Development of the Electric Light Bulb Industry in Japan

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Introduction

THE ELECTRICAL light system and the incandescent light bulb, its major component, were brought to market toward the end of the nineteenth century and became the cornerstone of the electrical power and electric appliance industries. Major electric appliance companies that led this development included General Electric (GE) and Westinghouse Electric in the United States, Allgemeine Elektrizitäts Gesellschaft (AEG) and Siemens und Halske (Siemens) in Germany. In the Netherlands, Philips was founded in 1891 as a light bulb manufacturer.¹ In Japan, manufacture of light bulbs began about ten years after the West. Hakunetsusha, which subsequently became Tokyo Electric Company, Ltd. [*Tokyo denki kabushiki kaisha*] and later Toshiba, was founded in 1890. Thus, the light bulb industry became the foundation for the development of electric appliance and electronics industries in Japan, too. Therefore the development of the light bulb industry is significant from an industrial history perspective.

1. Arthur A. Bright, Jr., *The Electric-Lamp Industry: Technological Change and Economic Development from 1800 to 1947* (New York: Macmillan, 1949); Harold C. Passer, *The Electrical Manufacturers, 1875 to 1900: A Study in Competition, Entrepreneurship, Technical Change, and Economic Growth* (Cambridge, MA: Harvard University Press, 1953); Thomas P. Hughes, *Networks of Power: Electrification in Western Society, 1880-1930* (Baltimore: Johns Hopkins University Press, 1983); A. Heerding, *The History of N. V. Philips' Gloeilampenfabrieken*, 2 vols., trans. Derek S. Jordan (Cambridge: Cambridge University Press, 1980, 1986).

In reviewing previous work related to the development of the light bulb industry in Japan, one finds numerous studies on the development of Tokyo Electric. Many studies such as those by Hasegawa Shin² and Nishimura Shigehiro focus in particular on the partnership into which Tokyo Electric entered with General Electric in 1905, its evolution over the years, and its impact on the light bulb industry.³ On the other hand,

2. Translator's note: Japanese names are given family name first, according to Japanese custom, except in bibliographic citations in footnotes.

3. Hiroshi Takeuchi, *Denki kikai kōgyō* [*Electric machinery industry*] (Tokyo: Tōyō Keizai Shimpōsha, 1966); Sadao Fujiwara, "Wagakuni denki sangyō ni taisuru chokusetsu tōshi: Dai ichiji taisen-zen no baai [Direct investment in the Japanese electrical industry: Instances prior to World War I], *Keizai ronsō* 110:1-2 (August 1972): 45-64; Toshiaki Chokki, "Nihon no kigyō keiei no kindaika to gaishi teikei kaisha: Meiji jidai no denki kikai kōgyō ni okeru mittsu no jirei [The modernization of Japanese company management and companies with foreign investment: Three examples from the electric machinery industry in the Meiji period], *Keiei shirin* 17:4 (January 1981): 117-30; Yoshikatsu Hayashi, "Denki sangyō ni okeru amerika no gijutsu dōnyū: Seiki tenkanki no mōhitotsu no nichibei kankei [Introduction of American technology in the electric industry: The other US-Japan relationship around the turn of the century]," *Shundai shigaku* 61 (March 1984): 31-73; Shin Hasegawa, "Gijutsu dōnyū kara kaihatsu e [From technology transfer to development]," in *Daikigyō jidai no tōrai*, vol. 3 of *Nihon keieishi*, ed. Eisuke Daitō and Tsunehiko Yui (Tokyo: Iwanami Shoten, 1995), 118-45; Shin Hasegawa, "Ōkuragumi no denki kikai bijinesu to AEG no tainichi senryaku: Daiichiji sekai taisen-zen ni okeru GE no tokkyō senryaku tono kanren de [Ōkuragumi's electric machinery business and AEG's Japan strategy: In relation to GE's patent strategy prior to World War I]" *Aoyama keiei ronshū* 30:1 (July 1995): 1-26; Shin Hasegawa, "Gaishikei kigō no keiei hatten to soshiki nōryoku: Tokyo denki no jirei bunseki [Development and organizational capacity of foreign-funded companies: A case study of Tokyo denki] *Aoyama keiei ronshū* 30:3 (November 1995): 13-30; Shigehiro Nishimura, "Daiichiji taisen izen ni okeru Tokyo denki no gijutsu kaihatsu to tokkyō kanri [Tokyo Electric's technology development and patent management in the Pre-World War I era]" *Keizai ronsō* 170:4 (October 2002): 52-71; Shigehiro Nishimura, "Senzen ni okeru GE no kokusai tokkyō kanri: 'Dairi shutsugan' keiyaku to Tokyo denki no soshiki nōryoku [International patent management at GE in the prewar era: The 'proxy application' contract and Tokyo Electric's organizational capacity]" *Keiei shigaku* 37:3 (December 2002): 28-56; Shigehiro Nishimura, "Senzenki ni okeru Tokyo denki no gijutsu dōnyū to gijutsu kaihatsu [Tokyo Electric's technology transfer and technology development in the prewar years]" *Keizai ronsō* 172:4 (October 2003): 20-42; Shigehiro Nishimura, "General Electric's international patent management before World War II: The 'Proxy Application' Contract and the Organizational Capability of Tokyo Electric," *Japanese Research in Business History* 21 (2004): 101-25; Shūjirō Ōuchi, "Senzenki no Tokyo denki no māketingu katsudō no 'tokushusei' Denkyū jigyō no chaneru seisaku wo chūshin ni [The 'uniqueness' of Tokyo Electric's marketing activities in the prewar years: Focusing on the channel strategy of the light bulb business]" *Shōkei gaku* 51:2 (December 2004): 21-36.

other studies focus on the light bulb industries in the 1930s. These studies focus in particular on the issues facing the small and medium enterprises in this industry.⁴

However, these studies have not considered directly the development process of the light bulb industry as a whole for two reasons. The first is that none has examined how Tokyo Electric has developed its business prior to the commencement of its partnership with General Electric. The second reason is that the emergence and development of other light bulb manufacturers have not been examined. Thus, this article will consider the development of the light bulb industry from the end of the 1880s to about 1907. This time period is chosen for the following reasons. The end of the Russo-Japanese War in 1905 marked a new phase of development for the light bulb industry. The end point of this time period is also marked by significant events in the development of the light bulb and electric light industries. In terms of product supply, Tokyo Electric's development into a major business began with the investment and technology transfer agreement with General Electric that was signed in 1905. In terms of demand, the opening of Tokyo Electric Light Company's [*Tokyo dentō kaisha*] Komahashi power plant in 1907 served as the starting point for the subsequent development of hydroelectric power generation and long-distance power transmission. These events aided in making electric light commonplace throughout the country.

Development of Market for Electric Lighting and Distribution of Light Bulbs

Beginning of Electric Lighting

Supply of electric power from a central power plant began in Japan in 1887 by the Tokyo Electric Light Company [*Tokyo dentō kaisha*],

4. Ōsaka Shiyakusho Sangyō-bu Bōeki-ka [Trade Section, Industry Division, City of Osaka], *Osaka no denkyū kōgyō* [*Light bulb industry in Osaka*] (Osaka: Ōsaka Shiyakusho Sangyō-bu Bōeki-ka, 1936); Zen'ichi Takitani and Shin'ichi Okamoto, "Denkyū kōgyō [Light bulb industry]," *Yushutsu zakka kōgyō-ron* [*Analysis of export sundries industry*] (Tokyo: Yūhikaku, 1942); Teruo Hirasawa, *Dai kyōkō-ki nihon no keizai tōsei* [*Economic controls during the Great Depression era in Japan*] (Tokyo: Nihon Keizai Hyōronsha, 2001).

founded in 1883. By the mid-1890s, major cities in Japan had an electric light company.⁵ Electric lights in operation increased from about 1,400 in 1887 to approximately 870,000 in 1907.⁶ Electric light spread further with private power generation. In 1893, approximately 48,000 electric lights were operated by power companies, while approximately 17,000 electric lights were supplied by private power generation. Many of these lights were set up by textile companies, the military, educational institutions, and mines.⁷

Electric light competed with other forms of modern lighting, such as kerosene lamps and gas lamps. Kerosene lamps became popular after the 1880s, first in urban areas and then in rural areas.⁸ Gas lighting service began prior to electric light. However, although gas and electric lighting services competed aggressively against each other in Tokyo and Yokohama, formation of gas lighting companies, in general, was not as active as that of electric lighting companies.⁹ Nationally, the competition between electric light and kerosene lamps was more significant.

In terms of service fees, the advantage of kerosene lamps over electric and gas lighting were obvious. In the city of Tokyo in 1900, kerosene-based street lighting cost 1.2 to 2.2 sen¹⁰ for half-night service per lamp and 1.4 to 2.4 sen per lamp for overnight service. Assuming that these fees are equivalent to per night fees, kerosene street lamps cost 36 to 72 sen per month. In comparison, gas light cost 1.44 yen per

5. Tōyō Kurihara, ed., *Denryoku* [Electricity], vol. 3 of *Gendai nihon sangyō hattatsu-shi* [History of industrial development in modern Japan] (Tokyo: Gendai Nihon Sangyō Hattatsu-shi Kenkyūkai, 1964), 34-5. Takeo Kikkawa, *Nihon denryokugyō hatten no dainamizumu* [Dynamics of development in the Japanese electrical power industry] (Nagoya: Nagoya Daigaku Shuppankai, 2004), 25-6.

6. Naikaku Tōkeikyoku [Statistics Bureau, Office of the Cabinet], ed., *Nihon teikoku tōkei nenkan* [Statistical yearbook of imperial Japan] (Tokyo: Tokyo Tōkei Kyōkai, 1891-1909).

7. Anonymous, “Zenkoku koritsu dentō tōkei [National statistics on stand-alone electric lights],” *Denki no tomo* 45 (April 1895): 168-9.

8. Keizō Shibusawa, ed., *Seikatsu-hen* [Daily life], vol. 12 of *Meiji bunka-shi* [Cultural history of the Meiji era] (Tokyo: Yōyōsha, 1955), 318, and 336-41.

9. Tūshō Sangyō-shō [Ministry of International Trade and Industry], *Denki, gasu jigyō* [Electric and gas industries], vol. 24 of *Shōkō seisaku-shi* [History of trade and industry policies] (Tokyo: Shōkō Seisaku-shi Kankōkai, 1979), 319-22.

10. Translator's note: one sen is one-hundredth of one yen.

month, and a sixteen-candela electric light from Tokyo Electric Light Company cost 1.20 yen for half-night service and two yen for overnight service.¹¹

Although it was more expensive, electric light had other advantages. For example, textile companies eagerly introduced electric light in order to prevent fires during the night shift.¹² Users chose electric light taking into consideration not only its cost but also other factors such as its ease of use, safety, and cleanliness.¹³ Electric light had advantages other than cost, and once utility rates began to come down, it spread despite its higher cost. The most important factor that made electric light easy to use was the incandescent light bulb.

Distribution of Light Bulbs by Electric Light Companies

The electric light companies used two systems of utilities rates: the fixed monthly fee and usage-based rate. The usage-based rate system was intended for large-scale users, and the fixed monthly fee according to brightness, e.g., one monthly fee for eight candelas, another rate for sixteen candelas, was much more commonly used. In addition to monthly usage fees, electric light companies charged the users fixture installation fees and the cost of light fixtures and light bulbs. It was common for electric light companies to purchase light bulbs from manufacturers or importers and supply them to users according to the terms of their service contracts. Around 1890, Tokyo Electric Light Company had two methods for charging its customers for their light fixtures and light bulbs: direct sales, where electrical wires, fixtures and light bulbs were sold to the customer at a fixed price, and equipment leases, where these items were leased to the customer and the customer was charged a monthly fee their use.¹⁴

Some electric companies employed both direct sales and leasing for

11. Anonymous, "San kaisha no tentō-sū oyobi tentō-ryō [Number of lights and lighting fees at three companies]" *Denki no tomo* 103 (February 1900), 106.

12. Tōyō Bōseki Kabushiki Kaisha, *Hyakunen-shi: Tōyōbō* [A hundred-year history of Tōyōbō], vol. 1 (Osaka: Tōyō Bōseki Kabushiki Kaisha, 1986), 30-4.

13. Fumio Makino, *Manekareta Purometeusu: Kindai nihon no gijutsu hatten* [Prometheus invited: Technological development in modern Japan] (Tokyo: Fūkōsha, 1996), 154-60.

14. Tokyo Denryoku Kabushiki Kaisha, ed., *Kantō no denki jigyō to Tokyo*

fixtures and light bulbs, but by 1898, Osaka Electric Light Company [*Osaka dentō kabushiki kaisha*] elected to use direct sales method exclusively. Osaka Electric charged 75 sen for light bulb replacement, and in comparison to the market price of 30-50 sen for a light bulb of 5-32 candelas, this rate was quite expensive. Furthermore, Osaka Electric forbade customers from changing fixtures or light bulbs on their own, and supplied the customers with equipment that had passed their own usage tests.¹⁵ Thus, the electric light companies tried to control and manage which light bulbs their customers used by supplying the bulbs themselves. Given such a distribution system for light bulbs, the electric light companies were important customers for light bulb manufacturers, importers, and wholesalers.

Emergence of Light Bulb Manufacturers and the Development of Competition

Commencement of Light Bulb Manufacture

When the electric light business first began in Japan, light bulbs were imported from the West. Eventually, entrepreneurs began to experiment with domestic production of light bulbs. Fujioka Ichisuke was one of the earliest to experiment with domestic production of light bulbs. Fujioka was a leader in the establishment of the Tokyo Electric Light Company. He supported Miyoshi Shōichi, a compatriot from the same hometown, and supported Miyoshi's attempt in the domestic production of power generators. Thus, Fujioka was a leading figure in the early development of the electric power and electric machinery industries in

Denryoku: Denryoku jigyō no sōshi kara Tokyo Denryoku gojū-nen e no kiseki [Electric power business in the Kanto area and Tokyo Electric Power Co.: Our history from the founding of the electric power business to the fiftieth anniversary] (Tokyo: Tokyo Denryoku Kabushiki Kaisha, 2002), 28; Tokyo Denryoku Kabushiki Kaisha, ed., *Shiryō-hen* [Archival records], vol. 2 of *Kantō no denki jigyō to Tokyo Denryoku: Denryoku jigyō no sōshi kara Tokyo Denryoku gojū-nen e no kiseki* [Archival records: Electric power business in the Kanto area and Tokyo Electric Power: Our history from the founding of the electric power business to the fiftieth anniversary] (Tokyo: Tokyo Denryoku Kabushiki Kaisha, 2002), 146-9.

15. Osaka Dentō Kabushiki Kaisha, *Osaka dentō kabushiki kaisha tentō kisoku* [Rules on lighting of Osaka Electric Light Company] (Osaka: Osaka Dentō Kabushiki Kaisha, 1898), 5-8; Anonymous, "Shōkyō bukka [Trade statistics and prices]" *Denki no tomo* 105 (April 1900), 216-7.

Japan. Fujioka studied engineering with William Edward Ayrton at the Imperial College of Engineering [*kōbu daigakkō*]. Following graduation in 1881, he became an assistant professor at the Imperial College of Engineering and was later promoted to full professor. Fujioka eventually became an assistant professor at the College of Engineering at the Imperial University.

In 1884, Fujioka was sent by his employer to the electric exhibition in Philadelphia and subsequently toured around the United States studying the electric industry.¹⁶ Fujioka's notebook from this trip includes his observations on the visit to the Edison Lamp Company, and includes notes in English and sketches on the production of filament, assembly of light bulbs, facilities, and raw materials.¹⁷

Fujioka went on another study tour of the West in 1886 when he was appointed the Chief Engineer [*gishichō*] at Tokyo Electric Light Company. In England, he visited the Swan United Electric Light Co., Ltd.,¹⁸ and studied glass manipulation techniques necessary for light bulb production.¹⁹ He also purchased machinery and tools for light bulb production experiments with the assistance of John Perry, a former instructor at the Imperial College of Engineering.²⁰ Although Thomas A. Edison manufactured carbon filament with bamboo, methodology to manufacture filament using non-fibrous cellulose was subsequently developed in England. This new method enabled production of filament

16. Hideo Segawa, *Kōgaku hakushi Fujioka Ichisuke-den* [*The biography of Fujioka Ichisuke, doctor of engineering*] (Tokyo: Kōgaku hakushi Fujioka Ichisuke-kun Denki Hensan Iinkai, 1933).

17. Archival materials, Iwakuni Gakkō Kyōiku Shiryōkan [Iwakuni Archives on School Education]. Fujioka left for the United States on August 17, 1884 and returned on December 8. The notebook is undated but the notes on the visit to Edison are dated "22nd October."

18. Keisei Kinoshita and Sajūrō Kōno, eds., *Kangyō kōseki-roku* [*Record of accomplishments in industrial development*], vol. 1 (Tokyo: Seinen Kyōiku Gikai, 1903-4), 228.

19. Dainihon Yōgyō Kyōkai [The Japanese Ceramic Association], ed., *Nihon kinsei yōgyō-shi* [*History of ceramics in early modern Japan*], vol. 4 (Tokyo: Dainihon Yōgyō Kyōkai, 1918), 50.

20. Segawa, *op. cit.*, 121, and 199; Shōtarō Yasui, ed., *Tokyo denki kabushiki kaisha gojū-nenshi* [*Fifty-year history of the Tokyo Electric Co., Ltd.*] (Tokyo: Tokyō Shibaura Denki Kabushiki Kaisha, 1940), 6-8.

that was more consistent in quality than bamboo.²¹ Fujioka purchased machinery that enabled this method of production.

In 1888, Fujioka and Miyake Junsuke, another graduate of the College of Engineering at the Imperial University, began experimental production of light bulbs at Tokyo Electric Light Company. Although Fujioka and Miyake were unsuccessful at producing filament with cellulose, they succeeded in producing a light bulb with carbon filament from bamboo. In 1890, Hakunetsusha²² was established as a spin-off from Tokyo Electric Light. Hakunetsusha was capitalized at 2,000 yen, and its production involved seven or eight employees, including Fujioka and Miyake. Initially, Hakunetsusha's products were sold exclusively to Tokyo Electric Light. The finished products were tested at Tokyo Electric Light and only those that passed were accepted.²³

The price of imported light bulbs was about 1.20 yen in 1887 but by 1895 it had fallen to 35-50 sen for bulbs made in Germany and 40-60 sen for bulbs made in the United States. In comparison, Hakunetsusha's light bulbs were priced at 0.70-1.00 yen in 1890, sixty sen in 1895, and as low as 37-45 sen in 1896. Although Hakunetsusha's light bulbs were of inferior quality and not necessarily lower in price than imports, their sales increased rapidly as the formation of new electric light companies increased and as Fujioka preached "encouragement of the use of domestically manufactured light bulbs." Hakunetsusha entered into a long-term volume contract with Tokyo Electric Light.²⁴ It is surmised that such contract was not concluded on economic calculation alone. Tokyo Electric Light's management was sympathetic to Hakunetsusha's efforts, and this contract required improvements in quality. Since Tokyo

21. Bright, *op. cit.*, 5, 64-6, 117-9; Heerding, *op. cit.*, vol. 1, 258-9.

22. Translator's note: Hakunetsusha means "incandescent company."

23. Yasui, *op. cit.*, 7-20; Haku Kasai, *Kōgaku hakushi Fujioka Ichisuke-kun den* [Biography of Fujioka Ichisuke, doctor of engineering] (Tokyo: Fujioka Ichisuke Juzō Kensetsu Jimusho, 1917), 40; Segawa, *op. cit.*, 190-200; Tadashi Fukatsu, "Hakunetsu denkyū kokusan no kaishi Meiji 23-nen wa ayamari [Meiji 23 as the first year of domestic production of incandescent light bulbs is incorrect]" *Akari: Shōmei bunka kenyūkai kaihō* [Light: Newsletter of the association for the study of lighting culture] 6 (182): 15-6.

24. Yasui, *op. cit.*, 5, 23-4, 42-3; Anonymous, "Hakurai hakunetsu tōkyū no daika [The price of imported incandescent light bulbs]" *Denki no tomo* 53 (December 1895): 495.

Electric Light performed strict tests on all light bulbs purchased, it became a highly demanding customer for Hakunetsusha.

Other companies followed Hakunetsusha in attempting to manufacture light bulbs. Hirose Shin began to study light bulbs beginning in 1884, and in 1890, obtained a patent for an electric light bulb [*dentōkyū*].²⁵ In 1895, Hirose brought his light bulb to the Imperial Navy but was denied purchase. In 1896, Hirose was allowed to retest his light bulb with the Imperial Navy; this time the light bulb passed inspection and he received an order from the Navy.²⁶

Expansion of Light Bulb Manufacturers' Business and Establishment of New Manufacturers

The demand for light bulbs increased with the installation of electric lighting but imported bulbs dominated the market for light bulbs. Okura and Company [*Ōkuragumi*], which served as an agent for AEG, and the Japan office of Siemens sold light bulb manufactured in Germany, and Bagnall and Hilles, Mitsui and Company [*Mitsui bussan kabushiki kaisha*], and Nippon Electric Co. [*Nihon denki kabushiki kaisha*] and others sold American light bulbs manufactured by General Electric and others. These light bulbs were sold both directly by the importers as well as through domestic sales agents.²⁷

Domestic manufacturers expanded their business as well. In 1896, Hakunetsusha was reorganized as Tokyo Incandescent Light Bulb Manufacturing Co., Ltd. [*Tokyo hakunetsu dentōkyū seizō kabushiki kaisha*] with an initial capitalization of 150,000 yen. Although the

25. "Sembai tokkyo no dentōkyū [An exclusive patent for electric light bulb]" *Osaka Asahi Shimbun* 3543 (December 2, 1890): 4; *Tokkyo Dai-999-go Meisai-sho* [Details of PatentNo. 999]

26. Advertisement, *Denki no tomo* 66 (January 1897): (23); *Denki no tomo* 69 (April 1897): 185.

27. Various articles and advertisements in *Denki no Tomo* from 45 (April 1895) to 124 (November 1901); Shigenori Katōgi, *Nihon denki jigyō hattatsu-shi* [History of the development of the electric industry in Japan], vol. 2 (Tokyo: Den'yūsha, 1918); Nihon Denki Kabushiki Kaisha, ed., *Nihon denki kabushiki kaisha shichijū-nenshi* [Seventy-year history of the Nippon Electric Co., Ltd.] (Tokyo: Nihon Keieishi Kenkyūjo, 1972); Tōru Takenana, *Zimensu to Meiji Nihon* [Siemens and Meiji Japan] (Hadano-shi, Kanagawa: Tōkai Daigaku Shuppankai, 1991); Kansai Denryoku Gojū-nenshi Henshū Jimukyoku, ed., *Kansai denryoku gojū-nenshi* [Fifty-year History of Kansai Electric Power] (Osaka: Kansai Denryoku, 2002).

senior management of the company subscribed to the majority of the shares, many affiliated with electric light companies also became shareholders of this new company. In particular, those affiliated with Tokyo Electric Light subscribed to ten to fifteen per cent of the shares.²⁸ By the second half of 1898, a new factory began operation. In 1899, the company's name was changed to Tokyo Electric Co., Ltd. [*Tokyo denki kabushiki kaisha*]. In the same year, Shinjō Yoshio, a graduate of the College of Science of Tokyo Imperial University, became its Chief Engineer. Furthermore, to improve the technology and to perform scientific studies on the products, a laboratory was established within the factory premises.²⁹

By 1907, at least thirty manufacturers had been founded. Many of these companies were small operations with ten to twenty workers, and many also operated businesses in electrical appliance manufacturing and/or sales. Some of these companies were founded by those who had left Tokyo Electric. For example, Namba Mamoru of Nishiki Shōkai was a former worker at Hakunetsusha and a 1898 graduate of the electrical engineering program at the Technical School [*kōshu gakkō*]. In 1907, Namba obtained a patent for the repair of old light bulbs jointly with Takeda Toshikuma, a former auditor at Tokyo Electric. Another example of a former Tokyo Electric worker who established his own business was Onda Shinjirō, who founded Onda Light Bulb [*Onda denkyū*]. Workers at other existing manufacturers became involved in the founding of new companies or in leaving and joining another company. For example, workers at Onda Light Bulb later split into two groups: one established Kōtō Light Bulb [*Kōtō denkyū*] and the other established Ishii Light Bulb Manufacturing [*Ishii denkyū seijōsho*].³⁰

Knowledge of light bulb manufacture most likely spread with the movement of engineers and workers but publications in Western

28. Tokyo Denki Kabushiki Kaisha, *Jigyō hōkokusho* [Semiannual report] (Tokyo: Tokyo Denki Kabushiki Kaisha, 1896-1904).

29. Yasui, *op. cit.*, 27-32, 51, 54-58, and 62.

30. Various articles and advertisements in *Denki no tomo* 29 (December 1893) to 195 (October 1907); Nihon Denki Kyōkai, *Nihon dengyōsha ichiran* [List of electrical businesses in Japan] (Tokyo: Nihon Denki Kyōkai, 1905-8); Tokyo Shiyakusho [City of Tokyo], *Tokyo-shi Tōkei Nempyō* [Statistical annual of Tokyo city] (Tokyo: Tokyo-shi, 1903-4); Kōgyō no nihon-sha, ed., *Nihon kōgyō yōkan* [Guide to Japanese manufacturing] (Osaka: Kōgyō no Nihon-sha, 1906, 1917); Nihon Denkyū Kōgyō-kai

languages, articles in journals and magazines such as *Denki no Tomo*³¹ and *Denki Gakkai Zasshi*³² and translations from Western languages also served as sources of information.³³ The spread of education in industrial engineering also played an important role. The senior management and engineers at light bulb manufacturers included graduates of the Tokyo Imperial University, the Tokyo College of Technology [*Tokyo kogyō gakkō*] and the Technical School [*kōshu gakkō*].³⁴

Industries related to light bulbs began to develop as well. Iwaki Glass [*Iwaki Garasu*], headed by Iwaki Takijirō, supplied glass parts to Hakunetsusha.³⁵ As for the manufacture of metal lamp base, it is said that Ōrui Uichirō was the first to refurbish lamp base from used light bulbs and supply them to Hakunetsusha. Manufacturers of new and refurbished lamp base appeared in Osaka as well.³⁶ Imported parts were also used. For example, Onda Light Bulbs manufactured bulbs using filaments manufactured in France.³⁷

[Japan Electric Lamp Manufacturers Association], ed., *Nihon denkyū kōgyō-shi* [*History of light bulb manufacture in Japan*] (Tokyo: Nihon Denkyū Kogyō-kai, 1963); Nōshōmu-shō [Ministry of Agriculture and Commerce], ed., *Kōjō tsūran* [*Directory of factories*] (Tokyo: Nihon Kōgyō Kyōkai, 1911); Nōshōmu-shō [Ministry of Agriculture and Commerce], ed., *Kōjō tsūran* [*Directory of factories*] (Tokyo: Nihon Kōgyō Kurabu, 1918); Osaka Shiyakusho, *op. cit.*, 25; Katōgi, *op. cit.*, 898-9; *Tokkyō Dai-12377-go Meisai-sho* [*Details of Patent No. 12377*]; Kokusan Kenkyūkai, ed., *Kokusan denkyū nenkan* [*Yearbook of domestically manufactured light bulbs*] (Tokyo: Kokusan Kenkyūkai, 1929), 3.

31. Translator's note: *Denki no tomo* translates roughly as Electricity Companion.

32. Translator's note: *Denki gakkai zasshi* is the Journal of the Institute of Electrical Engineers of Japan.

33. See, for example, Anonymous, "Hakunetsu dentō seizōhō [How to manufacture incandescent light bulb]" *Denki no tomo* 30 (January 1894): 15-7; Nakahara Iwasaburō, "Hakunetsutō [Incandescent light]," *Denki gakkai zasshi* [*Journal of the Institute of Electrical Engineers of Japan*] 67 (February 1894): 150-5. The latter is a translation from *The Electrician*.

34. Tadashi Ninomiya, ed., *Kōshu gakkō ichiran* [*Directory of the technical school*] (Tokyo: Kōshu gakkō, 1908), 42-4.

35. Yoshio Kinoshita, *Nihon rikagaku garasu yakudō hyaku-gojū-nenshi: Bakumatsu, Meiji, Taishō, Shōwa* [*150 years of chemical glass in Japan: A dynamic history through the end of the Tokugawa shogunate, Meiji, Tasho and Showa*] (Tokyo: Kinoshita Rika Kōgyō Co, Ltd., 1999), 122-3, and 130-1.

36. Osaka Shiyakusho, *op. cit.*, 130-1.

37. Advertisement, *Denki no tomo* 181 (August 1906): (39); 195 (October 1907): (63); 198 (January 1908): (32).

In the United States, the establishment of light bulb factory was easy with a small amount of capital and an engineer with the knowledge of bulb manufacturing process;³⁸ it is possible to make a similar observation about in Japan. The transfer of engineers and workers from one company to another, the spread of industrial arts education, information dissemination through magazine articles, the development of related industries, and the use of imported parts all made the entry into the business accessible.

Competition between Domestic Manufacturers and Imports

The market for electric light bulbs in Japan around 1903 can be characterized as follows: the total demand was 1.5 million bulbs; imported bulbs comprised seventy per cent of the market share, Tokyo Electric's products had about twenty per cent of the market, and the remaining domestic manufacturers had the remaining ten per cent of the market.³⁹ On the other hand, Shinjō Yoshio of Tokyo Electric stated that their company had sold approximately 200,000 bulbs out of the 1.5 million in demand.⁴⁰ Thus, Tokyo Electric's share of the light bulb market was between ten and twenty per cent. The dominance of imports in the Japanese light bulb market was clear, but it should also be noted that Tokyo Electric's annual sales volume between 1896 and 1904 was roughly equivalent to those of imports from Germany and greater than those from the United States until 1904. As shown in Table 1, in the Japanese light bulb market at the turn of the twentieth century, the products of Tokyo Electric and Germany dominated the market, while the American light bulbs had slowly increased its share of the market.

38. Bright, *op. cit.*, 78-9.

39. Kinoshita and Kōno, *op. cit.* 232.

40. Yoshio Shinjō, "Denki kikai seisakugyō no hattatsu (2) [The development of the electrical machinery manufacturing industry, part 2]," *Tōyō keizai shimpō* 281 (September 25, 1903): 1274.

Table 1: Tokyo Electric's Sales of Electric Light Bulbs and Imports from Selected Countries, 1896-1904

YEAR	Tokyo Electric	Imports				
		USA	Germany	England	Others	Total
1896	18,173	—	—	—		37,034
1897	26,443	—	—	—		57,777
1898	24,801	12,358	21,371	3,854	951	38,533
1899	38,466	19,789	24,002	18,109	5,812	67,712
1900	37,954	29,540	36,539	6,216	8,411	80,706
1901	31,205	25,081	56,231	10,653	3,619	95,584
1902	53,885	23,937	37,248	8,735	2,753	72,673
1903	40,996	40,841	68,580	8,998	4,230	122,649
1904	69,410	69,661	52,326	22,296	4,494	148,777

Unit: Yen

Sources: Ōkurashō [Ministry of Finance], ed., *Dainihon gaikoku bōeki nempyō* [International trade timeline of Imperial Japan] (Tokyo: Ōkurashō, 1898-1904); Tokyo Shibaura Denki Kabushiki Kaisha, ed., *Tokyo shibaura denki kabushiki kaisha hachijū-go-nenshi* [Eighty-five year history of Tokyo Shibaura Electric Co., Ltd.] (Tokyo: Tokyo Shibaura Denki Kabushiki Kaisha, 1963), 936; Tokyo Denki Kabushiki Kaisha, *Jigyō hōkokusho* [Semiannual Report] (Tokyo: Tokyo Denki Kabushiki Kaisha, 1899).

Around the same time, competition among manufacturers increased dramatically in the West, especially in continental Europe. In the United States, by 1896, an oligopoly was established with General Electric as its central player, and the price of light bulbs was maintained at around 17 cents (approximately 34 sen).⁴¹ However, in continental Europe, competition became fierce and many manufacturers were at the brink of failure. In 1903, an international cartel on carbon filament light bulbs, Verkaufsstelle Vereinigter Glühlampenfabriken GmbH was established, but even its basic price was 50 pfennig (approximately 25 sen), or lower than the American price. In Europe, retail sales to consumers amounted to the majority of the sales. Because the consumers did not have the capacity to test products for quality, they used price as an important selection criterion. As competition became fierce, manufacturers became lax in quality control, leading to problems with consumers.⁴²

These developments in the markets in the West also influenced the Japanese market. Between 1901 and 1902, German light bulbs were sold in Japan at a dumping price of 17 to 18 sen. To compete with these

41. Bright, *op. cit.*, 84, 88-9, 103-4, and 151. Independent manufacturers, which amounted to about seven per cent of the market, sold their bulbs at 11 cents.

42. Heerding, *op. cit.* vol. 2, 3-5, 16-9, 46-57, 67, and 71-123; *The Electrician* vol.36 (January 3, 1896): 308-9.

German light bulbs, Tokyo Electric sold its bulbs between 25 to 30 sen during 1899 and 1900, and by the end of 1901, at 18 sen, below its cost of production. On the other hand, American manufacturers such as General Electric began to sell high quality bulbs at relatively high prices around 34 to 35 sen and began to expand their customer base.⁴³ Bagnall and Hilles, which imported GE bulbs to Japan, also dealt in Tokyo Electric bulbs.⁴⁴ Competition against these high quality-high price products increased as well.

In contrast, some Japanese manufacturers sold their products at prices lower than the German imports or Tokyo Electric's products. These light bulbs had lower levels of vacuum inside the bulbs and thus lower in quality, but they were sold at approximately half the price of the imports.⁴⁵ This practice is apparent in Shinjō Yoshio's speech given to the Institute of Electrical Engineers of Japan in 1905. In a debate with Katōgi Shigenori, the head of Den'yūsha and the publisher of *Denki no Tomo*, Shinjō stated the following. In response to Katōgi, who argued,

While your company may be a major company ... your prices are too high. ... Why don't you make them cheaper? ... That's why people say that imports are better.

Shinjō responded as follows:

As an engineer, the issue is uniformity. If we wanted to make the bulb cheaply—for example, in Tokyo, there are some who sell them for fifteen or twenty sen—it's possible to do so. ... If we didn't pay attention to the placement of bolts, or how vacuum is created, it can be done.⁴⁶

According to Shinjō, because Tokyo Electric paid attention to product quality and uniformity, the cost necessarily became higher. Tokyo Electric decided that "if the products truly did not get better, it would not be able to chase the Germany products away,"⁴⁷ and chose to

43. Yasui, *op. cit.*, 66-7, 74-5, and 86-7.

44. Tokyo Denki Kabushiki Kaisha, *Jigyō hōkokusho* [Semiannual report], 1902.

45. Ōkurashō [Ministry of Finance], ed., *Gaikoku bōeki gairan* [Overview of external trade] (Tokyo: Ōkurashō Shukei-kyoku, 1901), 595.

46. Yoshio Shinjō, "Hakunetsu dentōkyū ni tsuite [On incandescent light bulbs]," *Denki gakkai zasshi* 207 (October 1905): 752-3.

pursue a high quality strategy rather than the low price strategy.

Tokyo Electric's Growth and Its Limitations

Formation of Mass Production Technology

Light bulbs are mass produced items according to specifications such as voltage, brightness, and power consumption; therefore, maintaining uniformity and interchangeability is of paramount importance.⁴⁸ For Tokyo Electric, development of mass production technology was an important issue. In 1900, Tokyo Electric succeeded in the mass production of cellulose filament, which was more uniform than carbon filament made from bamboo. In this production method, cotton was dissolved in a solution of zinc chloride and formed into a thread by “pushing it through a small hole.” Then, this thread was wrapped around a mold and baked to make the filament. Then a process called flashing followed: when the filament is placed in a hydrocarbon gas vaporized from volatile oils and electrical current is run through it, carbon that decomposes from the volatile oils deposits on the surface of the filament. This process makes the whole filament “uniform.” However, the mass production of uniform filament was difficult. For example, in flashing the voltage of electricity applied to the filament must be uniform but this was next to impossible in mass production, since even 0.1 second difference in duration of electricity application led to differences in the final product.⁴⁹

Tokyo Electric also made plans to produce glass bulbs and metal lamp base domestically in order to reduce production cost. In 1902, Tokyo Electric ordered a machine for making lamp base from the United States and opened a factory. Glass bulbs were purchased from Iwaki Glass [*Iwaki garasu*] but its share of the production cost was substantial and Iwaki Glass was unable to respond to Tokyo Electric's demands on quality and bulb shape. Thus, in 1902, Tokyo Electric began experimental production of its own glass bulbs.⁵⁰

47. *Ibid.*, 176-7. It was Shinjō's understanding that “German bulbs were not uniform,” (*Ibid.*, 744) and he thought that German bulbs were of poor quality.

48. Heerding, *op. cit.* vol. 1, 264, and vol. 2, 27.

49. Shinjō, *op. cit.*, 729-35.

In assembling the light bulb, the process of pumping air out of the bulb is extremely important. In this process, air is first pumped out with a vacuum pump; then phosphorus is inserted into the bulb and combined with oxygen inside the bulb to increase the level of vacuum.⁵¹ The second part of this process is called the Malignani method, and this was introduced at Tokyo Electric in 1899.⁵² Shinjō commented about this method that the “mixture of chemicals was a type of secret” and although he did not know what the precise formula was in the West, he had “conducted numerous experiments, and finally devised a formula” that allowed him to implement this method and obtain good results.⁵³ It is surmised that Tokyo Electric, while imitating Western technology, invented its own chemical formulae that allowed them to obtain a high level of vacuum. Furthermore, in 1900, a new vacuum pump from England was installed in the factory.⁵⁴

Tokyo Electric increased its production volume and productivity by developing mass production technology, investing in its facilities and equipment, and hiring more workers. After 1899, when the new factory went into operation and a new vacuum method was implemented, Tokyo Electric’s production volume and productivity increased substantially. Production volume increased from 58,000 units in 1898 to 137,000 units in 1899. Daily production increased from 252 units in 1896 to 457 in 1899 and 982 in 1903. Per unit manufacturing cost fell from 26 sen in 1896 to 17 sen in 1899.⁵⁵ Around 1890, Philips had conceived of a factory capacity with least production cost at 1,000 units per day.⁵⁶ Only ten years later, Tokyo Electric had reached a similar level with its production.

50. Yasui, *op. cit.*, 57-8, 75-8, and 336-7.

51. Yutaka Fukuda, *Dentō oyobi shōmei [Light bulbs and lamps]* (Tokyo: Den’yōsha, 1914), 82-4.

52. Yasui, *op. cit.*, 60-1; Shinjō, *op. cit.*, 739.

53. Shinjō, “Denki kikai,” 1275. Another advantage of the Malignani method was that the duration of the vacuum process was shortened. See Heerding, *op. cit.*, vol. 2, 61-3.

54. Yasui, *op. cit.*, 61.

55. Tokyo Denki Kabushiki Kaisha, *Jigyō hōkokusho [Semiannual report]*, first half of 1896 to second half of 1904. In 1899, the total cost per unit (sum of manufacturing cost, sales cost, and overhead) was 24 sen, and the average sales price was 28 sen.

56. Heerding, *op. cit.*, vol. 1, 269.

Sales to Electric Light Companies

As discussed in the previous section, Tokyo Electric developed a mass production system for a uniform electric light bulb, but uniformity was not the only relevant factor. For the incandescent light bulb, efficiency (as measured by watts per candelas) is inversely related to its expected life span, and the balance between these two opposing factors is an important component of product quality.⁵⁷ When electricity was sold at a flat monthly rate a highly efficient light bulb was more advantageous to the electric light company,⁵⁸ since they were able to light more bulbs with the same amount of electric power. In reality, some electric light companies did not pay attention to light bulb specifications or quality, and purchased bulbs of low efficiency or low quality by selecting on the basis of life span or price; however, such decision eventually turned out not to be economical.⁵⁹

There was a reason, however, that electric light companies paid close attention to longevity of the bulbs. Most electric light bulb companies leased equipment including light bulbs to their customers and received a monthly usage fee. Using this method, when the cumulative usage fee over the life of a light bulb exceeds the purchase cost of the bulb, the electric light company generates a profit, and when the cumulative usage fee is below the purchase price, a loss. Therefore, from the perspective of purchase cost and income from lease payments, a light bulb with a long life span is advantageous to the electric light company. Even at electric light companies that employed the direct sales method, some refused to replace a light bulb if it failed shortly after replacement.⁶⁰ It is surmised that many electric light companies did not like the frequent exchanges of light bulbs and thereby emphasized life span over efficiency of the light bulb. Shinjō commented as follows:

If we ask the electric light companies, they tell us that they prefer

57. Fukuda, *op. cit.*, 86-7.

58. Kaoru Fukui, "Denki hyakuwa, sono-2: Netsu dentōkyū no tokusei narabi ni sono himpyō no shinka [One hundred stories on electricity, no. 2: The characteristics of incandescent light bulbs and the truth about its product quality]," *Denki no tomo* 131 (June 1902): 329-35.

59. Tsunesada Fujita, "Hakunetsutō-kyū no seimei oyobi shokuryoku nit suite [On the life and brightness of incandescent light bulbs]," *Denki no tomo* 84 (July 1898): 453-7.

60. Anonymous, "Iwayuru denryoku tōyō ni tsuki [On so-called stealing electric power]," *Denki Shimpō* 49 (March 5, 1909): 2-3.

to get light bulbs with a long life span, even if it uses a little more electric power.⁶¹

He stated further that while American products had the average efficiency of 3.1 watts/candela, Tokyo Electric strove to achieve the standard of 3.8 watts/candela.⁶² To meet the demand of electric light companies that preferred longevity, Tokyo Electric produced light bulbs that were less efficient but provided a longer life span.

Tokyo Electric also recognized that the real operating voltage of electric light companies varied widely. Shinjō commented that even though the nominal voltage of the electric power line from the electric light company was 100 volts, there were differences in real voltage from one company to the next. Despite these differences, all electric light companies ordered light bulbs for 100 volts. If the light bulb companies sold the same bulbs to all of these companies without regard to the differences in real voltage, the light bulb company would fail. To combat such problems, Tokyo Electric collected data on the real voltage of various electric light companies and sold them light bulbs that were appropriate for each.⁶³

Thus, Tokyo Electric expanded its market by supplying light bulbs that met the preferences for longevity by the electric light companies and the variation in operation among different electric light companies. In the process of technology development, the level of quality control improved and the production and selection of light bulbs with specific efficiency and life span became possible. In addition, Tokyo Electric collected data on operation of electric light companies as they expanded their customer base. And by aligning its sales and production, Tokyo Electric was able to supply products that met the operating conditions of electric light companies. Although AEG's product line included a great variety in brightness, voltage and efficiency, its Japanese agent, Okura and Company, only dealt in light bulbs for 100/110 volts with efficiency

61. Shinjō, "Hakunetsu dentō-kyū," *op. cit.*, 755.

62. *Ibid.* General Electric produced light bulbs with three levels of efficiency: 3.1 watts/candela for electric light companies in large urban areas with good voltage control; 3.5 watts/candela for small-scale electric light companies, and 4 watts/candela for customers with private power generation whose voltage varied widely. Shinjō's comment was with respect to the light bulb with the highest efficiency.

63. *Ibid.*, 743.

rating of 3.5 watts/candela.⁶⁴ In other words, the light bulbs imported by Okura and Company were limited to a very narrow set of specifications and could not meet the wide variation in operating conditions of Japanese electric light companies. In contrast, Tokyo Electric was able to expand its market by supplying high quality bulbs and by closely aligning its sales and production.

Such alignment of sales and production at Tokyo Electric was similar to the process that took place at General Electric. GE produced three types of light bulbs at different efficiency ratings and sold them according to the operating conditions of electric light companies. Furthermore, the manufacturing process at that time was able to produce light bulbs that met the brightness specification at a given voltage only about 25 per cent of the time. As a result, GE made different light companies operate at different voltages and tried to match the appropriate light bulbs to each company.⁶⁵ Tokyo Electric also responded to the limitations of its manufacturing technology and the conditions of the Japanese market, and in order to supply high quality light bulbs, came to take a strategy analogous to GE.⁶⁶

Relationships with Electric Light Companies

One informative case study of the relationship between Tokyo Electric and its electric light company customers is the relationship between Shinjō Yoshio and Ueno Kichijirō, the General Manager of Yokohama Mutual Electric Light Company [*Yokohama kyōdō dentō kabushiki kaisha*]. Yokohama Mutual was the third largest electric light company in Japan in terms of the number of lamps installed, and an important customer of Tokyo Electric. Ueno was also an acquaintance of Fujioka Ichisuke and a shareholder of Tokyo Electric. According to a biography of Ueno, his relationship with Shinjō was as follows:

Mr. Shinjō at Tokyo Electric became quite indebted to Mr. Ueno, ... but in the beginning, he was brushed aside and ignored.... But, ... no matter how many times he was turned away, he came back asking again and again to have his light bulb tested.... Mr.

64. Advertisement, *Denki no tomo* 143 (June 1903): (1)-(2).

65. Passer, *op. cit.*, 106-8.

66. Shinjō's speech for the Institute of Electrical Engineers [*Denki gakkai*] given in

Ueno was finally moved by Mr. Shinjō's energy and put up his light bulbs in the red light district ... but they just went out and out.... But Mr. Shinjō never gave up, and came back again and again with improved ones. But the Japanese light bulbs back then were of such bad quality that filaments broke, and the glass broke.... "There's no way something like this would work—make one with a filament that doesn't break so much," he was scolded, and Mr. Shinjō worked and worked on improvements.... Mr. Ueno was so impressed with Mr. Shinjō's energy that he told him in all seriousness, "Since your light bulbs are so useless, why don't you go abroad and study them?" A bit later, Mr. Shinjō was to go to the United States, and after he went, a partnership agreement was concluded with GE....⁶⁷

One might infer from the above quotation that Tokyo Electric's products were of such poor quality that any discussion of trade-offs between efficiency and life span was moot, but preventing filament breakage was a most important issue. In order to supply light bulbs that met the demands of the electric light companies, Tokyo Electric maintained relationships with key contact persons at these companies, collected information, and made improvements to its products. In some cases, they were able to receive orders because of their energy and passion.

May 1905, a transcript of which was published in the Institute's journal (see Shinjō, "Hakunetsu dentōkyū," *op. cit.*), took place after Tokyo Electric concluded its partnership agreement with General Electric. Shinjō had visited the United States in August 1904, and it is possible that while a formal agreement with GE and official technology transfer may not have taken place, informal exchange of information may have occurred, and such information may have been included in his speech. However, Tokyo Electric's choice of low efficiency was a response to electric light companies' preference for bulb longevity, and the data collected by Tokyo Electric could only be obtained through long-term continuous contact with its customers. Thus, although analogous in form with GE's strategy, Tokyo Electric achieved its strategy of alignment between sales and production in response to the limitations of its own manufacturing technology and conditions of the domestic market rather than through explicit information exchange with General Electric.

67. Genta Yamamoto, ed., *Ueno Kichijirō-den* [*Biography of Ueno Kichijirō*] (Tokyo: Ueno Kichijirō-kun Denki Hensankai, 1933), 275-6 and 513-4.

Financial Outlook

Tokyo Electric expanded its customer base by supplying light bulbs that met the preferences for long life span of electric light companies and the variation in operating conditions among electric light companies, in addition to cost reduction and quality improvement that resulted from the implementation of new mass production technology. Between 1900 and 1902, Tokyo Electric's customer list included sixty electric light and electric railroad companies. The number of lamps installed by these companies totaled approximately 290,000. The national total was approximately 330,000, so Tokyo Electric had a business relationship with the vast majority of electric light companies in Japan.⁶⁸

Tokyo Electric's assets increased from approximately 38,000 yen in 1896 to approximately 267,000 yen in 1904. It continuously invested in its facilities and equipment and expanded its production capacity. Capital for equipment and operation was obtained through the payment on stock shares by shareholders.⁶⁹ However, uncollected debt and unsold inventory accumulated gradually. After 1899, inventory increased substantially, and by 1903, it reached approximately 75,000 yen, compared to its gross sales of 41,000 yen. In addition, the ratio of debt, such as payable and overdue bills, increased. In fiscal year 1899, Tokyo Electric's balance sheet showed total assets of 126,000 yen, with 109,000 yen of debt and 99,000 yen of capital. However, by the second half of fiscal year 1904, the balance sheet showed total assets of 267,000 yen with 109,000 yen in debt and 158,000 yen in capital. With the increase in the values of inventory and debt, the financial health of the company had deteriorated considerably.⁷⁰

Tokyo Electric's profitability was low. Following the opening of its new factory in 1898, its return on assets and asset turnover were highest

68. Tokyo Denki Kabushiki Kaisha, *Jigyō hōkokusho* [Annual report], 1900-1902; Naikaku Tōkeikyoku, *op. cit.*, vol. 20-24 (1901-1905); "Zenkoku dentō tōkei [National lamp statistics]," *Denki no tomo* 133 (August 1902): insert; Tokyo Denryoku, *op. cit.*, 71.

69. Translator's note: Joint stock companies in the Meiji period could be established with as little as one quarter of its nominal capital actually paid to the company by shareholders. Subsequent payments on the shares were determined by a vote of the shareholders.

70. Tokyo Denki Kabushiki Kaisha, *Jigyō hōkokusho* [Annual report], 1896-1904.

in 1899 at 6.4 per cent and 0.6, respectively; they were especially low in 1903, when competition against imported light bulbs became particularly fierce. However, operating margin (return on sales) was relatively high, as Tokyo Electric made profit on the sales of light bulbs. However, the fact that return on assets was comparatively low and that inventory had increased indicates that Tokyo Electric was not successful in expanding its market that corresponded to its expansion of production capacity. (See Table 2 for more details.) In other words, Tokyo Electric's strategy to pursue high quality did not immediately result in better financial outlook for the company.

Table 2: Tokyo Electric's Profitability, 1896-1904

Year	Total Assets (yen)	Total Sales (yen)	Net Profits (%)	Return on Assets (%)	Asset Turnover Ratio	Return on Sales(%)
1896	48,453	18,173	3,641			20.0%
1897	76,906	26,444	6,751	10.8%	0.42	25.5%
1898	97,286	24,801	2,638	3.0%	0.28	10.6%
1899	126,478	69,381	7,120	6.4%	0.62	10.3%
1900	193,294	47,515	8,453	5.3%	0.30	17.8%
1901	222,812	52,992	9,283	4.5%	0.25	17.5%
1902	247,315	53,885	8,436	3.6%	0.23	15.7%
1903	257,768	40,996	-7,773	-3.1%	0.16	-19.0%
1904	261,498	69,410	8,795	3.4%	0.27	12.7%

Note: In addition to light bulb sales, total sales for 1899-1901 includes income from electric subcontracting fees and sales of machinery and parts.

Sources: Tokyo Denki Kabushiki Kaisha, ed., *Jigyō hōkokusho* [Semiannual report], (Tokyo: Tokyo Denki Kabushiki Kaisha, 1896-1904).

From late 1903 to 1904, conditions favorable to Tokyo Electric developed. At the end of 1903, a price agreement was concluded between Tokyo Electric, Okura and Company, and Siemens at 25 to 30 sen per unit. Following the start of the Russo-Japanese War in 1904, shortage in the supply of imported light bulbs resulted from a ten percentage-point increase in import tariffs, shortage of commercial ships, and the rise in shipping charges.⁷¹ In fact, the number of imports

71. Tokyo Denki Kabushiki Kaisha, *Jigyō hōkokusho* [Semiannual report], first half of 1904. According to the Ministry of Finance, import tariffs on electric light apparatus and parts were 10 per cent and lamps, lanterns and parts were 20 per cent according to the 1899 Tariff Rate Law [*kanzei teiritsu hō*]. In 1904, the second extraordinary tariffs following the start of the Russo-Japanese War raised these rates to 15 per cent and 30 per cent, respectively. See ōkurashō [Ministry of Finance], ed., *Meiji taishō zaiseishi* [Meiji and Taishō fiscal history], vol. 8 (Tokyo: Zaisei Keizai Gakkai, 1938), 173-210.

from Germany decreased. However, the impact of revisions in tariffs and the war was limited, because imports from the United States increased. Tokyo Electric's total sales increased to 69,000 yen (see Table 1), but a proposal to increase capital domestically did not pass at its shareholders' meeting. Thus, Tokyo Electric was forced to enter into a partnership agreement with General Electric for its survival and development.⁷²

Structure of the Market and the Shape of the Industry

The main customers of the light bulb manufacturers were large-scale organizations such as electric light companies and institutions with internal power generation. These large-scale customers possessed some capacity to perform tests; thus, in dealing with these customers, poor quality products were identified and eliminated, and these customers were able to pressure the bulb manufacturers to improve their product quality. At the same time, in large volume transactions, if the manufacturer was able to supply good quality products consistently, somewhat higher price levels were tolerated. Tokyo Electric responded to these pressures from the customers and expanded their customer base by developing close alignment between sales and manufacturing and supplying products that met the quality and specification consistent with the customers' preferences for bulb longevity and their operational conditions.

However, the testing capacity of electric light companies and other large-scale users was limited and quite varied, and their purchasing methods varied substantially as well. Even at one of the most important the large-scale customers, the Imperial Navy, its tests could not eliminate all of the products that did not meet its quality standards.⁷³ Also, as mentioned previously, some electric light companies did not study light bulb specifications or quality and attempted to purchase at least cost light bulbs with the longest life span without regard to efficiency. The existence of such customers made easier the entry and survival of domestic manufacturers, including those of poor quality bulbs.

72. Yasui, *op. cit.*, 94-5.

73. Shigeyo Tada, "Wagakuni denki gyōsha no hansei wo unagasu [Calling our country's electric industrialists to reflect]," *Denki no tomo* 201 (February 15, 1908): 294-8.

Light bulbs were sold through multiple, complex channels. Not only were they sold directly from manufacturers or importers to electric light companies but also through multiple layers of domestic wholesalers and retailers of electric appliances. For example, among Tokyo Electric's customers around 1902 were electric light companies, international trade agents as well as electric appliance retailers and electric contractors.⁷⁴ The light bulb manufacturers sought to expand their sales by selling not only to their large-scale customers but also to these wholesalers and agents. Furthermore, some manufacturers and import agents even ventured into retail sales. Some light bulb manufacturers also developed a second line of business in electrical appliance sales. Hakunetsusha, for example, sold light bulbs retails to individuals living near its factory.⁷⁵

The development of the retail market can be inferred also from the fact that electricity theft increased substantially. Electricity theft in this context involves the customer changing the light bulb to one with higher brightness than contracted with the electric light company without the company's knowledge. Such theft began in large cities such as Tokyo and Yokohama and by 1909 it was beginning to increase in other areas as well. Such increase implies the development of a retail market for light bulbs. Individual customers, unlike the large-scale customers, do not have a sophisticated testing capacity, and rely strongly on price as an indicator. Thus, the retail market was a customer base that light bulb manufacturers, including those of poor quality, could develop further.⁷⁶

The structure of the light bulb market around 1900 enabled high quality, high price manufacturers such as Tokyo Electric to survive while also enabling small manufacturers a chance to develop their own niche. The Japanese light bulb industry developed a multi-layered structure, with Tokyo Electric competing against the imports to develop into a premier manufacturer, while smaller manufacturers also began to increase in number.

74. Tokyo Denki Kabushiki Kaisha, *Jigyō hōkokusho* [Annual report], 1902.

75. Yasui, *op. cit.*, 17.

76. Anonymous, "Iwayuru denryoku tōyō," *op. cit.*

Summary

The development of the light bulb industry began in Japan slightly later than in the West, but by 1890, domestic manufacturers such as Hakunetsusha began to develop. As in the United States, barriers to entry in terms of capital and technology were relatively low. The movement of engineers and workers across manufacturers, the spread of industrial engineering education, the publication of trade magazines, the development of related industries, and the import of parts all contributed positively to the development of the industry.

The major customers of the light bulb manufacturers were large-scale customers such as electric light companies. In dealing with large-scale customers with a capacity for product testing, mass production of light bulbs with uniform quality was paramount. Electric light companies tended to emphasize light bulb longevity in product selection. Moreover, electric light companies operated at different operational voltages even when nominally at the same voltage. Tokyo Electric developed mass production techniques and collected data on the operational conditions of various electric light companies, and expanded their market by supplying light bulbs that met the unique operational conditions of each electric light company and by meeting their preference for bulb longevity. At the same time, Tokyo Electric responded to the decline in light bulb prices while maintaining high quality, thereby increasing its market share. However, Tokyo Electric was unable to develop a market that corresponded to its increased production capacity, and its financial condition worsened. In other words, Tokyo Electric's high quality strategy did not immediately lead to an improvement in profitability.

Despite its financial difficulties, Tokyo Electric managed to secure its place in the market; at the same time, smaller scale domestic manufacturers increased. The limitations on product testing capacity on the part of large-scale consumers, the variation in their purchasing practices, the existence of intermediaries in the distribution of light bulbs, and the development of a retail light bulb market all contributed to the entry of small scale manufacturers, including those of poor quality products. The Japanese light bulb industry developed a multi-layered structure, with Tokyo Electric competing against imports and

developing into a major manufacturer, while smaller manufacturers slowly increased.

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