日本に於ける銑鐵製造の現狀及進歩

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THE PROGRESS AND THE PRESENT STATE OF THE PIG IRON MANUFACTURE IN JAPAN

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ABSTRACT

There had been, of course, the pig iron manufacture from ancient times in this country. But till the end of the ninteenth century, being carried in a traditional, rudimental manner, and having not much demand, it was very poor.

The progress of the iron manufacture as well as all other material civilization in this country has been much slower than that of many other countries, owing to the national isolation policy that continued for some two centuries and a half.

Although the application of the blast furnace process has begun in 1880, the bud of the present development of the modern pig iron manufacture, sprouted in the establishment of the government steel works in 1896. Since then they have, these thirty years, learned much from the advanced nations and studied also themselves, and it has progressed step by step to the present state.

The scarcity of iron during the world war suddenly excited the iron manufacture; and there appeared two hundred pig iron manufacturing works, big and small. After the war, the weak rooted works gradually disappeared, and there remain eight large plants and a few small ones at present in Japan proper, Korea and Manchuria.

The government and people are working upon their motto — "Self-support and self-sufficiency" of iron and steel. The latest annual production of the pig iron amounted to 1,517,751 tons, and this number corresponds to 79.7 per cent of the total demand.

Many of the iron deposits in Japan proper are impossible to work economically in normal time, therefore great parts of the ores required are now imported from Central China and Malay Peninsula. Those in Korea and Manchuria are so plenteous in amount as to meet the demand of the iron works there. The large quantity of iron sand which lies scattered in this country, is not yet practically utilized, though various studies have been done on it.

The difficulty of getting a fitted good coke for blast furnace working, is a rather serious subject than the obtaining of the ores. Indeed, the unfit quality of coke obstructs the advance of the blast furnace working in many cases.

There are at present twenty comparatively large blast furnaces over 100 tons of daily output.

14 (3 not active)	in Jadan proper
2	in Korea
4	in Manchuria

The largest of these produces about 350 tons a day. Besides, two 500 ton-furnaces are in the course of erection now. We think when glancing at all over the world, that the blast furnace equipment and operation in this country are not so much behind the times.

Recently the "one heat principle" for the iron and steel making has been loudly advocated; and pig iron is used not only in molten state. but the steel plants are tending to

equip closely the blast furnace simultaneously. The attentions are paid on the utilizations of the furnace gases and slag.

There are several iron manufacturing processes other than the blast furnace process. Some of them are out of use now, and some are not yet perfect in practice.

The products of the ferro alloys amount to 16,000 tons during one of the latest years and It corresponds to 76 per cent of the total demand in this country.

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I. The Historical Sketch of Japanese Pig Iron Manufacture.

(i) Old-Fashioned, Rudimental Age.

It is a historical fact that the iron was used in ancient times in this country, and the iron sand was said to have been already smelted in old times in Chugoku district, but its origin and course of progress are quite unknown.

In former days the iron manufacture in this country was mainly typified by sword-making and made progress especially in this direction, whereas the amount of iron used for farming, machine tools and other furnitures had been quite negligible. Thus the demand for iron was very small and could be supplied largely by the product from iron sand in Chugoku district.

At the end of the 17 th century, the foreign warships which appeared near the coast of this country excited deeply the feeling of natural defence and at the same time awakened the people to the necessity of iron manufacture, and since the middle part of the 18th century many iron smelting works had been opened at various places, namely, Kuji and Kamaishi in Iwate prefecture etc., besides Chugoku district. But they all ended in failure by the reasons that they used rudimental equipments and out of date method.

(ii) Adoption of the European, or Blast Furnace Method.

At the begining of Meiji era the government inangurated great reforms on all sides to keep pace with the world's progresses which had fallen behind, owing to the national isolation policy for a long time; and with regard to the iron manufacture it managed directly the iron mines of Chugoku district, and moreover, purchased Kamaishi mine in Meiji 7 (1874), Nakakosaka iron mine in Meiji 10 (1877). English men were employed to build the blast furnaces of European style at Kamaishi and pig iron was made there for the first time in Meiji 13 (1880). Just then a small furnace was also operated by a private enterprise at Kurikizawa, Iwate prefecture. The furnace at Kamaishi met with various difficulties and the works were closed after three years operation to be disposed of by the government to private persons. The Nakakosaka iron mine was also doomed to the same failure. The Kamaishi mine was revived by the hand of Mr. Chobei Tanaka in Meiji 20 (1887) and is now working prosperously after overcoming so many difficulties.

(iii) Establishment of the Government Works.

About in the 24th year of Meiji (1891) an establishment of a Government Steel Works was proposed by the government and people and the investigation committee concerning it, was organized. Just then a war broke out between Japan and China and the necessity of the above said steel works was perceived more and more. Thus the Imperial Government Steel Works were settled to establish in Meiji 29 (1896) and the construction of works was started at Yawata, Fukuoka perfecture, and the operation of No. 1. blast furnace was commenced in February Meiji 34 (1901).

At the same time Kamaishi mine made a remarkable improvement and increased the number of furnaces, and also small charcoal blast furnaces were operated at Masaki iron mine in Miyazaki prefecture and Sennin iron mine in Iwate prefecture.

The Imperial Steel Works stopped the operation of blast furnace after one year working in consequence of various circumstances, but held again at the time of the outbreak of the war between Japan and Russia. Since then the operation has been in good circumstances, the number of furnaces now being counted by the six.

In July, Meiji 42 (1909) the Hokkaido Coal and Steamship Co. Ltd. commenced a blast furnace workings at Wanishi, Hokkaido. This plant was stopped soon, and blew in again in December Taisho 2 (1913). Afterward this works were combined with Nippon Steel Works Ltd. and have four blast furnaces at present. In January Taisho 4 (1915) Penchihu Coal and Iron Co. Ltd. (a Japanese-Chines undertaking), began blast furnace workings at Penchihu, Manchuria.

(iv) The Influences of the World War.

In consequence of the outbreak of the Great war in Europe the demand for iron and steel increased suddenly and as it was difficult to import iron and steel products, there appeared an opinion of self-support of iron and steel in this country. The two facts, that the government issued an Encouraging Law for iron and steel manufacturing in Taisho 6 (1917) for the purpose of stimulating private enterprises, and the price of iron had remarkably risen, resulted in the large extension of all iron works to increase their production respectively, according to this state of the world. Moreover, closed works were reopened, many blast furnaces were newly builts pig iron making from steel scraps by cupola furnace or making pig iron by electric furnace etc. were tried, and hence in Taisho 7 or 8 (1918–1919) the number of pig iron manufacturing works, large and small, amounted up to 200, all in a very prosperous circumstances.

The Mitsubishi Iron Works at Kenjiho, Korea, were early enterprised, but they were put till June Taisho 7 (1928) that they produced pig iron. The South Manchuria Railway Co. Ltd. blew in the blast furnace at Anshan, Manchuria in April Taisho 8 (1919). The Oriental Iron Manufacturing Co. Ltd. establsihed blast furnace at Tobata, Fukuoka prefecture and began its operation in May Taisho 8 (1919).

When the Great War came to an end, the demand for pig iron decreased suddenly and the price of iron fell down considerably. Therefore many works which had no sound bases were gradually bunkrupted and even large works needed to regulate their workings, because the plants extended or newly built in prosperous time, were all rapidly constructed with high-priced materials and labours and invested comparatively large amount of capitals. Moreover the degree of fall in the prices of iron and steel products was far more than that of raw materials and wages. So the management of these works was not so easy. Inspite of such conditions the productive capacity of pig iron was brought back with rather increase within a few years as the result of endeavours of government and people for regulating and recovering of the works. The Oriental Iron Manufacturing Co. has left the operation of the Tobata Works to the Imperial Steel Works since April Taisho 10 (1921).

(v) Aspiring to "Self-Support and Self-Sufficiency."

On the other hand the demand for pig iron in this country is now increasing more and more, and with the object of meeting this demand, the extension and establishment of pig iron manufacturing works are now again setting on foot. The Asano ship building Yard Ltd. has newly built a blast furnace in Tsurumi factory in Yokohama and commenced the operation in Showa 2 (1927). The Imperial Steel Works attempted the improvement of old plants, and are now constructing a 500 tons blast furance at first. The Anzan Steel Works are now also erecting a 500 tons blast furnace. The Asano Ship Building Yard and the Nippon Steel Tube Co. Ltd. are said to build more a new blast furnace. Further, it is said that the Kamaishi Iron Works and the Kenjiho Iron Works design to reline old furnaces and to increase their capacity.

Thus the modern enterprises are all planned by steady steps and they are approaching to self-support and self-sufficiency of pig iron in this country by the permanent plan with large furnaces and newest equipments. We watch this tendency with close attention and wish to see it fullfilled as quickly as possible.

II. The Principal Pig Iron Manufacturing Works at Present Times.

The pig iron manufacturing works operated in comparatively large scale in this country and the works managed by Japanese or by the cooperation of Japanese and Chinese in Manchuria are eight in number, namely.

The Pig Iron Department of the Imperial Steel Works (Seitetsusho)
The Tobata Works of the Oriental Iron Manufacturing Co. Ltd.
(Toyo Seitetsu Kaisha)
—(now under the control of I.S.W.)
The Wanishi Works of the Nippon Steel Works Ltd. (Nippon Seikojo)
The Kamaishi Mining Works of the Kamaishi Mining Co. Ltd.
(Kamaishi Kozan Kaisha)
The Iron Department of the Asano Ship Building Yard Ltd.
(Asano Zosenjo)
The Kenjiho Iron Works of the Mitsubishi Iron Manufacturing Co. Ltd.
(Mitsubishi Seitetsu Kaisha)
The Iron Department of the Penchihu Coal & Iron Co. Ltd.
(Honkeiko Baitetsu Koshi)
—Joint undertaking of Japanese & Chinese.
The Anzan Iron Works of the South Manchuria Railway Co. Ltd.
(Minami Manshu Tetsudo Kaisha)

The Imperial Steel Works are the government works for steel making and are located at Yawata in the north part of Kyushu island facing the Dokai Bay, a little way from the Chikuho coal field. The Pig Iron Department of this works is producing every year about one half of the total production of pig iron in this country including Korea and Manchuria, operating six blast furnaces at present.

The Tobata works of the Oriental Iron Manufacturing Co. Ltd. are in Tobata about five kilometers from Yawata, and face the entrance of Dokai Bay. They have produced pig iron since Taisho 8 (1919) under the great scheme of sufficient supplying of iron and steel in this country. But owing to the weak tone of the market, they were brought to a standstill and the management was left to the Imperial Steel Works as mentioned before, and thus the whole pig iron produced there is now being sent to that works.

The Wanishi Works of the Nippon Steel Works were commenced at first by the Hokkaido Coal & Steamship Co. Ltd. and afterwards they were combined with the Nippon Steel Works Ltd. in Taisho 8 (1919). The works stand at Wanishi in Muroran City in the coast of the Funka Bay, Hokkaido.

The Kamaishi Works of the Kamaishi Mining Co. Ltd. are the oldest works in this country, based on the iron ore in the Kamaishi Mine and their furnaces were often improved. Tanaka Mining Co. managed them for a long time but afterwards the manager changed in Taisho 13 (1924) and the works have belonged to the present manager since that time. The pig iron produced here is almost supplied to their own steel plant and foundry. The works situate at Kamaishi, Iwate prefecture near the coast of the Bay.

The iron department of the Asano Ship Building Yard Ltd. was established in the Asano Ship Building Yard at Tsurumi in the coast of the Tokyo Bay, and produced pig iron from June Showa 2 (1927), soon after, the Steel Works are commenced there, too.

The Mitsubishi Kenjiho Iron Works belong to the Mitsubishi Iron Manufacturing Co. Ltd, and stand at Kenjiho, Korea, by the Daido River, where the ocean ships can drop anchors. With the object of smelting the ore in the neighbourhood, pig iron manufacturing was commenced in June Taisho 7 (1918) and then the steel making was also began but the latter was soon stopped.

The Penchihu Iron and Coal Co. Ltd. is cooperated by Japanese and Chinese but we mention here as the works have a deep relation to Japan. Penchihu (or Honkeiko) situates 76 kilometers south from Mukden, Manchuria, and the works were started as a coal mine undertaking but afterwards with the iron ore of Miaoerhkou 49 kilometers apart, it began iron manufacturing in Taisho 4 (1915).

The Anzan Steel Works were established by the South Manchuria Railway Co. Ltd. The company planned the exploitation of the iron ore in the neighbourhood

Table 1. The Number and Nominal Capacity of comparatively large Blast Furnaces.

Imperial Steel Works	*1×500 tons	2×330 tons	2×285 tons	2×250 tons
Tobata Works	1×300 〃	1×200 〃		
Wanishi Works	1×180 〃	2×130 〃	**1× 85 〃	
Kamaishi Works	1×250 〃	**1×200 〃		
Asano Works	1×150 〃			
Kenjiho Works	2×180 〃			
Honkeiko Works	1×180 〃	1×170 〃		
Anzan Works	*1×500 〃	2×300 〃		

* under erection ** Idle

of Anshan (or Anzan), and the No. 1 blast furnace was blow in, in April Taisho 8 (1919) under a large scheme, steel making was also planned but this was not realized. The works situate at Anshan, Manchuria, where is 311 kilometers from the harbour of Dairen and 90 kilometers from Mukden.

III. The Statistics About the Production etc. of Pig Iron.

Table 2. Annual Production of Pig Iron in Japan including Korea and Manchuria

Unit — 1,000 kg.

Year		Japan proper				Korea	Manchuria	Grand Total.
		Imperial S. W.	other large wks.	small works	Total.			
Meiji	32 (1899)	—	20,752		20,752	—	—	20,752
	33 (1900)	—	23,303		23,303	—	—	23,303
	34 (1901)	23,429	33,405		56,834	—	—	56,834
	35 (1902)	17,707	21,897		39,604	—	—	39,604
	36 (1903)	—	30,623		30,623	—	—	30,623
	37 (1904)	16,799	51,098		67,897	—	—	67,897
	38 (1905)	79,222	1,145 ?		80,367	—	—	80,367
	39 (1906)	100,451	40,828		141,279	—	—	141,279
	40 (1907)	95,249	44,824		140,073	—	—	140,073
	41 (1908)	103,324	42,499		145,823	—	—	145,823
	42 (1909)	107,565	56,679		164,244	—	—	164,244
	43 (1910)	126,894	61,124		188,018	—	—	188,018
	44 (1911)	143,978	59,089		203,067	—	—	203,067
Taisho	1 (1912)	177,160	60,595		237,755	—	—	237,755
	2 (1913)	176,650	63,713		240,363	—	—	240,363
	3 (1914)	210,736	71,675	17,810	300,221	—	—	300,221
	4 (1915)	243,646	61,738	12,364	317,748	—	29,909	347,657
	5 (1916)	286,807	74,070	27,814	388,691	—	49,022	437,713
	6 (1917)	304,618	107,239	38,785	450,642	—	38,610	489,252
	7 (1918)	271,578	150,812	160,368	582,758	42,698	45,712	671,168
	8 (1919)	281,135	200,935	113,448	595,518	78,384	106,082	779,984
	9 (1920)	242,903	186,156	91,977	521,036	84,118	116,037	721,191
	10 (1921)	345,596	86,272	40,857	472,725	83,010	93,951	649,686
	11 (1922)	453,556	78,648	18,641	550,845	83,179	59,842	693,866
	12 (1923)	491,302	98,647	9,749	599,698	99,933	97,849	797,480
	13 (1924)	477,095	101,673	7,162	585,930	99,795	134,376	820,101
	14 (1925)	555,997	120,882	8,299	685,178	99,160	136,685	921,023
Showa	1 (1926)	640,239	159,244	10,141	809,624	115,036	198,143	1,122,803
	2 (1927)	702,290	182,051	10,905	895,246	129,022	244,203	1,268,471
	3 (1928)	836,897	239,965	*10,000	1,086,862	146,212	284,677	1,517,751

Remarks:— * Presumed,

The production of Tobata Works of the Oriental Iron Manufacturing Co. is added to that of the Imperial Steel Works, since Apr. 16, 1921.

Table 3. Demand and Supply of Pig Iron.

Unit — 1,000 kg.

Year.		Production including Korea & Manchuria	Imports to Japan proper.	Exports.	Demand in Japan proper.	Ratio of home prod'n to demand.
Taisho	1 (1912)	237,755	228,546	324	465,977	51.0%
	2 (1913)	240,363	265,066	358	505,071	47.6
	3 (1914)	300,221	169,094	186	469,129	64.0
	4 (1915)	347,657	166,843	400	514,100	67.6
	5 (1916)	437,713	232,048	6	669,755	65.4
	6 (1917)	489,252	232,252	231	721,273	67.8
	7 (1918)	671,168	225,100	210	896,058	74.9
	8 (1919)	779,984	283,166	355	1,062,795	73.4
	9 (1920)	721,191	348,648	313	1,069,526	67.4
	10 (1921)	649,686	227,092	38	876,740	74.1
	11 (1922)	693,866	327,976	—	1,021,842	67.9
	12 (1923)	797,480	346,033	—	1,143,513	69.7
	13 (1924)	820,101	441,944	951	1,261,094	65.0
	14 (1925)	921,023	316,359	218	1,237,164	74.4
Showa	1 (1926)	1,122,803	399,640	30	1,522,413	73.8
	2 (1927)	1,268,471	472,947	106	1,741,312	72.8
	3 (1928)	1,517,751	386,821	unknown	1,904,572	79.7

Nextly, to obtain a concept on what position Japan stands concerning the pig iron manufacture in the world, we insert the following table. The numbers on it are the ratios of the presumptive amounts of production of the various countries in the year 1928 taking that of Japan including Korea and Manchuria, as unit.

Table 4. Relative Amount of Pig Iron produced in various Countries.

		%			%
U. S. A.	25.10	43.37	India	0.68	1.17
Germany	7.72	13.33	Poland	0.44	0.77
France	6.64	11.47	Spain	0.41	0.71
G. Britain	4.45	7.69	Italy	0.33	0.57
Belgium	2.56	4.42	Austria	0.30	0.52
Russia	2.21	3.81	Australia	0.29	0.49
Luxemburg	1.83	3.16	Sweden	0.26	0.45
Saar ter'y	1.28	2.20	China	0.20	0.35
Czechoslovakia	1.02	1.76	Hungary	0.18	0.32
JAPAN	1.00	1.73	others	0.30	0.52
Canada	0.69	1.19	Total	57.89	100.00%

IV. The Raw Materials.

(i) Iron Ore and Manganese Ore.

The most important factor in the Japanese iron industry is that of obtaining adequate supplies of the raw materials. There is a large quantity of Iron Sand and it was the important raw material for iron manufacture in old times. It is not considered, however, a proper raw material for the modern blast furnace process of large scale, because it deposits in the powder state and contains high titanium.

The iron ores are also widely scattered but the deposits are so small or so inconvenient for transportation that the economical working is impossible, excepting a few mines, namely Kutchan, Kamaishi and those in Korea and Manchuria.

Owing to these reasons, they have obtained a great part of the raw materials from foreign sources. That is, the Yangtse-Valley, China, has been an important iron ore resource for Japan from Meiji 33 (1900) up to this day. But from Taisho 9 (1920), the Malayan ore has become more important resource, and now the latter supplies more quantity than the former.

On the other hand, Japan has enjoyed the special right in South Manchuria, and the two iron works were established there to utilize the abundant quantity of iron ore in that district. The iron deposits consist of almost poor ore, but they have

Table. 5. Analyses of the Principal Iron Ores used lately in Japan.

Locality	Kind of ore	Fe	SiO_2	Al_2O_3	CaO	MnO	MgO	P	S	Cu
Japan proper,										
Kutchan	L	54.82	3.40	1.19	0.10	0.77	0.23	0.075	0.446	—
Kamaishi	M	55.14	9.23	1.76	6.98	—	1.57	0.042	0.719	0.223
Korea,										
Rigen	H	53.01	18.79	1.79	0.19	0.15	0.34	0.091	0.004	0.017
Inritsu	L	51.92	10.21	1.18	0.22	2.26	0.33	0.049	0.005	0.007
Sainei	L	51.16	12.38	1.68	0.26	1.55	0.35	0.041	0.001	0.004
Kaseimen	L	52.70	9.58	3.24	0.07	1.19	0.25	0.039	0.010	0.009
Kaisen	L	50.43	12.47	1.87	0.28	2.00	2.29	0.068	0.010	0.014
Manchuria,										
Miaoerhkou	M	64.01	5.68	1.28	0.45	0.14	0.03	0.015	0.116	—
Yingtaoyuan	H M	62.53	7.28	1.62	0.16	0.16	0.28	0.044	0.235	0.001
Wangchiaputzu	H M	54.51	20.68	1.00	0.15	0.16	0.51	0.039	0.300	0.001
Si-anshan	H M	57.20	14.90	0.95	0.14	0.27	0.25	0.120	0.029	0.001
Central China,										
Ta-washan, (Taiping)	H M	59.82	8.15	3.03	1.42	0.19	0.02	0.693	0.063	0.013
Ta-tungshan, (Taiping)	H	58.18	8.21	2.23	5.62	—	4.28	0.432	0.169	—
Taochung	H	54.65	17.59	1.35	0.45	0.19	0.24	0.008	0.005	0.005
Tayeh	M H	60.37	6.72	1.75	0.28	0.34	0.33	0.064	0.201	0.302
Haiangpishan	M H	59.97	10.13	2.12	0.21	0.33	0.08	0.045	0.033	0.230
Malay,										
Johore	H	64.47	1.62	2.78	0.14	0.20	0.31	0.186	0.019	0.013

solved decitedly the hard question of the utilization of these poor ores after much investigation.

It seems as if the ore supply of this country is uneasy, but in fact, it is never so, as compared with U.S.A. transporting the iron ore from the northern distreict of Minesota to Pensilvania, or from South America and Europe to the country, and also with Germany importing a most part of ores from the northern part of Scandinavia, Spain or Africa. When the utilization of poor ore in Korea is accomplished, the carrying distance may be more shortened.

Several examples of the composition of iron ores, and the supply and demand of them are shown in the table 5 and 6.

Table 6. Amount of Iron Ores produced and imported to Japan.

Unit—1,000 kg.

Year.	Production.					Imports to Japan				Grand total
	Japan proper	Korea	Manchuria	Iron sand	Total	from China	from Malay	from others	Total	
Taisho 6 (1917)	267,594	152,933	103,146	34,035	557,708	295,688	1,193		296,881	854,589
7 (1918)	378,114	430,787	189,357	37,948	1,036,206	359,698	1,232		360,930	1,397,136
8 (1919)	362,949	417,000	263,865	27,523	1,071,337	595,140	25,946		621,086	1,692,423
9 (1920)	314,858	447,249	175,966	9,134	947,207	650,527	11,841		662,368	1,609,575
10 (1921)	86,977	232,692	206,243	9,878	535,790	439,769	138,287		578,056	1,113,846
11 (1922)	39,744	185,584	140,128	6,067	371,523	644,730	173,780		818,510	1.190,033
12 (1923)	55,174	306,255	213,731	3,799	578,959	661,796	231,464		893,260	1,472,219
13 (1924)	57,922	323,639	220,105	3,118	604,784	800,157	264,933	42	1,065,132	1,669,916
14 (1925)	75,765	376,207	220,999	3,459	676,430	813,490	290,213	6	1,103,709	1,780,139
Showa 1 (1926)	130,420	387,717	566,543	4,469	1,089,149	502,747	290,053	30	792,830	1,881,979
2 (1927)	159,005	422,560	630,604	12,301	1,224,470	502,597	434,837	54	937,488	2,161,958

The manganese ore deposits lie scattering at various quaters in this country, but they are so small and the ore is not so good that the most part of requirements must be imported from China and Malay or other contries. The highest record of annual home production was 57,000 tons, and of late years it will be perhaps 20,000 tons thereabout.

Table 7. Analyses of the principal Manganese Ores used lately in Japan.

Locality	Mn	Fe	SiO_2	Al_2O_3	CaO	MgO	P	S	Cu
Average in Japan proper;	36.97	3.33	25.46	2.62	2.39	0.97	0.115	0.081	0.010
Canton, China;	36.80	12.30	6.80	4.90	0.49	0.32	0.379	0.044	0.213
Trengganu Malay;	19.13	30.94	7.19	3.40	0.27	0.68	0.104	0.040	0.135

(ii) The Utilization of Cinders.

The residual pyrite cinder from the manufactories of the sulphuric acid should be an important raw material for iron manufacture. Non cupriferous pyrite cinder is almost all used for the purpose; the cupriferous one is now in use mostly for the copper smelting, and a small part of it is treated by Lahmen's wet method and the residue, so called purple ore, is sent to the iron works.

On the other hand, the utilization of the soaking pit cinder, reheating furnace cinder, rolling mill scale, ferromanganese slag, steel furnace slag etc., has increased lately at an enormous rate. The cinder which had been abandoned from forges or smelting mills in old time, accumulates everywhere in the mountain land of Chugoku district, and it may be a pretty good raw material for the manufacture of iron.

Table 8. Analyses of the Cinders and Slags.

Kind	Fe	Mn	SiO_2	Al_2O_3	CaO	MgO	P	S	Cu	Remarks.
Pyrite cinders;	61.78	0.20	4.62	0.92	0.67	0.36	0.034	2.752	0.250	Average.
Purple Ore;	56.42	0.18	10.79	1.36	1.86	0.51	0.086	1.077	0.177	Osaka Smelting Co.
Soaking Pit cinder;	69.61	0.83	2.30	0.54	0.26	0.27	0.024	0.025	0.076	Imperial S. W.
Rolling mill scale;	73.0	0.65	3.40	—	—	—	0.020	0.018	0.088	Asano Works.
Open hearth slag;	17.24	9.27	17.18	5.21	34.43	7.46	0.958	0.177	0.011	Imperial S. W.
ditto;	7.58	4.43	23.43	5.34	42.63	7.55	0.506	—	—	Muroran Works.
Ferromanganese slag;	2.21	16.57	32.08	8.26	27.96	2.50	0.045	0.744	0.061	Electric Steel. W.
Forge cinder;	*60.16	0.45	22.32	2.74	2.42	0.72	0.037	TiO_2 2.56		Chugoku district. 〃

* contains metallic Fe.

(iii) The Agglomeration of the Fine Ore.

For the agglomeration of the fine ore, various methods were tried everywhere.

The Wanishi and Kamaishi Works have been operating the pot roasting method for a long time. The Imperial Steel Works are adopting a rotary kiln for this purpose, but it does not give satisfactory result economically.

Recently, the system A.I.B. sintering plant having 150 tons daily capacity, is now on the course of erection in the Imperial Steel Works to treat mainly the pyrite cinder, purple ore etc. The Kamaishi Works are erecting the Dwight Lloyd sintering plant which daily capacity is 75 tons. Both these plants will be completed in this year (1929).

(iv) The Fuels.

It is very difficult to obtain hard and good coke from Japanese coal, as it has less caking power, higher ash and volatile matter. The blast furnace operators are obliged to satisfy with the hardness and purity of the coke made by mixing, in even

the best case, a few parts of Chinese coal which has somewhat higher coking power. It is one of the most serious reasons for the technical difficulty of the blast furnace working in this country, that they can scarcely obtain a hard and low ash coke. This insufficiency of hardness makes them hesitate for the erection of a large blast furnace. In adition, its comparative high cost oppresses economically the pig iron manufacture in some cases.

Table 9. Examples of properties of Coke used in the Blast Furnace Plants.

Name of Works	Ash.	vol. M.	Fix. C.	T. S.	Porocity.	Hardness.
					%	%
Imp. Steel W.	17.47	2.72	79.00	0.81	43.94	**86.57
〃 〃 〃	20.66	2.52	76.82	1.97		
Wanishi Works	16.26	2.43	81.28	0.48	42.24	—
Kamaishi Works	14.60	1.15	84.25	0.42	44.76	82.60
Asano Works	*19.80	0.76	78.35	1.01	—	—
Kenjiho Works	18.92	1.80	79.28	0.83	42.10	92.76
Honkeiko Works	17.76	1.62	80.62	1.20	45.00	—
Anzan Works	13.16	1.85	84.99	0.68	—	—

* Purchased.
** Crushing test in revolving drum.

In the begining stage of a blast furnace operation almost all iron works used to equip beehive coke ovens or Halday ovens hurriedly, or manufactured the coke by open stalls, and afterwards substituted gradually the byproduct ovens as shown in the following table.

Table 10. Coke Ovens.

Name of works.	Type	Number of ovens	Total daily output (metric tons)
Imp. Steel Works	Solvay	150	500
	Koppers	120	362
	Kuroda	100	682
	Kuroda	100	715
	Kuroda (under erection)	75	605
Tobata Works	Kuroda	55	392
Wanishi Works	Miike	60	375
Kamaishi Works	Koppers	60	343
Kenjiho Works	Will-Putte	75	612
Honkeiko Works	Kuroda	60	495
Anzan Works	Koppers	160	800
	Fukamizu	5	25
	Koppers(under erection)	—	—

The Asano Works at Tsurmi have no oven and purchase coke from others but is expected to construct Koppers ovens in the near future. The Yawata Works is to adopt Kuroda ovens with dry quenching method of Collin style for the new blast furnace under construction and the Anzan Works adopt more Koppers ovens.

Lately the charcoal is not only high price but difficult to gather, so that it is used only for small blast furnaces in Chugoku district.

V. The Utilization of the Poor Ore and the Iron Sand.

(i) Treatment of Poor Ore.

Several hundred million tons of iron ore are hidden underground in Manchuria, but the rich ore is only about one per cent of them, and as the other are all poor ores containing about 37 % of Fe and 48 % of SiO_2 in rough average; the enrichment of it is a very important matter not only for the iron industry in that district but for that of Japan.

The Penchihu Coal & Iron Co. paid attention to this problem and erected the dressing plant at Nanfen 41 km. apart from Penchihu, which consists of five Gröndal's magnetic separators, five shaking tables and other accessories; the poor magnetite is enriched up to more than 60 % Fe. The practical capacity of this plant may be counted 70—100 tons of concentrate per day, according to the degree of concentration. This concentrate is briquetted by means of the press and the tunnel kiln in the Honkeiko Works.

The iron ore of Anshan district is almost hematite, so the reducing roasting must be applied previously. After much study, the Anzan Works designed a special kiln for this purpose. Combining this roasting kilns, magnetic separators and Dwight Lloyd sintering machines etc., a large plant having 900 tons daily capacity, has been installed there and has commenced its work successfully since May Taisho 15 (1926). The sintered ore thus made contains about 55 % of Fe and 21 % of SiO_2.

(ii) The study for Utilization of the Iron Sand.

The utilization of the iron sand is an important problem in this country which

Table 11. Examples of the Analyses of Several Iron Sands.

Locality	Fe	SiO_2	Al_2O_3	CaO	MnO	MgO	P	S	Cu	TiO_2
Funka Bay	55.68	9.66	2.00	1.65	1.49	4.21	0.369	0.022	0.150	9.36
Shimokita	25.41	41.13	—	—	1.75	—	0.050	tr.	—	3.46
〃	43.53	14.02	12.25	2.34	2.68	0.77	0.070	0.110	—	7.38
〃 (dressed)	55.06	4.80	1.56	0.35	0.67	—	0.023	0.005	0.074	13.55
near Kuji	21.87	48.54	—	—	1.01	—	0.020	0.570	—	1.68
〃 〃	51.78	4.16	3.48	0.74	0.98	1.46	0.062	0.082	0.019	15.98
Chugoku (washed)	52.27	12.48	2.06	1.41	1.89	0.98	0.042	tr.	0.057	5.37
〃 (〃)	60.42	5.42	1.60	1.59	1.01	1.56	0.169	0.159	0.059	5.79

has not much iron ore resources, such being the case many studies were done by the mining works, iron works and investigators.

We will state here different studies or experiences of recent utilizations of iron sand. About those in the ancient times, we will illustrate in another chapter.

(a) The Iron Sand at the Coast of Funka Bay, Hokkaido.

The Wanishi Iron Works took attention on the iron sand at the coast of Funka Bay near the works and with which the briquette was made mixing other ores partly, by means of the Schumacher process in Meiji 42 (1909). The iron sand briquette such made was used for the blast furnace up to 55 per cent of the total ore burden, though it attended some difficulties. But soon after it became out of use.

(b) The Iron Sand at Shimokita Peninsula Aomori prefecture.

From about Taisho 4 (1915), Dr. Kishi's Research Laboratory studied to get the iron from the iron sand scattering on the sea shore and hill side at Shimekita Peninsula. The iron sand, most part of which altered into the colitic limonite, could not be completely concentrated by magnetic means; it was therefore roughly washed with Wilfley table once more, and made to the briquette mixing with milk of lime. And it was tried to smelt in the specially designed gas reducing furnace or electric furnace. But this trial fell through. Then the Arsenal had proceeded the trial, but it did not succeed, too. At last in Taisho 9 (1920) the study has been left to the Imperial Steel Works.

The Imperial Steel Works concentrated the iron sand by washing and magnetic means at the native place, sintered by rotary kiln at Yawata, and smelted by the blast furnace and the electric furnace. The trial by the blast furnace was rather to know the influence of titanic oxide for furnace working. And they recognized that it was not all impossible to work, up to 3 per cent of TiO_2 in total ore charge if special attention paid. About the electric furnace method, it was concluded that the operation was not so difficult even in any rate of TiO_2 content, and besides titanic oxide itself should be utilized effectively. It is not, however, be able in present time, because the local conditions of deposite and complexity of the treatment raise its cost.

(c) The Iron Sand near Kuji, Iwate prefecture.

The iron sand which distributes widely along the hill side near Kuji, had been used, for a while, for iron manufacture in former times. Its appearance and compositions are similar those of Shimokita iron sand.

About ten years ago the Tokiwa Co. tried to make iron from the iron sand at Kuji by means of *Kakuro* (mentioned hereafter). After that, so-called ferrocoke was made from the mixture of coal and iron sand, and charged into the small blast furnace with other raw ore. These trials were soon stopped on account of the difficulties of furnace operation. Then a complete plant of the Anderson & Thornhill direct reducing process was established and its practical working bagan in June Showa

2 (1927). It is regrettable that this most modern working has stopped in the course without good result on account of various reasons.

VI. The Present State of the Iron Manufacture.

(i) The Blast Furnace.

The first blast furnace of European style built in this country was the 30 ton furnace at Kamaishi.

About 30 years ago it was thought to be impossible to operate any blast furnace more than 100 ton daily capacity in the poor conditions in this country i. e. iron ore is mainly dense magnetite, and coke is very bad quality. But afterwards, using differ-

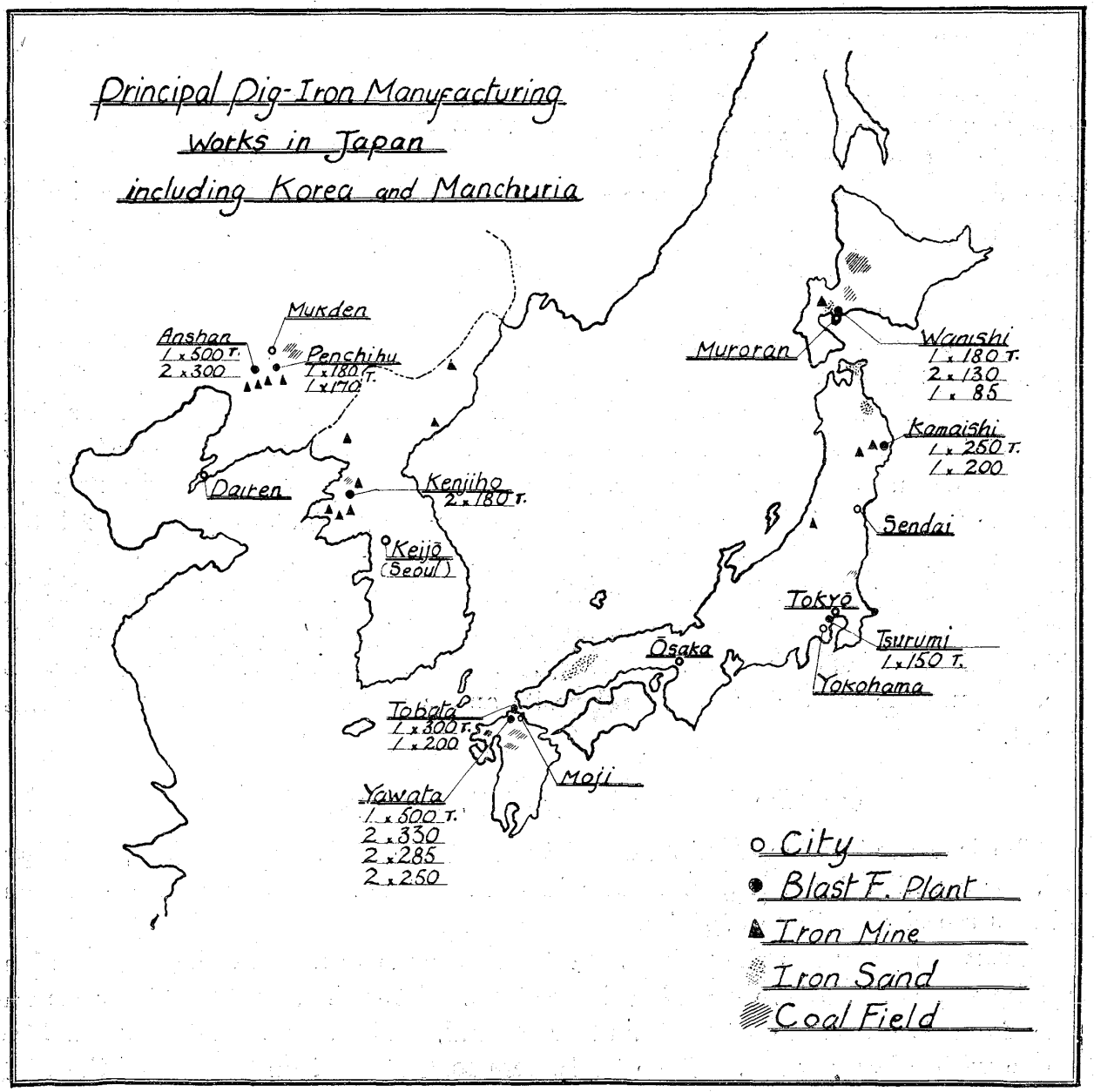

Plate 1.

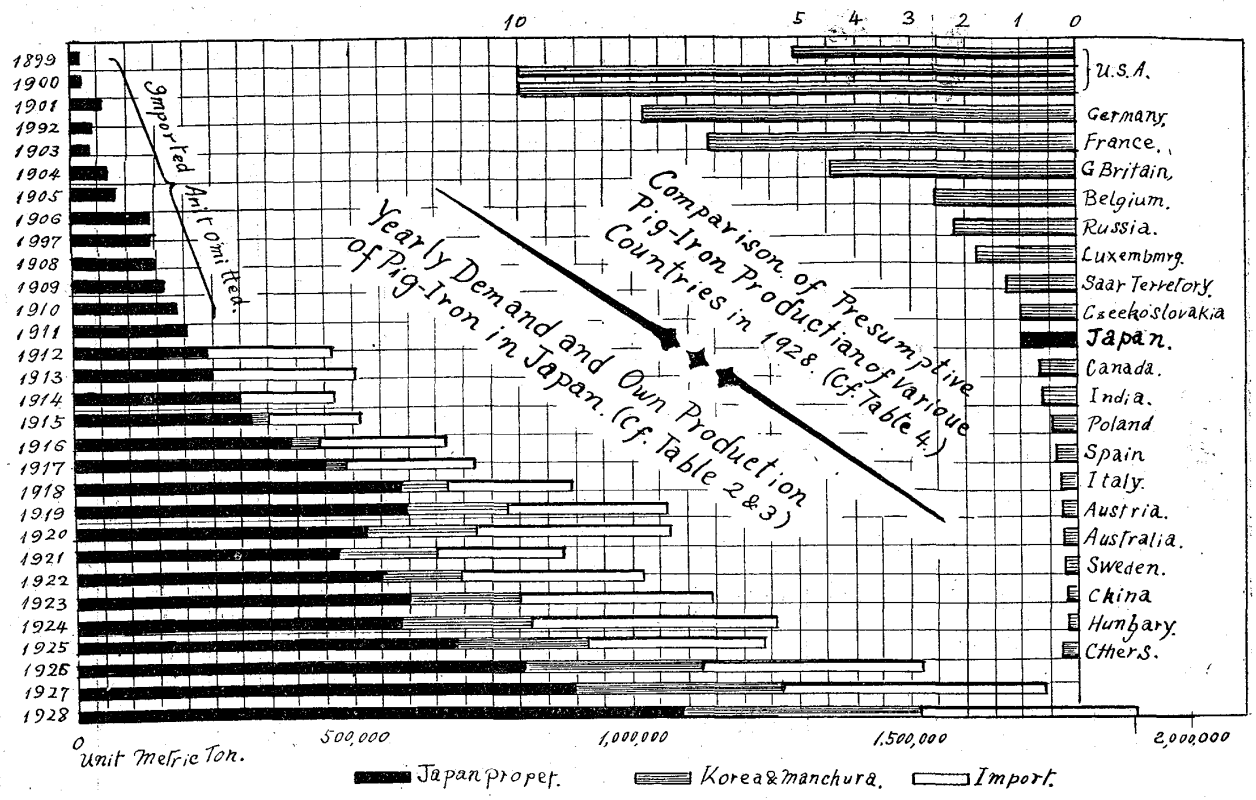

Plate 2.

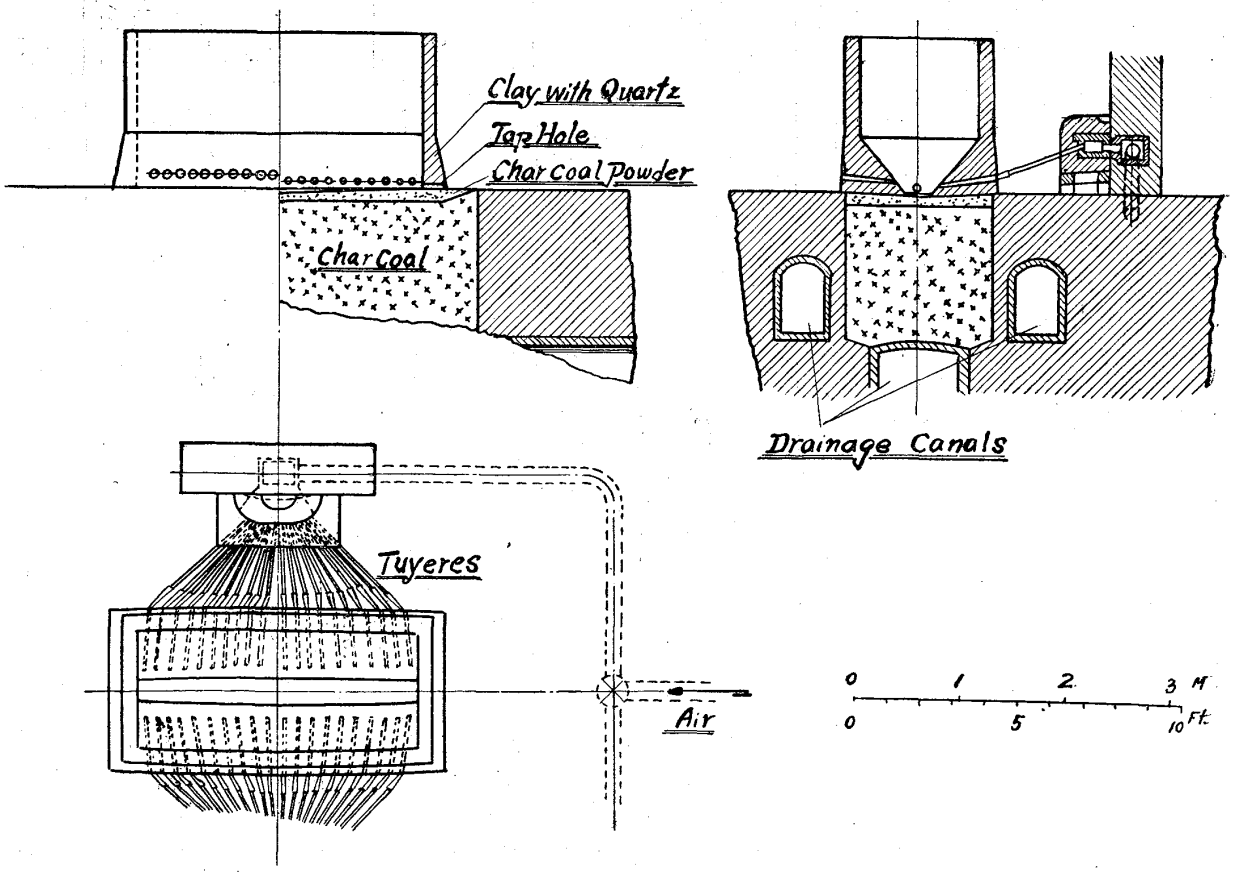

Plate 3. *Tatara* Furnace

Table 12. Dimensions etc. of Representative Blast Furnace in the Principal Iron Works.

Name of Works;	Imperial Steel Works			Kamaishi	Wanishi	Asano	Kenjiho	Honkeiko	Anzan Works	
Furnace No.;	No. III	No. VI	K No. I	No. IX	No. II	No. I	No. I & II	No. I	No. II	No. III
Date blown in;	November 1927	September 1925	Erecting	April 1929	July 1928	June 1927	Jnne 1918	June 1929	July 1926	Erecting
Diameter of Hearth; mm	4,700	4,700	5,400	4,700	4,100	3,600	3,404	3,500	4,601	5,639
〃 〃 Belly; 〃	6,300	6,700	6,700	5,866	5,600	5,500	5,791	5,400	6,801	6,858
〃 〃 Throat; 〃	4,600	4,680	5,100	4,000	4,000	3,800	4,115	3,850	4,521	5,182
Height of Hearth; mm	2,300	2,600	2,600	2,680	2,200	2,100	2,438	2,560	2,600	3,353
〃 〃 Bosh; 〃	3,730	4,000	3,500	3,000	3,300	3,500	4,458	4,306	4,301	3,200
〃 〃 Belly; 〃	1,520	8,000	2,200	2,500	2,000	1,300	1,549	1,220	1,521	2,438
〃 〃 Shaft; 〃		1,800								
(conical part)	18,450	13,800	14,000	11,228	11,500	11,200	12,891	12,072	13,183	12,802
(cylindrical part)	—	—	1,700	3,139	1,000	—	—	—	3,308	2,591
Total Effective Ht.; 〃	21,000	22,200	24,000	22,547	20,000	18,100	21,137	20,158	24,913	24,384
Numb. & Dia. (mm) of Tuyere;	5×140 5×130	5×160 5×130	12×—	10×122	9×130	9×125	8×127	12×125	12×135	12×150
Bosh Angle;	75°−54′	75°−58′	79°−29′	79°−0′	77°−11′	74°−49′	75°−01′	77°−33′	73°−11′	79°−13′
Effective Volume; cm³.	493	573	650	437	362	302	389	326	530	694
Nominal Capacity; ton.	285	330	500	250	180	150	180	180	300	500
Actual Output; annual av.	329	338	—	—	—	150	201	—	310	—
〃 (monthly average)	(366)	(374)			(199)					
Furnace Type or Construction;	Free standing type with sheet iron shell			Free standing type with steel band Thin wall bosh			Scotch type		Free standing type with st. band	Scotch type
Top Apparatus;	Revolving distributer		McKee's	Bucket		Brown's	Kennedy's	Pohlig's		McKee's
Hoist;	Incline			Vertical-horizontal		Incline				

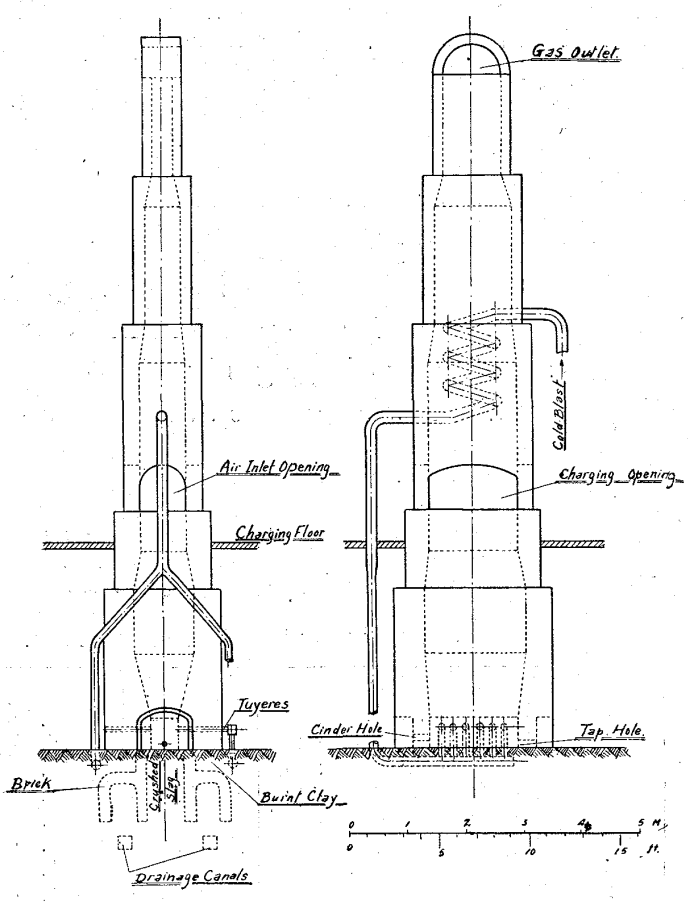

Plate 4. *Kakuro*

ent ores and somewhat better coke and also making a great progress in the technique they have 350 tons furnaces in these days, moreover 500 ton furnaces are now under construction.

At the Imperial Steel Works the effective inner volume of blast furnace for one ton pig produced per day was 3.2 cubic meters at begining, but it has already progressed to 1.5 cubic meters in recent times though it is yet inferier to many of European or American practice. And the inner profile of blast furnace tends towards the adaption of broad hearth, low bosh, and steep bosh angle in response to the tendency of the world.

(ii) The Hot Blast Stove.

Table 13. Type and Dimension of Hot Stoves.

	Side Combustion Two Pass (Cowper)			Central Combustion Three Pass (McLure)		
	Diam.	Height	Numb.	Diam.	Height	Numb.
	mm	mm		mm	mm	
Imp. Steel W.	6,000	30,000	16	6,500	30,000	8
				6,700	30,000	4 (under erection)
Tobata Works	6,096	21,335	4	6,500	30,250	4
Wanishi Works	5,650	21,500	3			
	〃	28,650	3			
	〃	27,000	3			
	〃	27,200	3			
Kamaishi Works	5,757	26,324	8			
	5,636	20,091	3			
Asano Works	5,650	27,162	3			
Kenjiho Works				6,096	29,159	8
Honkeiko Works				6,096	27,432	6
Anzan Works				7,315	28,683	8

The three-pass stoves in the Imperial Steel Works and the Anzan Works have their own special designed checker work respectively, which differ from that of McLure type.

The size of checker flue has become smaller in accordance with the progress of gas cleaning.

(iii) The Blowing Engine.

The blowing engines were only steam reciprocating piston type in early times, but gas blowing engine was used in Taisho 3 (1914) in the Imperial Steel Works for the first time, and after that, turbo blowers were adopted for the plants in Manchuria and Korea. The Imperial Steel Works is now setting two large gas blowing engines for the new blast furnace plant; and the Kamaishi Works will increase them anew, too.

Table 14. Types and Data of Blowing Engines.

Type of Engine	Number	HP.	Revol. P. Min.	Deriv. Vol. of Air m^3/min	Blast Pres. Hg/sq. cm.	
					Norm.	Max.
Imperial Steel Works,						
Horiz. Cross Comp. Steam Engine	4	850	40	600	—	0.70
〃 〃 〃 〃 〃	1	1,500	40	660	—	0.84
〃 〃 〃 〃 〃	1	1,600	40	800	—	0.84
** 〃 〃 〃 〃	1	1,600	42	420	0.79	2.10
Turbo. Electric driven	2	1,140	2,767	600	—	0.63
4 Cycle Tandem Gas Engine	1	810	95	500	0.70	1.05
〃 〃 〃 〃 〃	1	1,800	85	1,100	0.70	1.05
* 〃 〃 〃 with Scavenger	2	3,260	86	1,400	1.05	1.60
Tobata Works,						
Vertical Steam Engine	3	300	40	435	0.42	—
Horiz. Cross Comp. Steam Engine	4	400	50	300	0.61	—
Wanishi Works,						
Horiz. Cross Comp. Steam Engine	7	400	50	300	—	0.84
Kamaishi Works,						
Horiz. Cross Comp. Steam Engine	2	480	20	256	0.42	—
〃 〃 〃 〃 〃	2	250	34	218	0.42	—
〃 〃 〃 〃 〃	1	120	34	143	0.42	—
Verti. 〃 〃 〃 〃	1	400	34	354	0.42	—
* 4 Cycle Tandem Gas Engine	2	—	92	1,200	0.84	1.26
Asano Works,						
Horiz. Cross Comp. Steam Engine	2	350	50	300	—	0.63
Kenjiho Works,						
Turbo. Steam driven	3	1,500	3,300	900	0.63	1.05
Honkeiko Works,						
Turbo. Steam driven	2	840	2,500	720	0.42	—
〃 〃 〃	1	1,240	3,250	708	—	0.84
Anzan Works,						
Horiz. Cross Comp. Steam Engine	2	1,000	35	600	—	0.84
Turbo. Steam driven	1	3,000	3,000	1,060	0.91	
〃 〃 〃	1	2,090	2,800	1,000	0.91	
〃 〃 〃	1	2,000	2,950	700	0.84	
* 〃 〃 〃	2	5,000	2,860	1,260	0.91	

* Under manufacturing or erection.

** Blower for Bessemer converter, diverting now for blast furnace use.

(iv) The Raw Material Used.

The figures on the table 15, 16, and 17 are the records in late one year.

Table 15. Raw Materials used for a Ton of Pig Iron Produced.

	Iron Ores ton	Manganese Ores	*Miscellaneous	Total of Metal bearing Materials	Lime-Stone	Coke
Imp. Steel W.	1.453	0.056	0.247	1.756	0.374	1.056
Tobata Works	1.721	0.059	0.004	1.784	0.435	1.094
Wanishi Works	1.726	0.023	0.059	1.808	0.466	1.134
Kamaishi Works	1.517	—	0.240	1.745	0.273	1.061
Asano Works	1.448	—	0.285	1.733	0.405	1.091
Kenjiho Works	1.790	—	0.016	1.806	0.633	1.000
Honkeiko Works	1.592	0.013	0.020	1.625	0.563	1.205
Anzan Works	1.733	0.004	0.018	1.755	0.746	1.113

* Scrap, open hearth slag, ferromanganese slag, rolling mill scale, pyrite cinder, etc.

Table 16. Producing Districts of Iron Ores and their Amount consumed.

Unit—1,000 kg.

Locality \ Iron Works	I.S.W.	Tobata	Wanishi	Kamaishi	Asano	Kenjiho	Honkeiko	Anzan
Japan proper								
Kutchan	—	—	47,842	—	—	—	—	—
Kamaishi	—	—	5,799	79,482	—	—	—	—
Others	—	155	—	—	2,884	—	—	—
Korea								
(Limonite)	72,374	11,809	—	—	—	235,459	471	—
(Hematite)	67,252	9,378	34,941	—	285	—	—	—
South Manchuria								
Miaoerhkou	—	—	—	—	—	—	68,014	—
Yingtaoyuan	—	—	—	—	—	—	—	11,131
Wangchiapu-tzu	—	—	—	—	—	—	—	70,226
Si-Anshan	—	—	—	—	—	—	—	59,089
Others	—	—	—	—	—	—	1,521	—
(Agglomerates)	—	—	—	—	—	—	30,294	241,842
Central China								
Taiping	19,246	—	29,351	9,676	671	10,737	—	—
Taochung	109,583	68,198	—	—	—	—	—	—
Tayeh	130,141	70,011	—	—	—	—	—	—
Hsiangpishan	20,763	—	51,009	25,804	67,631	13,746	—	—
Others	30,816	—	—	—	—	—	—	—
Malay								
Johore	498,601	148,612	—	—	—	1,839	—	—
Total	948,776	308,163	168,942	114,962	79,471	261,781	100,300	382,288

The chief materials among the miscellaneous ones are the open-hearth slag and the pyrite cinder.

Table 17. Utilized Amount of metal bearing Auxiliaries.

	O. H. Slag	Pyrite Cinder
Imperial Steel Works	132,100 ton	24,500 ton
Kamaishi Works	14,700	—
Asano Works	10,600	3,330
Anzan Works	—	2,000

The blocks of the ore and limestone are crushed to moderate size by means of the crusher or hand cobbing. The Kamaishi Works have the roasting kilns to treat their own ore which is dense magnetite.

The connection devices between ore bin and furnace hoist in almost all plants are not in good order except the Anzan Works. To carry the ores from wharf to the furnace side, the aerial ropeways are equipped in the Imperial Steel Works; and the belt conveyor in the Asano Works. The coke is loaded into the carts or tubs in front of the coke oven. In general, the material handlings in the blast furnace plants are old-fashioned and laborious in this country.

(v) The General Working Methods.

Of course, the pressure and the temperature of blast vary widely according to the working conditions; we may mention, however, that these appear to be about as follows in normal state.

Table 18. Pressure and Temperature of Blast.

	Pressure Kg/sq. cm.	Temperature C°
Imp. Steel Works	0.65—0.75	600—700
Wanishi Works	0.30—0.70	400—700
Kamaishi Works	0.4	500—650
Kenjiho Works	0.75—0.80	700—800
Honkeiko Works	0.40—0.55	500—700
Anzan Works	0.55—0.80	450

The cast aluminium tuyere and lead pipe which the Imperial Steel Works adopted are yielding satisfactory results for many years. The latter is free from the corrosive action of sea water which is used for cooling of tuyere etc. The Kamaishi Works and Asano Works use their own patented shaped tuyere respectively.

VII. The Products and Their Utilization.

(i) The Pig Iron.

Both the Imperial Steel Works and the Tobata Works are producing the basic open-hearth pig iron and it is entirely used as a raw material for the steel making of the former. The other works are manufacturing the basic and foundry irons for sale or their own use. At Kenjiho Works the pig iron is again refined sometimes to low phosphorous one by the patented method. The ore and coke of the Honkeiko Works are able to make low phosphorous iron. The foundry pig made from Kamaishi ore only is good for the foundry use, and the iron from Chugoku iron sand is willingly used as the materials of the crucible steel as well as the special castings.

The application of the Thomas process, accordingly the manufacture of Thomas pig iron have been discussed frequently, and it remains as a serious question in the iron and steel industry in Japan.

Table 19. Production of Pig Iron of the principal Iron Works in the latest three years.

Unit — 1,000 kg.

Year / Name of Works	Showa 1. (1926)	Showa 2. (1927)	Showa 3. (1928)
Imperial Steel Works	532,908	540,499	650,574
Tobata Works	107,331	161,791	186,323
Wanishi Works	94,629	92,204	109,543
Kamaishi Works	64,615	67,683	75,737
Asano Works	—	22,164	54,685
Kenjiho Works	115,036	129,022	146,212
Honkeiko Works	51,816	51,308	64,039
Anzan Works	146,327	192,895	220,638
Total	1,112,662	1,257,566	1,507,751

Table 20. Composition of Pig Irons.

	C	Si	Mn	P	S	Cu	Remarks
Imp. Steel Works	4.20	1.76	2.06	0.382	0.025	0.091	Total average in 1928.
Tobata Works	4.12	1.41	1.22	0.192	0.036	0.125	Total average in 1928.
Wanishi Works	3.97	1.35	1.53	0.250	0.020	0.190	Average of basic pig.
Kamaishi Works	3.64	1.87	0.50	0.160	0.040	0.240	Pig iron No. 3
Asanó Works	4.05	1.60	0.88	0.875	0.042	0.214	Average in Feb. 1929.
Honkeiko Works	4.04	2.28	0.60	0.019	0.008	—	An example of low P. pig.
Anzan Works	3.81	2.02	0.18	0.124	0.041	—	Aver. of No. 2. fur. in 1928.

The advantage of "one heat process" has been advocated, and the use of pig iron in molten state are gradually increasing, the molten iron produced at Tobata Works is conveyed to the Imperial Steel Works on the water course of 5 kilometers since September Taisho 14 (1925) for this purpose the two special designed boats which carry respectively two 25 ton ladles, were built. In this works, the 91 per cent of the pig produced out of their own blast furnaces and 64 per cent of those in the Tobata Works, were used in the molten state in late one year. At the Kamaishi Works the 59.1 per cent were used in molten state, and at the Asano Works it amounted to 31.3 per cent.

Two Heyl & Patterson's pig casting machines are equipped in the Imperial Steel Works.

(ii) The Cleaning and Utilization of the Blast Furnace Gases.

In the Imperial Steel Works the blast furnace gases are passed, for the cleaning purpose, through the hurdle washer and nextly the centrifugal fan into which the water is poured. The gases once passed through the fan are used for the heating of the hot blast stoves, boilers, open hearth furnaces and the soaking pits. The gases passed twice are used for the gas blowing engines and the gas dynamos. Further, in the new improving scheme, it is decided to use for the coke ovens. The gas cleaning system at the Wanishi Works is similar to the above stated one.

In the Anzan Works there are four Theisen gas washers which are capable to clean each 450 cubic meters of the gas per minute.

The electric gas cleaning had once tried at the Wanishi Works; the Imperial Steel Works is now trying it on a small scale, and it will be soon installed on a practical scale. The Kamaishi Works will work a Cottrel plant at the end of this year (1929).

In the brief, the cleaning and utilization of the gases in this country seems to be behind times.

Here we insert the analyses of gases in the various works, through which we can guess a side of the results of the blast furnace working.

Table 21. Analyses of Blast Furnace Gases.

	CO_2	O_2	CO	H_2	CH_4
Imp. Steel Works	10.70	0	29.40	1.61	0.92
Tobata Works	12.29	—	25.46	—	—
Wanishi Works	11.40	0	29.30	2.00	0.30
Kamaishi Works	8.16	0.12	30.65	2.00	0.20
Asano Works	9.70	0.20	28.10	—	—
Kenjiho Works	14.20	0.10	25.50	2.10	0.30
Honkeiko Works	8.80	0.10	31.20	—	—
Anzan Works	10.17	0.20	29.78	—	—

(iii) The Slag and its Utilization.

Table 22. Slag Amount and its Compositions.

	Slag Amts. for pig (%)	SiO_2	CaO	Al_2O_3	MgO	MnO	FeO	P_2O_5	S
Imp. Steel W.	68	31.91	45.06	16.21	3.33	1.80	0.47	0.014	1.382
Tobata Works	60	36.71	43.38	15.59	—	—	—	—	—
Wanishi Works	62	35.69	43.71	14.50	—	0.43	0.52	—	1.344
Kamaishi Works	67	35.88	43.51	11.34	—	5.16	1.06	—	1.082
Asano Works	70	32.52	45.40	16.28	—	0.74	0.37	0.013	0.910
Kenjiho Works	76	34.52	41.87	12.76	4.72	1.50	2.20	0.010	1.218
Honkeiko Works	67	30.10	48.00	19.53	—	4.20	—	—	2.015
Anzan Works	72	41.03	44.81	9.24	2.92	0.18	1.24	0.016	0.906

A part of the slag is made into the slag brick in many works, and into the silicate cotton and slag cement etc. in some works. The Imperial Steel Works and the Kamaishi Works make comparatively much slag products.

Table 23. Slag Products and their Amount.

Product \ Name of Works / year	Imp. S. W. & Tobata W. 1926	1927	1928	Kamaishi Works 1926	1927	1928
Silicate Cotton (ton)	691	943	660	—	—	—
Slag Brick (〃)	65,336	75,860	136,509	5,464	4,003	1,878
〃 Mortar (〃)	247	218	53	1,060	1,644	1,450
〃 Cement (〃)	21,488	25,520	54,711	—	—	—
〃 Ballast (cub. m.)	41,891	50,743	69,647	—	—	—

VIII. The Iron Manufacturing Processes other than the Blast Furnace Method.

(i) The *Tatara* (Tread-Bellows) Process.

In Chugoku district, the *Tatara* process, by which the iron sand is smelted, has properly developed since ancient times. It had been a very important iron and steel making process down to the begining of the Meiji era (1868—1912) in Japan. But for the several years past the process has been entirely abandoned. We will briefly state on it, as we think it to be interesting historically.

The iron sand in this district is collected out of the earth of hill side, which contains only about 0.1—1.8 % of Fe, by means of the water flow.

The furnace is a kind of stall furnace as shown in Plate 3.

After the furnace being dried slowly, it is filled up with charcoal and fired at

the bottom; when the fuel blazes fiercely by blowing air blast, the iron sand is scattered into the furnace, then about 120 kilogram of charcoal and 100 kilogram of iron sand are charged alternately complying descent of the charge. The melted iron is tapped out at intervals, through the tap hole. After four days' continuous operation, the furnace wall wear away to out of use; then the blowing is stopped and the furnace is broken down to repair.

The amount of pig produced in one operation, is said to be about 5—6 tons according to the purity of iron sand and the capacity of the furnace. To obtain one ton of pig iron, about 2.5 tons of iron sand and about 3 tons of charcoal are required.

The pig iron manufactured by this process is of course the white pig, but sometimes the low carbon iron, hard to melt, may coagulate at a part of the furnace.

To send the air, tread-bellows was used in old times. It was replaced by water-trompe and then by the box-bellows connecting water wheel.

With such a *Tatara* furnace wa can also make steel directly, changing slightly its design and operation.

(ii) The *Kakuro* (Rectangle Furnace) Process.

The *Kakuro* in Chugoku district may be considered a furnace which was derived from the *Tatara* furnace in the Meiji era, and it is rather similar to the copper blast furnace. Many of the *Kakuro* existed at one time for the pig iron manufacture from the iron sand or old forge cinder, but there are now only a few. Plate 4 is a sketch of it now in operation.

The concentrated iron sand and charcoal are thrown into the furnace with the ratio 1.0 to 1.1—1.3 alternately, and its daily production is about 3 tons of the white pig. It can be worked continuously, but the operation is stopped after 20—50 days owing to the insufficient supply of charcoal and the small market of the product. Thus its annual production of a furnace is about 300—400 tons. It is said that about 3 tons of iron sand and about 3.5 tons of charcoal are necessary for making one ton of pig.

There are some smelting works which make the pig iron from the old forge cinder by the *Kakuro* or the small blast furnace, It is said, for example, that one ton of pig is made from 2.1 tons of the forge cinder, 1.7 tons of the charcoal and 0.4 ton of the limestone.

(iii) The Recarbonized Pig Iron.

The method for manufacturing pig iron from the steel scrap by the cupola or the electric furnace in which it is melted and carbonized, had been very prosperous during the Great War. Its annual production happened up to about 100,000 tons, although it is now decreased down to about 10,000 tons. The Sumidagawa Iron Refining Works in Tokyo was the largest producer of these kind of pig iron.

(iv) The Electric Smelting Process.

At the same time, the electric pig iron from the raw ore, was made also pro-

sperously. Of all equipments, the Grönwall, Lindbland & Stahlhame electric shaft furnace in the Electric Iron Works of the Nippon Steel Tube Co. at Fushigi, Toyama prefecture was the best equipped one. Since Taisho 9 (1920), the electric smelting of iron has been declined gradually and it is now quite negligible.

(v) The Direct Reducing Process.

The manufacture of the sponge iron was set about long ago in the Kawasaki Works of the Nippon Steel Tube Co. at Kawasaki, adopting the system of the Häganäs Bilbsholms Aktiebolag, Sweden, The result was not good, and the great earthquake crumbled down the apparatus. Lately a small trial of the same system is being done for utilization of iron sand in the same works.

The Imperial Steel Works made a success in the test of the sponge iron making from the rolling mill scale applying the coke oven. The Anzan Steel Works made also the sponge iron, for trial, from the iron ore concentrate, The Yasugi Steel Works at Yasugi, Shimane prefecture, is now manufacturing the sponge iron from the iron sand by means of the electric furnace for its own use. The quality of product seems not to be agreeable for sale.

About the enterprise at Kuji by Tokiwa Co., we have already stated before. The studies for making sponge iron, the direct reduction of ore, are now carried on by many investigators, but there is not yet any practical or economical one in this country.

(vi) The Electrolytic Process.

The study of the electrolytic iron was set about by the Physical and Chemical Research Laboratory in Tokyo, and it is already made industrially from the steel scrap since April Showa 3 (1928) by the Nippon Electrolytic Iron Works Ltd. at Amagasaki. That is, the thin iron layer which stick on the cathode plate, is rolled to the sheet for special use; its very pure quality is suit for the material of the crucible steel. Its annual production is about 70—80 tons. The Physical and Chemical Research Laboratory is investigation further for the electrolytic extraction of the pure iron from pyrrhotite or iron sand.

IX. The Ferro Alloys.

The ferro alloys manufacture in this country had been begun in the Kamaishi Iron Works in Meiji 33 (1900). At first the ferromanganese and spiegeleisen were made by the blast furnace, and subsequently ferro-silicon and silicospiegel. Afterwards, they have been made by the electric furnace, and the manufacture by the blast furnace disappeared in Taisho 9 (1920). Of all ferro alloy factories, the Electric Iron Works at Fushigi is the largest; but we can enumerate the following ones also; the Odera Works of Nippon Soda Co., the Electric Steel Works in Nagoya, the Kamaishi Mining Works and the Imperial Steel Works etc.

Table 24. Amount of Production of Ferro Alloys.

(unit—metric ton)

Year		Production in Japan.								Required amount	Proportion of home prod'n to req'ed am't.
		Ferro-manganese	Spiegel-eisen	Ferro-silicon	Silico-spiegel	Ferro-chrom	Ferro-tungsten & Ferro-molybden	Othere	Total	Imports		
Taisho	6 (1917)	7,339	1,707	2,431	306	214	153	—	12,150	2,830	14,980	81.1 %
	7 (1918)	11,647	2,174	6,994	1,246	1,376	220	13	23,670	1,221	24,891	95.1
	8 (1919)	10,831	2,067	2,948	150	920	115	60	17,091	3,154	20,245	84.4
	9 (1920)	4,203	2,084	930	34	1,522	66	—	8,839	1,075	9,914	89.2
	10 (1921)	4,515	453	904	—	1,537	25	141	7,575	1,137	8,712	86.9
	11 (1922)	4,449	1,759	1,535	—	408	12	302	8,465	1,629	10,094	83.9
	12 (1923)	7,780	1,528	1,354	—	256	—	135	11,053	1,493	12,546	88.1
	13 (1924)	9,260	1,819	974	—	391	—	31	12,475	4,665	17,140	72.8
	14 (1925)	7,046	1,911	1,848	—	42	5	81	10,933	2,352	13,285	82.3
Showa	1 (1926)	7,058	1,811	2,852	—	201	15	271	12,208	4,055	16,263	75.1
	2 (1927)	11,193	2,138	2,241	46	196	8	190	16,012	5,055	21,067	76.0

— The End —