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Technology Transfer and Foreign Qualified Students in Chemical Industry of Japan

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1. Chemical Technology

Technology is the application of science in a real and effective way for the use of human life. Chemical technology of today includes the application of technology in research and development of materials involved in chemical industries. In addition, chemical process design, equipment fabrication and product manufacturing are also related to this technology. Generally, chemical technology is used in the processes where unit operations are available from raw materials to products.

Chemical technology covers the following:

I. Process Design

II. Equipment Design

III. Plant Safety and Maintenance

IV. Supervision

Both engineers and technicians are working in industries, engineers work on design of manufacturing processes, and the research and development require higher knowledge based on education and training, while technicians are responsible for rather simple work such as operation, instrumentation, maintenance and analysis. Technicians cover the labor for overall supervision rather than individual skill in each operation. However, at the beginning of the Japanese industrial modernization as in Meiji Era, chemical technology was not specialized as in nowadays, engineers and technicians were ambiguous in definition. Attention may be focussed on foreign qualified students (abbreviated to FQS) who came back and played a great role in technology transfer to chemical industries, in particular, sulfuric acid, soda and ammonia-soda industries.

Table 1. gives all the details of FQS concerning this report.

Table 1

FQS	Year Birth	School graduated	Destination	Term	Contents	Ph. D
1. Utsunomia, Saburo	1834		A, U	1873, 75–76	Soda production	
2. Yamao, Yozo	1837		B	1863–70	Shipbuilding	
3. Tejima, Seiichi	1849		U	1870–74	Science	
4. Toyohara, Hyakutaro	1849		B	1871–73	Mintage	
5. Takamatsu, Toyokichi	1852	Tokyo U. Chem. (1878)	E, G	1879–82	Chemical tech.	Engg. (1888)
6. Yamaguchi, Takeshi	1853		B	1871–75	Mintage	
7. Taniguchi, Naoya	1854	Kaisei (1876)	E	1876–81	Applied chem.	Engg. (1888)
8. Nishikawa, Toranosuke	1855		E		Chem. ind.	Engg. (1901)
9. Hiraga, Yoshitomi	1857	Tokyo U. Chem. (1878)	E	1878–81	Applied chem.	Engg. (1899)
10. Nakazawa, Iwata	1858	Tokyo U. Chem. (1879)	G	1883–87	Applied chem.	Engg. (1891)
11. Dan, Takuma	1858	MIT. Mining (1978)	U	1871–78	Mining	Engg. (1898)
12. Kamoi, Takeshi	1864	Tokyo U.E. Appl. Ch. (1894)	G, A	1905–08	Electro chem.	Engg. (1910)
13. Nishikawa, Torakichi	1868	Tokyo U. Appl. Ch. (1893)	E, U E, G, U	1897–99 1909–10	Alkaline ind.	Engg. (1911)
14. Yoshikawa, Kamejiro	1869	Tokyo U.E. Appl. Ch. (1895)	G, E	1901–05	Electro chem.	Engg. (1906)
15. Emori, Jokichiro	1870	Tokyo U.E. Appl. Ch. (1894)	B, F, G	1899–1901	Applied chem.	Engg. (1902)
16. Matsui, Mototaro	1870	Tokyo U.E. Appl. Ch. (1905)	G	1901–11	Chemical tech.	Engg. (1924)
17. Iwase, Tokusaburo	1894	Kyushu U. Appl. Ch. (1904)	U	1916–17	Ammonia soda process	

notes: A : Austria B : England E : Europe F : France G : Germany U : America

2. Technology Transfer to Three Main Chemical Industries

2.1. Sulfuric Acid Industry (The Lead Chamber process) (3 6 10)

At the Tokyo Mint Bureau, plant equipment for the Lead Chamber Sulfuric Acid process, was imported from England. This process was industrialized some 130 years ago in 1749 in England. It was called "400 lb sulfuric acid room" from its daily production and was constructed by J. Walter, a foreigner employed by government (abbreviated to FEG). Later in 1872, FEG R. Finch, employed by Mint Bureau as the head of Sulfuric Acid section, started the construction of a 5 ton capacity plant, which was completed in 1873. H. Toyohara (4) and T. Yamaguchi (6), (numbers in parentheses refer to Table 1), were sent by the government to study mintage at the University College in England. Kindle and other FEG were relieved from the work and Toyohara, who had just come back from England, did an important role of FEG. "Everything should be done without the help of FEG" was the nationalistic slogan of the people. They tried to be independent in management and to maintain their own technology in the sulfuric acid manufacturing plant and also to promote and encourage the development of correlated industries. Engineers in those days were highly estimated for their tendency to have independant technology.

When the plant was expanded, reduction in manufacturing cost and improvement of materials were considered. In 1878, plant capacity was largely increased as in given in Table 2, and number of furnances were increased by four times as the starting one installed by R. Finch.

Table 2

year	production (ton)
M 6 (1873)	38
10 (1877)	1,063
15 (1822)	1,125

Sulfuric Acid Manufacturing Company (Capital of ¥100,000) was established as a private enterprise to cover raw material demand for LeBlanc Soda and for the increased export to Chinese market. Many of the Mint Bureau employees were transfered to this company in 1879 (M12) such as Toyohara (the head and teacher in charge), Irie (engineer in charge) and six other workers. They directed the equipment fabrication of the Lead Chamber Sulfuric Acid process and also trained the operators.

This was a typical conductive type of technology transfer, from government enterprise to private sector, with the understanding of foreign technology. After Finch and other FEG were relieved from duty, engineers developed originality in jobs like repairs, maintenance and equipment operation.

Stabilization of the transfered technology took many steps till it became independant. According to the first annual report by the directors of the Mint Bureau, condenser ruined in one year was repaired by FEG in 1875. An additional third concentrator was installed in 1876 after FEG were relieved. In July 1878, beam was broken at the center due to corrosion but it was not a big damage. Since 1880, repairs and improvements continued in every broken unit of the plant such as Lead Chamber for corrosion and exfoliation, sulfur burning furnace and towers. During construction in July 1881, beam dropped and broke many sulfuric acid glass bottles, this was due to weak timber having an estimated life of 2–3 years. As a preventive device for sulfuric acid corrosion, Lead Chimnies, one three feet diameter at the center and four one foot diameter on each corner of the concentrating room, were provided. Also an umbrella type cover was provided on each chimney as a protection against rain. Heats of formation and solution were distributed through these chimnies. Main beams were covered with thin lead sheet, with a narrow clearence provided to escape from thermal expansion.

2.2 Soda Industry (LeBlanc Soda process) (3 10)

At the end of 18th century chemical industries were much developed and hence it greatly increased caustic soda demand. Due to insuffitiency of natural soda, French Academy offered a prize for the manufacturing process of caustic soda from salt in 1775. French LeBlanc (1742–1806) invented the prize winning process of producing sodium carbonate from lime and coal, and also sodium sulfate from salt and sulfuric acid. Under the protection of Marquis Orlean, sodium carbonate plant of 300 Kg/day capacity was constructed at St. Denis, suburbs of Paris. This was the beginning of soda industry, but unfortunately French revolution forced him to close down this plant in 1793 and due to financial reasons LeBlanc committed suicide in 1806.

At Tokyo Mint Bureau, Saburo Utsunomia (1), Toyohara and other engineers designed the LeBlanc soda process using knowhow of the book *Manufacturing Methods for Sulfuric Acid and Soda* written by Lunge. For the investigation of diferent manufacturing methods, Utsunomia went to Philadelphia in November 1875 to see the World Exhibition on manufacturing methods for cement and soda.

Ryusuke Tokuno, director, Mint Bureau, invited Toranosuke Nishikawa (8) with great enthusiasm and planned the industrialization of soda industry on the basis of Nishikawa's research experience in England. Production of soda started, after two years of plant construction, in 1881. They repeated trial and error methods according to the advices and suggestions of Osaka Mint Bureau in order to fight against difficulties in both technology and skilled workers.

At first, sodium carbonate was produced by heating salt and sulfuric acid together. However, the mixture did not easily become muddy and therefore they found difficulty to reach the furnace where sodium carbonate was produced. Also, due to friction, furnace insulation bricks were rubbed off.

Centrifuge would have been useful for the separation of the impurity, sodium carbonate from soda crystal, but it was not easily available.

"Ceramic condenser was broken due to temperature variations, when the hydrochloric gas was introduced in. It was not easy to find the lead pipe for chlorine gas suitable to the dimensions of absorbing chamber for the production of bleaching powder. It was a big problem to design and operate such equipments as distilling tower, soda filter."

2.3. Ammonia-Soda Industry (Solvay process) (1. 3. 10)

In 1896, during his stay in Europe, Nishikawa Toranosuke of Osaka Ryuso investigated Castner process as electrolytic method for the conversion from LeBlanc process, but it was not materialized due to economic depression. At this moment, technology research for electrolytic production of caustic soda started. Professor Kamejiro Yoshikawa of Kyoto University was playing the leading role. On the request of Nippon Shamii Seizo Co., he started experiments on mercury electrolytic method in 1911 and continued research at Ryojun Kokado (later Ryojun Institute of Technology).

Tokugoro Nakahashi of Dainippon Engyo, was elected Chairman of the Organizing Committee for the industrialization of the mercuty method in 1914. Osaka Soda Co. Ltd. was started in October 1915 and production began in 1916 at Kokura. Mercury method had difficulty in operation and met many troubles, accidents and explosions. Air pollution due to chorine resulted in killing onion crops and gradual fading the greenary of old pine trees along streets near the plant.

This meant that the prevention of chlorine leakage was a big engineering and pollution problem, and in these circumstances continued operation of this plant was highly estimated. Soda production at that time are given in Table 3.

Table 3

	LeBlanc	Solvay	Total (10,000 ton)
1890 (M23)	39	63	102
1900 (M33)	20	130	150
1905 (M38)	15	175	190

Takeshi Kamoi (12), professor of Engineering University, insisted on soda production by Solvay (ammonia-soda) process in 1895 (M28). Soda ash is required to manufacture glasses and Asahi Glass Co. Ltd. intended to import the technology of Solvay process. In compilance with Asahi Glass Co, Torakichi Nishikawa (13) negotiated with Solvay to transfer its technology to Japan, in 1909. Iwata Nakazawa (10), professor of Engineering University, was an authority in soda industry. Nishikawa, a disciple of Dr. Nakazawa from Nippon Shamii, started LeBlanc process as the first private enterprise. When Nishikawa went to Europe to check the possibility of opening Kyushu Imperial University, he also negotiated with Solvay for the patent, but was refused. They said: "We don't sell the patent and design but we have an intention to open the company with investment cooperation. However, development of this enterprise was hopeless, where Japan had monopoly in salt."

The first World War heavily increased soda demand. In September 1914 (T3), government established the investigating committee on chemical industry, and the special committee on alkalines were in charge of the investigations in soda industry. I. Nakazawa, T. Nishikawa (13) and T. Emori (15) were the committee members.

On the basis of committee investigations, Asahi Glass Co. decided to have the soda manufacturing plant. Design was prepared by Gentaro Matsui (16), chief engineer at Osaka Alkaline Co. Ltd., Tokusaburo Iwase (17), of Kyushu Imperial University and later president of Toyo Soda Co. Ltd., and Shozo Nakahara. Three of the special investigating committee members were plant advisers. Design data were obtained from the text books by Lunge and by Schlibe.

a. *Manufacturing Method Of Sulfuric Acid And Soda*

Vol 3--- Ammonia Soda Process by Lunge (1906)

b. *Ammonia Soda Process* by Schlibe (1912).

Chemical plant equipment at that time were mostly imported ones as there were very few special makers for chemical plant equipments. No special manufacturer for the equipment of ammonia soda plant was existed. So finally, Iwanaga Manufacturing Co. (mainly involved in the manufacturing of spinning and weaving machinery) in Osaka was requested to work for the project. Design started in 1916, fabrication took one year and operation began in January 1917.

When the soda plant started its production, plant strength was:

Gentaro Matsui (Plant director)	
Clerical staff	8
Field engineers	8
Assistant engineers	6
Workers (skilled)	60
Workers (unskilled)	several tens.

Director Matsui had no experience with ammonia soda process, even though he had experience in LeBlanc soda process. Field engineers, all about twenty years of age, and newly graduated from university and higher technical college, had no experience of chemical industry. Assistant engineers were also fresh graduates of technical schools, and were beginners and underage workers with no experience in industry, raised in agricultural areas such as Saga, Ohita and Ehime. Only a few operators were retired naval firemen. Moreover three advisers, Nakazawa (10), Nishikawa (13) and Emori (15) also had no experience in the technology on ammonia soda process. They had much difficulty in continuous operation since

1. they could not expect any help or cooperation due to business secret,
2. almost all the equipments were black boxes controlled by valves and cocks, very often missoperated during two shift system,
3. due to impurity of raw salt and escaping nature of chlorine, accidents and trouble occurred in various parts.

Nishikawa went from Fukuoka to Makiyama factory, every week to check the plant and to direct and encourage the staff with confidence of Lunge's desciple and his ten years' experience in LeBlanc soda process. However, its production was only 22, 40 and then 160 tons during the first three months in spite of a target of 300 tons per month.

2.4 Engineering Education and Research (*8*)

Japanese modernization progressed with engineering education which was accepted as an important policy. "Even though there would not exist any industry to work with, if we train men, they will find industries." This was a well realized belief of technical bureaucrat Yozo Yamano (2). Ministry of Engineering was formed in October 1870 as the office to establish industries and services such as mine, iron manufacturing, lamp stand, railway and telegraph.

Kogaku-ryo started in August 1871 as the office to open the School of Engineering whose graduates were expected to serve in the Ministry of Engineering. In 1874, they defined that "Kogaku-ryo which falls under the jurisdiction is the school to train engineers for Engineering Ministry." Later this school became Engineering University and developed to Faculty of Engineering, Tokyo Imperial University.

FEG were responsible for the curriculum of this school. Here the standard of education was comparable to foreign universities and the graduates did not face any difficulty when they went abroad for further studies. However, according to the records of Engineering Ministry, "Even graduates from Engineering University with modernized education, could not be able to play the role of FEG teachers as they are, and they shall not be able to cover their duty unless they study abroad" (*9*). Educational and industrial research was started with the help from FEG and was gradually replaced by FQS who came back after completing their studies abroad.

Seiichi Teshima, (3) (2), known as the father of the industry education, borrowed money from his clan to study in U. S. A. . When his fellowship stopped by the fief, which was abolished to set up prefecture, he was asked to help Japanese ambassador plenipotentiary as interpretor. However, this job was not enough for living. He finally gave up and came back to Japan. When he went to World Exhibition in Paris, he recognized the reflection of diffused industrial knowledge which rooted from wide spread national education and resulted in the elaborate industrial products. For the progress and improvements of the manufacturing technology in the factory, equality reforms rising from workers and doing away with conventionalities were needed. He devoted himself to open the technical school and train both theory and practice. This school was not aimed at training workers, but was an educational system to educate teachers of workers and to train engineers for the supervision. This school is an antecedent of Tokyo Technical College. Teshima was the first president to this college and played a great role in engineering education.

According to the Dainippon Hakushiroku (5), there were 93 doctors of engineering in applied chemistry. Among these doctors, 53 had studied abroad and they spent 3.3 years and started at the age of 30 in average. When we count students staying less than one year, it amounts to 71 doctors, which is 76 per cent of the total.

Establishments of academic circles were indispensable for the promotion and development of science and Japan Engineering Society, Japan Mining Society, Society of Architecture, Society of Electrical Engineering, and Japan Society of Chemistry were organized by FQS and graduates from Engineering University.

3. Circumstances and Industrial Contributution of FQS

The difinition of FQS is not fixed but here I would like to those who were coming back to developing countries from advanced countries. FQS mainly devoted to abovementioned three main chemical industries are given in Table 1. Generally speaking, statuses where FQS have their activities may be classified into the following three categories.

A. Promoters and innovators of science and technology

- a1. technical innovators starting from FQS
- a2. inventors and creators of science and technology
- a3. brain drains

B. Students of the developed science and technology

- b1. circumstances where technology studied is not available
- b2. substitutes to FEG

C. Introducers of the advanced countries

- c1. introducers such as passengers and experienced people
- c2. assistants to FEG

3.1.1. Introducers as experienced people

When students had lack of basic knowledge and understanding, they started from the elementary education by private teachers after staying abroad due to their language inability. Even in such case they made their living in different circumstances and they had chances to experience and understand Western social culture, and we might be able to acknowledge the first FQS as playing the roles of introducers of occidental society.

However, according to the educational history (4) in Fukushima prefecture, FQS had different educational levels due to circumstances such as personal consideration and educational background as students. Here I quote an article from an English paper. "We are full of anxiety to have great danger in the future of Japan. Japanese industrialization is running as if galloping horses were forced to run···On the other hand, a green youth who studied abroad in two or three years and came back with poor knowledge is appointed as a high official, and important policies exert a wide influence upon him. We wonder if this green youth will be enough to engage in important politics. Many students stayed only a few months or a year and they got the idea that the advanced knowledges had firmly rooted in their minds. If they talk big to other people who never went abroad in outrageous manner, Japanese people may suffer from deluge of brag. They make a favorite of the country where they studied. While students who came back from U.S. advocate republican government, the English students voice unionism. Such opinions are in utter confusion. If Japan were under the control of these FQS, people of Japan could not be safe." (abstract from MacMillan Newspaper dated October 10th, 1872)

When the educational system was established in August, 1872, Ministry of Education decided the course of action for FQS and repealled system of sending students abroad by the Ministry.

3.1.2. Assistants to FEG

Toyohara, who studied mintage in England, worked for a while under the direction of FEG Finch for technical jobs such as construction, operation and maintenance of the 5 ton sulfuric acid manufacturing plant. Another example is Dan (11). He learned mining at MIT, and was obliged to be an assistant to a foreign teacher.

3.2. Students of the developed science and technology

3.2.1. Circumstances where technology studied is not available. (7)

FQS took a stand on students of the developed science and technology. But, when they came back to the circumstances where science and technology learned would not be available, they might be only introducers of advanced countries. T. Dan and K. Kaneko were in U.S. for eight years. They were accompanied by Lord N. Kuroda of Fukuoka clan. Dan studied mining at MIT, but he came back to Japan without any official job. When he was an English teacher at a college in Osaka, he sincerely thought "I wish I would come back to U.S. once more, then I shall be able to find my business for the studied field." Later, he became an assistant professor of Tokyo University in 1881 (M14), but he could not find any seat for mining. Moreover, he was obliged to be an assistant to FEG in astronomy. He became disgusted with Tokyo University in 1884 (M17), and got his jog in Ministry of Engineering to work in mining business in Miike mine of Mitsui.

3.2.2. Substitutes to FEG

Toyohara and Yamaguchi studied abroad the technology of Lead Chamber sulfuric acid and worked with FEG during construction and operation of the plant. Finally they substituted FEG. In education and research field, Takamatsu, Taniguchi, Hiraga and Nakazawa, who came back after studying abroad, gradually substituted and succeeded the professorship of FEG in Tokyo University. Utsunomia and Nishikawa tried to understand and to carry out the technology of LeBlanc soda on the basis of their learning the fundamental knowledge.

According to the advice and suggestions of the LeBlanc process requested by Osaka Minit Bureau, however, the infrastructures such as maintenances and machine tool works were to support the chemical technology and we may imagine many troubles happened in producing soda against heavy odds.

3.3. Promotors and Innovators of Science and Technology

3.3.1. Technical innovators starting from FQS

When we investigate the construction of the ammonia soda process, it is easy to understand the technical innovations from transferred technology.

Planning was made by Nakazawa, Nishikawa and Emori and the members of the special investigating committee of alkalines, and Matsui and Iwase as plant engineers. They were able to critically assimilate the conventional technology within the basic frame work of the modern science and tried to design the process. Adding new knowledge to process technology and machine tool technology of LeBlanc soda process equipment, they started to design ammonia soda process which was not experienced. Equipment was completed and they made it for themselves without any help of foreigners.

The History of Japanese Soda Industry surveyed the manufacturing technology of Asahi Glass Co. Ltd. at the beginning of operation.

(1) Due to much impurity content of brine in salt, contamintions happened to stick and plug in vessels and pipe. Therefore, cooling effect was decreased.

(2) Since plant machinery was not made by special makers for chemical industry, accidents such as ammonia gas leakage from vessels and pipelines and sodium becarbonate calciner trouble happened quite often.

(3) During summer, ammonia losses increased due to temperature rise in cooling water. It was the beginning of the technical advancement to study how to cope with the situation to establish the ammonia soda process.

3.3.2. Inventors, creators of science and technology and brain drains.

It is beyond the scope of this paper.

4. **Technology transfer as heat transfer analogy.**

This was published in the paper (*11*) and three transfer methods exist:

a. conductive technology transfer

b. convective technology transfer

c. radiative technology transfer

It is not easy to classify the circumstances under which FQS came back to work, but previous investigations give the following conclusions.

(1) Conductive technology transfer may be understood by the case such that FQS are playing role as introducers of the advanced country.

(2) When FQS are considered to be students of the advanced science and technology, these students are the media of convective technology transfer.

(3) If FQS contribute to the promotion and advancement of science and technology to add new knowledges, they are expected to have activities in radiative technology transfer.

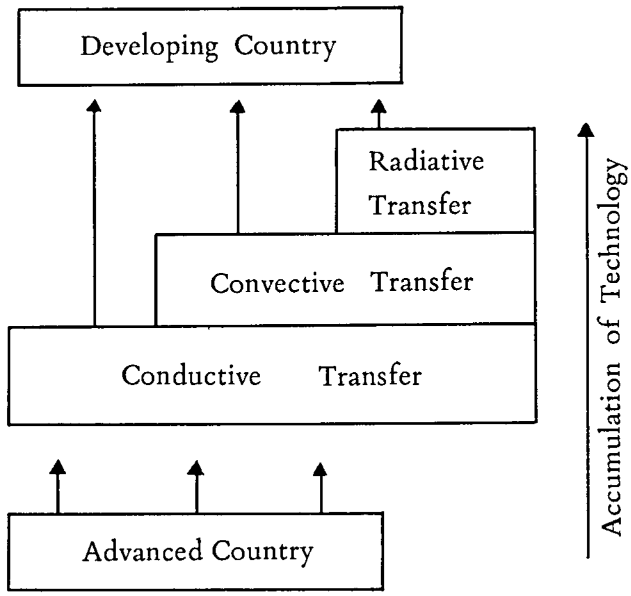
You may understand that circumstances where they play the active part are cultivated year by year, gradually.

On an analysis of chemical industries in Japan, the technology of the Lead Chamber sulfuric acid process was transferred conductively (Cth step). Convectional technology transfer occurs when the technology of the Bth step is available after overcoming the technology of Cth step.

The LeBlanc process was transferred convectively by the contribution of Bth level FQS.

I would say that the ammonia soda process was transferred radiatively where Bth step of technology was available to start Ath step technology. Ath level of FQS contributed to this kind of technology transfer.

This is expressed schematically in the figure:



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