The Establishment of the State-Owned Yawata Steel Works (1)

—— The Integrated Steel Works That Promoted Japan's Industrialisation When the Country Entered the Modern Industrial World as a Latecomer

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* note: "The Imperial Steel Works" or "The State-Owned Steel Yawata Works" is refered to "The Yawata Works" in general hereafter.

SUMMARY

The introduction of Western-type iron-making spurted toward the end of the Edo period. The 'Westen Impact' symbolised by the outbreak of the Opium War in China and the arrival of 'Black ships' forced Japan to build reverberatory furnaces for producing 'Warships and Cannons'. An engineering book published in Holland was translated into Japanese. Based on it, Japan's first reverberatory furnace was constructed in Saga Clan, and those derived from this furnace spread to 11 areas across the nation. This development laid the groundwork for Japan to replace the conventional 'Tatara' method with the Western-style charcoal blast furnace.

After Meiji Restoration, there were three 'State-owned Works', such as those in Kamaishi, Nakaosaka and Hiroshima, and unfortunately, these works resulted in failure for the reason of low productivity. In Kamaishi Mines, Tanaka Ironworks, which sold to a private sector, continued its operation in an insignificant size of Oshima-style's small blast furnaces. Meanwhile, steel-making at arsenals was experimentally tried.

In order to meet the increasing demand for steel, a first draft to be

proposed to the Diet in 1892 was prepared by the Ministry of the Imperial Japanese Navy. The Diet refused it because sufficient research on raw materials had not been conducted. The government accordingly set up a committee for conducting research on undertaking iron and steel making and on technical experiments as well.

A major turning point in this national undertaking was the outbreak of the Sino-Japanese War. In Feb. 1895, the House of Representatives of the Imperial Diet adopted "Plan to Construct State-run Iron Works" for the first time. Although "The Launch Plan" with the budget of about 4 millions yen to build the Works in Yahata was decided, it was significantly amended as a result of research on advanced steel-making technology in western countries conducted by Michitaro Oshima, the first main technological officer. In the revised plan, it was emphasised that Japan should become internationally competitive to expand the operational scale of the plant and eliminate unnecessary expenses. In response to the requirements of the emerging "steel era", it was required that no wrought iron should be produced.Since the production of military grade steel was "the most difficult challenge", it was postponed until later days. For these reasons, the up-to-date and suitable technology for manufacturing diverse types of steel materials was introduced from Germany, especially from a company named Gutehoffnungshutte A.G.(GHH). 15 German engineers and foremen were hired. Under the supervision of German experts, Japanese engaged in plant construction, machine installation, and then operating plants. The Yawata Works started not only as "a integrated work" of iron, steel, and rolling products, but also as "a compound company" which provided raw materials such as iron ores, coal and so on.

In Feb. 1901 blow-in was accomplished at the No.1 blast furnace. On November 18, 1901, a magnificent inauguration ceremony was held to celebrate the grand opening of "The Imperial Steel Works" in Yahata. However, the machines and equipments could not be operated smoothly for the reason of a financial shortage. The blast furnace performed poorly due to low quality coking coke. The government ordered the suspension of the blast furnace and the converter operations for "economic reasons". The way the Yawata Works should be implemented was thoroughly reexamined by "The Council" which the government set up.

The outbreak of the Russo-Japanese War contributed to the restart of the Works. After additional investments and discharges of foreign engineers and foremen, Kageyoshi Noro was invited as a special adviser. Noro reformed the blast design and improved coke-making. As a result of these success, the operation improved steadily. The Yawata Works accordingly managed continuous production. It moved forward and "Phase 1 of the Plant Extension Project" commenced, so that it accomplished 180,000 tons of steel products per annum. Through this achievement, its account turned to make profits for the first time in 1910.
The Yawata Works achieved and maintained autonomy through the process of technological transfer. The problem, however, was that the speed of Japan's industrialisation and the increase in demand were much higher than the pace of increase in production capacity of the Yawata Works. The "Phase II Extension Project" was continuously prepared.
Prior to World War II, as far as the construction of modern integrated milsl in Asia was concerned, the Han-yang Iron and steel works, the first blow-in, was established in China in 1894, several years earlier than the Yawata, and the Tata iron and steel Co. in India started in 1911, ten years after the Yawata. Comparing with these three Works, we clearly recognize two unique and superior features of the Yawata Works. They are the following points: (1) technology transfer with autonomy, and (2) contribution to progress in both national and local industrialisation.

Keywords
The integrated Steel Works　The Tawata Works
technological transfer　industrialisation　the foregn engineer

Japan's industrialisation spurted when the country faced the overwhelming power of western civilisation, symbolised by the arrival of Commodore Perry's black ships at Shimoda Port and the outbreak of the Opium War in China. Japan was amazed at the sight of the military superiority and material civilisation of western countries. It feared their power and felt intimidated, a feeling which propelled the country's maximum endeavour to catch up with the west as quickly as possible. Japan launched a major national initiative to develop military forces. Included in that scheme was the manufacture of cast-iron guns and steam-powered naval vessels in order to protect territorial rights. To achieve these goals, Japan decided to learn and introduce modern steel making technology from the west.

An engineering book was imported from abroad and translated into Japanese. Based on the contents of that book, Japan's first reverberatory furnace was constructed in Saga Clan in Kyushu. Using the cast iron from that plant, cannon and other artillery production commenced (1852). This gave significant momentum to the Japanese iron and steel making industry. Takato Oshima launched iron ore smelting in Ohashi in northern Japan, where a western-style charcoal blast furnace was blown in for the first time in Japan (1854). This development laid the groundwork for Japan to replace the conventional "Tatara" method with the modern iron and steel making technology developed in the west. In the Meiji Restoration and onward, the Japanese government deepened their understanding that the strength of western superpowers derived from their "coal and steel" industry. In order to modernise Japan, a state undertaking called "Rich Nation and Strong Army" was started along with a "Civilisation and Enlightenment" scheme. Domestic iron and steel production was acknowledged as the ground of modern nation building. The Ministry of Public Works was founded in 1870, and took the initiative in furthering domestic iron and steel production before its abolition in Dec. 1885. The Ministry took over and further nurtured Japan's industrialisation programme, which had been initiated by the Tokugawa Shogunate as well as local clan governments before the Meiji Restoration. Under the Meiji administration, the "promotion of modern technology and industry" was strongly recommended and implemented as a high priority. Specified in the agenda was industrial development including shipbuilding, mining, iron and steel making, railways and communications. The Ministry exercised leadership in Japan's infrastructure development. Unfortunately, however, all those projects failed to become economically viable. They had to be "disposed of" in the end, through being sold to the private sector. There were three state-owned iron works in those days, namely Hiroshima Iron Works (1875~1905), Kamaishi Iron Works in Iwate (1873~1882) and Nakaosaka Iron Works in Gunma (1878~1881). Hiroshima aimed to improve the conventional "Tatara" method, for which purpose it emulated the French sand-iron smelting method. The other two iron works introduced innovative technology from the United Kingdom, which had been developed during the Industrial Revolution. The British engineering method consisted of the blast furnace process (which was fuelled by charcoal in Japan), the hot blast stove process (pig iron making), the puddling furnace process (refining) and the rolling mill process (wrought iron products). After ownership of the Kamaishi Iron Works passed from the state to private hands, its charcoal blast furnace technology was inherited by Kamaishi Mines Tanaka Iron Works. In 1905, under the supervision of Kageyoshi Noro, a great Japanese pioneer in ferrous metallurgy, Japan's first coke blast furnace was blown in successfully at that plant.

Domestic iron and steel production and imports in the 1880s and 1890s (tons)

	Iron			Steel			Imported steel							
	Domestic	Imports	Total	Domestic	Imports	Total	Rails	Bars	Plates	Tin plates	Zinc plates	Wire rods	Skelp	Scrap
1882	NA	5,373		NA	27,459		7,450	15,700		130	202	806		3,171
1883	14,961	7,299	22,260	NA	26,956		1,225	15,953	3,434	599	502	2,873	447	1,923
1884	11,881	5,863	17,744	NA	27,242		7,239	10,979	3,763	618	335	2,955	398	955
1885	6,781	5,583	12,364	NA	34,132		13,883	11,837	3,711	628	615	2,297	661	500
1886	13,783	7,040	20,823	NA	45,859		20,201	17,227	4,772	639	469	1,787	189	575
1887	15,295	6,535	21,830	NA	59,996		30,040	18,395	5,723	398	925	2,253	1,180	1,062
1888	17,023	20,742	37,765	1,268	88,118	89,386	52,201	25,203	5,768	567	1,176	2,180	580	1,443
1889	20,083	9,807	29,890	1,080	64,453	65,533	24,698	24,810	6,635	525	1,580	2,644	589	2,972
1890	21,235	10,429	31,664	1,180	69,160	70,340	34,068	23,255	6,223	352	1,076	2,644	612	830
1891	16,592	12,191	28,783	719	60,166	60,885	21,427	26,765	6,452	517	1,052	2,374	879	700
1892	15,248	15,322	30,570	2,452	37,271	39,723	1,907	23,789	5,030	556	1,254	3,305	556	874
1893	14,654	23,285	37,939	1,657	63,961	65,618	22,521	27,267	6,958	579	1,906	3,695	516	519
1894	16,366	36,649	53,015	2,102	90,294	92,396	34,664	32,133	13,433	3,217	2,258	3,326	584	679
1895	23,027	35,316	58,343	1,850	104,930	106,780	26,582	49,038	16,607	3,008	1,570	4,462	1,196	2,467
1896	24,560	39,036	63,596	1,987	177,489	179,476	65,400	60,079	25,217	2,584	4,414	14,651	801	4,343
1897	20,589	43,642	64,231	1,082	193,737	194,819	87,093	61,790	19,704	5,534	6,950	9,541	756	2,369
1898	19,397	63,402	82,799	1,101	212,493	213,594	81,605	86,264	23,504	4,012	7,117	8,136	1,045	828
1899	19,397	27,244	46,641	2,288	109,432	111,720	8,163	44,802	26,591	3,947	9,168	14,054	700	2,007
1900	21,326	23,758	45,084	2,387	224,653	227,040	70,439	71,363	42,172	4,597	11,549	20,105	1,071	3,357
1901	56,834	43,160	99,994	6,033	141,375	147,408	28,758	59,221	24,835	5,521	8,073	11,822	974	2,171

Source: Seiichi Yonekura, The Japanese Iron and Steel Industry, 1850–1990, St. Martin's Press, pp. 29. 30.

NA: Not available

Meanwhile new developments were taking place in the west around 1880. The world was shifting from the “iron era” to the “steel era”. During the Franco-Prussian War, the superiority of the Krupp steel guns used by the Prussian military forces was firmly established. Given that evidence, the Japanese government strengthened its commitment to increasing pig iron and steel production at arsenals adjunct to the Imperial military. Japan aspired to expanding steel production, starting with Krupp crucible steel and then moving forward to the open hearth furnace system. The Japanese navy succeeded in the production of Krupp crucible steel in 1882, followed by another success in 1893 by the army. Although the open hearth furnace project began in 1890, the phase prior to the Sino-Japanese War was simply “experimental”. However, as railway construction made progress in Japan, steel imports increased, exceeding the threshold of 100,000 metric tons in 1890. In order to fulfil the increasing demand for steel, while the world was moving toward the “steel era”, various plans were prepared and published. A first draft was prepared by the Ministry of the Imperial Japanese Navy in 1891, followed by others. Subsequent to many twists and turns, a final plan entitled “Launch Plan for State-run Iron and Steel Works” was concluded after the end of the Sino-Japanese War.

Year Budget Pig iron Steel materials

		(million yen)	pig iron	steel	products (tons)
Navy’s Plan	1891	2.25	---	30,000	Steel 27,500 Wroughtiron 2,000 Crucible 500
Committee for Steelmaking	1892	2.75	--	60,000	Steel 56,000 Wroughtiron 4,000 Crucible1,000
Ad-hoc Committee	1893	3.60	60,000	85,000	Bessemer 42,000 Martin 42,000 Wroughtiron 9,000
Launch Plan	1895	4.09	36,000	60,000	〃 35,000 〃 20,000 〃 4,500 Crucible 500

A major turning point in this national undertaking of state-run iron works occurred when the Sino-Japanese War broke out. The declaration of war was in August 1894. The peace treaty at its end was signed in April 1895. When the war broke out, all cargoes of arms bound for Japan were "embargoed" at Singapore. Faced with this suspension of arms imports, Japan experienced enormous difficulties. There was grave concern that "if the war continued too long, the nation would suffer from extreme damage caused by the lack of arms supply." This situation was, in fact, the ultimate decisive factor in persuading the Imperial Diet members, who had been opposed to the bill concerning the construction of state-run iron works, to change their minds and endorse the scheme. In Feb. 1895, the House of Representatives of the Imperial Diet adopted the "Plan to Construct State-run Iron Works" for the first time. The Plan had been primarily drafted by Kageyoshi Noro some time before publication. Specified in the draft was the following:

1. While there are many different types, modalities and features of steel making technology available today, it would be neither easy nor economically viable to try to implement all those different methods all at once. It would be sensible, therefore, that the state-run iron works project start on a small scale, then expand gradually.
2. Both pig iron (wrought iron) and steel shall be produced.
3. Low grade wrought iron shall be produced as a substitute for pig iron. Sand iron, which is abundant in Japan, shall be used in the operation.

constructing site at the Yawata Steel Works, 1896

Map in 1896

The budget for this national programme was passed in the 9th assembly of the Japanese Imperial Diet in 1896. The government announced the state-run iron works project. After some twists and turns in personnel selection, Teiun Yamanouchi was eventually nominated first Chief Officer of the State-owned Steel Works. Michitaro Oshima, the eldest son of the abovementioned Takato Oshima, who was an engineering official at the Ministry of Agriculture and Commerce, was nominated first Main Technological Officer. Yamanouchi and Oshima carried out a field survey, based on which Yahata in Kyushu was selected as the plant construction site at the end of Oct. 1896. In those days, four to five metric tons of coal were necessary for the production of one ton of steel. It was for this reason that Yahata, located in a coal mining area, was chosen. It is worth noting that the State-owned Steel Works at Yahata had a different background from Kamaishi in Iwate, which was situated in an iron ore mining area. After the site selection, Oshima went abroad between Oct. 2, 1896 and Sep. 27, 1897 to research steel making technology in western countries. His mission included a survey of advanced steel plant facilities and machinery to prepare for purchases for the new plant. After his return to Japan, in the light of the survey results, the original "Launch Plan of State-owned Steel Works" was significantly amended. In the revised plan, it was emphasised that Japan should become internationally competitive in the emerging "steel era". It was recommended that an integrated plant producing both pig iron and steel be constructed and that the most up-to-date technology be introduced from Germany. The reason was that the German technology was the most suitable for manufacturing diverse types of steel materials. Oshima commissioned Gutehoffnungshutte A.G. (GHH), a German steel and machinery company, to design the plant. F. W. Luhrmann was assigned to the design of the smelter. R. M. Daelen was commissioned to design steel making and rolling mill processes. In March

1897, ten Japanese engineers were sent to Germany, where they participated in a two-year educational course as trainees. The official submission of the revised plan was made by Tsunashiro Wada, the successor to Yamanouchi, right after he took office as Chief Officer of the State-owned Steel Works at Yahata. The plan was submitted as an "Opinion Paper" to the Minister of Agriculture and Commerce. It included the following recommendations:

1. Because the demand for pig iron and steel has doubled since the Sino-Japanese War, it is recommended that the production of steel materials be doubled from the original plan, reaching the order of 180,000 tons. "In the light of military as well as economic requirements", it is advisable to "expand the operational scale of the plant, introducing perfect and complete facilities, eliminating unnecessary expenses, and thus achieving a large volume of production at a low cost."
2. In response to the requirements of the emerging "steel era", no wrought iron shall be produced at this plant.
3. The initial period shall be divided into two phases. In Phase I, the operation shall primarily be focused on the production of 90,000 tons of ordinary steel. Since the production of military grade steel is the "most difficult challenge" for the burgeoning steel industry in Japan, it is sensible to postpone its production until Phase II.
4. In order to secure the stable and low-cost supply of raw materials for the plant operation, it is recommended that iron ore and coal mines be acquired together with limestone quarries.

In response to this "Opinion Paper", an additional 6.5 million yen was injected in the budget, ensuring the total sum of 10.59 million yen for the Yawata Works project.

Because the Yawata Works intended to postpone the production of military grade steel to Phase II, the Imperial Navy decided to construct a steel mill of its own in Kure in Hiroshima. In 1890, prior to the outbreak of the Sino-Japanese War, the shipbuilding division of the Kure Navy Arsenal had already defined the construction of ironclad warships of the 10,000 ton class as their major objective. It had been observed that the ironclad battleship "Zhen-yuen" of the Great Qing Navy Beiyan Fleet, captured during the Sino-Japanese War, was capable of repelling all the shells fired at her, and was thus impervious to artillery attacks. The "supremacy" of the ironclad warship was unequivocally proved. The Navy made utmost efforts to start production of armour plates for battleships at its own steel mill. On the other hand, the Yawata Works maintained its policy of manufacturing military grade steel materials at its plant. In this context, when the Navy submitted its first budget draft to the Diet to endorse the increase in production capabilities at the Kure Navy Arsenal manufacturing plant, it was rejected. The budget was, however, approved in the following year, 1902. In 1906, nickel chromium steel armour plates were manufactured at Kure and mounted on warships. In the meantime, there were heated debates in a series of Diet sessions about which supplier should assume the responsibility of manufacturing military grade steel materials. The debates resulted in a clear division of products between the Yawata Works and the Kure Navy Arsenal Works. As far as military grade steel was concerned, it was established that the Yawata Works should engage in the manufacture of pig iron, shipbuilding materials, cylindrical steel rods to be used as shells for rapid firing guns and materials for gun mounts. On the other hand, the Kure Navy Arsenal Works was to manufacture materials for gun barrels, artillery guns, torpedoes, shells, armour plates and gun shields.

Expansion from Noro's plan to Oshima's

	Noro's	First Stage	Ohshima's Secondary Stage
pig iron by blast furnaces	43,000	120,000	240,000
Iron and steel products	60,000	90,000	180,000
Bessemer steel	35,000	45,000	
Open-hearth steel	20,000	45,000	
Wrought iron	4,500	―	
Crusible steel	500	―	

The construction of the State-owned Steel Works at Yahata made progress. Most of the building materials, equipment and machinery were purchased from Gutehoffnungshutte A.G. (GHH). Those items were "of extremely high quality manufactured by German leading edge technology". Under the supervision of German experts, Japanese engineers, operators and workmen engaged in the plant construction and machine installations. The foreign engineering team hired for this project consisted of three consulting engineers plus 12 others including foremen and workmen. The first Chief Adviser employed at the Yawata Works was the German Gustav Toppe. After completing his contractual term as managing director in charge of engineering at the Han-yang Iron and Steel Works in China, he took the office of chief executive engineer at Yawata. In 1898, German workmen were employed in plant construction as well as equipment installation. In 1900, Carl Haase, a Pig Iron Department's Chief Engineer, was employed to support the preparatory stage before the start up. Hartmann Schmelzer, a Chief Engineer for the Product Department, was also employed at the same time. The foreign engineers were highly paid. Foremen and workmen were hired according to GHH's recommendations. The German consulting engineers and workmen had worked at many prestigious German steel plants, developing their skills and expertise in various production backgrounds. Once the project started at the Yawata Works, however, innumerable problems surfaced. It turned out that the foreign engineers were reluctant to operate unfamiliar machines and equipment with which they had had no experience. Not all of them possessed skill and expertise impressive enough to their Japanese counterparts. Linguistically and emotionally, they failed to achieve smooth and amicable communication with the Japanese project team, including workmen. In addition, there was conflict among the German engineers and workmen themselves. Trouble continued. In order to resolve the situation, the foreign consulting engineers were fired in the end. A Japanese managing director of engineering was nominated to manage the project. Under his leadership, general managers were appointed and assigned to supervising foreign foremen and workmen as well as Japanese. In April 1901, Toppe and Schmelzer were fired before the completion of their contractual terms. In April 1902, Haase was also fired before the end of his contract.

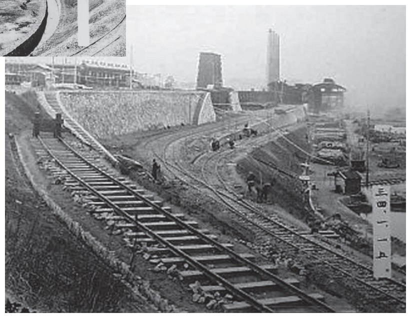
Foreign Technical Personnel Engaged in Yawata Steel Works

	Position	Contractual terms	dismissal
G.Toppe	Chief Adviser	1897.12.1 ～ 1901.12.1	1901.4.22
C.Haase	Chief Enjineer of Pig iron Department	1900.3.15 ～ 4 years	1902.4.14
H.Schmelzer	Chief Enjineer of Rolling Mill Department	1900.6.8 ～ 1904.3.31	1901.4.22
H.Lohberg	Foreman of Machine Shop	1900.12.1 ～ 1904.3.31	1904.2
W.Neuhauser	Foreman of Blast Furnace Plant	1900.3.15 ～ 1904.3.31	1902.8.10
H.Tummler	Foreman of Middle Bar Mill and Sheet Mill Plant	1900.6.15 ～ 1904.3.31	1903.9.30
W.Nalbach	Foreman of Blooming, Rail and Large Bar Mill	1901.1.20 ～ 1904.3.31	1904.3
A.Westphal	Foreman of Open-Hearth Plant	1901.2.1 ～ 1904.3.31	1904.3
J.Schmuch	Foreman of Open-Hearth Plant	1901.3.27 ～ 1904.3.31	1904.3
G.Heuser	Foreman of Middle and Small Bar Mill Plant	1901.3.27 ～ 1904.3.31	1904.3
C.Kohler	Foreman of Middle and Small Bar Mill Plant	1901.4.22 ～ 1904.3.31	1906.9.5 death
J.Bunse	Foreman of Blast Furnace Plant	1901.5.31 ～ 1904.3.31	1904.3
T.Maurer	Foreman of Bessemer Plant	1902.6.29 ～ 1904.3.31	1907.3
A.Stoellger	Foreman of Rolling Mill	1900.2.1 ～ 1904.3.31	1904.3
P.Held	Foreman of Blast Furnace Plant	1900.3.15 ～ 1904.3.31	1900.9.28 disapperance
G.Neuhaus	Worker of iron construction	1898. ～ for finishing	
N.Petto	Worker of Rolling Mill	?	
J.ReinMann	Worker of Machine construction	1899.8.14 ～ for finishing	1900.6.30
E.Gysling	Worker of Machine construction	1901.2. ～ for finishing	

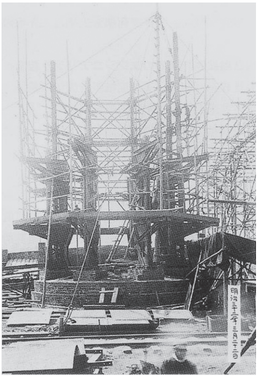
As for iron ore materials, it had been planned that Akatani iron ore mine in Niigata, the acquisition of which was funded by using the additional budget, would be developed as a primary supply source. In summer 1898, however, Sheng Hsuan-huai, a Chinese businessman and politician, who was the head of Han-yang Iron Works, proposed a barter trade between Japanese coke and Chinese iron ore. Consequently, a long-term purchase agreement was concluded with Sheng Hsuan-huai's company, which secured an annual supply of 50,000 tons of Ta-yeh mine iron ore for the next 15 years. As a result, the development plan for Akatani was abandoned. This means that, at that point, Japan opted to depend on foreign sources for the supply of iron ore. As to coal supplies, the Yawata Works acquired Takao coal mine and others at Chikuho in Kyushu, thus establishing the State-owned Futase Coal Mine.

When it was expected that the construction work at the Yawata Works would soon be completed, an organisational change took place in August 1900 to prepare for the start up. The Pig Iron Department comprised the pig iron production division and the pig iron material division. The Steel Department comprised the converter furnace division and the open hearth furnace division. The Rolling Mill Department comprised the steel bar & rod division and the steel sheet & plate division. The Japanese engineers who had been training in Germany returned home around that time. They were assigned to plant departments to lead daily operations. In December 1900, "Workmen's Work Rules" were set forth. In the following year, large scale recruitment started for more than 1,000 workmen. In February 1901, blow-in was accomplished at the No.1 Blast Furnace. Because the coke furnace was not yet ready at the plant, coking coal was prepared on a commission basis by a nearby private sector factory before being fed into the blast furnace. Immediately after start up, there were persistent failures. The operation gradually improved, however, becoming smooth around June. After the blast furnace blow-in, the open hearth furnace started up at the end of May, followed by the start up of the converter furnace in November. As for the rolling mill processes, the medium section and thin steel sheet rolling mills started up at the end of June. These were followed by both the small section rolling and blooming mills. A Beehive coke oven was constructed at a rapid pace, and completed in September, which enabled the plant to secure in-house coke production. On November 18, 1901, a magnificent inauguration ceremony was held to celebrate the grand opening of " The Imperial Steel Works " at Yahata.

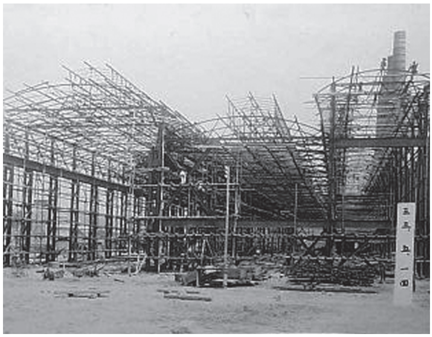
(1901)



constructing Railway (1901)



constructing No.1 Blast Furnace (1899)



constructing Steel-waking Plant (1900)

At the Yawata Works, especially in the blast furnace operation, things were “neither extremely bad, nor extremely good”. A kind of sub-optimal situation lasted for some time. The worst period was recorded in February 1902, when, “due to low quality coking coal”, the blast furnace performed poorly in banking. The “production of high quality coking coal” was urgently needed. This sluggishness bottomed out afterwards.

In subsequent months, daily production reached the 100 ton level as compared to the design volume of 160 tons per day. The bottom parts of converter furnaces were damaged and replaced several times. Steam for driving the converter furnaces was not in sufficient supply. In May 1902, because of frequent system failures and downtime, the converter furnaces operated for only 16 days, one half of the total working days. The situation was similar for the rolling mills. The supply of gas and steam to activate the mills was insufficient. High priority was given to the continued operation of the blooming and rail mills. As a result, the other mills with lower priority were operated only in the daytime, or subjected to an alternate on/off programme. Even though the machines and equipment represented leading edge technology, they could not guarantee smooth operation. Only when an organic coordination is in place between those facilities and supporting functions such as fuel supply, transportation and material handling, can a plant perform well. Moreover the immediate cause of such imperfections was a financial shortage. As the funding deficiency became more and more evident around 1900, the management of the Yawata Works continuously petitioned the government, asking for additional investment. In December 1901, with 20 to 30 percent of the works still unfinished, Tsunashiro Wada, then Chief Officer of the Yawata Works , submitted a petition for an additional 3.9 million yen investment, so that construction could be continued. Together with the petition, he submitted his resignation letter. His resignation was accepted by the government. (Later, he took leave from his post, and was eventually dismissed with a disciplinary reprimand.)

The petition for the additional budget was rejected in the Diet. When Lieutenant General Yujiro Nakamura of the Imperial Army became the Chief Officer of the Yawata Works in April 1902, the government set up a council called the "The Council of the Iron & Steel Production". Its purpose was to review and formulate a policy and measures for the drastic rehabilitation of the Yawata Works. Furthermore, when the pig iron inventory reached the order of 30,000 tons in July 1902, the government ordered the suspension of the blast and converter furnace operations for "operational and economic reasons". 600 workmen involved with those furnaces were fired. A recommendation was presented by the abovementioned "The Council", which advised that, "in view of the current difficulties surrounding the Yawata Works, including constraints in relation to accounting rules and procedures, delay in construction, an inconvenient commercial mechanism for trading activities, cumbersome procedures of financial calculations and others", the project be transformed from a state-owned enterprise to a legal entity in the private sector. The new organisation could be called the "Nippon Steel Company". The Council identified the "primary causes of poor performance and shortage of financial resources". It recommended that an additional investment worth 7.5 million yen be made. The recommendation stated that "as far as the future outlook of the iron and steel making enterprise was concerned, there should be no cause for concern, provided that proper management was exercised over the operation". It concluded that "appropriate management should not be too difficult to achieve", and that "the plant operation should not be economically unviable".

This recommendation about proper management of the Yawata Works was not adopted by the government, however. As for additional investment, the proposal was partly approved, allowing the Yawata Works to continue its remaining construction and installation work. All members of the senior management involved in the launching of the plant, including Michitaro Oshima, the main technical officials, were replaced (Oct. 1903). The operation of the blast and converter furnaces remained suspended. Nevertheless, under the supervision of Kaichiro Imaizumi, general manager of the steel material department, progress was made to resume the converter furnace operation, into which, together with in-house produced pig iron, Kamaishi-sourced pig iron and some scrap iron were fed. In 1904, the government expedited military development, in readiness for the anticipated outbreak of war. Under those circumstances, the rehabilitation of the Yawata Works was needed, and additional funds were provided in the name of contingency expenditure. In Feb. 1904, immediately after the outbreak of the Russo-Japanese War, Susumu Hattori, general manager of the pig iron manufacturing department, undertook to resume the blast furnace operation. At the end of March, all German foremen and workmen were fired except for the foreman of the converter furnace process. In April, the blast furnaces were blown in by the Japanese team members only, marking the restart of plant operation. However, the blow in had to be discontinued after only 17 days, because of banking. Another problem was that slag was obstructing the tuyères and tapping holes of the blast furnaces. After this failure, Kageyoshi Noro was invited as a special adviser to the Yawata Works, and the management relied on his judgement concerning the integrity of the blast furnaces.

After contributing to the drafting of the "Launch Plan of the State-run Steel Works" in the 1890's, Kageyoshi Noro had experienced a setback in his subsequent career. When corruption was revealed in relation to contracts for the purchase of water pipes for the Tokyo Metropolitan Water Board, his name was unfortunately included among those of the wrongdoers, entirely in error. As a result, he had to resign from all public positions. Subsequent to that incident, he came to engage in the iron-making industry in the capacity of "consulting engineer". He became a special adviser to the Kamaishi Mines Tanaka Iron Works, making a significant contribution to the furtherance of their business. In Kamaishi, in 1900, he succeeded in Japan's first production of manganese pig iron and spiegeleisen. In 1904, under his supervision, the construction of a third large blast furnace with a capacity of 60 tons was completed. In the previous year, 1903, two Siemens-Martin open furnace process units were introduced, each with a capacity of 5 tons. He also reformed rolling mills, so that cylindrical, square and flat steel rods and bars could be manufactured. Thanks to his endeavour, the Kamaishi Mines Tanaka Iron Works became Japan's first private-sector integrated mill, manufacturing both pig iron and steel. In 1900, he was also invited to take on the office of special adviser to the Hokkaido Coal Mining Railway Company. In that capacity, Noro designed a coke factory, taking the lead in its construction. Through this effort, he helped the company participate in the iron-making business. In the coke project, he used charcoal dust, the products of which were successfully sold in the market. In addition, Noro designed a blast furnace with a capacity of 20 tons to produce foundry pig iron from iron sand. When he had completed this design task, he received the invitation from the

Yawata Works. All the experiences that he had accumulated as a "consulting engineer" were to be fully capitalised on in his next career at Yawata.

Kageyoshi Noro took up office as special adviser to the Yawata Works from May 1, 1904. The general manager of the Pig Iron Department, Susumu Hattori, had been one of Noro's students, when the latter was a professor at the Imperial University of Tokyo. Hattori had prepared a document entitled "Report on Suspending of Blast Furnace Operating". Based on the information in that report, Noro tried to discover the cause of the blast furnace failure. His findings were as follows:

1. The temperature at the blast furnace floor was lowered due to structural defects. The area of the floor is too large when compared with the air pressure inside the furnace. The tuyères are also too large.
2. Low quality coking coal has been used in the operation.
3. A fundamental problem is that "foreign engineers and workmen have been in charge of operating the furnaces, although they have had no experience in dealing with Japanese raw materials."

Based on those findings, Noro reformed the blast design including tuyères and other parts. He improved the coke blending ratios, raw material treatment and the design of the coke oven. In July, he tried to expedite the bellows blowing process. He understood that "the probability of further failure was not negligible". Since the work was carried out in a "season most unsuitable for blowing-in", he faced tremendous difficulties. He tried every possible way to resolve the problems. He arranged for new tuyères of small diameter within a very short period of time. Eventually, he succeeded in resuming pig iron production. Consequent to that success, the operation improved steadily, and the blow-in of the No.2 Blast Furnace was accomplished in the following year. Each unit managed continuous production, affirming the integrity of the blast furnace technology executed at the Yawata Works.

July. 23, 1904　3rd blow-in at No.1 Blast Furnace ～ Jun. 2, 1910　Uninterrupted operation for 2, 140 successive days

Feb. 23, 1905　Blow-in at No.2 Blast Furnace (Reduction of size from $500m^3$ to $340m^3$)
～ Jun. 7, 1911　Uninterrupted operation for 2, 295 successive days

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During the Russo-Japanese War, the Yawata Works benefited from an additional investment coming from government contingency plan funds. Using those financial resources, the facilities were improved. The management of the plant was determined to move forward. The enterprise embarked on an initiative to accomplish 180,000 tons of steel material production per annum. This had always been their aspiration since the inauguration. To this end, “Phase I of Extension” project commenced. During the three fiscal years 1904 to 1908 - although, in fact, Phase I continued up until fiscal year 1909 - 10.88 million yen was invested in the construction of one more blast furnace. This became No.3 Blast Furnace. The investment encompassed the expansion of adjunct mills, the facilitation of transport systems and the construction of water channels from the River Onga to the plant site. When these additional facilities were complete, the Yawata Works became fully fledged with high integrity. There were three smelting furnace units, which produced 168,000 tons per year. As for coke ovens, there were 60 units of Koppe type coke ovens producing 32,587 tons of coke and 150 units of Solvay type coke ovens producing 162,279 tons. In total, slightly less than 200,000 tons of coke was produced. There were 11 basic open-hearth furnace units with a capacity of 25 tons each, producing 230,000 tons of steel per year. There were 2 acid converter furnace units with a capacity of 10 tons each producing 150,000 tons of steel a year. The Yawata plant had 2 blooming mills, from which 340,000 tons of steel ingots and billets were produced. In other words, the Yawata Works became a fully grown integrated mill that was capable of producing 180,000 tons of steel materials a year. Included in the list of steel products manufactured and supplied by the Yawata Works were conventional products such as 60 pound rails, large size steel products of not less than 8 inches, I-beams, angle steel, channel steel and other shapes in steel, fish-plates for rails, medium and small sized steel bars, steel plates, thin steel plates, corrugated steel sheets, bolts, nuts and steel outer rings. In addition to those conventional products, new ones were launched in the market. The list includes 75 pound/80 pound rails manufactured at the rail mill, 30 pound/ 45 pound rails for mining operations manufactured at the large size product mill, steel nails/steel wires manufactured at the wire mill, thin steel plates of not more than 5 mm thickness manufactured at the thin steel plate mill, universal-rolled open-hearth steel manufactured at the open hearth furnace mill, tool steel/high speed tool steel manufactured at the forging steel mill and speciality steel for gun barrels manufactured at the crucible steel mill.

The State-owned Yawata Works Utilities, Establishment of 180,000 tons of Steel

Department	Plant	Main utilities	1901		1906		1911	
Pig Iron Dep.	Blast Furnace Plant	Rosting Furnace	20					
		Blast Furnace	1	58,000	2	102,000	3	168,000
		Cowper's Hot Stoves	4		8		12	
		Blowing engines	3	1,800	4	2,400	5	3,200
		Ore crusher					2	40
	Coke Oven Plant	Coal Washing machineries			2	237,250	3	355,875
		Beehive	480	98,360				
		Haldy			90	43,362		
		Coppees System			60	32,587	60	32,587
		Semet-Solvay					150	162,279
	Productive Capacity per annum			98,360		206,890		194,866
Steel Dep-	Open-hearth Plant	Siemens-Martin Furnaces	4	60,000	8	150,000	11	230,000
		Gas Producers	6		17		24	
	Bessemer Plant	Bessemer Converter	2	150,000	2	150,000	2	150,000
		Blowing engines	2		2		2	
	Mixer Plant	Mixer					1	160
		Remelting Cupolas					3	
Rolling Mill Dep.	Blooming Mill Plant, No.1	Blooming Mill	1		1		1	
		Rolling mill engine	1	100,000	1	100,000	1	100,000
		Reheating furnaces	2		4		4	
	Blooming Mill Plant, No.2	Blooming Mill					1	
		Rolling mill engine					1	140,000
		Reheating furnaces					2	
	Productive Capacity of Crude Steel per annum			100,000		100,000		240,000
	Rail mill Plant	Rail Rolling mill	1	32,000	1	32,000	1	90,000
		Rolling mill engine	1		1		1	
	Rail and Girder Finishing Plant	Electric double straightening Machines	6	64,000	6	64,000	6	124,000
	Large Bar Mill Plant Middle Bar Mill Plant	Two high reversing			1	60,000	1	90,000
		Three-high	3	36,000	4	36,000	4	36,000
		Reheating furnaces	2		2		2	
	Small Bar Mill Plant No.1	Three-high for Roughing	1		1		1	
		Double two-high for Finishing	4	21,600	4	21,600	4	21,600
		Reheating furnaces	2		2		2	
	Small Bar Mill Plant No.2	Three-high for Roughing					1	
		Double two-high for Finishing					4	18,000
		Reheating furnaces					1	
	Wire Rod Mill	Rolling mill					13	
		Reheating furnaces					1	36,000
		coiler					4	
	Thick Plate Mill	Three-high					1	
		Siemens Gas Producer					10	47,900
		Siemens Reheating Furnaces					3	
	Sheet Steel Mill	Sheet mill		11,000		18,000		23,200
	Corrugat e Sheet Mill					1,800		2,700
	Flat Sheet Mill					16,650		25,900
	Bolt and Nut Mill					4,060		7,210
Productive Capacity of Steel Materials per Annum				100,600		172,110		416,050
Special Steel Mill Dep.	Crucible Steel Mill	Crucible melting fumace			8	★	3	★★
		Crucible melting fumace			1	★	1	★
		Crucible melting fumace					1	2t/11h
	Forged Steel Mill							14,240
	Spring Steel Mill							300
	Steel Wheels Mill							3,000
By-Product Dep.	Ammonium Sulphate Mill							2,000
	Tar Mill							8,900
	Fire-Brick Plant					10,200		10,800
	Limeston e Plant					4,130		9,260
	Slag Brick Plant							18,250

Source: 25 Anniversary of The Yawata Steel Works, 1924

The Yawata Works (1910)

Here let us look back at the way in which the Yawata Works was managed between the end of the Meiji era and the beginning of the Taisho era, by examining specific production and sales activities which drove the enterprise toward its goal.

Consumption of iron ores (tons)

		(prefecture)	Including ron (%)	1901	1902	1903	1904	1905	1906	1907	1908	1909	1910
Domestic	Yanahara	Okayama	55	13,549	1,574	0			7,780	651			
	Kawatana	Yamaguchi	47						2,370	1,206		90	42
	Kamaishi	Iwate	60	3,507	778	0	0	4,468	2,975	3,086	2,388	2,385	
	Tosa	Kochi	28						1,146			1,243	2,235
	Ohuku		55						1,830	2,549		334	8,384
	Abuta	Hokkaido	53						426	3,343	4,298	4,466	
Total including the others				17,056	2,352	0	0	4,468	17,888	13,423	6,686	8,626	10,625
China	Tayeh		65	27,023	11,759	880	45,093	120,903	121,472	121,696	134,140	104,329	126,665
Korea	Chaeryong		52	375	1,640	0	11,062	19,541			23,422	27,434	54,564
	Unryul		55								296	28,631	42,242
	Anak		53									27,749	55,433
	Kenjiho		54										1,139
Total including the others				375	1,640	0	11,062	19,541	0	0	23,518	83,814	156,489
Total				44,454	15,751	880	252,174	144,912	139,360	135,119	164,544	196,774	293,895

Source: Archives of the Yawata Steel Works

Initially, most iron ore used at the Yawata Works was imported from the Ta-yeh iron ore mine in China. In 1909 and onward, however, the volume of Korean iron ore increased considerably. As a result, the Ta-yeh materials accounted for less than 1/3 of the total in 1910. The Ta-yeh iron ore contained many iron compounds and a small quantity of silicate. The problem was that the concentration of harmful elements such as phosphorus, sulphur and copper was also high. For this reason, the grade of Ta-yeh iron ore was not satisfactory enough to fulfil the requirements for Bessemer acid converter furnaces or basic open hearth furnaces. In order to solve this problem, the management of Yawata launched an intensive and strenuous survey to discover better raw material sources. After the Japan-Korea Annexation, the Yawata Works placed both Unryul and Chaeryong iron mines on the Korean Peninsula under its control. Thus the company strengthened its commitment to exploring natural resources abroad.

Improvement of Coke Production

	Production (tons)	Adoption of Coke Ovens				Consumption of Coal (tons)	Percentage of Finished Coke (%)	Cost per ton	
		Type	Volumes (tons)	Inserting of Coal Per Oven (tons)	Curbonizing hours			Coke	Raw Materials
1900	3,280	Beehive	460	2	72				
1901	54,253								
1902	14,680								
1903	—								
1904	35,411	Haldy	90	4.8	36～48			14.5	
		Coppee	60	4.8	48				
1905	107,172	Coppee	60					8.2	
1906	126,967							10.6	
1907	121,739	Semet-Solvay	75	6	25	228,075	53.5	10.395	8.439
1908	108,638	Semet-Solvay	50	6	25	185,080	58.7	8.366	7.101
1909	136,756	Semet-Solvay	25			229,467	59.6	7.417	7.498
1910	153,291					266,235	57.5	7.985	8.101
1911	168,296					276,731	60.8	7.501	7.996

Source: A 80-year history of the Yawata Steel Works

Consumption of Coal for Coke

	1905		1907		1911		
	tons	(%)	tons	(%)	tons	(%)	Yen per ton
Futase	153,128	75.25	140,440	61.58	200,000	65.8	3.85
Miike	31,382	23.91	37,862	16.6	22,000	7.2	4.90
Takashima	16,965		20,164	8.84	12,000	3.9	6.55
Sohda			25,966	11.38			
Benxihu			12		40,000	13.2	7.73
K'ai-P'ing					30,000	9.9	5.85
Total including the others	202,169		228,071		304,000		4.74

Source: A 50-year History of the Yawata Steel Works, Saegusa and Iida, A History of Japanese Mining

Thanks to the introduction of the Semet-Solvay coke oven (1907), which was designed to recover by-products deriving from the process, the productivity of coke production significantly improved. The volume was elevated, while the cost reduced. By using the by-products from the ovens, the Yawata Works made inroads into the petrochemical industry, establishing a spin-off business, and thus generating additional profits. The breakdown of daily coke production per oven in those days indicated 0.5 tons from the Beehive oven, 1.5 tons from the Koppe oven and 2.6 tons from the Semet-Solvay oven (7.2 tons from the Kuroda type). The problem was that sub-optimal quality of coke had a negative impact on the pig iron making. Coking coals were primarily supplied from the Futase coal mine in Kyushu, added to which were those from Miike and Takashima coal mines in Kyushu. All of them had a high content of ash and volatile compounds, resulting in insufficient hardness and solidity. In order to improve the coke quality, the Yawata Works embarked on a new scheme in 1910, blending coals from Benxihu and K'ai-P'ing coal mines in China with Japanese coke. Chinese coking coals had excellent caking properties. If coke with a high ratio of residual ash and sulphur is fed into blast furnaces, a larger amount of limestone has to be added to the pig iron making process, so that the sulphur from the coke as well as that from the iron ore can be properly removed. However, an increase in the volume of limestone means a high operational temperature. High temperature makes it more difficult to produce pig iron with a low silicon concentration. It should be understood that low silicon content is an essential condition for the successful operation of basic open hearth furnaces.

Production of Fire Bricks (tons)

	Fire Bricks			
	Silica	Clay	Magnesium	Total
1905	4,552	1,070		5,622
1906	3,818	3,103	30	6,951
1907	4,310	2,303	113	6,726
1908	4,783	2,966	388	8,137
1909	6,505	3,740	699	10,944
1910	6,062	5,933	470	12,465
1911	7,754	6,012	947	14,713
1912	8,217	6,681	856	15,754

It is often said that, "every time a certain volume of steel is produced, the furnace made of silica bricks is considerably damaged and melted. Therefore, good care has to be taken of furnaces. Damaged sections should be repaired carefully with new silica bricks." As is clearly shown in this statement, the iron and steel making industry consumes a huge quantity of refractory bricks. "At the Yawata Works, the volume of refractory bricks accounted for about 15 % of the amount of steel products." In the steel making process at both the converter and open hearth furnaces, the bottleneck was that "the furnace walls and floor were often seriously damaged and destroyed". To solve this problem, a dolomite factory was set up in 1901 using magnesium lime (bitter salts) supplied from the Tsunemi district of Moji in Fukuoka as raw material. It was already evident that no private sector company was able to manufacture silica bricks of a quality to satisfy the refractory conditions necessary for iron and steel works. For this reason, the Yawata Works had decided to depend on imported refractory bricks, and this practice had continued. In May 1904, however, the company initiated the "provisional manufacture" of silica bricks on their premises. This decision was spurred by the discovery of the Akashiro Silica Stone deposits in Tsukumi in Kyushu. The management of the Yawata Works invited Kotaro Takemoto, an experienced engineer from Mitsuishi in Okayama, to assist the project. The result of this undertaking was that Japanese imports of silica stone completely ceased. In fact, in-house production of refractory bricks for furnaces had an enormous impact on the plant management in terms of both production volume and product quality. When No.3 Blast Furnace was built, all the refractory bricks for its structure were made by the Yawata Works itself.

Progress of Pig Iron Production

	Volumes of Blast Furnase	Daily Production per Furnase (tons)	Consumption Of Coke per Pig Iron (tons)
1901	1	82	1.63
1902	1	83	1.72
1907	2	132	1.13
1912	3	162	1.02

Cost of Pig Iron in 1909 (yen)

	Iron Ore	Coke	Limestone	Energy	Wage	Reparation	Miscellaneous expenses	Total
Yawata	11.885	11.635	0.370	0.588	1.512	0.715	1.713	28.422
USA	14.600	7.780	0.860	0.240	1.540	0.680	2.323	28.020

Source: Kageyoshi Noro

Cost of Pig Iron (yen per ton)

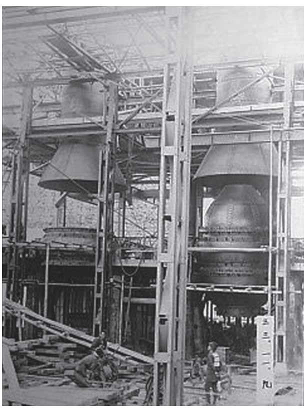
	Yawata		Kamaishi		England		Lorraine		USA	
	1914	1922	1909	1922	Pre-the first war	1923	Pre-the first war	1923	Pre-the first war	1923
Total	21.1	37.8	26.6	55.8	32.1	43.1	19.6	27.7	28.3	54.2
Coke	7.0	19.1	16.8	29.5	8.8	14.2	11.1	18.2	8.2	21.9
Iron Ore	9.2	13.8	4.0	9.0	18.7	20.2	5.5	4.7	15.0	19.8
Wage	1.0	2.8	1.3	5.0	2.0	3.6	1.5	3.1	1.3	3.6

Source: Tetuji Okazaki

After the rehabilitation programme, pig iron making at the plant in blast furnaces advanced steadily, to reach a level of 150,000 tons per year at the end of the Meiji era. In 1908, the volume virtually reached full capacity. A reliable indicator to measure the technological progress of a blast furnace is to see how much pig iron output is gained from one cubic metre of blast furnace structure after a 24-hour operation. The record indicates outputs of 173 tons in 1902, 291 tons in 1905 and 339 tons in 1908, evidencing a remarkable growth in the unit output of pig iron. Likewise, coke consumption achieved "outstanding improvement" as well. At the time of start up, the ratio of pig iron output to coke consumption was 1 to 1.7. It was down to 1 to 1.13 in 1907, followed by a further reduction to 1 to 1.02 in 1912. As for the unit production cost of pig iron, the "achievement was truly impressive". While the unit cost was 37 yen per ton at the start up period, it was down to 28.42 yen in

1909. In the same year, the average American production cost was 28.02 yen. The difference between the Yawata Works and the American average was "only minimal". The progress was indeed remarkable. Despite such great success, however, the enterprise was still prevented from moving forward to further expansion. The reason for this was that there was limited availability of raw materials in Japan, and that the Yawata Works was still technologically lagging behind in some aspects of pig iron making. Pig iron was used for the next stage of production, that is, steel making. The company did not have sufficient engineering resources by which to produce pig iron with a low silicon content, a condition particularly critical for basic open hearth furnaces. Under these circumstances, the Yawata Works was forced to start importing from the Han-yeh-p'ing Coal & Iron Company in China not only Ta-yeh iron ore but also Pingxiang coal. Furthermore, later, it began to import pig iron produced by the Han-yang Iron & Steel Works as well.

As for steel making, a dramatic increase was recorded in steel ingot production, thanks to the contribution made by the basic Bessemer converter process and the Siemens-Martin open hearth furnaces. With regard to the former, ingot production was 1,394 tons in 1901, growing to 21,334 tons in 1904 and further advancing to 69,797 tons in 1908. As to the latter, performance was also excellent, recording 9,947 tons in 1901, 40,873 tons in 1904 and 95,324 tons in 1908.



The Converters (1900)

Pig iron to be fed into converter furnaces was first treated in a metal mixer, completed in February 1907 at the Yawata Works. Sulphur was removed through this treatment. This process was to assure the uniform quality of pig iron. Nevertheless, there was still excess phosphorus in the pig iron. When it was used in the rolling mill process, product quality was sub-optimal. The quality of rails in particular was a serious problem. In 1908, a duplex system was incorporated as a countermeasure. First, molten pig iron was partly decarbonised and refined inside the converter furnaces, after which it was desulphurised inside the open hearth furnaces. There was a shortcoming

Production of Steel-making

	Products of Steel Ingot				Converter's Steel ingot for Duplexprozess (b)	Converter's Steel ingot (a+b)
	Total	Open-hearth	Crusible	Converter (a)		
1901	11,341	9,947		1,394		
1902	32,316	29,714		2,602		
1903	42,265	42,265		—		
1904	61,980	40,872		21,108		
1905	86,848	44,284	208	42,356		
1906	134,302	70,598	230	63,474		
1907	141,877	78,212	91	63,574		
1908	131,532	95,324	14	36,194	33,603	69,797
1909	157,720	119,566	138	38,016	37,214	75,230
1910	209,740	128,404	173	81,163	6,815	87,978
1911	233,459	149,460	284	83,715	10,417	94,132
1912	276,327	179,902	662	95,763	11,291	107,054

Source: Iron and Steel Society of Japan A History of LD Converter in Japan

in this duplex method, however, in that one process took quite a long time, long enough to occupy an entire converting cycle. Only 35 processes or so could be accommodated within a day. "The performance was far from satisfactory." Because of these limitations, the converter furnaces performed only at 60 % capacity. Noro wrote, “Even at this stage, the quality of pig iron has not improved enough. This prevents the steel making at converter furnaces from performing better.” Debate was under way among the engineers on whether or not the acid condition should be changed to basic to solve the problem. It was even asked whether or not the process should be given up altogether.

The open-heath furnaces made “great progress” later, however. The monthly production per unit was 621 tons at the start up period, while it grew to 814 tons in 1907. The yield of good quality steel ingots exceeded 90 % as well. In 1909, the monthly steel production exceeded 10,000 tons, which enabled those people at Yahata “to recognise a fist bright sign for the future development of the steel making business”.

The Open-Hearth (1901)

Progress of Operation at the Open-hearth

	Volimes	Products of Steel Ingot (tons)	Monthly Products per oven (tons)	Consumed Coal Per Steel Ingot (tons)	Percentage of Finished Steel Ingot（%）	Products per Operation (tons)
1901	2	9,946	621	721	83.0	19.2
1902	4	29,713	728	576	86.6	21.1
1903	4	42,264	880	552	85.1	21.9
1904	4	40,642	846	550	82.0	20.4
1905	5	44,284	785	535	82.1	21.0
1906	8	70,597	735	544	88.4	22.9
1907	8	78,212	814	455	91.0	22.0
1908	8	95,323	992	394	89.6	20.9
1909	10	119,430	1,080	413	89.5	21.6
1910	11	126,997	962	433	88.1	22.9
1911	12	145,954	1,039	395	90.0	23.0
1912	12	173,568	1,205	356	93.8	23.7

Source: The Japanese Iron and Steel History; Meiji period

Demands of Steel Materials in Japan and Products at Yawata in 1911 (ton)

	Import	Domestic	Total	Yawata	
				Products	Supply
Bloom and Steel Ingot	4,512	495	5.007	496	454
Bars	130,413	68,252	198,665	37,577	39,779
Shaped Steel				21,517	18,990
Sheets and Plates	67,825	30,859	98,084	30,786	29,433
Tin Plates	25,367	0	25,367		
Electric or Zinced Plates	43,564	2,134	45,698	2,134	2,327
Heavy Rails	89,516	65,993	155,509	61,139	59,902
Light Rails				4,855	3,366
Materials for Railway	4,050	6,286	10,336	6,565	6,236
Steel Wheels				1,140	1,237
Wire	29,450	8,186	37,636	8,186	7,378
Ribboned Steel	1,148	0	1,148		
帯及箍（たが）	2,288	0	2,288		
Wire-ropes	1,197	0	1,197		
Pipes and Tubes	31,358	0	31,358		
Nails	34,514	6,000	40,514		
Materials for Building Construction	17,134	0	17,134		
鍛成品				530	458
Crucible Steel				108	90
Other				6,461	9,143
Total	482,336	188,205	670,541	181,494	178,795

Source:

Steel products grew steadily. When the expansion project was concluded, the actual production reached 170,000 tons, which represented 98 % of the design full capacity 180,000 tons per year. Thanks to the improved steel ingot quality and progress in rolling mill processes, the loss ratio of materials between the crude steel stage and the final stage of steel products was reduced from 50 % at the start up to 36.7 % around 1908. Nevertheless, engineers were still facing serious quality problems. Quality issues were particularly obvious in rails manufactured from the converter steel ingots. "Strictly speaking, most rails manufactured by converter furnaces failed to satisfy the official quality standard". The Railways Bureau's standard specified that phosphor contained in 60 pound and 75 pound rails be not more than 0.12 %. Yawata's products did not fulfil that requirement. Due to high contents of phosphor, the Bessemer steel of the Yawata plant was fraught with cold brittleness. Since a large volume of air was blasted into the furnace during the deoxidization, porosity was caused by oxygen. Cracks were also made. "The status of state-run enterprise made the situation even more complicated. Because it was state-run, the Yawata Works was obliged to follow the government policies and needs, contributing to the country. It had to accommodate diverse orders from its clients, manufacturing a wide variety of products, sometimes in small volumes. It was inevitable that the efficiency of rolling process stayed low."

Domestic iron and steel production and imports in the 1900s (tons)

	Iron									Steel			Imported steel					
	Domestic	(Yawata)	(Kamaishi)	(Others)	Imports	Exports	Total demand	Self-sufficiency(%)	Yawata's share(%	Domestic	(Yawata)	(Kamaishi)	(Others)	Imports	Exports	Total demand	Self-sufficiency(%)	Yawata's share(%
1901	49,147	23,660	15,037	10,450	43,160		99,994	57	48	6,033	1,678		2,554	186,042		192,075	3	28
1902	45,866	17,709	19,278	8,879	29,346	35	68,915	57	39	31,033	19,786		8,868	192,413	5,263	218,183	14	64
1903	29,286		21,103	8,183	37,608	84	68,002	45		39,788	28,688		8,664	231,430	4,479	266,739	15	72
1904	50,706	16,676	26,649	7,381	64,130	148	138,835	53	33	59,945	37,479	2,741	17,654	253,999	3,755	310,189	19	63
1905	124,689	79,182	37,552	7,951	147,719	140	226,847	35	64	71,127	40,313	2,461	25,622	378,041	3,957	455,211	16	57
1906	141,279	100,232	29,484	11,563	101,659	373	242,565	58	71	69,375	62,840	2,349	906	348,136	4,942	412,569	17	91
1907	140,073	95,240	30,740	14,750	97,158	492	236,739	59	68	90,579	79,145	3,144	5,675	464,063	17,028	537,614	17	87
1908	145,823	103,303	34,692	7,828	95,552	686	240,689	61	71	99,255	97,350	1,315	500	439,939	11,719	527,475	19	98
1909	164,244	105,571	38,792	19,881	118,299	489	282,054	58	64	102,982	97,059	4,894	574	280,104	15,054	368,032	28	91
1910	188,018	126,894	51,476	9,641	105,505	569	292,954	64	67	167,967	153,491	5,684	7,861	366,027	17,247	516,747	33	88
1911	203,067	142,978	45,616	14,478	192,388		395,455	51	70	191,700	169,521	7,882	13,398	488,911	25,666	654,945	29	89
1912	237,755	177,160	48,648	11,947	228,546	324	465,977	51	75	219,714	196,388	9,410	12,664	622,002	36,107	805,609	27	85
1913	240,363	176,184	47,067	17,112	265,066	358	505,071	48	73	254,952	217,391	9,970	27,317	527,626	31,421	751,157	34	78