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Science and Technology (Japan)

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Despite its image as a "European" war, the First World War exerted a tremendous influence on science and technology in Japan. The war's impact on Japanese military technology was certainly felt, but it mainly took the form of economic stimuli to Japanese industry, the institutionalization of scientific research and expansion of Japanese higher education in science and engineering, and the realignment of international relations of Japanese scientific communities. The First World War paved the way for Japan to become a fully-fledged scientific and technological world power.

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Introduction

The Japanese government declared war on Germany on 23 August 1914, defying the long distance between Japan and the main battlefields in Europe. In spite of Japan's military engagement in the Asian and Pacific theatres in 1914, Anglo-Japanese naval cooperation in the Mediterranean in 1917 and the Siberian Intervention in 1918-1922, the First World War was very much a European war in

the consciousness of most Japanese, both now and then.[1] This does not mean, however, that the First World War did not have any significant impact on science and technology in Japan. Quite the contrary is the case. Its impact on Japanese military technology was certainly felt, but it mainly took the form of economic stimuli to Japanese industry, the institutionalization of scientific research and expansion of higher education in science and engineering, and the realignment of international relations of Japanese scientific communities.

The Impact on Military Technologies

The First World War has been often dubbed “the Chemists’ War,” which speaks to the huge influence of chemistry on warfare by means of explosives and poison gas. The Japanese case is no exception. In 1915, the Army Technology Review Board (*Rikugun Gijutsu Shinsabu*), as well as army surgeon Chikahiko Koizumi (1884-1945) at the Army Medical College (*Rikugun Gun’i Gakkō*), began to investigate chemical weapons being used in Europe. This led to the inauguration in 1918 of the Chemical Weapons Laboratory at the Army Medical College, led by Koizumi. In 1919, the Army Technical Department (*Rikugun Gijutsu Honbu*) established the Army Institute for Scientific Research (*Rikugun Kagaku Kenkyūjo*) to close in on the massive technological development in warfare during the First World War, including chemical warfare.[2]

Likewise, the war reinforced Japan’s production capabilities of cordite, a smokeless explosive used as gun propellant.[3] The navy had been completely dependent on imports from Britain for cordite until the Russo-Japanese War in 1904-1905. Upon the request of the Japanese navy, the Japanese Explosives Company was established in 1905 with British capital and technology to construct a cordite factory in Hiratsuka, Kanagawa Prefecture. The technology transfer from British to Japanese engineers proceeded smoothly and was complete by the outbreak of the First World War. Its production method was further improved, and its capabilities reinforced, by Japanese engineers with stimulus from the British government’s request to provide cordite during the First World War. The Hiratsuka Factory was transferred to the navy in 1919 and became its explosives arsenal.

The impact of war was not restricted to poison gas and explosives. The Japanese production of optical weapons such as rangefinders, periscopes, battery commander’s telescopes, and optical glass started because the country’s import stopped due to the outbreak of the First World War.[4] The main players here were navy and army arsenals, private companies like the Nippon Kogaku (Japan Optics, today’s Nikon, est. 1917), and physicists like Hantarō Nagaoka (1865-1950) and Seiji Nakamura (1869-1960), both professors of physics at Tokyo Imperial University. The navy arsenal introduced a new optical design technology from Britain, whereas the Nippon Kogaku invited German engineers for technology transfer. The R&D of optical weapons in the navy and army became a remit of the Navy Institute for Technological Research (*Kaigun Gijutsu Kenkyūjo*, est. 1923) and the Army Institute for Scientific Research. The optical industry in Japan became self-reliant by the late 1920s. This last example points to a widely observed pattern of how the First World War affected Japanese industries: international trade interruption due to war encouraged domestic production in

many industrial sectors.

Effects on Heavy and Chemical Industries

Japanese industrialization began in earnest soon after the Meiji Restoration in 1868. Technological development was led by textile industries such as reeling, spinning, and weaving, but their efforts to penetrate Asian markets faced competition from European and American counterparts. The First World War brought a wartime economic boom to Japanese industry due to the drastic reduction of European and American goods into Asian markets.[5] The textile industry was not the only beneficiary of this wartime boom: shipbuilding no longer needed to be subsidised, and railway vehicle, automobile, and airplane industries took off in Japan in this period.[6]

However, the First World War was a mixed blessing for Japanese industry, for it caused a serious shortage of raw materials such as steel for the fledging heavy and chemical industries. The Allied blockade of German products, especially chemicals, exacerbated the situation. Against this backdrop, the Japanese government created several “study commissions” (*chōsakai*) to analyse and discuss policies to protect and further develop Japanese industry *in toto* as well as strategically important branches of it, e.g., the chemical, pharmaceutical and steel industries. For example, based on recommendations by the Steel Industry Study Commission (est. 1916), a law was enacted in 1917 to extend tax and duty waivers and subsidies to national as well as to private steel companies. As a result, private steel companies mushroomed in Japan during the First World War.[7]

One of the most consequential of such study commissions was the Chemical Industry Study Commission (*Kagaku Kōgyō Chōsakai*).[8] It was instituted by the Ministry of Agriculture and Commerce in October 1914 at the request of the Tokyo Chamber of Commerce (*Tokyo Shōgyō Kaigisho*) and the Society of Chemical Industry of Japan (*Kōgyō Kagakukai*). Its members consisted of senior chemical technologists and chemists at universities, higher technical schools, and national research institutes, including Toyokichi Takamatsu (1852-1937) and Joji Sakurai (1858-1939).

The commission’s discussions were focused on three major areas: synthetic organic chemistry (e.g. dyestuff and pharmaceutical industries), the ammonia soda industry, and the electrochemical industry. In each of these, the commission’s recommendations had substantial impact, creating a whole industry (synthetic organic chemistry), providing technical information and academic contacts for wartime and post-war development by private companies (ammonia soda industry),[9] and accelerating the existent R&D at the (Tokyo) Industrial Laboratory and broadening the scope of the industry (electrochemical industry).

The impact of the war on the chemical industry in Japan became apparent in other ways as well.[10] The Paris Economic Conference in June 1916 triggered a discussion within the Ministry of Agriculture and Commerce and the army on the need to domestically industrialise the production of ammonia by the Haber-Bosch process, and of nitric acid by the Ostwald process, for the sake of the

post-war economy. Based on this discussion, the Temporary Nitrogen Research Institute (*Rinji Chisso Kenkyōjo*) was established in 1918. The institute eventually succeeded in developing a production method using a new type of iron catalyst, which was industrialised by the Showa Fertilizer Company (*Showa Hiryō*) in 1931.

The Institutionalisation of Scientific Research and the Expansion of Higher Education

The remit of the Chemical Industry Study Commission was not limited to strictly industrial issues. One of the agendas was a proposal for establishing an Institute of Chemical Research to promote original basic research, submitted by Sakurai in December 1914.[11] It led to the establishment of the Institute of Physical and Chemical Research or *Rikagaku Kenkyūjo* (RIKEN), which has been widely considered as one of the most important scientific research institutes in Japan since its inception in 1917. The movement towards the establishment of the RIKEN started before the First World War.[12] In April 1913, the US-based Japanese industrial chemist Jōkichi Takamine (1854–1922) proposed the founding of a national institute for scientific research (*Kokumin Kagaku Kenkyūjo*) by drawing on his own observation of American examples, such as the Carnegie Institution for Science (est. 1902), and his knowledge of the Kaiser Wilhelm Society in Germany (est. 1911). Takamine's main point, as well as that of later proponents of the RIKEN, was what we now call the "linear model" of science and technology, which argues that basic scientific research is essential for technological development. It aroused considerable interest among Japanese chemists, including Takamatsu and Sakurai, as well as businessman Eiichi Shibusawa (1840-1931) and politician Shigenobu Ōkuma (1838-1922), who became prime minister in April 1914. Takamine's idea was turned into a petition to establish an institute for chemical research (*Kagaku Kenkyūjo*), which was submitted to the Lower House of the Imperial Diet in March 1914. Yet the movement reached a deadlock due the outbreak of the war.

For Sakurai, however, the First World War was actually a "blessing from heaven."[13] Not only did the war highlight the shortage of raw materials for industries, but news, observations, and discourse from abroad on how science and technology revolutionised warfare during the First World War gave powerful rhetoric to those who advocated creating a research institute, crystallised in Sakurai's dictum: "Today's war is the war of applying physics and chemistry."[14] Sakurai's proposal above to the Chemical Industry Study Commission was to resuscitate the movement, which was redirected in March 1915 toward establishing an institute for physical and chemical research by involving physicists like Aikitsu Tanakadate (1856-1952) and Nagaoka. The RIKEN was established in March 1917 after fundraising and lobbying effort to industrialists, politicians, and the Imperial household by, among others, Shibusawa, Sakurai, and Minoru Nagaoka, bureaucrat of the Ministry of Agriculture and Commerce who originally suggested including physical research in RIKEN's mission.[15]

Another important development took place during the First World War for the institutionalization of scientific research in Japan: the emergence of the research institute attached to a university, or

daigaku fuchi kenkyūjo (*fuchiken*).[16] This new type of institution had a legal status (by means of an imperial ordinance), personnel, and budget separate from its parent university, meaning that such institutes could concentrate their effort on research. The first *fuchiken*, the Institute of Infectious Diseases attached to Tokyo Imperial University (*Tokyo Teikoku Daigaku fuchi Densenbyō Kenkyūjo*), was established in 1916 following the controversial transfer of the institute from the Ministry of Home Affairs to the Ministry of Education.[17] The second one, the Aeronautical Research Institute (*Kōkū Kenkyūjo*), also attached to Tokyo Imperial University, had more direct connections with the war. Its antecedent, Aeronautical Research Institute, Tokyo Imperial University, was established in 1918 and gained *fuchiken* status in 1921. The movement to establish this institute had started soon after the outbreak of the First World War. Its leaders, Tanakadate and his former teacher and president of Tokyo Imperial University, Kenjirō Yamagawa (1854-1931), took advantage of public interest triggered by the extensive use of airplanes for war purposes in Europe as one of their primary rationales for establishing such an institute.

This institutional format, the *fuchiken*, later spread to other imperial universities and became a model for increasing the research capabilities of universities. For example, the Research Institute for Iron, Steel and Other Metals (*Kinzoku Zairyō Kenkyūjo*, today's Institute for Materials Research), Tohoku Imperial University, was established in 1922, and the Institute for Chemical Research (*Kagaku Kenkyūjo*), Kyoto Imperial University, in 1926, both with *fuchiken* status. Notably, these two institutes have their origins in war-related research projects during the First World War: the invention of KS Steel in 1917 by Kōtarō Honda (1870-1954), and the R&D of Salvarsan, a drug used for the treatment of syphilis and previously imported from Germany, in 1915 by Mitsuru Kuhara (1856-1919).

Schemes to provide research grants also started to develop during the First World War.[18] The Ministry of Agriculture and Commerce inaugurated the Grant for the Promotion of Inventions (*Hatsumei Shōreihi*) in 1917, and the Ministry of Education the Grant for the Promotion of Scientific Research (*Kagaku Kenkyū Shōreihi*) in 1918, both of which provided individual researchers with modest funding. They were the only funding schemes offered by government ministries until the advent of the much larger Grant-in-Aid for Scientific Research (*Monbushō Kagaku Kenkyūhi*) in 1939. At this time, private foundations also started to provide research funding, such as the Keimeikai (est. 1918), Harada Sekizenkai (est. 1920), and Saitō Hō'onkai (est. 1923).

The above attempts at increasing research capabilities had their parallel in the expansion of higher education in science and engineering to train technical experts. They were both underpinned by the public awareness, shaped by the First World War, that science and technology had become a driving force of modern warfare. As a result, engineering became a promising, sought-after profession for many Japanese, and led to the expansion of higher education in engineering between 1818 and 1924.[19] Likewise, a new imperial university, Hokkaido Imperial University, was established in 1918 with the Faculty of Agriculture, which has its origin in the Sapporo Agricultural College (est. 1875).[20] It was soon followed by the massive expansion of higher education, with four new faculties at

imperial universities, ten new higher schools (preparatory schools for imperial university entrants), six new higher technical higher schools, four agricultural higher schools, seven commercial higher schools, and one pharmaceutical higher school and foreign language school each. This expansion started in 1918 under the Takashi Hara (1856-1921) administration and was completed by 1927.

Realigning the International Relations of Japanese Scientific Communities

Arguably, those Japanese whose lives were most directly affected by Japan's entry into the First World War were overseas students and researchers working in Germany. In the 1870s, more overseas students despatched from the Japanese Ministry of Education went to Britain or the United States rather than to Germany. From the 1880s onwards, the overwhelming majority, especially in medicine, science, and agriculture, chose Germany as their destination of study. They suddenly found themselves in an enemy country and had to move to the United States, a neutral country until 1917, by the order of the Japanese government.[21] This leads to the fourth aspect of the impact of war on Japanese science and technology, the realignment of the international relations of Japanese scientific communities.

The First World War severely disrupted the international cooperation of scientists, making international scholarly organizations such as the International Association of Academies (est. 1899) and International Association of Chemical Societies (est. 1911) defunct.[22] To discuss the post-war reconstruction of international cooperation, scientists from allied countries held two Interallied Conferences of Scientific Academies at the Royal Society in London in October 1918 and at the Académie des sciences in Paris in November 1918. Its outcome was the International Research Council (IRC), established in Brussels in July 1919. The IRC was conceived as an umbrella organization to coordinate research in different nations and in different disciplines, so its members consisted of national research councils or academies and discipline-based international unions, including the International Union of Pure and Applied Chemistry (IUPAC, est. 1919) and International Union of Geodesy and Geophysics (IUGG, est. 1919).

The IRC adopted the controversial policy of temporarily not accepting members from former Central Powers countries such as Germany and Austria, the so-called "German exclusion policy." Things did not change much until after the IRC was reorganised into the International Council of Scientific Unions (ICSU) in 1931.[23] The two delegates to the two interallied conferences from the Imperial Academy (*Teikoku Gakushiin*), Tokyo, were Sakurai and Tanakadate. They, and especially Sakurai, supported the German exclusion policy and came under fire from pro-German colleagues such as Matarō Nagayo (1878-1941), professor of pathology at Tokyo Imperial University. After prolonged and heated discussion, Sakurai and Tanakadate eventually succeeded in establishing the National Research Council of Japan, or *Gakujutsu Kenkyū Kaigi* (GAKKEN) in August 1920 as the Japanese national member of the IRC for the purpose of "coordinating research in science and its application both domestically and internationally, and to promote and encourage research."[24] This meant that

Japanese scientists of all disciplines would officially represent national scholarly communities in international congresses through the GAKKEN, which drew its members from academia, government (mostly from industrial and agricultural research institutes), and the military.

A major concern of the Japanese scientists who criticised Sakurai and Tanakadate was the possibility that Japan's support of the IRC cause might displease German professors and make overseas studies in Germany difficult or even impossible even after the First World War had ended.[25] Their fears did not come true: Japanese overseas students and researchers returned *en masse* to Germany after the war. In 1920-1924, out of 727 overseas students despatched from the Ministry of Education, 596 went to Germany.[26] At the same time, the destinations of overseas students had also diversified since the end of war, and the United States emerged as their major destination, on par with Germany. Six hundred and twenty-one students visited the States in the aforementioned period.[27] Equally important is the official disconnection of the Japanese scientific communities from their German counterparts until Germany was officially admitted to international unions (in 1930 in IUPAC's case) and well after the IRC was reorganised into the ICSU. As James Bartholomew succinctly put it, the establishment of the GAKKEN "best exemplified the growing independence of Japanese science" and "helped liberate Japanese science from its obsession with Germany."[28]

Conclusion

Examples discussed in the above sections amply demonstrate that the First World War brought Japanese academia, government, military, and industry closer, paving the way for Japan to become a fully-fledged scientific and technological world power. Yet it was a tortuous path, due primarily to the re-entry of goods from Europe and the United States into the market and a long economic recession in post-war Japan, followed by the devastating Great Kantō Earthquake in 1923 and the Great Depression in 1929. For example, the industrialisation of the ammonia-soda process and ammonia synthesis in Japan, both mentioned in this essay, did not bear fruit economically until the 1930s.[29] Likewise, the RIKEN, Tohoku's Research Institute for Iron, Steel and Other Metals, and Kyoto's Institute for Chemical Research suffered from chronically inadequate government budgets and donations and partly had to support themselves by selling R&D products.[30] Thus, the next leap in the development of Japanese science and technology would be in the 1930s, further exemplified by the Japan Society for the Promotion of Science (*Nihon Gakujutsu Shinkōkai*) established in 1932, just one year after the Manchurian Incident in 1931, amid rising Japanese militarism.

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Notes

1. ↑ Yamamuro, Shin'ichi: Fukugō sensō to sōryokusen no dansō. Nihon ni totteno Daiichiji Sekai Taisen (Faultline between complex and total war. World War I from the perspective of Japan), Kyoto 2011, Jinbun Shoin, pp. 9-11; Inoue, Juichi: Daiichiji Sekai Taisen to Nihon (The First World War and Japan), Tokyo 2014: Kōdansha, p. 6.
2. ↑ Grunden, Walter E.: Secret Weapons and World War II: Japan in the Shadow of Big Science, Lawrence, Kan. 2005: University Press of Kansas, pp. 167-170; Tanaka, Hiroaki: Nihon no dokugaku sen no rekishi (History of Japanese gas warfare), in: Kagakushi 38/4, December, 2011, pp. 210-220. In 1923, the Army Institute for Scientific Research was divided into three departments, of which Department 3 was devoted to chemical warfare.
3. ↑ Nagura, Bunji: Daiichiji Sekai Taisen ki no Nihon Bakuhatsubutsu Kaisha to gijutsu iten (The Japanese Explosives company and Technology Transfer during World War I: The Relationship between the British Government and the Shareholders), in Gunrjishigaku 46/4, March 2011, pp. 61-78.
4. ↑ Hiroshige, Tetsu: Kagaku no shakaishi. Kindai Nihon no kagaku taisei (Social History of Science. Scientific Research System in Modern Japan), Tokyo 1973: Chūō Kōronsha, p. 86; Ikegami, Shunzō: Nihon no kōgaku kōgyō ni okeru gijutsu iten. Kokusan sokkyogi no kenkyū kaihatsu o tsūjite (1913 nen – 1923 nen) (Technology transformation of the optical industry in Japan. Research and development of Japanese rangefinders, 1913-1927), in Kagakusi kenkyu, Series II, 47/3, September, 2008, pp. 129-139.
5. ↑ Kamatani, Chikayoshi / Tsūshō Sangyōshō (ed.): Shōkō seisakushi. Dai 13 kan: Kōgyō gijutsu (History of Commercial and Industrial Policies in Japan. Vol. 13: Industrial technology), Tokyo 1979: Shōkō Seisakushi Kankōkai, pp. 177-179 and 191; Gordon, Andrew: A Modern History of Japan: From Tokugawa Times to the Present, 3rd Edition, Oxford 2014: Oxford University Press, pp. 139-144.
6. ↑ Kamatani, Shōkō 1979, 204-208. For unexpected impact of war on many other industrial sectors in Japan, see, for example, Tajima, Natsuko: Sensō ga motarashita seihan insatsujutsu no gijutsu kakushin. Taishōki no Nihon insatsukai to Daiichiji Sekai Taisen Posutā (Technical Innovation of Plate-making and Printing Techniques by the War. Japanese Printing World in Taisho Era and the World War I Posters), in: Mediashi kenkyū 37, March 2015, pp. 69-93.
7. ↑ Kamatani, Shōkō 1979, 202-204.
8. ↑ For the next two paragraphs, see Kamatani, Chikayoshi: Gijutsu taikoku hyakunen no kei. Nihon no kindaika to kokuritsu kenkyū kikan (Long-term plan for a technological power. Japanese Modernization and government research institutes), Tokyo 1988: Heibonsha, pp. 180-198.
9. ↑ See also Miura, Yūichi: Iwase Tokusaburō to Ochi Shu'ichirō. Tokuyama ni okeru anmonia sōda kōgyōshi ([Chemical technologists] Tokusaburō Iwase and Shu'ichirō Ochi. History of the development of the ammonia-soda process at Tokuyama [Nihon Sōda]), in Kagakushi 42/3, October, 2015, pp. 117-130.

10. ↑ Kameyama, Tetsuya: Nihon saisho no ōgata purojekuto wa ikanishite suikō saretaka. Rinji Chisso Kenkyūjo ni tsuite (How the first big project was carried out in Japan? On the Provisional Nitrogen Research Institute), in: Yoshimoto, Hideyuki, et. al.: Kagaku to kokka to shūkyō, Tokyo 1995: Heibonsha, pp. 252-276; Kameyama, Tetsuya: Kokusan gijutsu ni yoru anmonia gōsei no kaihatsu to kigyōka (Development and commercialization of Ammonia Synthesis by Japanese domestic technology), in: Kagaku to kyōiku 64/1, January, 2016, pp. 12-15.
11. ↑ Kamatani, Gijutsu 1988, 199-222; Kikuchi, Yoshiyuki: World War I, International Participation and Reorganization of the Japanese Chemical Community, in: Ambix 58/2, July, 2011, pp. 136-149, on pp. 139f.
12. ↑ Kamatani, Gijutsu 1988, 199-222 and Kikuchi, World War I 2011, 139f.
13. ↑ Bartholomew, James R.: The Formation of Science in Japan. Building a Research Tradition, New Haven, Conn. 1989: Yale University Press, 199.
14. ↑ Kikuchi, World War I 2011, 139.
15. ↑ Kamatani, Gijutsu 1988, 210.
16. ↑ Kamatani, Chikayoshi: Daiichiji Taisen to kenkyū taisei no kōchiku. Aratana COE toshiteno daigaku fuchiken (World War I and the construction of a scientific research system. The research institute attached to an imperial university as a new type of COE), in: Yoshimoto, Hideyuki, et. al.: Kagaku to kokka to shūkyō, Tokyo 1995: Heibonsha, pp. 218-251.
17. ↑ Bartholomew, The Formation 1989, 201-212.
18. ↑ Hiroshige, Kagaku 1973, 102f and 154; Bartholomew, The Formation 1989, 247-254; Hashimoto, Takehiko: The Hesitant Relationship Reconsidered. University-Industry Cooperation in Postwar Japan, in: Branscomb, Lewis M., et al.: Industrializing Knowledge: University-Industry Linkages in Japan and the United States, Cambridge, Mass. 1999: The MIT Press, pp. 234-251.
19. ↑ Nishiyama, Takashi: Engineering War and Peace in Modern Japan, 1868-1964, Baltimore, Md. 2014, Johns Hopkins University Press, pp. 14-15.
20. ↑ Hiroshige, Kagaku 1973, 97-100
21. ↑ Tsuji, Naoto: Kindai Nihon kaigai ryūgaku no mokuteki hen'yō. Monbushō ryūgakusei no haken jittai ni tsuite (Transformation of the rationale for Overseas Studies in Modern Japan. On the actual situation of overseas students despatched from the Japanese Ministry of Education), Tokyo 2010: Tōshindō, pp. 50-57 and 145.
22. ↑ Kevles, Daniel J.: 'Into Hostile Political Camps': The Reorganization of International Science in the First World War, in Isis 62, 1971, pp. 47-60. Schroeder-Gudehus, Brigitte: Les scientifiques et la paix: La communauté scientifique international au cours des annés 20, Montreal 1978: Les Presses de L'Université de Montréal.
23. ↑ Greenaway, Frank: Science International. A History of the International Council of Scientific Unions, Cambridge 1996: Cambridge University Press, p. 40.
24. ↑ Kikuchi, World War I 2011, 140-146; Kikuchi, Yoshiyuki: An Emperor's Chemist in War and Peace. Sakurai Jōji during the Russo-Japanese War and World War I, in: Wittner, David G. / Brown, Philip C. (eds), Science, Technology, and Medicine in the Modern Japanese Empire, London; New York 2016: Routledge, pp. 50-61, on pp. 56f.
25. ↑ Bartholomew, The Formation 1989, 260; Tsuji, Kindai 2010, pp. 171-173.
26. ↑ Tsuji, Kindai 2010, 51.
27. ↑ *Ibid.*

28. ↑ Bartholomew, The Formation 1989, p. 254.
29. ↑ See the references in Notes 10 and 11.
30. ↑ On the effort of the third president of RIKEN, Masatoshi Ōkōchi (1878-1952) to reform the RIKEN and improve its financial standing by establishing the so-called RIKEN Concern, see, e.g., Saito, Ken: Ōkōchi Masatoshi. Kagaku gijutsu ni shōgai o kaketa otoko (Masatoshi Ōkōchi. The Man who devoted the whole life to Science and Technology), Tokyo 2009: Nihon Keizai Hyōronsha. On the situation of Tohoku and Kyoto institutes, see Kamatani, Daiichiji 1995, pp. 246 and 248f.

Selected Bibliography

Bartholomew, James R.: **The formation of science in Japan. Building a research tradition**, New Haven 1989: Yale University Press.

Grunden, Walter E.: **Secret weapons and World War II. Japan in the shadow of big science**, Lawrence 2005: University Press of Kansas.

Hiroshige, Tetsu: **Kagaku no shakaishi. Kindai Nihon no kagaku taisei (Social history of science. Scientific research systems in modern Japan)**, Tokyo 1973: Chūō Kōronsha.

Ikegami, Shunzō: **Nihon no kōgaku kōgyō ni okeru gijutsu iten. Kokusan sokkyogi no kenkyū kaihatsu o tsūjite (1913 nen – 1923 nen) (Technology transformation of the optical industry in Japan. Research and development of Japanese rangefinders, 1913-1927)**, in: Kagakusi kenkyu, Series 2 47/3, 2008, pp. 129-139.

Inoue, Juichi: **Daiichiji Sekai Taisen to Nihon (The First World War and Japan)**, Tokyo 2014: Kōdansha.

Kamatani, Chikayoshi: **Gijutsu taikoku hyakunen no kei. Nihon no kindaika to kokuritsu kenkyū kikan (Long-term plan for a technological power. Japanese modernization and government research institutes)**, Tokyo 1988: Heibonsha.

Kamatani, Chikayoshi: Dai ichiji Taisen to kenkyū taisei no kōchiku. Aratana COE toshiteno daigaku fuchiken (World War I and the construction of a scientific research system. The research institute attached to an imperial university as a new type of COE), in: Yoshimoto, Hideyuki, et. al.: Kagaku to kokka to shūkyō, Tokyo 1995: Heibonsha, pp. 218-251.

Kamatani, Chikayoshi / Tsūshō Sangyōshō (eds.): **Shōkō seisakushi. Dai 13 kan. Kōgyō gijutsu (History of commercial and industrial policies in Japan. Industrial technology, volume 13)**, Tokyo 1979: Shōkō Seisakushi Kankōkai.

Kameyama, Tetsuya: **Kokusan gijutsu ni yoru anmonia gōsei no kaihatsu to kigyōka (The development and commercialization of ammonia synthesis by Japanese domestic technology)**, in: Kagaku to kyōiku 64/1, 2016, pp. 12-15.

Kameyama, Tetsuya: Nihon saisho no ōgata purojekuto wa ikanishite suikō saretaka. Rinji Chisso Kenkyūjo ni tsuite (How the first big project was carried out in Japan. On the Provisional Nitrogen Research Institute), in: Yoshimoto, Hideyuki, et. al.: Kagaku to kokka to shūkyō, Tokyo 1995: Heibonsha, pp. 252-276.

Kikuchi, Yoshiyuki: **World War I, international participation and reorganisation of the Japanese chemical community**, in: Ambix 58/2, 2011, pp. 136-149.

Kikuchi, Yoshiyuki: **An emperor's chemist in war and peace. Sakurai Jōji during the Russo-Japanese War and World War I**, in: Wittner, David G. / Brown, Philip C. (eds.): Science, technology, and medicine in the modern Japanese Empire, London; New York 2016: Routledge, pp. 50-61.

Miura, Yūichi: **Iwase Tokusaburō to Ochi Shu'ichirō. Tokuyama ni okeru anmonia sōda kōgyōshi (Tokusaburō Iwase and Shu'ichirō Ochi. History of the development of the ammonia-soda process at Tokuyama)**, in: Kagakushi 42/3, 2015, pp. 117-130.

Nagura, Bunji: **Daiichiji Sekai Taisen ki no Nihon Bakuhatsubutsu Kaisha to gijutsu iten (The Japanese Explosives Company and technology transfer during World War I. The relationship between the British government and the shareholders)**, in: Gunjishigaku 46/4, 2011, pp. 61-78.

Tajima, Natsuko: **Sensō ga motarashita seihan insatsujutsu no gijutsu kakushin. Taishōki no Nihon insatsukai to Daiichiji Sekai Taisen Posutā (Technical innovation of plate-making and printing techniques by the war. Japanese printing world in Taisho era and the World War I posters)**, in: Mediashi kenkyū 37, 2015, pp. 69-93.

Tanaka, Hiroaki: **Nihon no dokugaku sen no rekishi (History of Japanese gas warfare)**, in: Kagakushi 38/4, 2011, pp. 210-220.

Yamamuro, Shin'ichi: **Fukugō sensō to sōryokusen no dansō. Nihon ni totte no Daiichiji Sekai Taisen (Faultline between complex and total war. World War I from the perspective of Japan)**, Kyoto 2011: Jinbun shoin.

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