Econ. J. of Hokkaido Univ.,
Vol. 28 (1999), pp. 29～56

Japanese Steel Engineers*
– Technology Transfer and Succession –

Kikuji YONEYAMA

The purpose of this paper is to analyze the Japanese historical background of technology transfer from advanced countries.

Samurai engineers played an important role in industrialization under the strong influence from the west.

Japanese engineers even those who learned western engineering only by reading books was able to design, construct and operate western style iron making furnaces. This endogenous development of the iron industry cultivated the foundation for the effective technology transfer from abroad.

General skilled workers also contributed to technology transfer using the spirit of *Kaizen*. After World War II, Japan's second stage of technology transfer occured. Based on the succeessful technology and skills from the senior employees, engineers and skilled workers polished up the imported technology. In the 1980's, Japan achieved its desire to catch up with the west.

During the same period, Japanese engineers with field science and field engineering promoted the transfer of appropriate and key technology to developing countries.

This new type of engineer can develop new principles from today's difficult situations with which human kind are confronted on a global scale. He also can invent new methodologies and use engineering for problem solving.

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* The author is particularly thankful to Professor Koji Taira, University of Illinois for valuable discussion and comments. The author is thankful to Dr. Peter Firkola, Associate Professor, Hokkaido University for his stimulative discussion.

1. Introduction

In 1990's after the bubble economy, the Japanese manufacturing industry is faced with the problem of hollowing out of industries due to the strong Yen rate. On one hand, Japanese companies are strongly urged by foreign countries to offer effective technology transfer at their oversea business activities. On the other hand improvements in R & D for new technology and new industrial products in R & D division are the immediate problems to solve. Innovation in the domestic base factory is the crucial issue for management.[1]

In 1980's Japanese companies promoted the business restructuring and reduced the number of new employees to cope with the recession.[2] Therefore the percentage of young employees has been going down and the relative weight of old and middle-aged employees has been going up. In these next 10 years, a large number of old employees will be retiring.

To overcome these difficulties, the hiring of talented young employees is an important managerial problem. At the same time, the succession of technology and skill from the skilled old generation to the unskilled young generation is a critical problem to maintain the core competencies within the organization.[3]

This paper will examine the transfer and succession of steel making technology, the consciousness and behavior of engineers from the Meiji period in Japan.

The role of engineers in 21th century will then be examined.

The Methodology used for this research was interviews with skilled workers and engineers at steel works using free-answer style questions as well as field observations. A document survey and literature survey was also carried out.[4]

2. Transfer of Western Technology

(i) Oshima Takato and the Western Style Blast Furnace

Oshima Takato(1826–1901) was born the son of medical doctor for the Morioka clan *(Han)*. He was a famous Japanese engineer. He was a key figure in the indigenous development of the Japanese steel industry using materials (iron ore) from Iwate prefecture at the end of *Edo* period.[5]

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1 Kahokusinposha (1997), "Factory in the Village," (in Japanese) Shinhyosha.

2 Yoneyama Kikuji (1989), "Economic Restructuring and Regional Development in Hokkaido" *Hokudai Economic Papers, Vol. XVIII, 1989.*
Yoneyama Kikuji (1994), "Business Restructuring and Training for Job Conversion in the Japanese Shipbuilding Industry," *Economic Journal of Hokkaido University, Vol.* 23, 1994.

3 Yoneyema Kikuji (1993), "Construction and Operation of the Most Advanced Factory and Shop Management," (in Japanese) *Keizaigaku Kenkyu (Hokkaido Daigaku), Vol.* 43, *No.* 3.
Tsusho Sangyosho (1992), "Succession of History of Industrial Technology and Creation for the Future," (in Japanese) Tsushosangyo Chosakai.

4 Herbert J. Rubin & Irene S. Rubin (1995), "Qualitative Interviewing," SAGE Publications.
Orr, Julian E. (1996), "Talking about Machines," Cornell University Press.

5 For more information about his life, refer to the following book.

Oshima studied Dutch in *Edo* (the capital). He then went to Nagasaki to study western medical science, pharmacology, refining of iron ore, mining and military tactics. After leaving Nagasaki, he went to Osaka to enter a private school *(Teki Juku)*.[6] At that school he developed his language ability and studied through intensive discussion with his colleagues in the dormitory.

In 1856, he was in charge as a chief engineer, to construct and operate a western style reverberatory furnace. He also succeeded in casting a big canon used for defending on the beach of Japan. After coming back to his home town (the *Morioka* clan), in 1857 he constructed a western style blast furnace at Ohashi village in Iwate prefecture based upon information from a Dutch book of engineering.[7]

First, as a mining engineer, Oshima carried out field research to investigate the iron ore deposits in the mountain area of Iwate prefecture. Second, as an entrepreneur, he organized powerful merchants to get the necessary funds and started up a new business organization for iron manufacturing. Third, as a plant engineer, he designed a western style blast furnace. Fourth, as a construction engineer, he made the decisions for plant site location and led the bricklayers, charcoal makers and general workers in the construction. Finally, as a plant manager, he led his men, bricklayers, charcoal makers and general workers in the operation of the blast furnace. He learned much from the know-how of Japanese traditional iron making technology, and also respected the opinion of those who were doing the actual work.

Oshima had a soft and rational way of thinking in spite of the strict daily life under the Edo feudal system. After leaving from his home town which was based on a rigid social rank system, his spirit of rationalism was developed during his Dutch studies in Edo, Nagasaki and Osaka.

As the son of medical doctor for Morioka clan he could go to learn Dutch studies beyond the boundary of the local clan *(Han)*. In those days, people who aspired to learn Dutch studies would share the latest information at private schools with nation wide network. They paid attention only to information and knowledge from the west, neglecting social rank and status.

Teki Juku had two main curriculum for the students. There were the language and general education school, and the post graduate medical school. This school

Nakazawa Shuzou (1974), "The Beginning of Japanese Iron Manufacturing," (in Japanese) Jinbutu Oraisha.

6 Umetani Nomoru (1996), "Ogata Koan and Teki Juku," (in Japanese) p.62–63, 94–95, Osaka University Press.
Ban Tadayasu (1978), "People Concerning *Teki Juku* - The School of Dutch Studies," (in Japanese) Sougensha.

7 Okada Hirokichi Ed. (1990), "From *Tatara* to Modern Manufacturing," *(Tatara kara Kindai Seitetsu e)* p. 180–224 Heibonsha.
Mori Kahei & Itahashi Hajime (1975), "Formation of Modern Steel Industry : Pre-history of Kamaishi Works," (in Japanese) p.69–127, Kamaishi Seitetsusho.

had a meritocracy system based upon language ability and intellectual ability in medical science. Students enjoyed discussion free from the federal social rank system.[8] The school tradition of *Teki Juku* had encouraged the young Oshima to contribute to the independence of Japanese society against the influence from the west.

After finishing his studies at three different schools, he went into the practical business world. He trained as an engineer for the construction and operation of a reverberatory furnace with the Mito clan. Oshima's ambition and spirit as an engineer led him to observe issues in the field. He wanted to study advanced theories for recognizing and analyzing problems, also wanted to solve problems based on applying the theories to original data and using practical skills and know how.

Oshima was a typical engineer. His spirit of contributing to the nation and problem solving using original data from the field was succeeded by Yokoyama Kyutaro and Takahashi Matasuke. They overcame the failure of iron-making technology transfer from the UK conducted by *Kobusho* (Japanese Government Ministry) at Kamaishi Mining Iron Works in the 1870's.[9]

(ii) Technology Transfer at Yokosuka Shipyard

In 1865, the Edo government constructed a shipyard at Yokosuka village in Kanagawa prefecture with the French government's technological and financial support. A French engineer, Mr. Verny was the leader of the construction, the operation and the technology transfer of modern western shipbuilding technology. The technology transfer system (school regulation and curriculum) was designed based on the policy that "everything will follow French naval academy regulations." Japanese trainees were divided into two groups. The first group were engineering trainees *(Gishi Denshusei)* who were selected from educated young Samurai. The second group were the skilled worker trainees *(Gishu, Shokkoseito)* who were selected from the young common people (farmers, craftsmen and merchant class). This status

8 Mr. Hukuzawa Yukichi, founder of Keio Gijuku University entered into *Teki Juku* in 1855. In 1857 he became the head of students at *Teki Juku.*
He enjoyed too much his student life at *Teki Juku,* where he studied physiology, medical science, physics, chemistry and others.
Hukuzawa Yukichi (1978), "New Edition Autobiography of Hukuo," *(Shin Tei Hukuo Jiden)* School tradition of *Teki Juku* p.63–94, Iwanami Shoten.
Naramoto Tatsuya ed. (1978), "Japanese Private School," *(Nihon no Sijuku)* Kadokawashoten.
The characteristics of *"Shijuku"* at the end of Edo period was the strong relationship between teacher and students and also among students. They developed friendly competition to make themselves study as hard as possible.

9 Kamaishi Seitetsusho (1955), "70 Years History of Kamaishi Works," (in Japanese) p.41–60, Kamaishi Seitetsusho.

system inside the firm was designed to match the Edo feudal system in Japan.

Japanese skilled workers trainees *(Shokkoseito)* were trained on the job by the French foreman and by skilled workers at the shipyard in the morning. In the afternoon they attended the in-firm training school to study solid geometry and other required subjects.

The general manager of interpretation was in charge of training and taught classes in French and engineering for shipbuilding. The manager of construction also taught classes for trainees when he was not busy directing construction.

The main target for technology transfer was based upon the study of the French language and special engineering for shipbuilding. The trainees were taught to follow the instructions of the French manager of construction and foreman. They were also taught to do their best to learn the skills of French skilled workers. But they were forbidden to express their own opinion or to follow any other person's instructions. The simple and clear chain of command was taken very seriously for the smooth technology transfer.

It is natural that the men of a backward nation would be humble when studying foreign advanced science and technology. However, to put too much stress on this attitude led to a tendency to follow the advanced technology with no original ideas.

One hundred Japanese general workers were selected to become trainees. Until then they had been iron-workers and woodworkers with traditional Japanese skills. Japanese skilled iron-workers were assigned for the training of western ironwork and also skilled wood-workers were assigned for the wood working.

French skilled workers transferred western technology and skill to the Japanese skilled workers in the necessary areas. If one Japanese unskilled worker would learn enough to put the job into effect, he would pass his knowledge and skill on the other Japanese unskilled worker. From one skilled worker to an other unskilled worker, the western technology and skill were transferred one after another. The Japanese trainees, they competed with each other for the completion of the shipbuilding job.[10]

In this way the original Japanese on the job training system was developed with the help of French Engineers, foremen and skilled workers at Yokosuka Shipyard in the 1860's.

Patriotic Samurai engineers contributed to the newly born modern Japan through the industrial activities in Yokosuka shipyard, a big experimental field of

10 Yokosuka Naval Authority "The History of Yokosuka Naval Shipyard," (originally published 1915) (in Japanese) p.7, Harashobo.
Yokosuka Naval Authority "The History of Education and Training for Engineer and Worker at Yokosuka Naval Shipyard," (in Japanese) (reprinted edition 1984) p. 22, Hobunkaku.

technology transfer.[11]

The prototype of the Japanese industrial training system was designed by the first systematic technology transfer from the French. That is "Off-the-Job Training" (Off-JT) composed of language education and engineering education in special fields . The other is "On-the-Job Training" (OJT) at a workshop to learn the skills. The Edo feudal social system divided the Japanese into two social ranks, Samurai and others. This social rank system had been successful into the placement of employees at the management bureaucracy system of the modern industry.

The company system, *"Gishi"* (Engineer) for Samurai and *"Gishu"* or *"Shokko"* (skilled worker) for common people was directly linked with the later developed school education system. An individual with an academic career with higher education would be given the job of *"Shokuin"* (engineer, clerk or manager). The individual with only a general education career would be given the job of general worker.

Shokuin was paid by monthly salary. *Koin* (general worker) was paid by the day. The wage, bonus and welfare systems are clearly divided into these two types inside the company. The traditional *Edo* feudal system was reorganized to promote effective technology transfer from the West. School careers and length of service are an indication of the ability of the newly technology transferred job. The prototype of the *Nenko* seniority system was originally designed at the Yokosuka Shipyard.[12]

(iii) The Failure of Kamaishi Mine and the Success of Governmental Yawata Steel Works

In 1874, the Ministry of Industry (Meiji central government) imported two blast furnace plants with 25ton production volume from the UK. The Ministry constructed the iron-making plants and tried to operate the plants. British engineers and skilled workers were invited to assist in the iron making technology transfer. In spite of the foreign engineers' guidance, this works failed in its operation. The causes of the failure were due to the fact that British engineers and skilled workers did not carrry out a careful investigation into the quality and quantity of local materials (iron ore and charcoal). British engineers neglected the locally specific conditions for plant operation. Believing too much in the British way as the most adv-

11 For more information about *"Samurai* Engineers" refer to the following books:
Miyoshi Nobuhiro (1983), "Education for Engineers in the Meiji Period," (in Japanese) p.88–92, Chuo-Koron Sha.
Miyoshi Nobuhiro (1979), "Study on the Formation History of Japanese Industrial Education and Training."

12 Hujita Wakao (1961), "Study of Labor Agreements in Japan," (in Japanese) p.3–4, Tokyo University Press.

anced technology in the world, they had an interest only in selling the plants to Japan, an underdeveloped island country and to earn their money. The British engineers had no intention to promote technology transfer from the UK to Japan, and also had lacked sense of experiment and field work. They did not understand the basic principle that the treatment of local materials is the key for a successful iron making operation.

From 1874 to 1882, many attempts were made at developing the Kamaishi Mines. But the operation failed and no technology transfer was achieved. At first, British engineers' intellectual arrogance and misleading were the causes of the failure of technology transfer. In addition, Japanese officers from the Ministry neglected to make use of Japanese engineer's experiences and proposals by Oshima Takato.

Finally the Ministry decided to shut down the plant because of the shortage of materials supply and governmental financial difficulties. One ambitious merchant in Tokyo, Tanaka Chobei recieved the information that government had a plan to sell all plants to the private sector. He bought the plants and founded the iron making company, Tanaka Kozan Seitetsusho. Tanaka ordered his men, Yokoyama Kyutaro and Takahashi Matasuke to operate the British-made blast furnace effectively. Yokoyama, who was not an engineer with the experiences of plant operation, failed 47 times. But one day, he got a new idea for materials treatments. The iron ore already used were again placed into the blast furnace. By this invention of materials treatement technology, he succeeded in the operation of the blast furnace in 1877. Yokoyama restarted from the indigenous level of iron making technology which was developed by Oshima in 1857.[13]

Tanaka's management strategy was based on the technological success of Oshima's style of blast furnace operation. In 1894, he invited Dr. Noro Kageyoshi, Professor of engineering for iron making at Tokyo University as a technical adviser and employed his apprentice, Komura Koroku as a chief engineer. Komura challenged to operate the British made 25ton blast furnace and succeeded in taping coke iron. This taping of coke iron was the first successful case in Japanese iron making history.[14]

In 1925, Skaredoff, a refugee engineer from Moscow guided the new operation technology of the open furnace at Kamaishi. But he had no practical experience to operate the actual production process. During the technology transfer, Masuda Seiemon, a young steel worker for the open furnace made every endeavor to follow the arrogant guidance of Skaredoff. Skaredoff ordered Masuda to chop the test piece by hammer.

13 Kamaishi Works (1955), "70 Year History of Kamaishi Works," (in Japanese) p.91–92, Kamaishi Seitetsusho.

14 ibid. p.60–61.

After checking the chopped side, Skaredoff threw away the test piece into the bushes in front of the steel factory. At the beginning, Masuda could not understand the meaning of hammer work. But he was clever enough to gather the disgurded test pieces from the bushes. Finally, he deciphered the meaning of test piece hammer work. Skaredoff judged the component of steel based on the conditions of chopped side. Masuda could find out the meaning and know how of judgment from Skaredoff's activities. This is the unwritten history of technology transfer for steel component judgment.[15] Masuda typically performed the Japanese traditional craftsmanship, spirit oriented in the production field and practical skill.

Yawata Steel Co., a national enterprise integrated steel mill was launched in 1901. This national strategic plan was designed on the basis of the success at Kamaishi Works. It was constructed and operated with the technological assistance of a German steel company. All plants for iron and steel making were imported from Germany. A total 19 German engineers and foremen came to assist in the construction and operation of the plants from 1897 to 1904.

Unfortunately the operation performance was not at the expected level of production volume and quality.[16] German engineers' and their techniques proved to be ineffective in Japan. German people had a sense of racial superiority to Japanese, whom they saw as underdeveloped Orientals. And they overestimated German technology just as the British did at Kamaishi.[17]

Mr. Tanaka Kumakiti (1873–1972), a worker at the blast furnace tapping watched calmly and analyzed the German engineers' and foremen' s activities for guidance. Even without German language ability, Tanaka could find the mistakes in operation techniques.[18] For several years he had been to German steel works for training of foreman jobs. He saw the mud gun machine for the tapping of the blast furnace for the first time, Tanaka was prohibited to touch the machine or to see the plans of the machine. But he made an effort to understand the total structure of the machine and to draw the plans only by looking at it. This is the origin of the mud gun

15 Interview with Matsuda Seiemon. He was the former general foreman at the steel plant in Kamaishi Works (at Kamaishi, March 1971).
Yoneyama Kikuji (1978), "Technological Change and Shop Management," (in Japanese) p.123–126, Bokutakusha.

16 Saigusa Hiroto & Iida Ken-ichi (1957), "Developmental History of Modern Japanese Iron and Steel Making Technology," (Kindai Nihon Seitetsu Gijutsu Hattatsushi) p. 419, Toyo Keizai Shinposha.

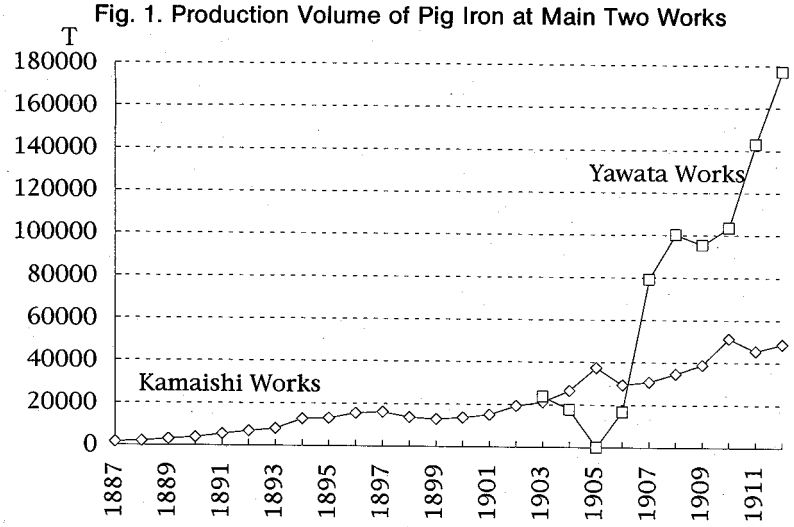
17 Ibid p. 419.
Two German engineers were arrogant to guide Japanese engineers and workers. They were drinking beer on the workshop floor.
Tanaka Kumakiti (1959), "Tanaka Shukuro Talks About His Memories," (Tanaka Shukuro Omoide o kataru) Tekkokai 1959. 3, p.33.

18 Wakasugi Kumatarou (1943), "The Life of Blast Furnace Foreman, Tanaka Kumakichi," (Tanaka Kumakichi den), p.50–69, Kokumin Kogyogakuin Shuppan.

machine made in Japan.[19] A Japanese engineer, Dr. Noro Kageyoshi designed the remodeling of No. 2 blast furnace. In February 1905, only one month later the start of operation with maximum production volume bigger than official production capacity(120 t) was attained under Noro's leadership. Moreover this operation was attained with a better coke ratio than that of No. 1 blast furnace.[20]

At this stage Japanese engineers succeeded in technology transfer and operated the western blast furnace and other plants by themselves and improved on the transferred technology. (Fig. 1)

Fig. 1. Production Volume of Pig Iron at Main Two Works



[Soruce] Saigusa & Iiida : *Kindai Nihon Seitestsu Gijutu Hattatsushi,* p.656.

Oshima Takato's engineering spirit was to carry out ongoing investigations in the field to discover solutions. This spirit of field engineering was developed by Noro Kageyoshi. The traditional Japanese craftsmanship was also developed by Tanaka Kumakichi at Yawata and Masuda Seiemon at Kamaishi. The field engineering spirit and craftsmanship were integrated to create a breakthrough in the difficulties of operation of the steel works.

From the early days of Yawata Works, the in-firm status system (*Shokuin- Koin* system) was started. This system originated at Yokosuka Shipyard at the end of the Edo feudal period. In 1910, the training center for young workers *(Yonen Shokko Youseisho)* was founded. This was a three year training course for young workers with primary school education aimed at developing core (backbone)

19 Interview with Tanaka Kumakichi at Yawata (1970 June).
Mainichi Shinbun Ed. (1981), "Men of the Three Generations," (Sandai no Otokotachi) Mainichi Shinbunsha.

20 Saegusa & Iida, Ibid. p.536.

workers.

This original system was revised to create effective human resources management. Thus the Nenko system was integrated steadily into Japanese industrial society. It was set up based on transferred technology, in-firm training, long-term apprenticeship on the workshop, academic career and livable wages. The internal labor market was formed based on job rotation and promotion from within the workshop.

3. The Succession of Technology

Economic recovery from the ruins after the war was started by the governmental economic policy of priority production system. A special procurement boom due to the Korean war could put large scale production back on track. Although the World War II brought tragic effects on the Japanese and Japanese society, necessary human resources especially engineers and skilled workers were maintained. The surviving engineers did their best to repair the deeply damaged production facilities which were bombed during the war.

While carring out the repair and restoration activities, the succession of technology and know how was intensively transferred from the older, skilled group to the newcomers. Technological innovation followed this maintaining and succession process was planned and led by the engineers' voluntary research activities. Newly employed engineers who were University graduates were educated and trained by the man of experience inside the firm. The motto was that we must regard reason as most impotant, think the problem through and discuss the issue. They were given OJT through on focusing on the next problem and target.[21]

In this way, the succcesion of technology was steadily put into effect. The senior engineers with experience passed on their original knowledge and ideas to the younger engineers. Teamwork by the different generations was developed for changeable problem solving to introduce new technology and new machines.

At the same time new types of special field engineers appeared. They had a through knowledge of production activities. Those with high school education were given training and education at the in-firm training school and OJT at the workshop level.[22]

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21 Interview with Mr. Nakagawa Hajime, Vice President of Nippon Steel Co., (1995. Feb. Sapporo). Nakagawa Hajime (1995), "The Advance of Steel Making Engineers' Round Table Conference with Ishihara," Memoirs of Ishihara Shigetoshi *(Ishihara Shigetoshi Kaiso Roku)* p. 246–249, Committee for Publishing of the memoirs, Tokyo.

22 Nippon Steel Muroran Works. Company newsletter, *"Shirakaba"* No. 380, (March 25, 1959). The manager of personnel encouraged the newly employed men with the message that they are the first men who have graduated. They were assigned to the following workshop ; Quality control section(process control), Energy control section (instrument), Industrial engineering section(efficiency check), maintenance section, and the most automated continuous sheet mill, the wire rod mill.

They had a strong intellectual interest to learn everything and were eager to develop themselves.

These types of engineers integrated engineering theory and practice and came to occupy an intermediate position between engineer and skilled worker (technician). Job rotation in a limited area made them walking dictionaries at the mills. They played an important role in the invention of new operation technology and improvement of mills.

For example at Nippon Steel Muroran Works, in Feburary1942, the official commendation rules for invention and improvement were already established.[23]

The spirit of invention and improvement *(Kaizen)* survived under the severe conditions of war time and in the confusion of defeat.

They had already mastered the art of improvement *(Kaizen)* during training school. They confronted using their own know how for technological innovation (the introduction of new production technology, new machines, the construction of a new factory).

The engineer's thinking to design the new production process, to install a new machine and to start up production were usually aimed at the hardware itself.

Japanese software oriented way of thinking, the *Kaizen* approach to a problem were mixed with engineering theory by the above mentioned type of engineer. They tried to introduce statistical quality control methods combined with small work groups. Statistical quality control methods were originally developed by American scientists and engineers.

But at the factory level, the engineers who were in charge of production control had wide and strong power and responsibility for the quality of the products. The workers were required to do the tasks designed by the production control engineers. They had no chance to express their own ideas for the improvement of quality. The job was divided strictly between engineer and worker.

In a Japanese factory, engineers with high school education and training within company training school played an unique role combining engineering theory and practice. The key concept was *Kaizen.*

The *Kaizen* way of thinking led them to start QC circle activities at the work-

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Shirakaba, No.846 (April 5, 1975).

In November 1967, 304 young pupils sat for the entrance examination. The ratio of applicants to recuited number of pupils was 7.6 times.

A scholarship of 3 thousand Yen was given to 1st grade students and 2nd grades students. 5 thousand yen was given to 3rd grade students. This education system (curriculum, scholarship and promise of getting job at Muroran Works) appealed to talented young students.

23 Nippon Steel Muroran Works (1959), "50 years History of Muroran Works," (in Japanese) p.520–521, *Shirakaba,* No.66 (July 1, 1944).

The company committee commended 40 cases in total. Engineers with University education played monopolistic roles.

shop level. New technology, new machines, a scientific approach for problem solving and the Kaizen spirit led Japanese manufacturing industry to world top level from beeing on bottom.[24]

During the period of rapid economic growth, Japanese engineers had been very curious to learn about new foreign industrial products and new technology. They made efforts to play with the foreign technology which does not fit in Japanese social atmosphere and situation and made careful improvements to the foreign technology and products from Japanese viewpoints. Finally, they accomplished the exquisite technological balance and elements and components of the product. In the long run these engineers' activities made money for the company.[25]

In 1969, a small size machinery company (K Company, 12 employees, maker of hard tools) had an effective OJT system developed by the work group. There were no work standards, mannual, standard time or standard work volume designed by the management. Among the work group, "a tree of skill" or "diagram of skill" in other words human networks were developed. Human relations between the technical leader and followers were the key for group cohesiveness. This "tree of skill" or "diagram of skill" was the basis for indigenous R & D activities.[26] (Fig. 2)

The development of Japanese engineers' abilities were achieved thanks to the following conditions. They have clear awareness of the issues. They have superior ability for problem finding. These are the preconditions for subjective study and research activity.

It is necessary that their boss must have technological speciality for problem solving. Effective leadership was taken by the boss to promote the project. The boss entrusts the engineer with a responsible job. Related staff support the engineer's action. These activities would help engineers to develop their own abilities while gaining self-confidence.

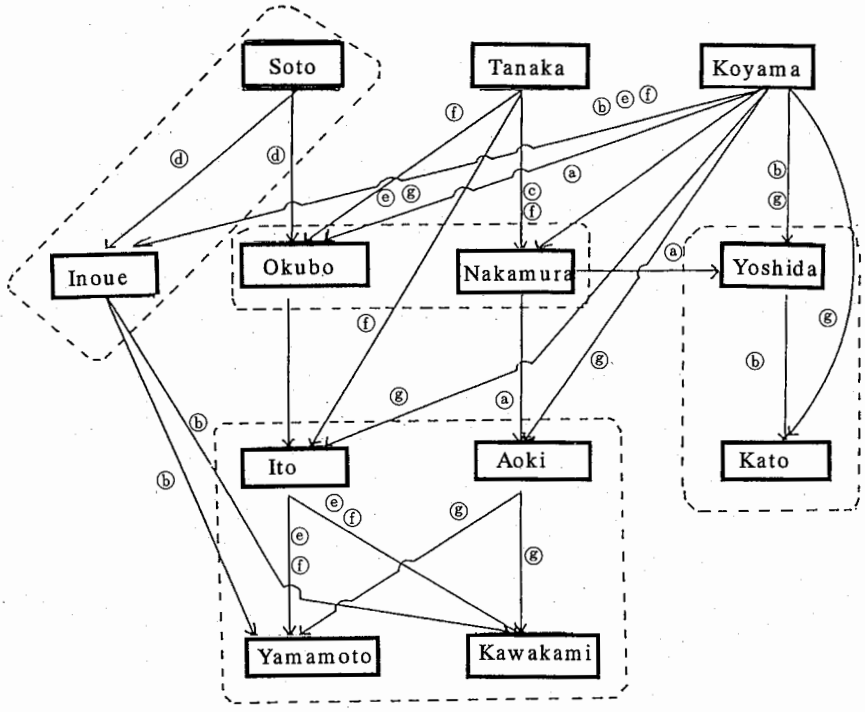
A desirable job rotation route for the production engineers would be: production section → management section → production section. The route for the plant engineers would be : production section → plant section. The route for industrial engineers would be: production section → management section. The route for R

24 Interview with Mr. Kuwabara Shigeru, Muroran Works Engineer (1994 July), *Shirakaba* (March 25, 1964).
"I believe that QC circle activity is the best activity to change the simple task into ones own work, to find the meaning of work and the meaning of professional life as a human nature. People may call me a fool of QC. I will do my best to look for the meaning of life in this way."
This message tells the real story of the engineer's mind to invent and improve the technology and production activity.

25 Hoshino Yoshiro (1966), "Spending Their Days in Curiosity and Tension" in Tsurumi Shunsuke & Hoshino Yoshiro "Japanese Way of Life," (in Japanese) p.127, Kodansha.

26 Yoneyama Kikuji (1977), "The Creation of New Workshop Culture," (in Japanese) *Romukenkyu*, 1977 July, p.14–23.

Fig. 2. K Company (Maker of Hard Tools) 1969
Correlation between Technical Leader and Followers



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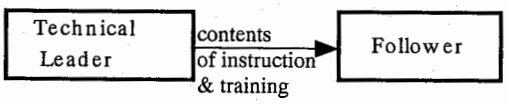


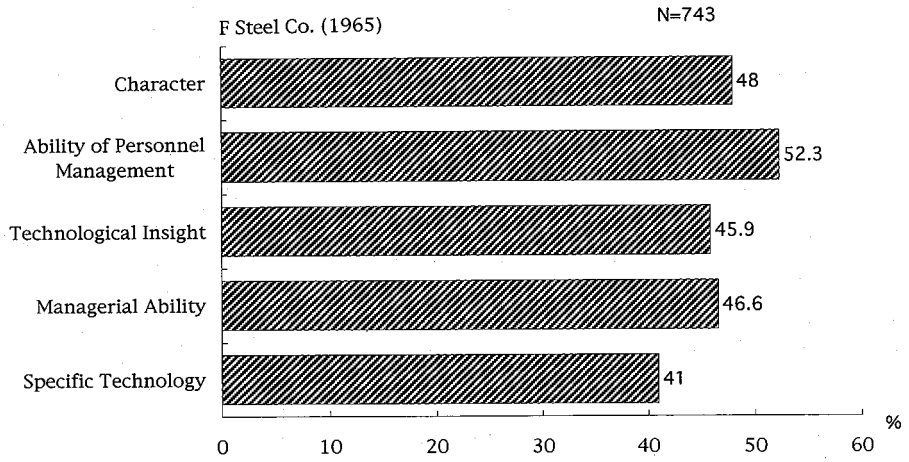
Contents of Instruction and Training

ⓐ : Automatic cutting lathe for finishing
ⓑ : Hand operated cutting lathe for finishing
ⓒ : Axis grinder
ⓓ : Axis rough finising
ⓔ : Axis jointing
ⓕ : Welding
ⓖ : Screw cutter, Mold making

: Lunch Group at the same table

& D engineer would be : production section → R & D section. The route for sales engineer would be : production section → sales section. These effective job rotation patterns indicate that experience in the production field is the key to developing engineers' skills and knowledge in the manufacturing industry.[27] Supervisors played an important role in technological succession to young engineers. (Fig. 3)

Fig. 3. Development as an Engineer by Supervisor's Direction (%)



4. Technology Transfer to Foreign Countries

In 1950's Japanese steel industry started technology transfer overseas. The first project was a joint venture for an integrated steel mill with Brazil. In 1958 USIMINAS steel works started and the blast furnace (No. 1) was constructed in August 1959. This project was conducted by Japanese governmental foreign policy. All big steel companies and plant makers followed the Japanese government's policy for the economic and technological cooperation with Brazil after World War II.[28]

The USIMINAS project was an integrated sell mill with 500,000 tons /year crude steel production. At that time Brazilian people had an image of Japan as an agricultural country based on Japanese peasant immigrants who came to Brazil.

This caused a serious image gap. Trying to overcome this gap, Japanese engineers contributed to build an integrated steel mill for the development of the

27 F. Steel Company. Head Office, Department of Education and Training (1965. 1), "Research on the Opinion for the Development of Technology," (Questionnare survey of 743 engineers of the company), p.98, Tokyo.

28 The author had already published one book and one paper about Malayawata project.
Yoneyama Kikuji (1990), "The Development and Transfer of Appropriate Technology- The Foundation of Malaysian Steel Industry," (in Japanese) Bunshindo.
Yoneyema Kikuji (1996), "Development and Transfer of Appropriate Key Technology" *Economic Journal of Hokkaido University*, No.25, 1996.

national economy.[29] Their actions were based on friendship and economic cooperation between Japan and Brazil. Later in 1964, under-developed countries strongly requested economic and technological cooperation with advanced countries at UNCTAD (United Nations Conference on Trade and Development).

The USIMINAS project for Brazilian autonomous development preceded this UNCTAD declaration by 10 years.[30] The second big project of technology transfer of steel making was the Malayawata project. This project developed with Malaysia was the real beginning of technology transfer. This is because for this project appropriate new technology was developed for a small scale integrated steel mill.

In 1957, Tunk Abdul Rahman (1903–1990) assisted by T. H. Tan (1914–1985) succeeded in establishing independence from British colonization. Independent Malaya led by ambitious Prime Minister Tunk Abdul Rahman started a new nation building plan.[31]

The bureaucrats of the central government for a multi-racial society carefully observed Japanese diplomatic policy and leading company's business activities. The Japanese government wanted to regain respect in the international community as a nation promoting peace in the world. The USIMINAS project was a symbol of this Japanese policy.

After World War II, Malaya has been a main iron ore supplier to the Japanese steel industry. But Malaya's mines could not supply enough iron ore demanded by the Japanese market not only in quantity but also in quality. Japanese steel industry developed a large big scale special ship to carry iron ore at a low cost. The industry also tried to diversify the supply source of iron ore. Therefore Malaya's export to Japan was declining.

At that time Vice-President Inayama Yoshihiro(1904–1987) of Yawata Iron & Steel Co. (later Nippon Steel Co.) made several visits to the U.S., Mainland China, India and Europe to secure access to natural resources, technology, capital and develop product markets in the world. The top officials of Malaya recognized Mr. Inayama as a leading business man.[32]

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29 Yukawa Masao (1961), "The Prospects for MINAS Steel Works," (in Japanese) pp.46–49, *Tekkokai*, 1961 March.

30 JAPAN- USIMINAS Corporation (1969), "Ten Year History of the Company," (in Japanese) Tokyo.

31 Tunk Abdul Rahman Putra (1977), "Looking Back-The Historic Years of Malaya and Malaysia,"
"T. H. Tan is a name that will long be remembered by Malayans of pre-Merdeka days and those who are alive today."
"To me, T. H. Tan will always be associated with our first successful mission to London," Obituary on Tan Sri. T. H. Tan by the Tunk.
The Star, November, 5, 1985.
Hagiwara Yoshiyuki (1996), "Rahman and Mahathir," (in Japanese) Iwanami Shoten.

32 Later Inayama became recognized as a big "steel man." *Business Week*, 1962 September 29.
Steel (Nippon Steel : Anatomy of a Giant), 1962 December 24.

These leading Malayans (T. H. Tan group) made a request to Inayama to cooperate in the construction of an integrated steel mill in Kuala Lumpur. Mr. Inayama was on his way back to Japan from Europe in November 1958.[33]

Mr. Inayama accepted this proposal informally. Prime Minister Abrul Rahman asked him to set a new steel mill during Inayama's second visit to Kuala Lumpur in February 1959. Mr. Inayama accepted officially Prime Minster's proposal as a representative director of Yawata Iron & Steel.

Inayama's basic plan was to develop close relationships with key persons in the world. In the first stage, he made an effort to set up a human network. In the next stage, he made the strategic decision to develop a new business with these acquainted foreign key person. His colleagues', directors of Yawata did not object to his lofty idea of cooperation with developing countries.

Japanese companies which participated in USIMINAS project with Brazil learned many lessons from the experiences of this project. These lessons included

(1) The importance of mutually trustworthy relationship between partners
(2) The importance of long-term continued cooperation
(3) Both sides must be enthusiastic about for technology transfer. To maintain this atmosphere, it is necessary to set up a concrete system
(4) For the host country, the transferred technology must be adopted based on an objective evaluation of its own technological abilities.[34]

For the foundation of basic industry for example, the iron and steel industry, developing countries need technology transfer from advanced countries. For this purpose, the industrial infrastructure is especially important. Large amount of capital is necessary to build up new plants. Therefore governmental support is the key for that investment. For foreign investors, the political and economic stability is a major issue.[35]

Malayan enterprisers intended to build up a large scale integrated steel mill with one million tons/year production capacity.

But there was only 100 thousand tons/year demand of iron & steel products in the Malayan domestic market.

The data gathered on political and economic condition in Malaya suggested impossibility. There was no feasibility judging from the short-term profitability. Most directors of Yawata evaluated this project as a risk based on cost/benefit analy-

33 "Inayama points out that this meeting was an exquisite timing for the project."
Lee Poh Pin (1977), "Japan's Decision to Establish Malayawata," p.10. V. R. F. Report 1977 Institute of Developing Economies, Tokyo.
Nippon Steel (1985), "Honooto tomoni- History of Yawata Steel," (in Japanese) p.745, Tokyo.

34 Oishi Shoji (1977), "Hardship at USIMINAS is living today," (in Japanese) *Nippon Steel* 1977, Tokyo.

35 Yawata invested merely 380 million Yen for the USIMINAS project.
Yawata Iron & Steel "Financial Statement," (1960 & 1961 edition) Okurasho Insatsukyoku.

sis of investment. Vice President Inayama explained his ideas and plan to the directors of the company. He explained that Malaya had helped the Japanese steel industry by supplying iron ore. Thanks to this supply, the Japanese steel industry has recovered and was reconstructed from the ruins of the World War II. Therefore this time, Japanese must help Malaya's industrial development". He took action regardless of the company's short-term profit.[36]

His "top down" style of leadership for strategic decision making was different from the ordinary Japanese consensus formation "bottom up " style, in the business company. His idea was that economic and technological cooperation has to be done understanding the partner's perspective and allowing benefit to him. The first objective was to construct a feasible steel mill and the second was to build up an autonomous management organization for good performance.

The gap between market size and a prestigious large scale integrated steel mill could not be solved using the usual scale down approach. The difficult problem was solved by the development of an original key technology "blast furnace using rubber wood charcoal". This system was invented by Dr. Oiwa Yasushi, engineer at Yawata.

Before participating in the Malayawata project, Oiwa had lived in Singapore from February 1956 to July 1959 as a manager of JETRO's office. There he had developed field research for numerous developed or underdeveloped iron ore mines, tin mines, bauxite mines and rubber plantation located in Peninsular Malaya.[37]

Next he spent one year from 1959 as a research fellow at Colorado School of Mines. The result of the joint research with two associate Professors were published in book form.[38]

In December 1962, when he had engaged in propelling the Malayawata project to implementation, he expanded the results of his research activities in America.

He worked out a unique and original methodology to organize any business enterprise that was to be a main body of a given natural resource development venture.

Elaborating on his methodology, he made clear eight indispensable requirements in the organization of every such enterprise as follows :

(1) To make sure a planned enterprise would really contribute to the autonomous stabilization and overall development of a given country possessing the natural

36 Interview with former Vice-President of Malayawata Steel, Mr. Sakai Yosio (Nov. 1978, Tokyo).

37 Oiwa Yasushi (1959), "Malaya in Transfiguration," (in Japanese) JETRO, Tokyo.

38 Yasushi Oiwa, C. Nordquist and O. Lentz (1961), "The Mineral Industry of Japan and South East Asia," Colorado School of Mines Press.
O. H. Lentz (1962), "A Sequel to the CSM-South East Asia Study " Colorado School of Mines. Dr. Lentz prized the joint research as a pioneering contribution to the whole literature of economics of mines as seen from many different viewpoints.

resources to be involved by the enterprise

(2) To make sure a planned enterprise would go well along the line of economic development policy in the newly rising country

(3) To make sure the participation of local capital and local enterpreneures in a planned enterprise

(4) To make sure a planned enterprise would be based on a well-coordinated plan for the development of given resources

(5) To create a foothold in a planned enterprise for the possibility of international introduction of capital

(6) To make sure a sufficient overseas market exists for any mineral product of a planned enterprise

(7) To make sure a planned enterprise would be a parent organization of the metallurgical industry and machinery industry into which it should be developed in near future

(8) To make sure a planned enterprise would be an education and training center for the engineering and managerial leaders of the enterprise.[39]

There were several steps to develop the small scall blast furnace system by wasted rubber wood charcoal. During his stay in Malaya and Singapore, he used to see big fires at many rubber plantations every March and April. He thought it was wasteful to let a big tree burn like that.[40] This was the basic experience for him to get an imagination that people somehow utilize wasted natural resources. At just this time, he found a paper titled "Pulp and Paper Manufacturing in Malaya".[41] This paper suggested the possibility of charcoal made of rubber wood. He designed and carried out the experiments for charcoal making by local Malayan (Matan) kiln system. The results were satisfactory. It was testified that local material, rubber wood would be a good material for charcoal by local technology.

This experimental results served as a major breakthrough leading to the operation of blast furnace for an integrated steel mill. He believed in the possibility of a blast furnace using rubber wood charcoal.

In 1960 more than 40 units of charcoal blast furnaces were operated in Brazil. And the Wood Distribution Charcoal Iron & Steel Co., in Western Australia operated two charcoal blast furnaces. In 1961, the company produced 52,000 tons of pig iron eucalyptus charcoal.[42]

39 Oiwa Yasushi (1963), "Development of Mineral Resources in Southeast Asia," (in Japanese) *Nihonkogyo Kaishi*, p.74, No. 896, Feb. 1963.

40 Oiwa Yasushi (1981), "The Beginning of Charcoal Iron Making in Malaya," (in Japanese) p.51, *Tekkokai*, July 1981.

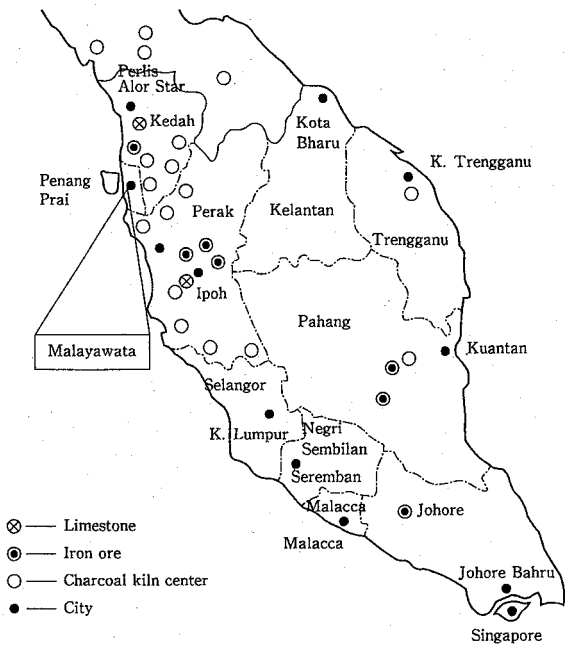
41 J. D. Peel (1960), "Pulp and Paper Manufacturing in Malaya," *Malayan Forester*, Vol. 23, No. 1, January 1960.

42 Oiwa Yasushi (1980), "The Chronological History of Malayawata Steel," (in Japanese) Unpublished Mimeo.

In this way the difficult problem from technologically unknown factors were overcome step by step using data from field research and scientific experiments. Dr. Oiwa and his colleague engineers could draw the grand design of an integrated steel mill using the rubber wood charcoal blast furnace.

The small size traditional Malayan (Matan) type charcoal making kiln and technology had to be improved for large scale production. Because this kiln was made from charcoal of mangrove only for cooking use. The appropriate key technology was developed by the organic integration of local resources, traditional local technology and most advanced theory and practice. Seven big kiln centers were constructed for supplying the rubber wood charcoal to Malayawata Steel Works. Malayawata Steel Works and the material supplying seas is shown in Fig. 4.

Fig. 4. Material Supplying Areas for Malayawata



(Source) Malayawata Steel.

Engineer Oiwa applied " Miura charcoal making Theory" for the development of the traditional Malayan system.[43] An imagination by his basic experiences in

43 Miura Ihachiro (1943), "The Study of Charcoal," (in Japanese) Kyoritsu Shuppan Sha.
Professor Kishimoto Jyokichi, Tokyo University of Education supported this R & D process. He was the successor of Miura Charcoal Making Theory."
Oiwa & Kishimoto (1973), "Studies on the Charcoal Making Process with Rubber Wood as Raw Material for Integrated Steel Mill in Malaysia," *Nihonringyo Kaishi*, Vol. 55, No. 5.

Malaysia enabled him to develop the appropriate key technology.[44]

In keeping with governmental policy "Malaysianization", Japanese managers and engineers wanted to employ as many as young Malaysians with knowledge and engineering skills as possible.

The employment examination was composed of a health exam, basic scholastic ability, technical knowledge and character test by interview. Finally 18 engineers and 29 technical assistants were employed. (Fig. 5) The education and training program for them in Japan are shown in Fig. 6.

On May 20th, 1967, Malayawata, the first integrated steel mill in Southeast Asia started to operate. The results of operation and dispatched Japanese engineers is shown in Fig. 7.

Based on the friendship with Prime Minister Abdul Rahman, President Inayama made strategic decisions making aiming at contributing to Malaysian industrialization. Japanese engineers and skilled workers did their best following his leadership to realize this ambitious project. The final success of Malayawata project suggests the basic concepts and principles for overseas technological cooperation.[45] (Fig. 8. & Fig. 9.)

Fig. 5. Trainees of Malayawata Steel

Speciality / Ethnicity / Factory Workshonp	Engineer			Technical Assistant		
	Malay	Chinese	Indian	Malay	Chinese	Indian
Blast furnace	1	3	0	0	4	0
Sintering	0	3	0	1	2	0
LD converter	0	2	1	1	6	0
Rolling mill	0	3	0	1	5	2
Power plant	0	1	0	0	2	0
Maintenance shop	0	2	0	0	3	0
Analysis & Test	0	2	0	0	2	0
Subtotal	1	16	1	3	24	2
Total	18			29		

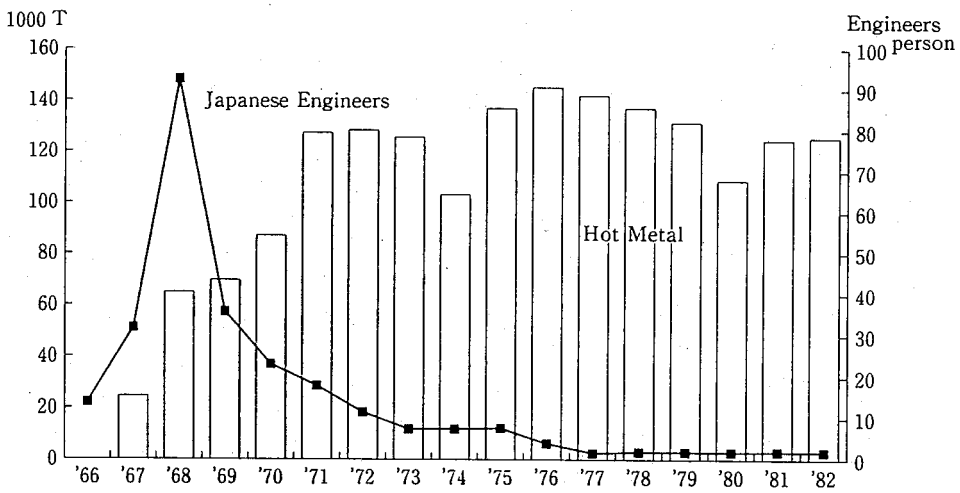
44 Interview with Dr. Robert Carpenter, former Professor of Colorado School of Mines. (1982 March, Denver, Colorado)
From the viewpoint of specialist for mineral resources, he praised Dr. Oiwa's imagination and practical solution. Japanese engineers could set up the first integrated steel mill in Southeast Asia by utilizing thrown out over-aged rubber wood and local natural resource, poor quality iron ore.

45 International Financial Corporation (IFC), "Annual Report" 1968.
"The IFC assisted project uses charcoal made of over-aged trees from Malaysian's rubber plantation as a principal raw material.
Torii Yasuhiko (1978), "Economic Effect Analysis of an Integrated Steel Mill in Developing Country," (in Japanese) Kokusaikyoryoku Suishinkyoukai Malayawata Steel employed 1238 persons and its sub-

Fig. 6. Education and Training Program for the Trainees of Malayawate Steel

		Engineer	Technical Assistant
Japanese Language Course		5 weeks	5 weeks
Study tour		5 days	5 days
Date : Arrival at Yawata Works		1966. 3 . 18	1966. 9 . 9 (1st Group) 1966. 11. 11(2nd Group)
Education & Training Term	Introduction	2 weeks	1 week
	Practice	9 months & 2 weeks	3 months & 3 weeks
Textbook		50 types (in English & Japanese)	50 types (in English & Japanese)
Instructor		Member of Malayawata Group Will be dispatched engineer	Member of Malayawata Group Will be dispatched engineer
Contents of Education & Training		Basic theory Practical operation management	Operation of machine & apparatus Practical work of operation
Place of education & training		Yawata works Associated companies	Yawata works Associated companies
Date : Departure from Japan Arrival at Malayawata		1967. 1 . 13	1967. 1 . 13(1st Group) 1967. 3 . 24(2nd Group)

Fig. 7. Production Volume and Dispatched Japanese Engineers



sidiary company Malayawata Charcoal Co., employed 672 persons in 1971. In total 1900 persons were employed in the production process. More over this project created job opportunities for about 5200 persons. (1900 persons at Malayawata Steel+3300 persons at Malayawata Charcoal.)

Fig. 8. R & D and Transfer of Appropriate Technology at Malayawata Steel

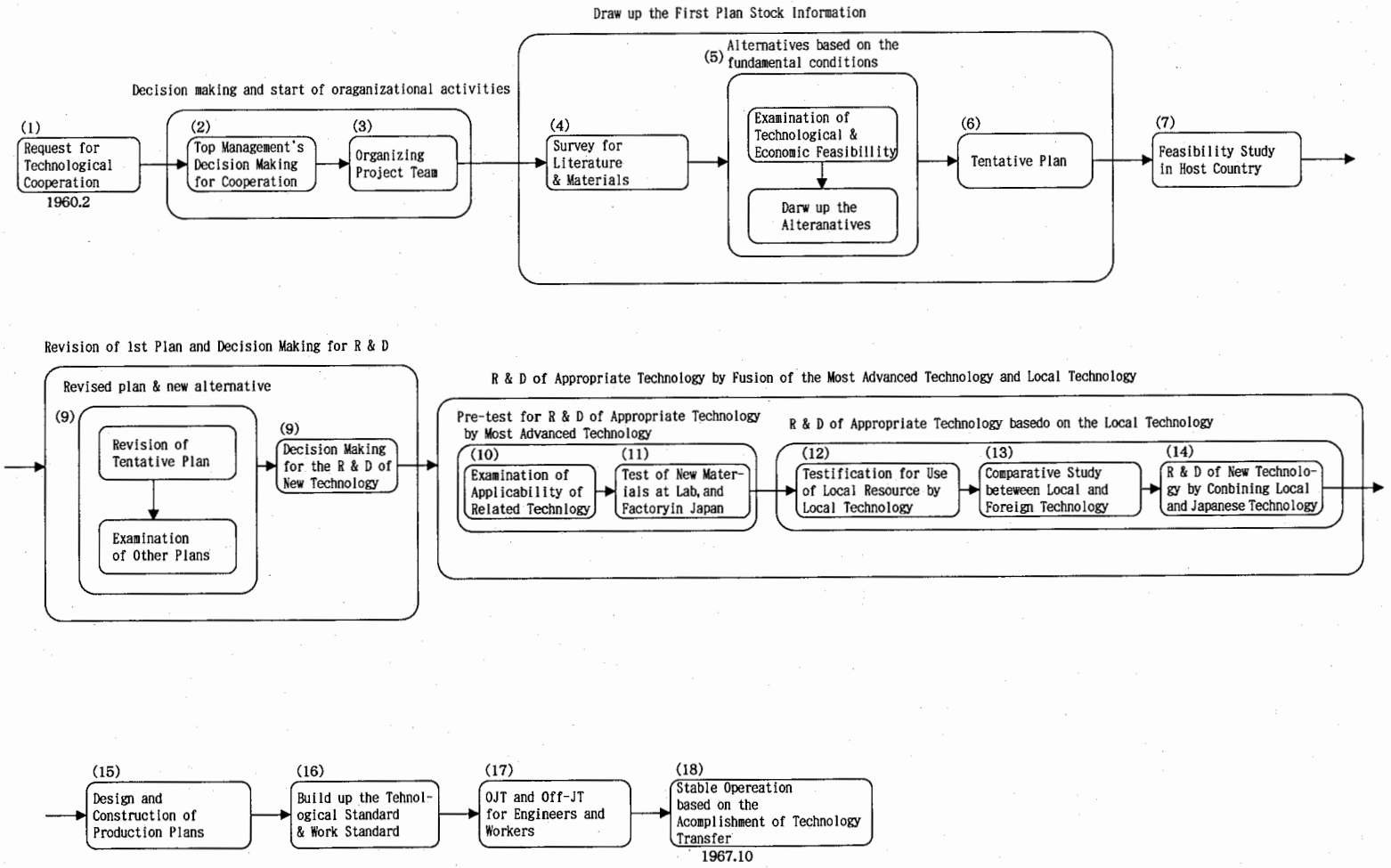
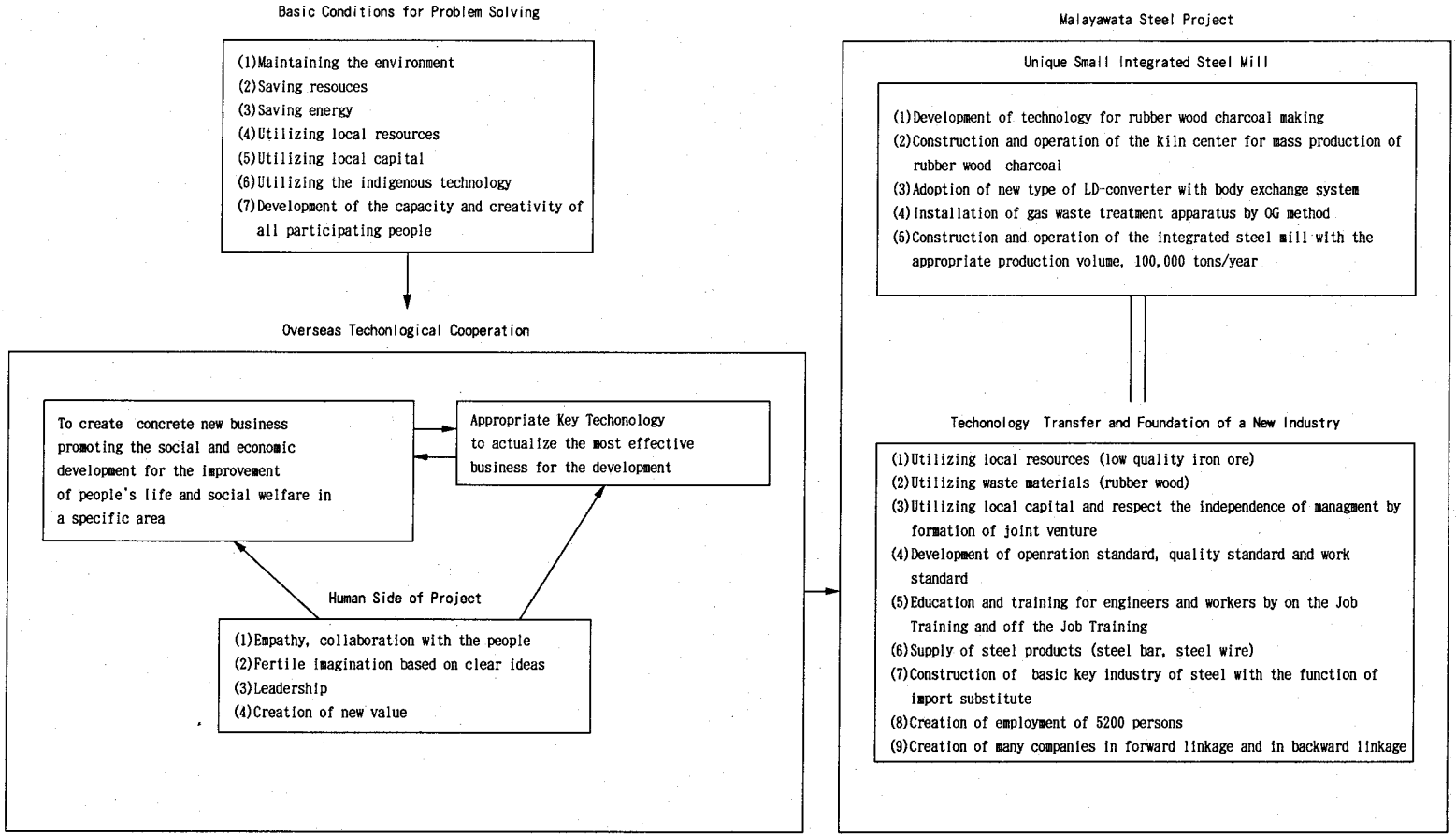


Fig. 9. Overseas Technological Cooperation to Malaysia



5. Conclusion

In the 1860's, the Meiji central government promoted "the encouragement of new industry" as a national policy to maintain independence against the growing influence from the western world. To achieve the national target, engineers originally coming from the Samurai class propelled the industrialization and modernization. They had patriotic spirit to contribute to the nation through industrial activities.[46] The *Samurai* engineers were eager to learn engineering from advanced countries for technology transfer and putting it into practice on the production field. This spirit continued from the end of Edo feudal system to end of the World War II. Militarism and fanatic expansionism due to imperialism led to Japan's invasion of Asian countries. The following defeat deeply damaged Japanese people and society. The military fanatic dictatorship prohibited people's rational way of thinking during the war time. When the military dictatorship disappeared after the defeat, people's, especially engineers', intellectual curiosity returned at a grass roots level. Engineers again started to learn advanced science and technology. The main reason was the lack of natural resources in Japan for people to live on. They believed that only industrial activities would supply food and necessary goods to the Japanese people.

They imported many new industrial goods and new technologies from advanced countries, especially from U.S.A. The life long employment system enabled them to dedicate all their life as a company man. They succeeded reconstructing the economic conditions, and the rapid economic growth followed. In 1970's, both of the oil shock hit Japan, but Japanese engineers made efforts to research and develop energy saving technology. So, Japanese industry was able to by-pass the U.S.A. and western countries using energy saving technologies. Compact small cars are the symbol of these technologies. In 1980's, Japan finally has been able to catch up with the advanced countries. The Meiji leaders dream was finally accomplished, one century after the day of opening up to foreign countries.

Today's the affluent society is operated by mass production, mass communication, mass distribution and mass consumption system.

This system ignores industrial waste and home waste. To waste huge amounts of resources and energy, polluted water has brought out a new type of pollution problem on a global level, in stead of on a local level for example the well-known Minamata disease.[47]

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46 Eiko Ikegami (1995), "The Taming of the Samurai : Honoric Individual and the Making of Modern Japan," Harvard University Press.

47 Ui Jun (1973), "The Principles of Pollution," (in Japanese) Vol.I, Aki Shobo.
Just after the opening of 70's, the pollution problems which were in hiding at the period of rapid economic growth were exposed to the public eye. The first oil shock in 1973 appealed the limit of globe. After completing their school work, they will enter the business world as engineers. How

Pollution from factories, cars, homes and urban areas is gradually changing the global environment. In 1996, the Hanshin Awaji earthquake disaster occured in Japan. This natural disaster put a fundamental question to the Japanese common sense of modern science and technology.[48] Human-kind must have a more humble nature. We must find harmony with nature.

Japanese engineers have to contribute more to the human society for people in developing countries and maintaining the global environment in the 21st century. Not as a company man and nor technocrat, but as an independent citizen of the earth, a new type of engineer ought to be trained. This kind of new engineers will have a lofty ambition, fresh sensitivity and vigorous intellectual curiosity.[49] He will contribute to human society and the natural environment by professional abilities as an engineer.[50]

This engineer will have a sense of field science and field engineering based on a global viewpoint. He is an issue and field oriented specialist. His heart, hand and brain are smoothly linked to each other. He will propel the project beyond the boundary of organizations and different cultures on the earth.[51] (Fig. 10)

Professor of Industrial Management, Hokkaido Univ.

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did the students recognize their own future work ?

Students of Tokyo Institute of Technology. Free answer style Questionnaire (1976. 11. 6) "What is your image of work in today's industrial company ?" N=55.

The students of the Faculty of Engineering commented as follows :

"Overcoming my anxiety, I will seek for my professional life touching directly nature itself and the materials. To make concrete products will make my life worth living." 9 persons (16.4%).

Based on the materials, facts field and natural sciences, they as engineers will propel rational problem solving. But persons graduating from literature and social science will do their job through human relations, not based on concrete facts and a rational way of thinking. They felt repelled to that manner.

They will trust in their own skill and continue to make products.

"Not losing out in the competition with persons without rationalism, non-engineers, I will put all the skills I have into making products." (7 persons. 12.7%)

For the problem-solving of today's industrial society, not legal regulation and control but new R & D of technology will contribute.

"Safety, pollution, occupational diseases and other problems will be solved by science and technology." (1 person. 1.8%)

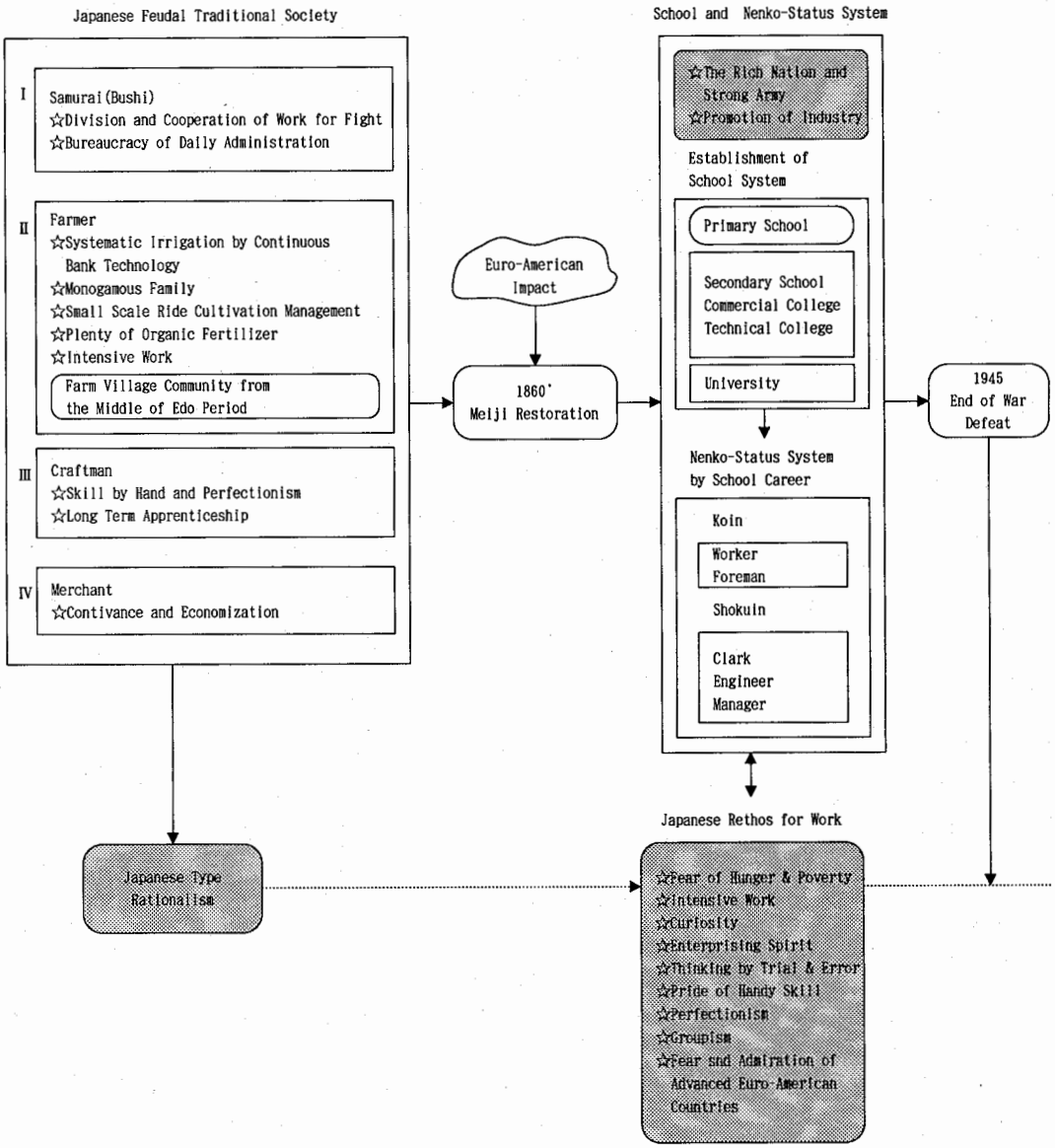
48 Hoshino Yoshiro & Hayakawa Kazuo Ed. (1996), "The Hanshin Earthquake Disaster Puts a Question to Modern Technology," (in Japanese) Gijutsu to Ningen.

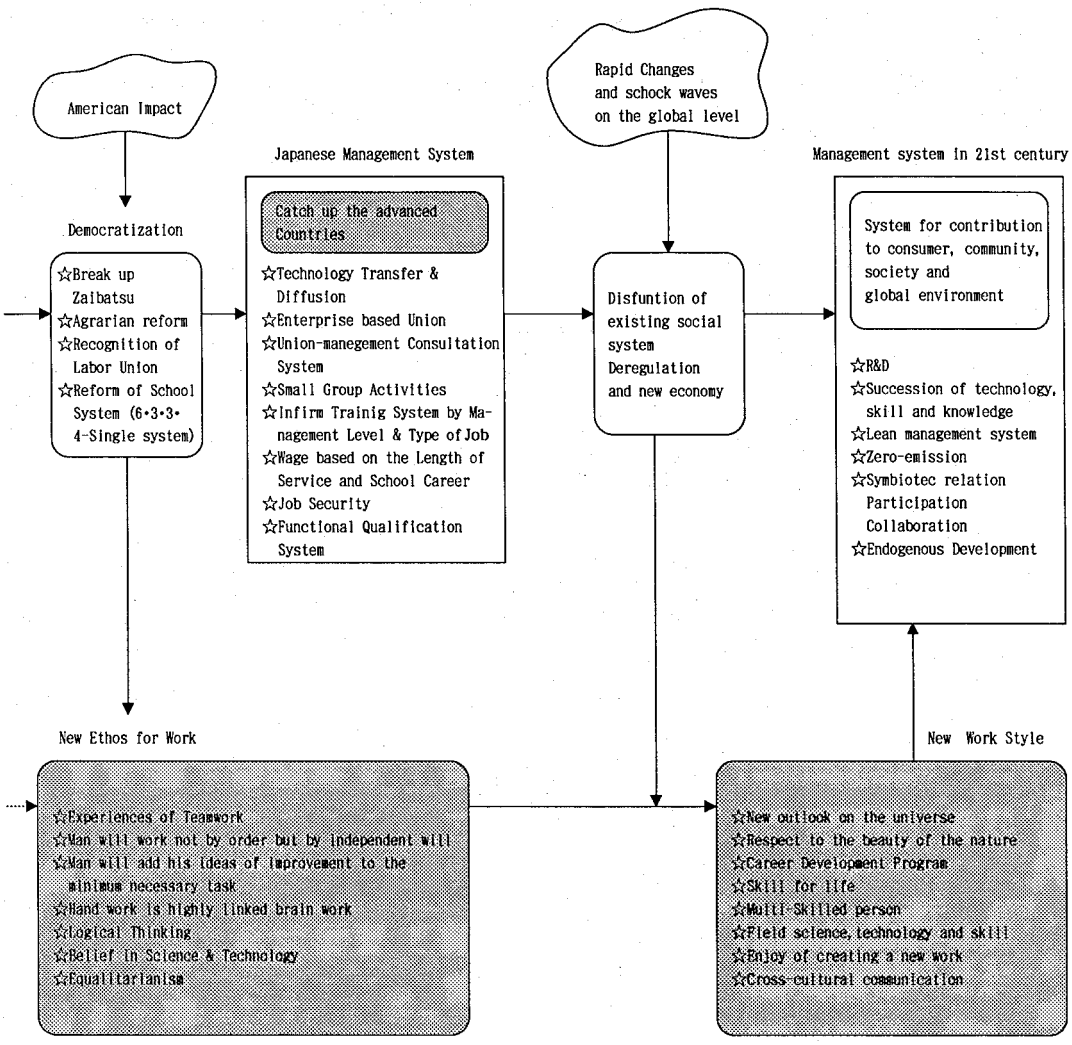
49 Eugene S. Ferguson (1992), "Engineering and the Mind's Eye," The MIT Press.
Yoneyama Kikuji (1993), "Introduction to the Science of Creation," (in Japanese) Bunshindo.
Sasaki Tadashi (1995), "Hypothesis is the beginning– World of Engineer's spirit to open the tomorrow," (in Japanese) Kurestosha.

50 The Institute For Himalayan Conservation (1997. July) "Nurturing Creative in the Himalayan- In pursuit of an alternative development model based on participation and field research," (Occasional Paper No. 2) The Institute For Himalayan Conservation (IHC), Tokyo.

51 Nishibori Eizaburo (1903–1989) is the most representative engineer of this type. He was a father of

Fig.10. Industrialization and the Japanese Ethos




American Impact
Rapid Changes and schock waves on the global level
Japanese Management System
Management system in 21st century
Democratization
☆Break up Zaibatsu
☆Agrarian reform
☆Recognition of Labor Union
☆Reform of School System (6•3•3•4-Single system)
Catch up the advanced Countries
☆Technology Transfer & Diffusion
☆Enterprise based Union
☆Union-manegement Consultation System
☆Small Group Activities
☆Infirm Trainig System by Management Level & Type of Job
☆Wage based on the Length of Service and School Career
☆Job Security
☆Functional Qualification System
Disfuntion of existing social system Deregulation and new economy
System for contribution to consumer, community, society and global environment
☆R&D
☆Succession of technology, skill and knowledge
☆Lean management system
☆Zero-emission
☆Symbiotec relation Participation Collaboration
☆Endogenous Development
New Ethos for Work
☆Experiences of Teamwork
☆Man will work not by order but by independent will
☆Man will add his ideas of improvement to the minimum necessary task
☆Hand work is highly linked brain work
☆Logical Thinking
☆Belief in Science & Technology
☆Equalitarianism
New Work Style
☆New outlook on the universe
☆Respect to the beauty of the nature
☆Career Development Program
☆Skill for life
☆Multi-Skilled person
☆Field science, technology and skill
☆Enjoy of creating a new work
☆Cross-cultural communication

References

1. Nishibori Eizaburo (1958), "The Dairy of Wintering Party at the South Pole," (in Japanese) Iwanami Shinsho.
2. Nishibori (1985), "Only One Fact Is Better Than One Hundred Discussions," (in Japanese) Nihon Kikaku Kyokai.
3. Nishibori (1990), "The Power of Creation," (in Japanese) Kodansha.
4. Imai Ken-ichiro (1993), "Bringing up Engineers as International Professionals," (in Japanese) *Engineers*, p.8–12, August 1993.
5. Yomiurishinbunsha Ed. (1991), "Question to Education of Science and Engineering," (in Japanese) Shinchosha.

Japanese field scientist and field engineer. His life and works encourage the young generation to challenge a pioneer work.

He graduated from Kyoto University, Faculty of Science in 1928. He recieved Dr. of Science (Chemistry) from Kyoto University in 1936. He was Associate Professor at Kyoto University.

1936 transferred to Tokyo Shibaura Electric Co. he developed the research for vacuum tube.

1955 he moved to the Japan Telegraph and Telephone Co. as Head of Special Research.

1957 Leader of the first Japanese South Pole Expedition.

1965 became Executive of the Japan Nuclear-Ship Development Agency.

Also led successfully two times in 1973 and 1979 Japanese party for Himalayan mountaineering.

He was an all-round player of wide range intellectual field of science and technology.

He developed as a pioneer the field science approach to R &D of Vacuum Cube, Plant Management, Quality Control and Atomic Energy.

Moved from one organization to the other for his research project, and he changed research theme every 10 years. After 10 years he accomplished top ranked results.