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1. Introduction

This study aims to elucidate how China has been developing industry so rapidly since 1978, by overviewing the rapid growth of the Chinese iron and steel industry under the government's "economic reform and open diplomacy" policy since 1978, and evaluating the reality of capital investment and technical innovation based on the case of Shoudu Iron and Steel Company.

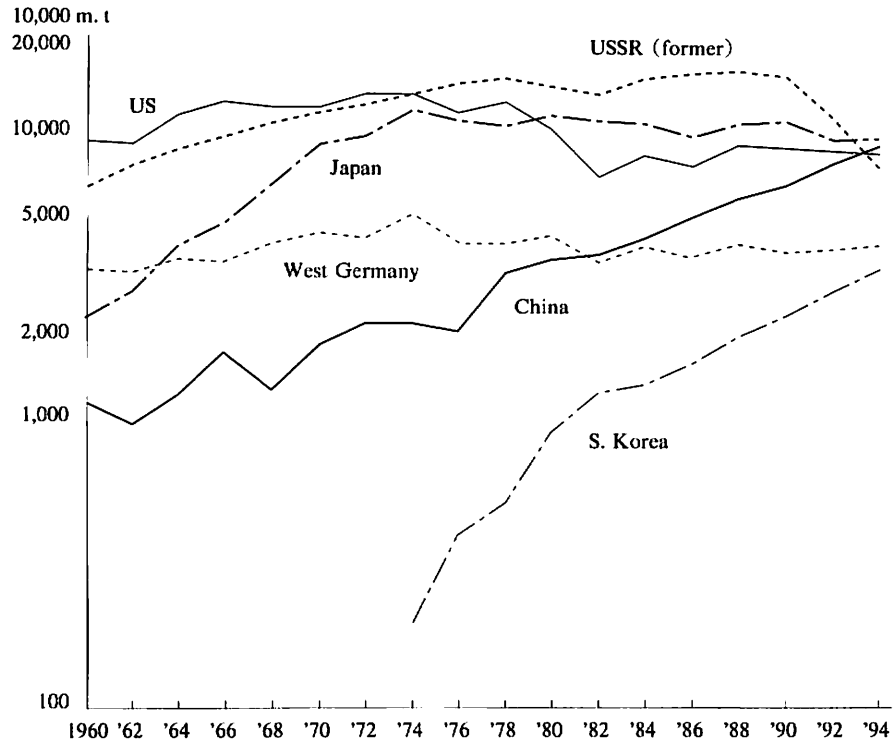
To explicate the developmental history of the Chinese iron and steel industry, it is necessary to study in detail the conditions of the industry, including its production structure, industrial structure, details of various types of enterprises, and the technical innovation in each enterprise. As a part of that comprehensive study, this report focuses on the specific case of Shoudu Iron and Steel Company while overviewing the industry's developmental history, because little is known about the real situation of the industry on the enterprise level.

In this paper, the current situation of iron and steel production in China and other major countries is discussed first. Next, the history of the Chinese iron and steel industry since 1949 is divided into three periods, and the nature of the current trend is discussed from a historical viewpoint. Then, the characteristics of Shoudu Iron and Steel Company differentiating it from other major iron and steel companies in China are defined. Finally, technical innovation in Shoudu Iron and Steel Company is evaluated based on the above observations.

2. The Situation of the Iron and Steel Industry

Figure 1 shows the shift of iron and steel production in major countries between 1960 and 1994. The trends can be summarized by dividing production into two time periods. First, until 1974 when the first oil crisis occurred, iron and steel production had been stagnating or gradually decreasing in the Western industrialized countries, including the U.S. and West Germany, while the Soviet Union had steadily increased production and Japan had dramatically increased it from 22 million tons in 1960 to 120 million tons in 1973. In this period, the U.S., the Soviet Union, EC, and Japan

Figure 1 Steel Production in the Six Major Steel Producing Countries



Source: Japan Iron and Steel Federation, "Japan Iron and Steel Statistical Yearbook", 1966, 1973, 1984, 1994.
Note: Production of West Germany includes production of East Germany since 1992.

were the world's four major suppliers of iron and steel.

Second, since 1974 production has been dramatically increased in Korea, China, Taiwan, Brazil, Spain and India: in 1994, the production of iron and steel in Korea and China reached 34 million tons and 92 million tons, respectively. China's production was comparable to that of Japan and the U.S.. On the other hand, in the four production bases that produced the majority of steel before 1974, production has been stagnating. The U.S., for example, decreased its production significantly in the 1980's, to 67 million tons in 1982. The former Soviet Union has been showing a disastrous decease from 163 million tons in 1988 to 78 million tons in 1994, hinting at a collapse of the very structure of production. The overall industrial development in some NIES countries and China from the 1970's to the 1990's is clearly reflected in their iron and steel production. The rapid development of China since 1978 in particular is attracting the world's attention. In the following chapter, the ups and downs of the Chinese iron and steel industry, whose production exceeded 90 million tons in 1994, will be overviewed mainly in terms of its economic policy and technical development.

3. History

The history of the development of the Chinese iron and steel industry after

World War II may be divided into three periods based on its relationship with the government's economic policy:

(1) The first period is from 1949 to 1957, immediately after the People's Republic of China was established and the policy to promote heavy and chemical industries was adopted. The first 5-Year Plan that started in 1953 falls into this period. In fact, it was the first Chinese industrialization policy. What best characterizes this period is that emphasis was put on the construction of heavy and chemical industries, such as coal and mining, electricity, iron and steel, machinery (including weapons) and chemicals, all of which was supported by comprehensive aid from the Soviet Union. (The Soviet-China Friendly Alliance Aid Treaty and The Agreement for Long-Term Loans to China were signed in 1949, and The Soviet-China Economic Aid Agreement in 1953.) "At that time, the one and only model for Chinese Socialism was Soviet Socialism.....the Soviet Union seized heavy industrial facilities in the former 'Manchuria', especially machines in ironworks and power plants, immediately after the withdrawal of the Japanese Army, and took them home. During the Chinese first 5-Year Plan that started in 1953, however, the Soviet Union sent the latest equipment back to China to be installed at the former plant sites. Of course, it was not free of charge, but a number of engineers and managers were sent with it to assist with setting up and operating the new equipment, managing, training operators, making national plans, and implementing the plans....."[1]

In the sector of the iron and steel industry, the most important project was the construction of factories for Anshan Iron and Steel Company established before World War II, and so "2.96 billion yuan, which accounted for 52% of all capital investment in the industry, were put into Anshan Iron and Steel Company."[2] Other new iron and steel mills, such as Baotou, Wuhan and Taiyuan Iron and Steel Companies, were constructed as well. Production of new iron and steel products, such as heavy rails, bearing steel, seamless pipes and silicon strips, started and many innovative production technologies were adopted, including the use of sintered ore, reduction of the operating time of open-hearth furnaces, high-pressure operation of blast furnaces, and experimental operation of continuous billet casting plants. In this period, it became possible for China to build their first iron and steel industry and start technical innovations, only by importing new technology all at once from the Soviet Union. Indeed, it was the first period in Chinese industrial history when heavy and chemical industries were formed.

(2) The second period lasted 20 years from 1958 to 1977. As a whole, it was a period when China promoted industrialization by themselves. However, it can be subdivided into three periods: the Dynamic Advancement Policy period from 1958 to 1960, the Adjustment Policy period from 1961 to 1964, and the Inland Development Policy period from 1965 to 1977 when the government intended to scatter industrial bases throughout the nation. The Dynamic Advancement Policy, which overlaps with the second 5-Year Plan, was in fact a policy developed to achieve high economic growth on its own. In this period, China developed a policy to construct a unique socialist country through the creation of farmers' communes. There was a political conflict between the Soviet Union and China behind this move. The high economic growth in this period was actually achieved independently under that policy.
The policy yielded considerable success in some areas, but it also produced a number

of adverse effects. The Adjustment Policy Period was the period when the Dynamic Advancement Policy was criticized for having gone too far.

In the Inland Development Policy period, which overlaps with the time of the third 5-Year Plan, the government divided the nation into three economic zones and tried to scatter industrial bases throughout the country, thereby aiming to reinforce the national economic foundation on its own. Under this policy, major industrial bases and local minor enterprises were established. In fact, this industrialization policy was promoted under the quasi-wartime circumstances when the conflict between the Soviet Union and China intensified and the Vietnam War started. China was also in the midst of chaos over the Cultural Revolution.

The iron and steel industry in the second period, including the three sub-periods described above, is characterized as follows:

(i) In the time of the second 5-Year Plan, "the intensive investment in heavy industries from 1958 to 1960 created even more modern mining and manufacturing facilities than in the time of the first 5-Year Plan. The total investment in the construction of the industrial infrastructure amounted to 100,741 million yuan in the three years. In particular, investments were concentrated in the iron and steel industry where the total amount of capital investment reached 11,736 million yuan, which accounted for 21.5% of all investments in heavy industries."[3] This clearly shows that the iron and steel industry was regarded as the most important industry in the second 5-Year Plan as well as the first. The iron and steel mills which had been under construction since the previous period finally started to run. Operation of the blast furnaces in two of the three major production bases, Baotou and Wuhan Iron and Steel Companies, started in 1958. "Furthermore, construction of small projects were started, and ironworks with an annual production capacity of under 0.5 million tons were constructed in 18 sites throughout the country."[4]

(ii) As the conflict with the Soviet Union intensified, China adopted a policy to build their own socialist country by themselves. They put emphasis on the development of the iron and steel industry while expanding people's communes and promoting the construction of irrigation systems in rural areas. In order to meet the increased demand for iron and steel, not only was the construction of large ironworks accelerated but also the production by small blast furnaces was encouraged in rural areas. If it had been managed rationally, this policy could have satisfied the demand of small, local industries and rural communities. In reality, the plan to increase iron and steel production collapsed accompanying a monumental waste of resources, because people lacked even the minimum scientific know-how necessary for producing iron and steel, correlations with other industries were ignored, and the plan was carried out in an impulsive mass-movement style.

(iii) The greatest emphasis was still on the iron and steel industry during the Inland (Mao's "the third line") Development Policy period. The policy is explained as a sort of decentralization of industry under quasi-wartime circumstances. Panzhihua Iron and Steel Company in Sichuan Province and other small ironworks were constructed under the policy. Which shows that the Chinese government placed importance on the role of small enterprises, while promoting the construction of large mills.

(iv) As described above, the Chinese economic policy dramatically changed during those 20 years, but it appears to have approached economic development in

two ways. First, it intended to establish modern ironworks and to promote research and implementation of new technology. For example, the experimental study of LD converters (1958), the improvement of tapping ratios (1959), the trial manufacture of thin seamless pipes (1960), the construction of LD converters (1964, 1965), and the experimental study and operation of continuous casting plants (1966) were done in this period. Second, a number of smaller businesses were established over extensive areas in order to meet the demand from the whole country. This layed the foundation for the decentralized configuration of Chinese industry, though the low efficiency of those medium and small-scale industries soon caused problems. The high ratio of smaller factories in today's Chinese iron and steel industry is, perhaps, the result of this policy. In such a vast country, the policy to encourage minor ironworks could be geo-economically rational, if it was well planned and managed. For, the construction of large iron and steel mills requires a huge capital investment, and it takes a long time to recover the investment due to the low turnover of capital. When the cost of transportation is also taken into consideration, it is clearly rational to establish small factories in many local areas.

(3) The third period is from 1978, when the government turned its attention toward the "economic reform and open diplomacy" policy, up to the present. The Chinese government has been pursuing measures to extend the managerial autonomy of each enterprise, while reducing government interference, thereby aiming to accelerate economic growth and improve productivity. It is an economic reform policy that intends to extend the market economy, and at the same time an industrialization policy that invites foreign investment in the special economic zones along the coast to make China a driving force. In this way, the Chinese economic policy has been undergoing a third major transformation, and elements of the market economy have been increasingly visible in Chinese Socialism. Under this policy, the iron and steel industry has been dynamically expanding, and production is approaching the level of their counterpart, Japan. It is becoming the core of Chinese industrialization.

The expansion of the iron and steel industry is progressing in two directions. First, in the sector of large-scale enterprises, government-owned companies with greater managerial autonomy have been actively expanding their facilities and fostering technical innovation. As a result, they have been steadily expanding their production scale, the variety of products and improving productivity, as seen in the example of Shoudu Iron and Steel Company. Second, the world's latest large-scale iron and steel mills are being established along the waterfront, including Shanghai Baoshan Iron and Steel General Works. Through them, the advanced technology has been gradually introduced to other steel plans following those models.

Thus in 1995, after the ups and downs of those three periods, China finally emerged as one of the world's major iron and steel producers. If the present high economic growth policy works well, the Chinese iron and steel industry will continue to expand and strengthen its capability for supplying metal materials. Then, it will not be long before China becomes the largest iron and steel producer in the world.

4. Industrial Structure

The Chinese iron and steel industry is supported by a number of business enterprises. The nature of these enterprises vary according to the types of facilities owned and their business scale.

(1) There are four types of facilities: iron and steel mills (with a blast furnace, steel-making plant and a rolling plant), steel mills (with a steel-making plant and a rolling plant), rolling mills (with only a rolling plant), and merchant blast furnaces (with only a blast furnace). This does not differ from their predecessors in developed countries. However, the percentage of iron and steel mills is low in China when compared to developed countries, and there are a lot of steel mills, rolling mills and merchant blast furnaces.

(2) In terms of business scale, all the large-scale enterprises are iron and steel mills. The top 10 iron and steel companies play an especially important role. The middle-scale enterprises range from comparatively large-sized iron and steel mills (with an annual crude steel production of 1.5 to 2.5 million tons) to a large number of small iron and steel mills. The high percentage of middle and small-scale enterprises characterizes the structure of the Chinese iron and steel industry.

(3) There are innumerable minor ironworks, and most of them are merchant blast furnaces and rolling mills. As a whole, the most prominent structural characteristic of the Chinese iron and steel industry is regarded to be the high ratio of merchant blast furnaces.

Table 1 shows the features of the top 10 iron and steel companies, including Shoudu. They have the following characteristics:

(1) Four iron and steel companies, Anshan, Shoudu, Shanghai Baoshan, and Wuhan are large ironworks comparable to the world's major ironworks. The other six are middle-scale ironworks, with an annual production of 1.8 to 3 million tons.

(2) Though they are all government-owned companies, their status in the industry vary considerably: (a) Anshan and Wuhan Iron and Steel Companies were established during the first 5-Year Plan. Considerable deterioration is now visible in their

Table 1 Big Iron and Steel Corporations in China (1993)

	Sales	Profit	Number of Employee	Production			
				Iron	Steel	Rolled Steel	Iron Ore
	(10 billion yuan)		(1000)	(10000 metric ton)			
Anshan	189	21	208	837	769	611	2608
Shoudu	221	43	262	556	702	532	2394
Baoshan	182	32	32	657	698		
Wuhan	132	1	139	545	524	499	508
Benxi	64		101	305	257	198	1149
Taiyuan	60	5	69	177	222	157	367
Maanshan	65	20	83	239	212	198	736
Baotou	71	8	105	291	308	208	769
Panzhihua	53	3	102	291	240		2
Tangshan	57	7	56	134	181	155	269

Source: "China Iron and Steel Yearbook, 1994".

facilities and requires updating. Baotou and Panzhihua, which were established during the self-development period, have the same problem. (b) Established in the 1980's, Baoshan is the latest ironworks with state-of-the-art design, and production and management technologies transferred from Nippon Steel Corporation in Japan. (c) On the other hand, Shoudu is an old company with a long history. It was first established in 1917 as an iron ore mine, and since 1949 it has gradually developed into an iron and steel mill. At first, it was producing mainly pig iron under the government's policy, but in 1978 it was granted a considerable range of managerial autonomy. Since then, while making a profit-paying contract with the government, it has been actively updating production facilities through intensive capital investment, and adjusting the balance of production processes (the balance among pig iron making, steel-making and rolling processes) as an iron and steel mill. With this, it has finally entered the stage where it can take advantage of the economies of scale. Moreover, it has improved labor efficiency by tightening the management of administration and of labor, and it has evolved into a megacorporation comparable to Anshan and Shanghai Baoshan Iron and Steel Companies.

Thus, the type of the companies within the industry is different. In order to evaluate the development of the Chinese iron and steel industry and its technical advances, it is especially important to study cases like Shoudu where they are carrying out capital investments and technical innovations on their own.

5. Shoudu Iron and Steel Company

(1) Outline of the Company

Shoudu Iron and Steel Company is a government-owned enterprise located in the suburbs of Beijing. Its main business is the production of iron and steel (carbon steel and special steel), but it is also a huge conglomerate holding various divisions, including mining (iron ore), heavy machinery, electronics, architecture, and shipping divisions. The employees number about 260,000, not only because it has many affiliated business divisions, but also because it has extensive welfare divisions and employs members of the Communist Party, as is typical of a state enterprise.

(2) Production Facilities

To understand the nature of Shoudu as an iron and steel company, it will be useful to evaluate its production facilities and their capacities as compared to those of, for example, Shanghai Baoshan Iron and Steel Company.

As shown in Table 2, Shoudu has four small and medium-sized blast furnaces to make pig iron, with a total production capacity of approximately 5.5 million tons. On the other hand, Baoshan has only large-sized blast furnaces. As for steel plants, both Shoudu and Baoshan have only LD converters. Shoudu is different from other large ironworks in that it developed a compact 5-ton and 30-ton converters on its own and used it from the beginning. As of 1996, it has three 210-ton large converters, two of which are used ones purchased from foreign company and translocated. As for a plant to make semi-products for rolling, it has both blooming and continuous casting systems. In recent years, Shoudu has been actively installing continuous casting systems and operating them successfully. Its rolling systems are mainly for making

Table 2 Production Facilities and Capacities of Soudu and Baoshan

	Soudu	Baoshan
Blast Furnace	576 m^3 (1 unit) 1726 m^3 (1) 2500 m^3 (1) 2100 m^3 (1)	4063 m^3 (2 units)
LD Converter	210 ton (2) 30 ton (2) 80 ton (3)	300 ton (3)
Electric Furnace	100 ton (2)	
Blooming Mill	1.26 million ton (2)	2.10 million ton
Continuous Caster	0.45 million ton (Billet, 3) 1.20 million ton (Slub, 1)	4.00 million ton
Bar & Section Steel	(2)	
Wire Rod	(4)	
Thick Plate	(1)	
Seamless Pipe	(1)	0.50 million ton (1)
Hot Strip Mill	under construction	3.70 million ton (1)
Cold Strip Mill	under construction	2.40 million ton (1)
Tin Plate		0.37 million ton (1)
Galvanized Sheet		0.16 million ton (1)

Source: (1) Shoudu; Materials by Shoudu.
(2) Baoshan; Kyoichi Mitaji, 'Shanhai-Hozan-Seitetusho Kensetu to Sonogo no Keika' (Construction Process of Shanghai Baoshan Iron and Steel Mill and after that), "Tekkokai" (Journal of Japan Iron and Steel Federation) September 1992.

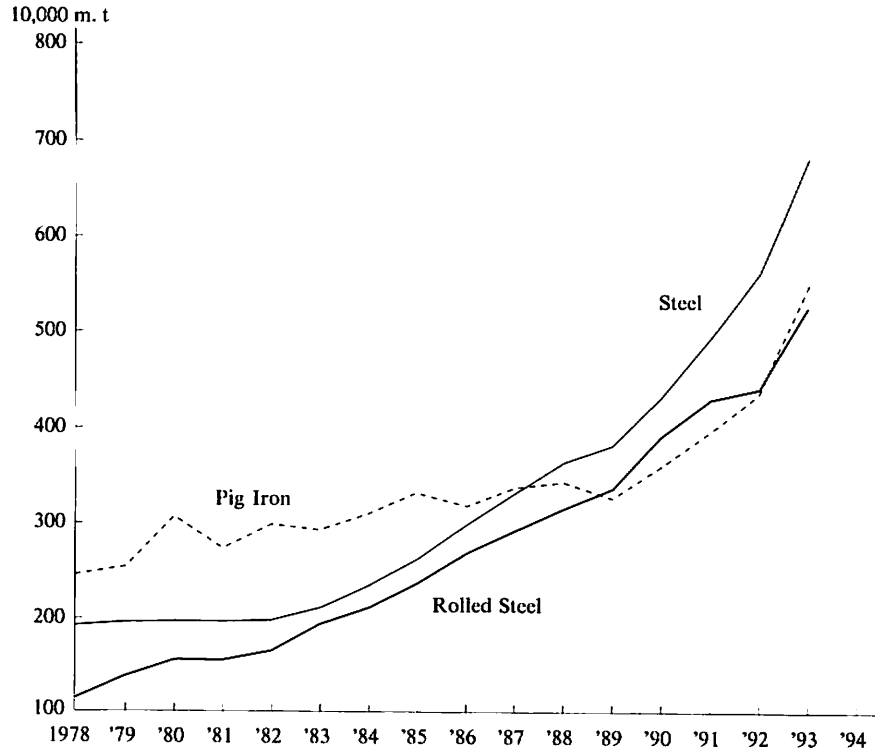
wire rods and section steel, but it is also equipped with systems to make steel plates of medium thickness and steel pipes. This list of facilities shows that Shoudu is a steel mill focusing on products to be used for architecture and construction. This is the main difference from Baoshan whose main product is steel sheet. However, Shoudu is now constructing a new steel sheet plant on its premises. When it is completed, Shoudu will be equipped with all the facilities necessary to make all the key steel products from bars to steel sheet. The new steel sheet plant is a result of capital investments based on speculation that future demand from the electric and automobile industries will be high.

Thus, Shoudu has been gradually updating the production system over its long history, using both used plants and new ones, unlike Baoshan which installed new facilities all at one time in the 1980's. Shoudu focuses on the production of wire rods, which is advantageous to the company because the demand is secured in today's China while the infrastructure is being built. Shoudu can serve as a good model for other ironworks seeking modernization.

(3) Capital Investment and Integrated Production of Pig Iron and Steel

Since 1978, Shoudu has been intensifying self-management and making investments in facilities overall, but especially intensive investments have gone into steel plants, while large LD converters and continuous casting mills were added. Consequently, Shoudu is successfully transforming itself into an iron and steel mill with well-balanced production capabilities in three main processing areas (pig iron

Figure 2 Production at Shoudu



Source: "Chronorogical table of Shoudu, 1978~1990" and "China Iron and Steel Yearbook", 1991~1994.

making, steel-making and rolling). As the transition clearly reflects the development process of the iron and steel industry itself since 1978, it should be examined in detail (See Figure 2).

From Figure 2, the following facts are known. First, the production of pig iron, crude steel and steel products in 1978 was 2.42 million tons, 1.79 million tons and 1.18 million tons, respectively. This production scale was far smaller than the world's major ironworks and even other Chinese steel mills. However, Shoudu steadily increased the production over the next ten years: the production of pig iron, crude steel and steel products in 1993 reached 5.56 million tons, 7.02 million tons, and 5.32 million tons respectively. Now it ranks among the world's leading steel mills in the production of crude steel. The increase rate in production from 1978 to 1993 was 230% in pig iron, 390% in crude steel and 480% in steel products. Production has been skyrocketing since 1985, encouraged by the start of operations in large-scale plants that are described later. Indeed, Shoudu is supporting the high growth of the Chinese iron and steel industry.

Second, the increase in the production of pig iron, crude steel and rolled steel products between 1978 and 1993 suggests that the nature of the company changed considerably. From 1978 to 1987, the production of pig iron was larger than that of crude steel. That means that Shoudu was serving as a supplier of pig iron to other steel mills without blast furnaces, rather than as a full-fledged iron and steel company. This may have been the result of a government policy, but the fact that Shoudu

owned a large iron ore mine was perhaps another reason. However, as clearly shown in Figure 2, the production increase in pig iron remained small between 1983 and 1989, though the production of both crude steel and steel products steadily increased. This is positive evidence that under the government's economic reform policy Shoudu acquired larger managerial autonomy and promoted capital investment in plants, aiming to adjust the balance among the three production processes and transforming itself into a full-fledged iron and steel company. It means that larger managerial autonomy enabled Shoudu to shift its emphasis from production based on the government's plan to production based on cost-effectiveness of individual enterprises and allowed them to pursue an investment policy to achieve it. In terms of cost-effectiveness of an individual iron and steel maker, it is rational to give priorities to the balance among the three production processes; pig iron making, steel-making and rolling. For, in the well-balanced production structure of an integrated steel-maker, the production of pig iron never exceeds the production of crude steel which uses scraps as a one of its materials, and there should not be much difference between the production of crude steel and that of steel products.

Thus, the steady increase in production indicates not only the quantitative growth but also the qualitative growth of Shoudu, as it pursued a managerial policy to achieve cost-effectiveness as an independent enterprise by completing the infrastructure for integrated steel production.

(4) What the Construction of the Second Steel Factory Means

Of the newly constructed facilities mentioned earlier, the construction of Shoudu's second steel factory not only had an extremely important meaning to the company, but also was an epoch-making event to mark the turning point in the Chinese steel industry's path towards modernization. The second steel factory is a large-scale steel mill, which is equipped with two large LD converters connected to two continuous billet casters and a continuous slub caster, and produces 3 million tons of crude steel per year (as of 1993).

What did the installation of large LD converters mean to the company? Shoudu purchased them from a closed Belgian steel mill, transported and installed them by themselves. As widely acknowledged, mainstream steel production technology in the world has been shifting to LD converters, whose operational efficiency is far higher than that of open-hearth furnaces, since 1955. The ratio of converter steel production in major steel producing countries ranges from 60 to 69% (see Table 3). However,

Table 3 Steel Production by Manufacturing Process (1993)

(Unit %)

	China	S. Korea	Japan	Taiwan	US	EC	USSR (former)
Open-Hearth Furnace	14.2						47.8
LD Converter	63.8	66.8	68.8	52.2	60.6	66.5	39.2
Electric Furnace	21.8	33.2	31.2	47.5	39.4	33.5	13.0
Others	0.2			0.3			
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source: Japan Iron and Steel Federation, "Japan Iron and Steel Statistical Yearbook, 1994".
Note: EC includes 12 Countries.

open-hearth furnaces were still the mainstream in the Soviet Union and China in the 1960's and 1970's. Even in the U.S., they accounted for about 12% of all facilities in 1980. Though the ratio in the Soviet Union is still exceptionally high, China rapidly decreased it to 14% by 1993. Shoudu started to run a 30-ton converter in 1964, earlier than any other steel mill in China. Construction of additional large converters undoubtedly strengthened Shoudu's capability for mass-production, improved productivity, and reduced costs.

Then, what did the introduction of continuous casters mean? The continuous casting system is used for casting ingot steel, that has been refined by a converter, directly into semi-products for rolling, such as slubs, billets and blooms. It can dramatically reduce the production process, in comparison to the conventional blooming method, because it can finish the work of two processes in only one process. It is an overwhelmingly efficient technology in terms of operation time, yield, basic energy units and the number of operators. It was one of the most innovative technologies to help the Japanese steel industry achieve competitiveness in the world market, along with LD converter technology. Around 1963 Japan started actively importing this technology which was being developed in Germany, Switzerland, Austria and the former Soviet Union. As shown in Table 4, other countries rushed for this technology, too, and even though China got a late start, steel production by continuous casters accounted for about 35% of all technologies employed in 1993. Shoudu has greatly improved productivity by introducing LD converters and continuous casters for billets, blooms and slubs, and by connecting the two systems.

As is evident from the developmental history of the steel-making technology described above, Shoudu's completion of a large-scale steel mill equipped with LD converters and continuous casters in the late 1980's was not a noteworthy technical achievement for the world. However, when evaluating the significance of the construction of the second steel factory today in the mid-1990's, we have to keep the following facts in mind. First, China too was already conducting research on LD converters and continuous casting systems from the late 1950's to the early 1960's, and constructed small LD converters and continuous casters. The Institute of Iron and Steel carried out experiments on continuous casters in 1956, and the Annealing Industry Department adopted a policy centering on converters in 1960. Shoudu itself has a long history of research and development, from the experimental study and operation of a 5-ton converter and a small-sized continuous caster in 1958 to the applied study and operation of a 30-ton converter in 1964. That means that neither Shoudu nor the Chinese steel industry as a whole neglected to study and assimilate

Table 4 Steel Production by Continuous Casting

(Unit %)

	China	S. Korea	Japan	Taiwan	US	EC	USSR (former)
1980	11.4	32.4	59.5	56.5	20.3	38.6	10.7
1985	14.7	63.3	91.1	87.2	44.4	66.9	12.5
1990	22.3	96.1	94.0	96.1	68.0	87.7	18.0
1992	30.0	96.8	95.4	93.9	79.3	91.9	16.3
1993	35.0	97.8	95.7	97.9	85.5	92.7	19.6

Source: Japan Iron and Steel Federation, "Japan Iron and Steel Statistical Yearbook", 1993~1994.

foreign technologies. There were times when they actively conducted studies. And their level of study was not particularly behind the world's standards. There was not much of a time lag between China and Japan, which introduced and proliferated converter steel-making and continuous casting technologies simultaneously in the 1950's and 1960's. China was actually laying the groundwork for technical innovation.

Nevertheless, for 10 years from the mid-1960's to the mid-1970's, circumstances prevented China and Shoudu from implementing new technology in actual mills and did not foster technical innovation. Moreover, due to the managerial restrictions imposed by the government, Shoudu lacked the economic need for actively adopting new technology, and the managers and engineers lacked the right to invest in it by themselves. In this regard, the self-development policy under the conflict between the Soviet Union and China and the Cultural Revolution painfully hindered technical innovation. This is why China lagged behind its competitors in the world in iron and steel technology and Shoudu had to wait until the late 1980's before they could introduce large LD converters and large continuous casters in spite of its accumulated technical skill. (Even Baoshan did not introduced them until the late 1980's.)

Another important fact is that the entire process from the installation of the converters and continuous casters until they became fully operational became an important opportunity for Shoudu and the Chinese steel industry as a whole to acquire new technology. For example, Shoudu purchased used converters from a foreign company and the engineers in the construction department dismantled, transported and installed them in a short period of time (about one year). They had to modify used plants, and they also added a process computer to control their operation. This all-out movement, especially the collective effort to translocate and remodel the plant reminds us of unique Chinese "human sea tactics", however, by purchasing used plants they not only saved cost and construction time, but they also accumulated technical experience in dismantlement, installation and modification of large equipment and machinery. It should be noted that this process also stimulated Shoudu's other divisions, including the Heavy Machinery Corporation and the Electronic Engineering Corporation, into redesign and fabrication of large equipment and machinery, and development of computer-related technologies.

The installation process of the continuous casting system played an especially important role in the acquisition of new technology. Though Shoudu had a small caster for experiments, this was its first experience to install a large continuous billet caster and operate it steadily. The new system was introduced to be used with existing pig iron making and rolling plants, therefore it became necessary to devise an optimum installation and operation method for it, while adjusting the balance of production capacity among blast furnaces, converters, continuous casters and rolling plants. Of course, it was never easy to solve those two problems, because the continuous caster had to be located so as to link the iron and steel-making plants and the rolling plant. The problems could never be solved without basic technical kno-whow, including control of casting temperature, cooling temperature at the caster's inlet, quality of the firebricks at the inlet and lagging. Somehow they overcame these technical obstructions and proved their high technical standards. It is certain that the engineers accumulated valuable experiences though this job, but it may also be true that Shoudu could do it because the engineers had greater power in decision making

within the company at that time. When evaluating the feasibility of the plan, it is not sufficient to consider the contents of the plan, cost and management's assessment. For, such an investment plan on the corporate level can be rationally implemented only if engineers participate in decision making.

Another fact that should be noted is that not all steel mills in China are being operated with high-standard technologies. There are still open-furnace steel mills, and the rate of prevalence of the continuous casting system is still low. However, it means that the Chinese steel industry still has vast room for further improvement in production efficiency.

Thus, if the technical standard of the Chinese iron and steel industry is evaluated based on the history of technical advances in the steel industry after World War II and the historical background of China, it becomes clear that the Chinese iron and steel industry (and perhaps the traditional heavy and chemical industries as a whole) has a rich history of accumulating basic technologies. Its capability to assimilate and develop the most advanced technologies suggests that China should never be underestimated as just another developing country.

6. Conclusions

Since 1978, the Chinese iron and steel industry has developed rapidly and has emerged as one of the leading steel producers, comparable to the U.S. and Japan. To know what has made it possible, we have hitherto reviewed its developmental history, industrial structure, and examples of technical innovation. However, these examples are on the positive side of the Chinese steel industry, and there are still many problems to be solved behind it. The biggest challenge is how they can update obsolete facilities of the many large ironworks, promote technical innovation and distribute high-standard technologies throughout the country. In other words, how they can transfer Shoudu's unique experiences in technical innovation to other large steel mills and apply the foreign technologies acquired by Baoshan to them.

Then they need to improve the quality of products. With the future changes in industrial structure, especially the future extension of durable consumer goods, production of steel plates, pipes and special steel will be increased and higher quality will be demanded.

Another big challenge is technical innovation in minor ironworks (steel mills, rolling mills, and merchant blast furnaces). Here, the main task will be the extension of the scale of business by consolidating small enterprises and improving operation technology. They may have much to learn from developed countries where recent progress in electric furnace operation technology and the emergence of new technologies, such as the reduction melting system, are becoming advantageous to middle and small-sized steel mills because they require less capital investment.

Finally, when the budget for equipment is limited, they should consider the possibility of improving operation technology by remodeling old plants. In this regard, they have a good example in Shoudu.

Under these circumstances, the Chinese central government should adopt a powerful industrial policy (for technical innovation and investment coordination), at least for the iron and steel industry, to extend enterprises' autonomy and encourage

engineers' participation in the decision-making process, and at the same time to promote technical innovation and the consolidation of enterprises. Such a policy may seem to contradict the current trend toward the market economy, but in the history of economics it is widely acknowledged that such a policy is a requisite for developing countries.

Notes

1)～4) Yoshiro Hoshino (1993), pp.107～111, pp.223～225.

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