatment. Additions of carbon to the mixture before balling should be made to determine the effectiveness of reducing conditions within the pellet in the early stages of heating as a means of eliminating arsenic. The amount of such additions of carbon will have to be determined by systematic experimental work.

3. All pyrite cinder of very high sulphur content should be crushed to minus 3/8″ before sintering. All sulphur bearing limonite should be crushed to 5/8″ before sintering. The amount of coke used in the sintering mixture should also be regulated to permit the production of sinter containing about 0.06% of sulphur.

4. The adjustment of the carbon content of the sinter mixture to obtain good desulphurization will reduce the strength of the sinter produced, but increase its reducibility and decrease the contamination with coke ash. In order to avoid excessive breakage in handling, air cooling should be substituted for water cooling, Rough handling should be avoided so far as possible, and the sinter should be subjected to any necessary rough handling while it is still hot. After air cooling, it should be handled carefully during transportation to the blast furnace.

5. All coke used as fuel in the sinter mixture should be crushed to minus 1/8 inch. This will greatly facilitate more uniform mixing and tend to prevent over-burning of the sinter in localized areas.

6. Grizzly screens are inadequate for screening sinter and result in the recycling of large amounts of coarse sinter. They also leave a large amount of fines in the sinter going to the blast furnace. Proper screening of the sintered product on shaking or vibrating screens at 5/8 of an inch would give better control over the amount and character of return fines. Regular measurements should be made on the amount of return fines in the sinter mixture.

7. The amount of moisture in the sinter mixture should be determined at least once an hour and facilities should be provided for prompt adjustments in the water content of the sinter feed. Rapid determinations of moisture can be made with a calcium carbide tester. The volume of acetylene generated by a mixture of calcium carbide and a wet sample of known weight gives a measure of the water present in the sample.

8. Devices such as finger grizzlies and fluffers should be installed wherever feasible to obtain a loosely packed bed of high permeability. This is particularly important in the sintering of high moisture charges susceptible to packing which

decreases air flow, sintering rates and production. A graduation of sizes, from coarse pieces at the bottom of the bed to fine sizes towards the top, increases the permeability of the bed and increases grate life.

9. The speed of Dwight Lloyd sintering machines should be adjusted so that the sintering zone reaches the bottom of the bed near the end of the machine. Air cooling towards the end of the bed should be held at a minimum to increase output as the capacity of the sintering equipment which is inadequate in most of the plants in Japan.

10. The practice of removing the central portion of cone shaped storage piles and sending the supposedly fine material to the sintering machine should be abandoned. Coarse particles which are always present in this material upset blending of the sinter mixture and the entire sintering operation.

11. Many of the difficulties encountered in the sintering practice of Japan are due to the low capacity of the screens used. The use of modern high capacity single and double docked vibrating screens preferably with the finer screens electrically heated would overcome these difficulties.

12. All dense coarse imported ore should be crushed to about 2″ and the minus 5/8 pieces produced in crushing should be sintered. Deviations from this size of crushing can be made according to the porocity of the individual ore and the results of reducibility tests. Magnetic ores should be crushed to 3/4″ before they are used in the blast furnace. Magnetic concentration of all magnetite and sintering of the concentrate is a still more satisfactory procedure. Moderate sizes of coarse ore supplemented with easily reduced low sulphur sinter would produce burden mixtures that can be smelted with weak coke made primarily from the high volatile coals of Japan.

13. A standard procedure should be developed for evaluating iron ore on the basis of iron content, and transportation charges. Suitable penalties for high silica content should be applied. These penalties should be based upon the additional slag produced from siliceous charges, the coke and flux required to form, melt, and preheat this additional slag and the increase in processing costs or costs above raw materials resulting from decreased output. Millions of dollars are being spent to import expensive coal for the production of coke required to slag off silica.

14. As soon as the foregoing recommendations on the preparation of iron ore can be put into effect, importations of very expensive coal should be reduced, providing that Japanese production of high volatile coking coal can be adequately increased.

15. Active research should be undertaken by mining companies to treat the large deposits of sulphide ore by improved selective flotation. The objective would be to produce an iron sulphide concentrate and a copper sulphide concentrate with less copper sulphide left in the iron sulphide than at present.

The iron sulphide concentrate should then be turned over to chemical companies for roasting, sintering and the recovery of sulphur as sulphuric acid or as elemental sulphur. Because of the need for recovering sulphur from the sintering operation as well as from roasting, these operations must be closely integrated. About 10 percent sulphur should be left in the roasted iron sulphide (or unroasted iron sulphide should be added to it) to supply fuel for sintering, thus eliminating the use of coke in sintering.

With improved flotation practice the sintering produced by the chemical companies would be very high in iron and very low in silica, and should be forwarded to steel companies for use in blast furnaces. More extensive use of such a product would reduce slag volumes and the coke required to make a ton of pig iron.

16. The nodulizing process, under investigation in a pilot plant of the Kokan Kogyo Mining Co., may prove to be the most practical method for treating high sulphur and high moisture limonite. Recent trial runs, in which coke breeze was omitted from the charge at the writer's suggestion, produced nodules containing as low as 0.09 percent sulphur from ore that contained 3.34 percent sulphur. Details of these tests were submitted to the writer as this report was nearing completion.

Blast Furnace Practice

17. Efforts consistent with the demand for pig iron and for low fuel consumption should be made to increase the production rate of individual furnaces. Current tonnages in Japan are about 68 percent of those of furnaces of comparable size in the United States. Generally low blast pressures indicate that wind volumes and blast temperatures can be increased with an increase in output. A reduction in slag volume by using smaller amounts of siliceous ore would lower coke rates and thus increase output.

18. Provisions should be made to try out high top pressure operation in Japan. By the end of 1951, or soon thereafter, 13 blast furnaces in the United States and one in Great Britain will be equipped for high top pressure operation. Solutions to the major mechanical difficulties have been

found, and most of the major steel companies in the United States are planning to try out high pressure operation. Two of the American companies are now using it with good results.

19. Inasmuch as results from the oxygen enriched blast on a basic iron furnace in the United States were generally unsatisfactory, its application on basic iron furnaces in Japan should be withheld for the present.

20. Test on ore preparation should be made by all the companies in Japan except at the Kamaishi plant, where ore preparation is well advance.

Materials should be prepared for full scale tests of 10 days, to be followed by test periods of one month operation with all dense ore crushed to about 2 inches and with as much sinter as is available. The results shown in Fig. 2, are an illustration of what can be learned from such tests.

21. Facilities for recovering fine ore from gas washers should be installed at the earliest opportunity. Failure to recover this material represents an economic waste of expensive iron and carbon material. The sludge from gas washers is being recovered in the States where iron ore costs about one-half as much as it does in Japan. This sluge is filtered and the filter cake is sintered.

Appendix

Table 1. Chemical composition of iron ore.

Part I—Imported ore

	Fe	FeO	SiO_2	Al_2O_3	CaO	MgO	Mn	P	S	Cu		C.W.	Moist by Diff.
	%	%	%	%	%	%	%	%	%	%	%	%	%
U.S.A.											TiO_2		
Utah	57.96	4.94	6.12	1.67	2.79	1.68	0.142	0.489	0.022	0.007	0.202	2.08	4.10
Utah	56.70	4.29	7.00	2.18	2.63	2.48	0.286	0.536	0.031	N.D.		N.D.	5.97
Utah	58.29	N.D.	6.63	1.89	2.31	1.77	0.06	0.39	0.04	Tr.		2.64	4.1
Utah	57.12	3.15	7.10	2.32	3.51	2.31	0.41	0.420	Tr.	0.010	0.22	1.96	6.0
Malaya													
Dungun	55.92	2.77	4.20	6.57	0.27	0.07	0.103	0.076	0.134	0.058		7.50	6.50
Dungun	59.05	1.09	4.70	3.89	0.169	0.359	0.046	0.036	0.102	0.022		N.D.	10.81
Dungun	60.70	3.12	3.36	3.84	0.49	0.941	0.17	0.060	0.112	0.031		3.12	7.1
Dungun	53.89	4.31	6.10	7.57	0.89	0.24	0.54	0.051	0.155	0.076		7.13	11.47
Dungun	56.47	2.35	5.38	3.38	0.56	0.724	0.39	0.055	0.097	0.041		8.12	11.50
India													
Goa	60.72	1.22	1.82	4.59	0.57	0.036	0.68	0.051	0.028	Tr.		5.72	2.07
Goa	58.17	2.78	2.55	6.32	0.049	0.399	0.349	0.064	0.042	N.D.		N.D.	2.39
Goa	54.0	5.0	6.5	7.0	0.75	0.2	0.2	0.1	0.1	Tr.		N.D.	4.0
Goa	61.69	N.D.	1.83	5.15	0.16	0.34	0.44	0.07	0.05	Tr.		N.D.	1.2
Goa	59.45	N.D.	2.18	4.18	0.21	0.554	0.38	0.131	0.15	Tr.		7.8	3.8
Calcutta	65.49	0.91	1.06	1.50	0.14	0.695	0.21	0.08	0.028	0.01		2.63	2.4
Calcutta	63.17	N.D.	1.90	2.83	0.18	0.33	0.10	0.03	0.03	Tr.		N.D.	1.0
Calcutta	64.0	2.2	3.0	1.0	0.6	0.8	0.1	0.05	0.04	0.04		N.D.	3.0
Philippine													
Larap	57.60	18.90	8.06	2.88	1.27	1.97	0.42	0.131	0.615	0.051		2.80	10.3
Larap	60.5	7.0	7.0	3.0	0.5	0.05	0.10	0.12	0.51	0.05	0.5	N.D.	5.0
Larap	57.90	15.84	8.64	3.17	0.97	1.00	0.111	0.151	0.448	0.065	0.23	3.10	N.D.
Larap	59.35	8.83	7.00	2.97	0.70	0.55	0.17	0.255	0.440	0.09	Ig Loss 3.71	N.D.	5.0
Samar	60.38	6.03	7.25	3.28	0.221	0.235	0.425	0.047	0.021	0.011		2.49	6.06
Samar	57.06	5.68	8.76	4.69	0.128	0.496	0.524	0.058	0.058	0.014		N.D.	11.72
Samar	56.5	2.5	10.0	4.5	0.5	0.4	0.045	0.06	0.03	0.01	TiO_2	N.D.	11.0
Samar	59.5	6.4	7.04	4.68	0.75	0.553	0.49	0.081	Tr.	0.010	0.3	3.08	10.7
Calambayangan	54.90	8.48	8.80	4.75	1.60	0.69	0.57	0.123	0.350	0.067		4.43	N.D.
Calambayangan	59.27	14.80	6.88	2.07	1.16	0.86	0.36	0.150	0.879	0.051		2.80	7.72
Marindugue	61.49	22.09	5.58	0.95	5.40	0.51	0.53	0.045	0.224	0.050		1.00	N.D.
China													
Hongkong	50.03	20.92	11.50	1.13	1.41	12.15	0.668	0.011	0.027	0.005		1.01	1.48
Hongkong	48.26	N.D.	10.37	1.63	2.46	13.82	0.71	0.03	0.03	Tr.		N.D.	4.1
Hongkong	51.88	20.71	9.68	2.12	2.11	12.74	0.66	0.015	0.011			1.15	2.0
Shihlu (Sekiroku)	58.80	3.25	11.12	2.20	0.35	0.818	0.27	1.057	0.158	Tr.	0.42	0.44	3.5
Tientu (Dendoku)	62.29	N.D.	3.40	2.72	0.37	0.47	0.86	0.04	0.05	0.01		2.31	4.0
Sweden	67.25	N.D.	1.92	0.88	0.82	0.82	0.17	0.08	0.03	Tr.		3.14	4.0

Part II—Domestic ore

	Fe	FeO	SiO_2	Al_2O_3	CaO	MgO	Mn	P	S	Cu	As	C.W.	Moist by Diff.
Kutchan	54.79	N.D.	4.85	1.65	0.20	0.20	0.207	0.097	0.619	N.D.	0.558	12.70	16.30
Kutchan	52.78	N.D.	8.10	1.09	0.11	0.24	0.122	0.119	0.436	N.D.	0.349	11.65	16.00
Tokushunbetsu	50.60	N.D.	12.20	1.51	0.28	0.18	0.081	0.200	0.212	N.D.	0.392	11.25	21.30
Tokushunbetsu	51.89	N.D.	8.30	1.53	0.31	0.07	0.133	0.105	0.516	N.D.	0.174	12.20	20.00
Fujikoshi	45.15	N.D.	21.88	N.D.	N.D.	N.D.	0.09	0.037	0.220	0.102		N.D.	N.D.
Ogawa	35.30	N.D.	15.36	N.D.	N.D.	N.D.	0.78	0.270	0.167	0.170		N.D.	N.D.
Kamaishi, lump	56.84	23.78	8.64	1.78	6.87	1.20	0.207	0.036	0.227	0.114		N.D.	0.91

Kamaishi, lump	55.68	23.67	9.94	0.40	7.19	1.54	0.136	0.058	0.352	0.133		N.D.	1.02
Kamaishi, lump	48.81	N.D.	11.57	3.05	12.17	N.D.	0.26	0.12	0.57	N.D.		N.D.	3.5
Gunma, crude	52.90	N.D.	2.00	0.38	0.69	0.26	Tr.	0.834	1.85	Tr.		N.D.	12.0
Gunma, crude	49.28	1.44	4.74	1.14	0.21	1.35	0.29	0.940	2.458	0.051		12.86	14.6
Gunma, crude	51.06	0.53	3.58	2.16	0.74	0.248	0.19	0.804	1.504	0.020		13.65	9.0
Gunma, crude	50.62	0.94	2.15	2.00	0.63	0.16	0.31	0.948	2.508	0.060		11.00	N.D.
Gunma, roasted	55.92	N.D.	10.30	4.15	1.19	1.45	Tr.	0.834	1.85	Tr.		0.98	2.0
Akatani	45.39	6.58	17.46	1.51	2.68	4.16	0.21	0.119	0.69	0.09		0.96	4.5
Akatani	50.00	3.5	18.0	1.2	1.5	1.8	0.16	0.08	0.7	0.07		N.D.	5.0
Akatani	38.69	5.21	29.02	7.98	1.33	1.61	0.52	0.098	0.294	0.055		2.34	6.3
Tosu	42.79	N.D.	20.04	N.D.	N.D.	N.D.	0.89	0.209	0.124	0.033		N.D.	N.D.
Kanahira	43.67	N.D.	24.02	N.D.	N.D.	N.D.	0.18	0.138	0.099	0.006		N.D.	N.D.
Muramatsu	46.08	2.14	20.50	2.89	0.74	2.39	0.34	0.101	0.15	Tr.		3.14	4.0
Iwabuchi (roasted)	56.36	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	0.010	4.19	N.D.		N.D.	2.0
Shuzawa	51.80	0.97	4.62	1.92	0.88	1.02	Tr.	0.390	1.30	Tr.		13.24	10.0
Shuzawa	54.75	0.88	2.96	1.71	0.22	0.18	Tr.	0.197	0.65	Tr.		14.30	12.1
Heating furnace slag	65.95	38.82	2.80	0.58	1.60	0.83	1.05	0.178	0.15	0.10		10.54	7.0
Heating furnace slag	70.74	60.11	0.76	1.30	1.32	0.91	0.40	0.258	0.06	0.18		N.D.	1.1
Takai	49.29	4.91	9.84	2.48	0.71	1.07	0.37	0.283	1.068	0.031		12.02	20.5
Takai	46.16	5.82	14.48	3.46	0.42	0.89	0.23	0.237	0.832	Tr.		13.18	22.0
Matsuo	49.92	1.95	7.72	5.06	0.49	0.659	0.18	0.168	0.973	Tr.		13.64	16.5
Kitahira	41.34	3.22	15.60	7.50	1.31	0.69	0.57	0.216	0.213	0.54		10.40	19.76
Namerikawa	50.52	5.75	7.55	3.85	1.88	3.08	0.18	0.435	0.825	0.121		9.70	17.02

Manganiferous iron ore

Tokoro	37.11	N.D.	17.70	1.59	4.67	0.62	10.05	0.670	0.031	N.D.		N.D.	2.55
Tokoro	33.61	N.D.	15.35	1.90	5.98	0.96	12.56	0.945	0.058	N.D.	TiO_2	3.65	4.40
Kunimiyama	28.13	N.D.	19.98	2.58	5.35	2.22	12.01	0.190	Tr.	0.020	1.16	7.09	3.3
Otaki	32.67	N.D.	18.14	3.98	7.43	2.072	7.87	0.497	0.019	0.051	0.58	6.03	7.0

Part III—Others

Pyrite-Cinder	47.45	8.21	21.35	N.D.	N.D.	N.D.	0.10	0.049	1.52	0.436		0.95	N.D.
Pyrite-Cinder	55.10	8.84	10.22	0.58	0.92	1.26	Tr.	0.04	1.64	0.32		N.D.	7.59
Pyrite-Cinder	48.66 or 60.92	2.06 or 17.98	4.82 or 17.98	0.92 or 4.76	0.47 or 2.49	0.99 or 1.83	0.08 or 0.24	0.01 or 0.03	0.590 or 4.295	0.260 or 0.966		N.D.	N.D.
											TiO_2		
Iron sand	58.08	34.91	4.50	N.D.	N.D.	N.D.	0.448	0.227	0.045	N.D.	9.50	0.23	N.D.
Iron sand	54.79	30.78	7.56	2.16	1.06	3.909	0.52	0.013	0.027		10.52	N.D.	4.3
Flue dust	41.77	27.94	10.00	N.D.	N.D.	N.D.	0.554	0.122	0.227	0.059	C	1.20	N.D.
Flue dust	32.6	23.75	8.64	1.92	11.42	1.66	0.20	0.14	0.52	Tr.	13.42	N.D.	N.D.
Mill scale	66.6	17.41	0.76	4.28	0.26	0.36	1.26	N.D.	0.30	N.D.		N.D.	N.D.
Open hearth slag	21.31	22.28	16.50	2.47	31.25	6.81	6.81	1.15	0.15	0.025		0.70	N.D.
Open hearth slag	21.27	21.35	18.00	2.38	28.71	5.79	7.11	1.18	0.17	0.017		N.D.	N.D.
Open hearth slag	N.D.	21.08	13.10	4.80	35.89	8.63	5.92	N.D.	0.45	N.D.		N.D.	N.D.
Open hearth slag	19.20	12.02	15.06	5.31	35.56	11.21	5.62	0.87	0.32	Tr.	TiO_2	N.D.	2.0
Open hearth slag	22.66	25.04	16.38	3.12	33.19	6.08	8.65	0.90	0.39	0.010	0.16	0.32	3.0
Open hearth slag	19.16	18.59	16.70	3.30	37.77	6.20	5.66	0.97	0.18	0.087		N.D.	4.3

Part IV—Chemical composition of sinter

Plant													
A	55.10	15.76	14.84	4.10	1.23	0.91	0.01	0.018	0.53	0.75		0.48	4.0
A	55.44	26.27	13.46	4.72	1.34	1.601	0.27	0.030	0.132	0.436	1.36	0.10	3.5
A	54.81	25.09	14.06	5.59	1.21	1.27	0.27	0.048	0.241	0.389	Tr.	N.D.	3.0
No.1	57.83	26.41	11.45	3.11	0.68	1.03	0.360	0.154	0.050	0.048	0.040	0.24	N.D.
No.1	55.02	19.04	12.30	3.14	1.24	0.83	0.407	0.146	0.065	0.084	0.053	0.48	N.D.
No.1	55.10	18.95	12.80	2.76	1.37	0.87	0.332	0.142	0.058	0.058	0.092	0.75	N.D.
No.2	59.15	11.08	6.88	1.30	4.35	1.15	0.305	0.022	0.066	0.057		N.D.	0.91
No.2	57.91	8.89	6.94	1.56	4.79	1.34	0.307	0.052	0.067	0.076		N.D.	N.D.
No.2	59.13	12.50	7.34	1.46	4.54	1.25	0.250	0.038	0.027	0.105		N.D.	N.D.
Plant													
No.3	58.03	12.65	11.41	2.03	0.87	0.74	0.27	0.358	0.173	0.10		0.68	3.0
No.3	58.45	N.D.	8.15	2.75	1.74	N.D.	1.43	0.386	0.198	0.16		N.D.	4.0
No.4	57.93	13.80	10.66	2.58	2.26	5.190	0.58	0.120	0.094	0.257		N.D.	1.0
No.4	56.63	22.15	11.78	1.22	6.06	1.035	0.45	0.081	0.068	0.206		N.D.	2.1
No.4	53.86	17.52	12.20	3.42	6.32	1.420	0.40	0.080	0.054	0.110		N.D.	1.6
No.6	57.35	17.73	11.30	3.45	1.85	0.69	0.42	0.087	0.237	0.522		N.D.	2.70
No.6	55.96	16.13	11.38	3.48	1.36	0.56	0.38	0.102	0.302	0.306		N.D.	4.34
No.6	56.29	26.23	10.50	3.58	2.33	0.79	0.74	0.189	0.508	0.285		N.D.	N.D.
No.6	58.90	23.87	8.95	2.90	1.26	0.71	0.40	0.213	0.423	0.300		N.D.	N.D.

Table 2. Screen analyses of iron ore and sinter.

Part I, Imported ore

Plant No. 1	+50mm	−50+25mm	−50+10mm*	−10+0mm	−10+1.5mm	−1.5mm
Utah	0.33%	17.25%	34.71%	47.44%	30.36%	17.08%
Dungun	45.60		26.90	27.50	14.90	12.60
Hongkong	74.20		19.10	6.70	4.40	2.30
Goa	86.50		9.20	4.30	3.18	1.12
Larap	52.63		31.16	16.21	7.69	8.52
Samar	31.90		38.10	30.00	17.00	13.00

Plant No. 2	+100mm	−100+40mm	−40+10mm	−10mm
Dungun		32.7	42.3	25.0
Utah		8.2	32.2	59.6
Samar		48.6	33.6	17.9

Plant No. 3				
Utah	20.76	30.51	16.43	32.30
Dungun	10.20	18.60	32.50	38.70
Hongkong	62.30	23.10	5.40	9.20
Goa	16.90	4.49	20.70	13.0
Calcutta	35.60	46.70	12.60	7.1
Samar	20.50	18.30	22.6	38.6
Larap	15.50	50.80	15.80	17.9
Tientu	10.97	21.06	29.63	38.34
Tayeh	5.40	23.70	50.80	20.10
Sweden	14.01	29.04	30.77	26.18

Plant No. 4	+70mm	−70+50mm	−50+30mm	−30+10mm	−10mm
Utah		4.15	15.39	33.90	46.65
Utah		7.20	18.17	37.37	37.26
Dungun	9.94	8.19	14.91	32.29	35.67
Goa	13.88	18.59	30.10	25.59	11.86
Goa	20.90	23.03	26.47	17.87	11.73
Calcutta	21.82%	23.99%	27.26%	18.13%	8.80%
Larap	8.66	11.44	23.84	26.27	29.78
Larap	6.18	10.80	19.79	26.21	26.56
Samar	12.30	13.27	21.51	26.36	26.56

Plant No. 5	+30mm	−30+15mm	−15mm
Utah	20.10	27.80	52.10
Hongkong	21.46	32.99	45.55

Plant No. 6	+50mm	−50+10mm	−10mm
Dungun	52	26	22
Samar	46	26	28

* No. 1 の Dungun～Samar を除いて −25+10 の誤りと思われる．

Part II, Domestic ore

Plant No. 1	−50mm	−50+25mm	−50+10mm*	−10+0mm
Kutchan	35.60%	22.90%	14.20%	27.30%
Tokushunbetsu	39.90	28.20	11.10	20.80
Tokoro	37.10	21.70	17.00	24.20

Plant No. 2	+100mm	−100+40mm	−40+10mm	−10mm
Kamaishi, lump		42.7	47.6	9.7

Plant No. 3	+10mm	−10mm
Akatami	45	55
Muramatsu	75	25
Gunma	70	30
Shuzawa	70	30
Kamioka	92	8
Kamaishi	91	9

Plant No. 4	+70mm	−70+50mm	−50+30mm	−30+10mm	−10mm
Akatani	18.89	13.98	16.88	16.88	33.37
Matsuo	14.79	9.16	9.50	27.11	39.44
Gunma	27.21	16.05	17.57	16.25	22.92
Takai	1.86	5.28	8.07	38.51	46.28

Plant No. 6	+30mm	−30+15mm	−15mm
Gunma	42.06	20.96	36.98

* −25+10 の誤りと思われる．

Part III, Sinter

Plant No. 1	+25mm	−25+15mm	−15+10mm	−10+5mm	−5mm
	19.4%	24.9%	27.1%	15.3%	13.3%
	20.4	26.5	27.0	13.6	12.5
	14.3	23.7	29.7	16.7	15.6
Plant No. 2	+100mm	−100+40mm	−40+10mm	−10mm	
	6.4	26.2	37.3	30.1	
	6.3	30.2	38.7	24.8	
Plant No. 3	+10mm	−10mm			
	65	35			
	60	40			
Plant No. 4	+70mm	−70+50mm	−50+30mm	−30+10mm	−10mm
	7.39	6.07	13.60	42.30	30.64
	9.92	6.07	13.58	43.65	26.78
	1.82	3.11	9.81	52.71	32.55
Plant No. 6	7.2	18.6	21.1	37.0	15.1
	10.5	12.3	18.2	40.7	18.3

Table 3. Typical method for ore handling.

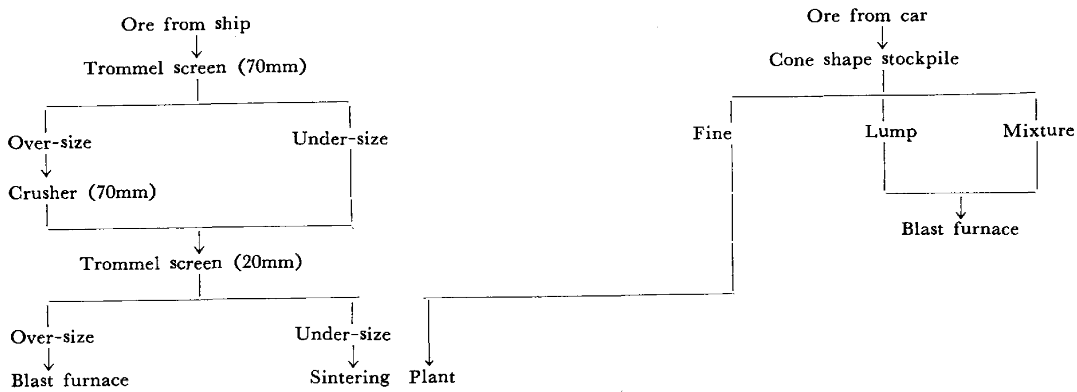

Table 4. Sintering mixture

Plant	No. 1		No. 2			
Type of machine	Pallet		Pan		Pallet	
Composition of ore mix	Domestic limonite	52.0%	Magnetic conc.	46.21%	Magnetic conc.	50.97%
	Imported ore	13.8	Magnetic grain	19.45	Magnetic grain	20.13
	Iron sand	14.9	Magnetic fine	8.40	Magnetic fine	5.15
	Pyrite cinder	6.4	Iron sand	13.54	Iron sand	11.58
	Flue dust	5.3	Roll scale	1.59	Flue dust	12.55
	Coke breeze	7.6	Pyrite cinder	10.81		
		100.00		100.00		100.00

Moisture content in ore mix	12∼13%	7 %	7 %
Size of ores	−30mm	−15mm	−15mm
Size of coke breeze in mix	−9mm	−5mm	−10mm
Coke breeze used per ton sinter	8.7%	4% Breeze, 1% Sawdust	6 %
Size & amount of return fines	−20mm, 30%	−20mm, 24%	−20mm, 24%
Depth of charge	300mm	255mm	220mm
Time of sintering	30 min	40min	27.6 min
Rate of sintering	10mm/min	6.4mm/min	8 mm/min
Suction	700g/cm^2	800 g/cm^2	500 g/cm^2
Kind of ignition fuel	Blast furnace gas	Coke oven gas	Coke oven gas
Condition of ignition	Fair	Poor	Fair
Cooling method	Water	Air	Mostly air
Nominal production capacity	1 400 t/day	600 t/day	300 t/day
Actual production capacity	1 036 t/day	450 t/day	250 t/day
Quality of sinter			
Sulphur content	0.065%	0.07%	0.04%
Carbon content	0.29%	N.D.	N.D.
Screen analysis	32.3%, −10mm	24.8%, −10mm	30.1%, −10mm

Table 5. Chemical analysis of limestone.

Plant	SiO_2	Al_2O_3	CaO	MgO
No. 1	0.69%	0.53%	54.40%	0.40%
	0.88	0.42	54.20	0.40
No. 2	1.08	1.02	53.98	0.58
No. 3	0.79	0.45	55.41	0.68
No. 4	2.16	N.D.	51.58	2.22
No. 5	0.28	0.11	54.87	0.60
No. 6	0.66	N.D.	54.17	0.88

Table 6. Screen analysis of limestone.

Plant	mm +50	mm −50+25	mm −25+10	mm −10
No. 1	35.5%	17.1%	20.0%	27.4%
Plant *	**mm +100**	**mm −100+40**	**mm −40+10**	**mm −10**
	5.1%	50.1%	22.2%	22.6%

* Table 6 下欄のプラント番号が脱落している.

Table 7. Chemical analysis of coke.

Plant	Moist by diff. %	V.M. %	F.C. %	Ash %	Sulphur by diff. %
No. 1	15.96	1.76	84.40	13.84	0.46
	9.45	1.70	84.19	14.11	0.50
No. 2	4.67	1.93	84.05	14.02	0.54
	2.55	1.63	87.27	11.10	0.567
No. 3	3.16	1.70	87.24	11.06	0.565
	3.4	0.6	84.8	14.3	0.61
No. 4	3.9	0.6	85.0	14.1	0.59
No. 5	1.20	1.30	84.19	14.49	0.63
No. 6	1.41	1.96	82.46	15.58	0.63
	1.57	1.73	82.69	15.58	0.71

Table 8. Screen analysis of coke.

Plant	mm +100−40*	mm −40+15	mm −15	
No. 1	88.2%	11.0%	0.8%	
	77.7	19.9	2.4	
Plant	**mm +50**	**mm +25**	**mm +15**	**mm −15**
No. 2†	86.3%	94.4%	98.8%	1.1%
	80.4	93.4	99.3	0.7
Plant	**mm +50**	**mm −50+25**	**mm −25+15**	**mm −15**
No. 3	57.6%	24.9%	15.5%	2.0%
No. 4	61.2%	35.9%	1.8%	1.1%

* −100+40 または単に +40 の誤りと思われる.

† No. 2 だけが累積分布となつている.

Table 9. Drum index of coke.

Plant	+50mm	+38mm	+25mm	+15mm
No. 1	28.45%	58.46%	79.50%	88.45%
	11.4	34.04	59.26	79.13
No. 2	N.D.	N.D.	64.59	84.54
	N.D.	N.D.	63.51	86.71
No. 3	11.2	N.D.	66.7	85.9
	8.1	N.D.	58.1	83.2
Plant	**+15mm**			
No. 4	92.0%			
Plant	**+50mm**	**+38mm**	**+25mm**	**+15mm**
No. 5	15.8%	36.73%	65.7%	84.0%
Plant	**+25mm**	**+15mm**		
No. 6	N.D.	91.31%		
	88.85	92.35		

and practice.

No. 3 Pallet	No. 4 Pan	No. 5 Pallet	No. 6 Pot	Pan
Gunma 25% Bed ore 12 Return fines 25 Kamaishi 6 Scale 11 Flue dust 1 Pyrite cinder 15 Breeze 5 100	Pyrite cinder 39.2% Gunma 9.4 Akasaka 3.8 Hongkong 1.7 Utah 7.9 Dungun 1.3 Samar 7.9 Scale 11.4 Ironsand 10.5 Flue dust 6.5 100.0	Pyrite cinder 46.7% Domestic ore 10.0 Imported ore 4.0 Scale 5.8 Flue dust 2.4 Return fines 25.6 Coke breeze 5.5 100.0	Pyrite cinder 50.0% Domestic ore 14.0 Iron sand 2.3 Flue dust 0.3 Scale 9.5 Return fines 19.0 Coke breeze 4.9 100.0	Pyrite cinder 58.9% Domestic ore 7.2 Iron sand 0.70 Flue dust 5.2 Scale 1.5 Return fines 20.9 Coke breeze 5.6 100.0
16~17%	13%	12%	13%	13~14%
−25mm	−20mm	−15mm	20% over 10mm	11% over 10mm
− 8 mm	−10mm	−10mm	−10mm	−10mm
9.6%	6 %	6 %	5.3%	6.1%
−15mm, 42%	−18mm, 25%	−26mm, 40%	−15mm, 23%	−15mm, 30%
300mm	300mm	250mm	300mm	300mm
18min	35min	27.5 min	55 min	45min
17mm/min	8.6mm/min	9.1mm/min	54mm/min	6.7mm/min
1 000 g/cm²	900 g/cm²	900 g/cm²	800 g/cm²	1 000 g/cm²
Coke oven gas	Coke oven gas	Blast furnace gas	Coke oven gas	Coke oven gas
Good	Poor	Fair	Poor	Fair
Water, 0.5 t/t sinter	5min, Air ; then, water	Water	Water	Water in some extent
1 700 t/day	640 t/day	300 t/day	450 t/day	1 125 t/day
1 090 t/day	500 t/day	240 t/day	450 t/day	900 t/day
0.155%	0.78%	0.3%	0.4%	0.1 to 0.3%
N.D.	0.08%	N.D.	N.D.	N.D.
16.4%, −10mm	25.4%, −10mm	16%, −10mm	18.3%, −10mm	48%, −15mm