The Department for Arms Production of the University of Tokyo and the beginnings of the Japanese precision machine industry (1930–1960)*

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Abstract

This paper focuses on the contribution of university professors to the development of the Japanese precision machine industry (watches, cameras, sewing machines). They played a key role in this process, at first while training a new generation of production engineers who were hired after the war by precision machine firms, but also through their research on the improvement of the quality of machine tools and the precision of parts. The present article focuses on two professors of the Department for Arms Production (*zohei gakka*; renamed the Department of Precision Engineering after 1945, *seimitsu kikai kogakka*) of the University of Tokyo, Aoki Tamotsu and Okoshi Makoto, both of whom were instrumental in modernizing companies in the precision machine industry between 1930 and 1960.

Classification codes: N65, N85, O32, O38

Keywords: War production, precision machine industry, The University of Tokyo

Introduction

In the years following the end of World War II, precision machines became one of Japan's main exports to the world market. While heavy industry was restructuring and several other sectors were geared to the domestic market, there was strong growth in the export of precision machines, designed to bring in the foreign currencies necessary for rebuilding the country's economy.[1]

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1 On the history of the Japanese precision machine industry, see Sawai Minoru, "Paneru hokoku: 1950-60 nendai no keikikai kogyo: kozo to yakuwari", *Keieishigaku*, Vol. 41 No. 4 (2007), pp. 35-40 and *Nihon no keikikai kogyo*, Tokyo: MITI, 1958.

Tab. 1: Part of the production exported in the Japanese precision machine industry, as a % of value, 1937-1965

	1937	1950	1955	1960	1965
Sewing machines	6.9	96.9	70.1	45.9	34.6
Cameras	9.6	18.1	16.7	28.8	39.9
Watches	1.4	5.5	0.7	1.5	15.8

Source: Dainihon gaikoku boeki, *1937-1965 (exports);* Kogyo tokeihyo, *1937-1965 (production)*
Note: 1939 instead of 1937 for sewing machines (they are not included in the official production surveys before 1939)

The arrival of these products on the world market occurred gradually, at first with sewing machines, from the end of the 1940s onwards, then cameras, in the 1950s, and finally watches, in the 1960s (see table 1). These various sectors had their own dynamics, characterized notably by a tendency towards withdrawal to the domestic market for sewing machines and a late expansion of watches towards the world market. The withdrawal of sewing machines as shown in this table should however be qualified by the fact that 1950 and 1955 were peak export years – for the entire period 1951–1955 they accounted for 51.3% of overall production – on the one hand, and that they were primarily meant for foreign markets at the end of the 1940s rather than the domestic market, where the demand was not sufficiently high yet, on the other hand.[2] As for watches, they stood out on account of their late arrival on the world market compared to other precision machines, a phenomenon essentially due to the growing expansion of the domestic market and the difficulties encountered in perfecting a product that could compete with Swiss watches.[3] Nevertheless, beyond these sectoral specificities, the precision machine industry as a whole presents a similar profile, as it was an industry hardly geared to exports before the war which became a major player on the world market after 1945. At the peak of its commercial expansion before the war, in 1937, this industry exported less than 10 per cent of its production. It was not competitive with either Singer sewing machines or foreign-made cameras and watches, either mass-produced (United States) or high-quality goods (Germany, Switzerland).

In view of these conditions, the changeover of these sectors into an export industry was not a self-evident phenomenon. In the international literature, this change has not been tackled very much and has usually been presented as either the consequence of the State's industrial policy at a macroeconomic level (protection of the domestic market, support of exports) or the result of factors coming under classical theory, such as the expansion of demand through access to the American market.[4] This contribution focuses on the changes in the production system in the precision machine industry and is consistent with an approach close to the revisionist school, which highlights the key

[2] See *Nihon mishin sangyoshi*, Tokyo: Nihon mishin kyokai, 1961 and Hondai Susumu, "Keikikai kogyo no hatten to buhin no kikaku hyojunka – sekiyu hatsudoki to mishin no jirei", *Daito bunka daigaku kiyo, shakai-shizenkagaku*, 23 (1985), pp. 252–267.

[3] *Seiko no sengoshi*, Tokyo: Seiko, 1996.

[4] The most widely known example being Johnson Chalmers, *MITI and the Japanese Miracle: The Growth of Industrial Policy, 1925–1975*, Stanford: Stanford University Press, 1982. For the camera industry, see Nelson Patricia Ann, *Rivalry and Cooperation: How the Japanese Photography Industry Went Global*, University of Warwick, unpublished PhD thesis, 1998.

role of the State while emphasizing elements of public intervention other than so-called industrial policy. Indeed, the State played a key role by training engineers at universities and its numerous R&D centers, enabling the precision machine industry to become competitive on the world market.

For this industry, the issue was not to recover after the war any markets lost due to the conflict but rather to boost competitiveness by improving its production system, with a view to manufacturing products whose quality and cost made it possible to challenge first movers. In the sewing machines sector, the mass production of a copy of a Singer machine – followed by the introduction of Swiss and German innovations – within a production system based on a pronounced vertical division of labor ensured the quick success of this industry against the American multinational.[5] In the camera and watch industry, the situation of the world market was more complex, as it was relatively polarized between expensive high-quality products made in Germany and Switzerland and simple and cheap mass-produced goods turned out in the United States. The issue for Japanese manufacturers was to incorporate some elements from both of these production systems and to mass-produce high-quality goods, such as single-lens reflex cameras and self-winding watches, within what can be called a hybrid production system.[6]

This change was made possible by the intervention of production engineers, who restructured production within enterprises by introducing new technologies relying on standardized work (blueprints with tolerance norms, measuring instruments) and high-quality parts (precision machine tools). These engineers were already present in several industrial sectors before 1945, for example aeronautics and machine tools, where they restructured the production system.[7] In the precision machine industry, however, they were largely absent, a fact that can explain the lack of competitiveness of this industry's products in the second part of the 1930s. Their arrival in mass after the war was due to the development of the training of production engineers in the interwar years and World War II. Indeed, the growing needs of the arms industry led to the development of engineering faculties to meet the demands of Army and Navy armories and shipyards. Among these training centers, there was the Department for Arms Production (DAP) of the Faculty of Engineering of the University of Tokyo, which is the subject of this contribution.[8] It played a key role in training engineers for the arms industry until 1945, and was redirected after the war towards the precision machine industry.

1. From the Department for Arms Production (DAP) to the Department of Precision Engineering (DPE)

The Department for Arms Production (*Zohei gakka*, DAP) was one of the ten departments of

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5 *Nihon mishin sangyoshi*, op. cit., pp. 192–222.

6 Donzé, Pierre-Yves, "The hybrid production system and the birth of the Japanese specialized industry: Watch production at Hattori & Co. (1900–1960)", *Enterprise & Society*, vol. 12 No.2, forthcoming in 2011.

7 Maeda, Hiroko, *Senjiki kukoki kogyo to seisan gijutsu hensei – Mitsubishi kuko enjin to Fukao Junji*, Tokyo: Tokyo University Press, 2001 and Yamashita, Mitsuru, *Kosakukikai sangyo no shokubashi, 1889-1945 – Shokunin waza ni idonda gijutsushatachi*, Tokyo: Waseda University Press, 2002.

8 Germany and Japan seem to be the only countries to have had university departments specialized in arms production. *Tokyo daigaku hyakunenshi – bukyokushi*, Tokyo: Tokyo University Press, 1984, vol. 3, p. 238.

the Faculty of Engineering of the University of Tokyo.[9] Opened in 1887 to train engineers for the armories of the Army and the Navy, in the interwar period it underwent a process of diversification and specialization that led it to tackle mass production systems and the precision machine industry.

Until the beginning of the 1920s, the department was successively directed by Amano Tomitaro (1887–1903) and then by Okouchi Masatoshi (1903–1926), backed up by lecturers sent by the Army and the Navy. The main interests were artillery, ballistics and the production of explosives. The manufacture of mines and torpedoes led to the creation of a second chair specialized in this field, entrusted to lecturers (1901) and then to Professor Aoki Tamotsu (1911). The production of torpedoes, considered until World War II as one of the most complex precision machines, was then entrusted to a third chair specialized exclusively in this field, occupied by Aoki (1920) and then by Nishimura Genrokuro (1943). At the same time, the second chair pursued its work on mines, extending it to cover new fields such as optical instruments, where teaching was provided by Assistant Professor Majima Masaichi (1920).[10] In 1928, the second chair was reorganized and redirected towards the production of precision machines, with several specialized lecturers (optics, radars, mines, etc.) under the guidance of Professor Aoki. In addition, the production of weapons (cannons, tanks, special arms) was separated from the first chair and became the fourth chair, headed by Majima (1921), Okoshi Makoto (1941) and then by Shibata Haruhiko (1944). Finally, a fifth chair was created in 1944, for the production of precision arms, under the direction of Okoshi. Until the end of the war, the DAP thus played a key role in training engineers for the arms industry.

After 1945, the DAP was reorganized and redirected towards precision machines and was renamed the Department of Precision Engineering (*Seimitsu kogakka*, DPE). It consisted of only three chairs, occupied until the beginning of the 1960s by Aoki Tamotsu, Okoshi Makoto and Nishimura Genrokuro. Each year, the DPE welcomed 17 new students, mainly destined to enter precision machine firms. It maintained this structure until 1963, when it was restructured and enlarged to answer the new needs of this industry (automation, medical instruments, mechatronics, etc.).[11]

From the late 1920s to the early 1960s, the DAP / DPE presents a certain continuity as regards the level of the staff and the interest in precision machines. R&D activities and teaching on the introduction of a new production system in the arms industry were applied after the war to the precision machine industry. The careers of Professors Aoki and Okoshi were emblematic of this path.

2. From torpedoes to watches: Aoki Tamotsu (1882–1966)

Born in 1882, Aoki trained at the DAP under the guidance of Okouchi Masatoshi and graduated in 1908.[12] He became Assistant Professor in this department in 1909 and was entrusted with lecturing on torpedoes and mines, a field in which he specialized. After a two-year stint in the United States, France

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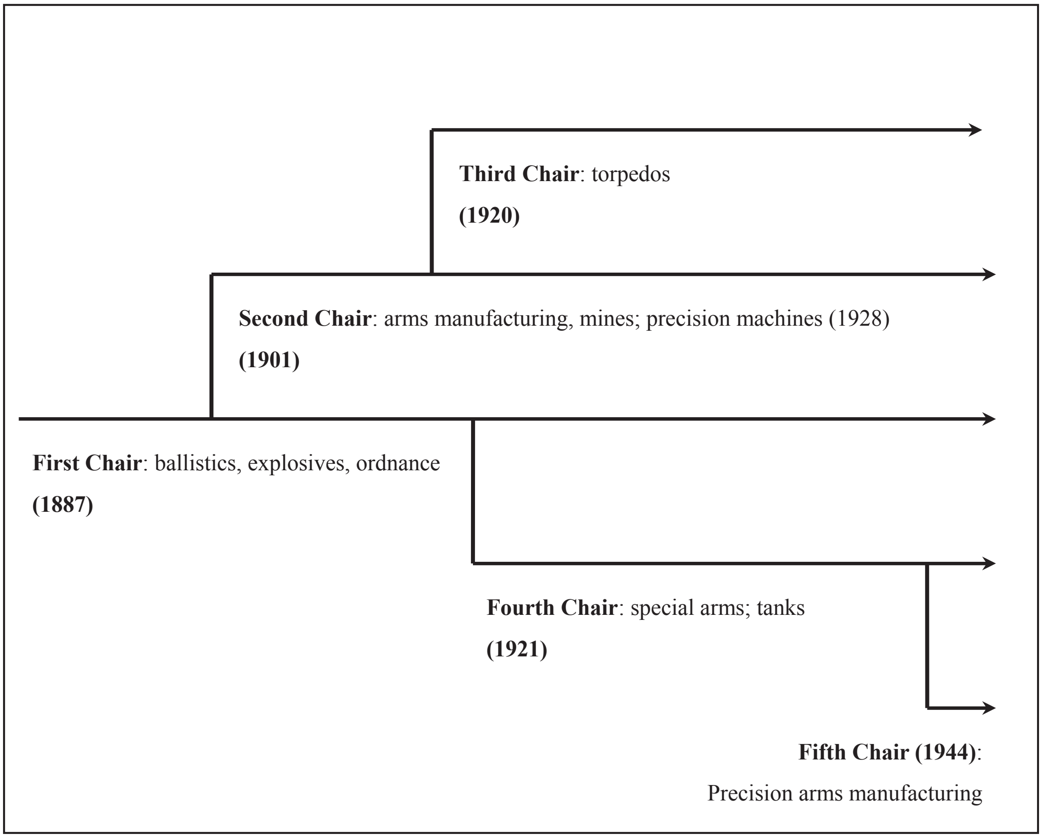
9 The others are aeronautics, applied chemistry, architecture, civil engineering, electricity, machines, metallurgy, mines and shipbuilding.

10 http://kotobank.jp (site accessed 19 June 2010). He especially carried out R&D in the field of radars.

11 *Tokyo daigaku hyakunenshi*, op. cit., pp. 242–243.

12 *20 seiki nihon jinmei jiten*, Tokyo: Nichigai, 2004, vol. 1, p. 12 and Iseki, Kuro, *Dainihon hakaseroku*, Tokyo: Atene shobo, vol. 5, 1930, pp. 355–356.

Fig. 1: Organization of the DAP (*Zohei gakka*) of the University of Tokyo, 1887-1945



Source : Tokyo daigaku hyakunenshi – bukyokushi, Tokyo: Tokyo University Press, 1984, vol. 3, pp. 235-252.

and Switzerland (1917–1919), he was appointed Professor for the third chair, devoted to his specialty (1920). He published four papers on this topic between 1915 and 1922 in the *Journal of the Society of Mechanical Engineers* (*Kikai gakkai shi)*, obtaining a PhD in 1922 for his work on torpedoes. He was also interested in the workings of mechanical arms, such as guns.[13] Finally, he published four books on weapons (1914, 1925, 1937, 1942).

At the same time, Aoki pursued some research in the field of the precision machine industry, particularly in watchmaking. Indeed, he applied his work to introducing mass production in arms manufacturing in the civilian industry, where he also encouraged the use of high-precision machine tools and the introduction of gauges and instruments for controlling the work.[14] Accordingly, he supervised the redirection of the second chair of the DAP towards precision machines in 1928 and was among the founding members, as well as President until 1947, of the Society for Precision Engineering (*Seimitsu kogakkai*), an association bringing together since 1933 engineers involved in

[13] Aoki, Tamotsu, "Gekkei yakushin sokudo ni kansuru kenkyu", *Zohei iho*, 4/1 (1926).

[14] Aoki, Tamotsu, "Waga kuni no seimitsu kogyo kanken (keisoku kikai kigu, kogaku kikai)", *Kikai gakkai shi*, 34/166 (1931), pp. 152-187, and "Seimitsu kogaku to sangyo gorika", *Seimitsu kikai*, 1/3 (1933), pp. 59–63.

R&D in the precision machine industry, born from the split with the Association of Explosive Arms (*Kahei gakkai*), which grouped together beginning in 1904 researchers of the arms industry.[15]

Moreover, in 1935 Aoki did a five-month inspection tour of Europe (Germany, Switzerland, France, United Kingdom) and the United States.[16] In all, he visited 84 companies – of which more than half were in Germany – 6 R&D centers, 8 museums and exhibitions, 5 institutes and 1 technical college. This European tour is very important for the DAP's turn towards precision machines, as it enabled Aoki to acquire some knowledge of key technologies for these sectors. He focused in particular on three of them. The first one was machine tools, notably lathes, the main objective of this inspection tour. At the time, the Japanese machine tool industry was underdeveloped, and Japan relied heavily on imported machines in the first half of the 1930s.[17] Yet as Aoki himself pointed out, this special focus can be explained by the fact that "engineers must learn basic knowledge about machine tools. The less developed sector of our country is machine tools, and if we do not develop it, there will be a severe impact on precision engineering, of course, and moreover on national defense."[18] Thus, for Aoki, the development of a military power relied on the use of precise machine tools empowering it to mass produce weapons and armaments. He visited most of the machine tool makers of Germany, Switzerland, UK and the USA, paying close attention to the technical characteristics of machines (materials, speed, tools, gauges, micron). However, the development of such an industry, as in Germany or in Switzerland, relies not only on technical norms, but also on the training of technicians and engineers to use these technologies properly. That is why Aoki visited such places as a technical college in Zurich (Technische Hochschule), a German institute (Der Deutsche Frauenarbeitsdienst) and the electrical appliances multinational enterprise Siemens, which had an in-house program for the training of workers. The second technology Aoki was looking for in the West was measuring instruments. These were important for the adoption of mass production because they made it possible to measure the accuracy of the parts made by machine tools. They were thus a tool for the quality control of production. Aoki visited measuring instrument manufacturers in all the countries to which he travelled, with a special focus on the International Bureau of Weights and Measures (Paris), the National Bureau of Standards (Washington) and the Société Genevoise d'Instruments de Physique (SIP), at Geneva, which produced top-of-the-range instruments. Thirdly, Aoki was interested in optical industry. Here as well, the objective was to supply the Army and the Navy with precise optical instruments. Aoki visited 11 optical instrument manufacturers, among which the most known German producers (Carl Zeiss, Zeiss Ikon), and some R&D centers specialized in this industry (Institut d'Optique, Paris; Institut für Technische Optik, Berlin). He gave special attention to the production of lenses, the key part in the manufacturing of a high-precision product.

During the next ten years, between 1935 and 1945, Aoki worked on the equipment necessary for setting up mass production (measuring instruments, machine tools, standardized parts, new alloys).

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[15] This association published the journal *Seimitsu kikai* since 1933.

[16] Aoki, Tamotsu, "Obei shisatsudan", *Seimitsu kikai*, 3/28 (1936), pp.1–17 and 3/36 (1939), pp. 352-365.

[17] Tsushosangyosho (ed.), *Shoko seisakushi*, Tokyo: Tsushosangyosho (MITI), vol. 18, 1976 and Sawai, Minoru, "1930 nendai no nihon kosakukikai kogyo", *Toshi seido shigaku*, 97 (1982), pp. 32-50.

[18] Aoki,Tamotsu, "Obei shisatsudan", *Seimitsu kikai*, 3/28 (1936), p. 2.

He published several reference books on such matters, two of which were reedited in 1948, and he supervised until 1945 the translation of some fifteen publications written by German engineers on machining methods and metalworking (see table 2). As a result of his commitment to the domestic machine tool industry, he was appointed President of the 20th Sub-Committee of the Japan Society for the Promotion of Scientific Research, dedicated to machine tools (1940).[19] Three years later, he headed a R&D group for the production of pinion cutters, set up by the Army and bringing together some 40 members from universities – including his colleague Okoshi Makoto – , public and private R&D centers, and the main domestic machine makers (1943).[20]

Beside his academic work, Aoki was involved in the watchmaking industry, where he helped enhance the technological level. As parts were not yet fully interchangeable, the assembling of full watches relied on trained artisans, and Aoki supported the growth of this industry by developing training for this technical staff. He headed the Precision Industry High School (*Koto seimitsu kogakko*) when it was co-founded in 1933 by the Faculty of Engineering of the University of Tokyo and the Horological Institute of Japan (*Nihon tokei gakkai*).[21] The objective of this evening school, whose teachers all came from the Faculties of Engineering of Tokyo and Tohoku Universities – among whom Okoshi Makoto – was notably to participate to the training of watchmakers able to work on the assembling of watches. Finally, in 1938 Aoki published a book destined for watchmaking students.

After the war, Aoki was entrusted with one of the three chairs of the DPE and specialized in improving the technical level of watch industry. His discourse had not fundamentally changed but he began to focus on watchmakers. In one of the first volumes of the journal *Horology* (*Tokei*), released in 1949, he promoted the adoption of some methods of the mass production system, taking the example of the British alarm clock factory, Smith English Clocks Ltd., which was producing goods with interchangeable parts half-automated assembled.[22] In 1950, he also mentioned Ford and Singer as examples from which to draw inspiration.[23] At the same time, however, he stressed the need to manufacture high-quality goods, that is, goods produced using precise machine tools, working with the micron as a reference unit.[24] Here, the models were Swiss, particularly the company Tavannes Watch Co.: even if it did not realize mass production, strictly speaking, it had achieved a high degree of accuracy for its parts.[25] In particular, Aoki recommended using Swiss-made Bechler automatic lathes.[26] During his 1935 European tour, he indeed visited several of the most well-known machine tool suppliers of the Swiss watch enterprises (Aciera, Bechler, Mikron, Safag). In the 1950s, the Seiko engineer in charge of the development of machine tools, Tomine Ritsu, a DAP graduate, went thus to Switzerland and visited some of the companies his professor had entered some twenty years

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19 Aoki, Tamotsu,"Nihon gakujutsu shinkokai dai 29 shoiinkai (seimitsu kikai toku ni kosakukikai) ni okeru kenkyu", *Nihin kikai gakkai ronbunshu*, 7/26-2,4 (1941), p. 1.

20 Aoki, Tamotsu, "Pinion – katta ni kansuru zadankai", *Seimitsu kikai*, 10/121-123 (1943), pp. 615–634.

21 Yamaguchi, Ryuji, "Nihon tokei gakkai yuraiki II", *Kokusai tokei tsushin*, 1979, p. 109.

22 *Tokei*, 2 (1949), pp. 35–39.

23 *Tokei*, 1950, pp. 7–10.

24 *Tokei*, 3 (1949), p. 99.

25 *Tokei*, 1950, pp. 7–10.

26 *Tokei*, 1950, pp. 7–10.

Tab.2: Main publications of Aoki Tamotsu

Year	Title	Status	Note
1914	*The world of weapons*	Author	
1925	*Theory on the motion control during a shooting in water from the side weapons of a ship*	Author	
1935	*Industry and workforce training*	Author	
1935	*Methods of capacity measure*	Author	
1935	*Precise measure and measure instruments*	Author	Reedited in 1948
1937	*Reading-book on weapons*	Author	
1938	*Horology*	Author	
1940	*Study on the design of precision machines*	Author	Reedited in 1948
1941	*Gearing device of machine-tools*	Co-translator	H. Rognitz, *Die Getriebe der Werkzeugmaschinen*
1941	*The use of electric heat in the steel and the non-steel metal industry*	Co-translator	O. Wundram
1941	*Broaching machining*	Co-translator	L. Knoll
1941	*File*	Co-translator	B. Buxbaum
1942	*War and Precision Industry*	Author	
1942	*Electrical tools and compressed air tools*	Co-translator	H. Graf
1942	*Screw cutting*	Co-translator	O.M. Müller, *Gewindeschneiden*
1942	*Tempering Steel*	Co-translator	H. Herbers
1942	*Milling cutter*	Co-translator	P. Zieting & E. Brodner, *Die Fräser,ihre Konstruktion und Herstellung*
1943	*Handbook on electrical melting for industry*	Co-translator	R. Hesse
1943	*Processing and making of cast metal sand*	Co-translator	U. Lohse, *Formsandaufbereitung und Gussputzerei*
1943-1944	*Method of production of shoe trees*	Author	
1944	*Tools and other maintenance and examination instruments for the factory*	Co-translator	P. Heinze, *Prüfen und Instandhalten von Werkzeugen und anderen Betriebshilfsmitteln*
1944	*Press machining*	Co-translator	E. Krabbe
1944	*Free forging*	Co-author	Together with P. H. Schweissguss
1944	*The economical use of single axe lathes*	Co-translator	H. H. Finkelnburg, *Die wirtschaftliche Verwendung von Einspindelautomaten*
1947-1948	*Horology*	Author	Reedited in 1949
1949	*The industry of the new generation*	Co-translator	A. P. Young
1950-1951	*Practical Benchwork for Horologists*	Co-translator	L. & S. Levin
1954	*Industrial measurement*	Author	
1958	*Theoretical horology*	Co-translator	J. & H. Grossmann, *Horlogerie théorique*

Source: National Diet Library Catalog, Tokyo previously.[27]

Aoki also engaged in several associations after the war to help realize this aim. In 1946, he became President of a committee founded to supervise the adoption of standardization norms in the watchmaking industry, to which Okoshi also belonged, along with representatives of watchmaking companies.[28] Morever, in 1948 he restructured the Horological Institute of Japan (*Nihon tokei gakkai*).[29] While it was directed in the interwar period towards retailers and supported continuous training for the repair of watches, under the influence of Aoki, this institute became a scientific society similar to these existing in Switzerland and in Germany, that is, a body destined for production engineers of industrial firms and interested in the improvement of parts and mechanisms. Aoki also published several books on training watchmaking technicians, i.e. mid-level technical staff. In 1947–1948, he brought out a new handbook in two volumes, *Horology* (*Tokei*). Finally, he translated two technical books during the 1950s, one written by the American Louis and Samuel Levin, producers of machine tools for watchmakers and jewelers, the first edition of which came out in 1938 and was reedited many times in the United States, and one published by Jules Grossmann and his son Hermann, respectively professors at the watchmaking schools of Le Locle and Neuchâtel, in Switzerland.

In addition, Aoki was active as an independent consultant. He was engaged immediately after the war by the company Toyo Watch to give advice on technological matters.[30] The content of his action is unknown but he probably helped oversee the restructuring of production in this manufacture of clocks and watches founded in 1920 and converted to war production in 1936. Restructured after the war, it became the third producer of watches in Japan under the name of Orient Watch.[31] Aoki also sat on the Board of Tsugami Precision,[32] a gauge and machine tool maker that employed five graduates of the DAP / DPE in 1955 and that undertook to copy Bechler Swiss automatic lathes for the watchmaker Daini Seikosha in 1957.[33]

3. Okoshi Makoto (1899-1969) and the improvement of machining methods

The second person who played a key role in the technological development of the Japanese precision machine industry is Professor Okoshi Makoto.[34] Until the end of the war, he pursued a career as a researcher and teacher devoted to the improvement of metalworking and machining methods. He was close to Professor Okouchi, under whom he studied at the DAP. After he graduated in 1923,

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[27] Donzé, Pierre-Yves "The Watchmaking Enterprises and the Growth of a Special-purpose Machine Tool Industry in Japan (1890-1960)", *Osaka Economic Papers*, vol. 60 no. 1, June 2010, p. 31.

[28] *Nihon tokei kyokai 30 nen shi*, Tokyo: Nihon tokei kyokai, 1980, p. 23.

[29] Yamaguchi, Ryuji, "Nihon tokei gakkai yuraiki", *Kokusai tokei tsushin*, 1979, pp. 42–48.

[30] *Kokusai tokei tsushin*, 1979, p. 47.

[31] *Toyo seimitsu kogyo kabushikikaisha shi*, Tokyo: Toyo seimitsu kogyo kabushikikaisha, 2005.

[32] *Kaiin shimeiroku*, Tokyo: Gakushikai, 1955, p. 8.

[33] Donzé, Pierre-Yves, "The Watchmaking Enterprises and the Growth of a Special-purpose Machine Tool Industry in Japan (1890-1960)", *Osaka Economic Paper*, vol. 60/1 (2010), pp. 20–34.

[34] *20 seiki nihonjin*, op. cit., vol. 1, p. 470, http://kotobank.jp (site accessed 27 April 2010), Kinoshita, Naonaru, "Okoshi Makoto sensei no omoide", *Seimitsu kikai* 45/3 (1979), pp. 1–4 and *Okoshi Makoto hakase kanreki teinen taikan kinen*, Tokyo: Okoshi Makoto hakase kinen jigyokai, 1960.

Okoshi rejoined his master at the Institute for Physical and Chemical Research Center (*Rikagaku kenkyujo*).[35] Founded in 1917 with a joint investment by the State and the private sector, this center aimed at carrying out applied research in physics and chemistry for private companies. In 1927, at the instigation of Okouchi Masatoshi, a private enterprise was founded under the name of Physical and Chemical Industry Company (Riken Industry Company since 1941), in order to industrialize and commercialize products developed by the R&D center.[36] At this point, Okouchi left his position with the DAP in 1926 and continued his career as a director of the R&D center and a president of the production company, two positions he held until 1942 and 1946, respectively.[37] Okoshi Makoto was thus called by his professor to work in one of the best R&D centers of the country in 1923 (*Rikagaku kenkyujo*). They co-published two papers on new small drilling machines (1928).[38] Okoshi then stayed at this center until the end of the war, working successively as a researcher (1932) then chief researcher (1945). At the same time, he began an academic career at the DAP, where he earned his PhD in 1931. He was engaged as a lecturer (1930), and then Assistant Professor (1931), to give lessons on machining soon after the second chair was redirected towards precision machines. In 1941, he was appointed Professor in charge of the fourth chair (special weapons and tanks), and then of the fifth chair (mass production of arms) when it was created (1944).[39]

The work Okoshi did in the years 1930–1945 primarily focused on ways to improve the precision of various machines (gauging machines, cutting machines, milling machines). Between 1934 and 1945, he published 39 papers on these questions, mainly in the reviews *Seimitsukikai*, *Kikai gakkaishi* and the *Bulletin for the Manufacture of Arms* (*Zohei iho*). In addition, he attended a meeting chaired by Aoki on improving pinion cutters (1943). The objective of Okoshi's work was to improve the quality of the equipment of weapons factories, through a better understanding of machining processes and increased precision for machine tools. Very early on, however, he showed a keen interest in the possible application of his work to the civilian sector, notably in the precision machine industry. In an article published in 1934, he highlighted, using the examples of the firms Nihon Kogaku Kogyo (Nikon) and Takachiho Works (Olympus), how the use of precision machine tools and measuring instruments made it possible to manufacture high-quality goods.[40] What is more, in a long article that came out in 1932 in the journal *Seimitsu kikai*, he explained the need for the Japanese precision machine industry to start conducting fundamental research designed to improve product quality, with the aim of becoming competitive on the world market. The example of the mass production of weapons and of munitions highlighted the necessity of adopting new tools (gauges, tolerance norms, measuring

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35 Udagawa, Masarau (ed.), *Nihon no kigyokashi*, Tokyo: Bunshindo, 2002, p. 205.

36 Saito, Satoshi, *Shinko kontserun riken no kenkyu: Okouchi Masatoshi to riken sangyodan*, Tokyo: Jichosha, 1987. This center carried out research on atomic bombs during World War II.

37 Udagawa, Masarau (ed.), *Nihon no kigyokashi*, Tokyo: Bunshindo, 2002, p. 205.

38 Okouchi, Masatoshi and Okoshi, Makoto, "Kiri no sessakuryoku ni tsuite oyobi kogu kenmaki no shinkoan", *Kikai gakkai shi*, 31/136 (1928), 331–333, and "Ido kaju ni yoru renzokuryo no tawami oyobi shichu ni oyobosu chikara", *Kikai gakkai shi*, 31/136 (1928), pp. 620–624.

39 *Tokyo daigaku hyakunenshi*, op. cit., pp. 237–238.

40 Okoshi, Makoto, "Seimitsu kikai kigu", *Kikai gakkai shi*, 37 (1937), pp. 20–28.

instruments, etc.), high-precision machine tools and adequate materials.[41]

In 1945, Okoshi was entrusted with one of the three chairs of the DAP when it was restructured as the Department of Precision Engineering (DPE), becoming at the same time Professor at the Faculty of Engineering of the University of Tohoku. When he retired from both these chairs, in 1960, he was appointed Professor at Toyo University, a private Tokyo-based institution. By the 1950s, he had become one of the most renowned professors in the field of precision machines. He served successively as President of the Seimitsu Kikai Gakkai (1950-1951) and of the Nihon Kikai Gakkai (1954-1955), and was awarded the Japan Academy Prize in 1952.

Okoshi's R&D activities were still about machining and the improvement of machine tools. He published tens of articles on this subject in the main scientific journals of the country (*Seimitsukikai*, *Kikai gakkaishi*), also directed his interest towards new horizons, such as the production of syringes (1950)[42] or of roller chains (1953).[43] Above all, he continued after the war his efforts in the 1930s to stress the need to transform the production mode in the precision machine industry (watches, clocks, sewing machines, optical apparatuses) to enable it to compete on the world market.[44]

Moreover, in 1957, he directed a research group that travelled to the United States to study the collaboration between industry and universities in the training of engineers and common R&D (see table 3).[45] For seven weeks, they visited most of the American engineering faculties, R&D centers and private companies, where they observed concrete cases of collaboration between the private and public sectors (commissioned research, evening courses for engineers, tax exemption for private gifts to engineering faculties, etc.). Special attention was paid to the training of scientists and engineers in universities, which occurred with the active support of private firms for the ongoing training of their engineers. Okoshi gives the example of the so-called Honors Cooperative Program at Stanford University, whereby 27 private firms sent their own engineers to the university three days a week for five years and provided financial support for this program. This made it possible for the firms to keep their own engineers trained at the highest level and to benefit from the latest technologies developed at universities.[46] As for R&D commissioned by private firms from universities, it took place within an organized framework, as the universities had set up special structures – such as the Industrial Associate Plan at California Institute of Technology or the Industrial Liaison Program at M.I.T. – to supervise its development. In 1957, when Okoshi visited these universities, the percentage of private funding for all R&D expenditures was quite high (31% at California Institute of Technology, 24% at Illinois University, 17% at M.I.T.).[47] Moreover, the group directed by Okoshi also visited some special independent centers for customer-based R&D attached to universities (Mellon Institute, Stanford

41 Okoshi, Makoto, "Seimitsu kikai kogyokai ni okeru kisoteki kenkyu kadai", *Seimitsu kikai*, 5/60 (1938), pp. 505–507.
42 Okoshi, Makoto and Fukui, Shinji, "Chushabari ni kansuru kenkyu", *Ikakikaigaku zasshi*, 5 (1950), pp. 4–9.
43 Okoshi, Makoto and Nakayama, Kazuo, "Rora chein no taimamosei ni tsuite", *Seimitsukikai*, 19/222 (1953), pp. 324–328 and 19/224 (1953), pp. 396–399.
44 Okoshi, Makoto, "Boekijo yori mita waga kuni seimitsukikai kogyo no genjo", *Seimitsukikai*, 14/166–167 (1948), pp. 87–89.
45 Okoshi Makoto, "Beikoku ni okeru kogyo kyoiku no jitsujo", *Seimitsu kikai*, 24/5 (1958), p. 233–238.
46 Okoshi, Makoto, "Beikoku ni okeru kogyo kyoiku no jitsujo", *Seimitsu kikai*, 24/5 (1958), p. 235.
47 Okoshi, Makoto, "Beikoku ni okeru kogyo kyoiku no jitsujo", *Seimitsu kikai*, 24/5 (1958), p. 236.

Research Institute). As for the private firms which were visited, Okoshi did not give any details in his report but most of them were leading multinational enterprises in aeronautics (Hughes Aircraft), automobile (Ford), electrical appliances (Western Electric, Westinghouse Electric) and machine tool (Cincinnati Milling Machine) industries, which all had in-house training facilities and outsourced some R&D and technical staff training to universities.

Tab. 3: Institutions visited in the United States, 1957

Type	Nom	Localité
University	Stanford University	San Francisco
University	California Institute of Technology	Pasadena
University	University of California	Los Angeles
University	Northwestern University	Chicago
University	Illinois Institute of Technology	Chicago
University	University of Illinois	Illinois
University	University of Cincinnati	Cincinnati
University	Carnegie Institute of Technology	Pittsburgh
University	Columbia University	New York
University	Polytechnic Institute of Brooklyn	New York
University	Yale University	New Haven
University	Massachusetts Institute of Technology (M.I.T.)	Boston
University	Northeastern University	Boston
University	George Washington University	Washington
Research Center	Stanford Research Institute	San Francisco
Research Center	Research Laboratory of Quaker Oats Co.	Chicago
Research Center	Institute of Gas Technology	Chicago
Research Center	Armour Research Formation of Illinois Institute of Technology	Chicago
Research Center	Mellon Institute	Pittsburgh
Research Center	Bureau of Standards	Washington
Private Firm	Hughes Aircraft Co.	Los Angeles
Private Firm	Western Electric Co.	Chicago
Private Firm	Dandley Machine Tool Co.	Chicago
Private Firm	Cincinnati Milling Machine Co.	Cincinnati
Private Firm	Westinghouse Electric Co.	Pittsburgh
Private Firm	Ford Co.	Detroit
Private Firm	Ex-Cell-O Co.	Detroit
Private Firm	Harada Inc.	Kalamazoo
Other	Museum of Science and Industry	Chicago
Other	American Society for Engineering Education	Illinois
Other	Engineers Society of Cincinnati	Cincinnati

Source : Okoshi Makoto, “Beikoku ni okeru kogyo kyoiku no jitsujo”, *Seimitsu kikai*, 24/5 (1958), p. 233.

Heading the Machine Experiment Station

Okoshi thus had a keen interest in the development and strengthening of cooperative R&D between universities and private companies. When he traveled to the United States, he was already very mindful of this necessary collaboration. Indeed, soon after the war, he engaged in such a policy when he headed the Machine Experiment Station (*Kikai shikenjo*) of the Ministry of Commerce and Industry (1946–1950).

The Machine Experiment Station was founded in 1937 by the Ministry of Commerce and Industry (MCI; Ministry of International Trade and Industry, MITI, since 1949) with the aim of supporting the technological development of the machine industry, particularly automobile and machine tools.[48] It also promoted the development of the weapon industry during the war and was redirected towards civilian industry after 1945. When it was reorganized in 1946, the MCI entrusted its direction to Okoshi Makoto, with the objective of supporting the precision machine industry in its reconversion towards exports. Shortly after joining the MCI, he set out his view in an article entitled "The reconstruction of Japan and the mission of the Machine Experiment Station".[49] As a result of the dissolution of the *zaibatsu* and the cessation of military R&D, only the State was left to spearhead the research activities needed to improve the technological level of the precision machine industry. This function was granted to the Machine Experiment Station when Okoshi arrived at its head.

Beside its work on automobile and machine tools, which were still major concerns, Okoshi also organized research on watches, optical apparatuses and sewing machines. In 1946, the Station had four divisions (machines; measuring instruments and precision machines; materials; automobiles) and employed 354 persons.[50] Its main activity consisted of testing the quality and operation of various machines produced by private firms. The Station engineers disassembled them, analyzed their functioning and evaluated their quality in comparison with the foreign products that dominated the world market (Swiss watches, Singer sewing machines, German cameras).[51] Some research work aimed at improving precision and part durability. Moreover, in order to promote competition between domestic firms and improve their product quality, the Station organized quality contests for sewing machines (1947–1949), watches and alarm clocks (1948–1953) and cameras (1948–1954). Likewise, Station researchers carried out R&D to improve these objects. Between 1946 and 1960, the Station registered 61 patents,[52] including one under the name of Okoshi Makoto for a cutting tool for stones.[53] Several of these patents were subsequently used by private firms, notably Olympus Optical Industry.[54] Finally, the Station supervised the launching of common R&D with private firms and universities, mainly in the camera and watch industry, with the aim of improving the quality of parts and also their mass production. The example of watchmaking, an industry with which Okoshi worked closely,

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[48] *Kikai shikenjo 25 nen shi*, Tokyo: Kikai shikenjo, 1963.
[49] Okoshi, Makoto, "Nihon saiken to kikai shikenjo no shimei", *Kikai shikenjo shoho*, 2/2 (1947), pp. 2–4.
[50] *Kikai shikenjo 25 nen shi*, Tokyo: Kikai shikenjo, 1963, p. 12.
[51] *Kikai shikenjo 25 nen shi*, Tokyo: Kikai shikenjo, 1963, pp. 64–73.
[52] *Kikai shikenjo 25 nen shi*, Tokyo: Kikai shikenjo, 1963, pp. 41–43.
[53] *Kikai shikenjo 25 nen shi*, Tokyo: Kikai shikenjo, 1963, p. 41. Patent No. 182,324.
[54] *Kikai shikenjo 25 nen shi*, Tokyo: Kikai shikenjo, 1963, p. 45.

illustrates the various issues of this strategy.

The common R&D activities in the watchmaking industry

In the watchmaking industry, Okoshi organized workshops between researchers from universities and private companies.[55] This R&D group lasted from 1946 to 1949. Bringing together 49 members, it was chaired by Okoshi and had other personalities from the DAP, such as Aoki, several government officials from the Machine Experiment Station and the MITI, and representatives from the watch and machine industries. Its main objective was to gather and share various capabilities and information. It is worth mentioning the presence of delegates from machine tool firms (Sonoike, Maruwa Seiki, Tsugami, Mitsubishi Heavy Industry), a factor which reflected the importance attached to production technologies. Okoshi was also president of one of the six sections of this R&D group, the one focusing on manufacturing processes (other sections dealt with mechanism efficiency, gears, wheels, materials, and liaisons).[56] This group presented a total of 177 papers. This scientific activity was then pursued from 1950 onwards by the Horological Institute of Japan, presided by Aoki.[57]

4. The careers of the engineers trained by Aoki and Okoshi

The directories of the alumni association *Gakushikai*, which brought together the graduates of the old imperial universities, make it possible to determine the employment of the engineers of the DAP then the DPE at different points in their career.[58] The comparison between the positions occupied in 1942 and in 1955 highlights both the specialization of these engineers in armament and munitions during the war and the redirection of careers towards the civilian industry, particularly in the precision machines sector after 1945.[59]

This source includes 242 graduates from the DAP in 1942, out of whom the place of employment is known for 235. These engineers were largely directed to work in the field for which they had been trained: weapons production.60 Two major places of employment can be highlighted. The first one is the Army and the Navy, which employed about one-third of all DAP graduates (33.5% in 1942). Table 5 gives an overview of the sections of the Navy and the Army where these engineers were active. Most of them were employed in the Navy (51), where they especially carried out R&D on sea mines and torpedoes: 10 were engaged in this specific field, of whom 5 were at the second section of the Headquarters for Naval Vessels, 3 at Kure Shipyard and 2 at Yokosuka Shipyard. At the time, torpedoes were considered as the most complex precision machine, and the experience gained in this sector during the war was used by several precision machine makers after 1945. This was for example

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55 *Nihon tokei kyokai 30 nen shi*, Tokyo: Nihon tokei kyokai, 1980, pp. 16–18.

56 Nihon gakujutsu shinkokai dai 95 iinkai hen, *Tokei seisan gijutsu no kenkyu*, Tokyo: Nihon gakujutsu shinkokai, 1951, p. 3.

57 *Nihon tokei kyokai 30 nen shi*, Tokyo: Nihon tokei kyokai, 1980, p. 17.

58 Even if all the graduates did not join this association, a large number of them were members, and this source gives an excellent overview of the employment of the imperial university graduates and their career paths.

59 *Kaiin shimei roku*, Tokyo: Gakushikai, 1942 and 1955.

60 On the R&D activities of the Navy in the interwar period, see Sawai, Minoru, “Senkanki ni okeru kaigun gijutsukenkyujo no katsudo”, *Osaka Economic Papers*, Vol. 58 No. 1 (2008), pp. 1-16.

Tab. 4: Employment shift of DAP graduates who were members of the Gakushikai in 1942

	1942		1955	
Fonction	Number	%	Number	%
Army, Navy	81	33.5	2	0.8
University, schools	13	5.4	15	6.2
Administration	10	4.1	11	4.5
Research Centers	5	2.1	1	0.4
Industry: electrical appliances	13	5.4	12	5.0
Industry: machine-tools	17	7.0	21	8.7
Industry: metallurgy	18	7.4	18	7.4
Industry: precision machine	22	9.1	33	13.6
Industry: various	53	21.9	60	24.8
Independent / other	1	0.4	4	1.7
Not mentioned	9	3.7	22	9.1
Absent	-	-	43	17.8
Total	242	100	242	100

Source: Kaiin shimeiroku, *Tokyo: Gakushikai, 1942 and 1955.*
Note: in 1955, the engineers covered by the category "Army, Navy" were members of the Self-Defense Force (jieitai).

the case with Suzukawa Hiroshi, who entered the second section of the Headquarters for Naval Vessels after graduated from the DAP (1940) and was hired by Canon after the war, where he became head of the industrial design division in 1955. The second point was that both the Army and the Navy employed several DAP graduates in their aeronautics R&D centers. These high-tech research centers were also important steps in the career of the engineers who took over the technological development of several private companies after the war. In the precision industry sector, this was in particular the case with Nakajima Fujitaro, employed by Takano Precision Industry in 1955, with Fukuoka Shigetada, who joined Nikon after the war and went on to become its President, and with Kensuke Shoji, Managing Director in 1955 of Kinka Machine Co., a producer of parts for sewing machines. Thus, most of the DAP graduates engaged by the Army and the Navy worked as engineers for the production of weapons and R&D in related fields. After the war, nearly all of them found employment in the industry. In 1955, while the fate of 18.6% is unknown – dead or no longer members of the *Gakushikai* – and the occupation of 10.5% is not mentioned, 65.1% were working in the industry. There was thus a huge shift from the military to the civilian industry. Yet, apart from Japan Steel Works, which took on seven DAP graduates after the war, no company employed more than two of these engineers. They scattered towards many companies, notably in the precision machine and the machine tool industries, as shown by the few examples given above.

Tab. 5: Place of employment of DAP graduates within the Army and the Navy, 1942

Place of employment	N
Navy	**51**
Headquarters for Naval Vessels	13
Imperial Navy Technical Research Institute	3
Aeronautical Research Institute	7
Yokosuka Naval Shipyard	6
Kure Naval Shipyard	5
Hikari Naval Shipyard	2
Sasebo Naval Shipyard	2
Maizuru Naval Shipyard	1
Not mentioned (officer, soldier)	12
Army	**30**
Army Technical Headquarters	8
Science Research Center of the Army	3
Aeronautical Research Institute	4
Tokyo Arsenal	2
Tokyo Second Arsenal	2
Kokura Arsenal	1
Incheon Arsenal	1
Osaka Arsenal	1
Army Fuel Arsenal	1
Not mentioned (officers)	7

Source: see tab. 4.

Despite the important weight of the Army and the Navy, they were definitively not the only employers of the DAP graduates in 1942. Indeed, as can be seen from table 4, 123 of them, that is more than half of the all the graduates (50.3%), worked in private companies. This means that some DAP-trained engineers entered private companies without having worked for the Army or the Navy. Moreover, only a very small number of them were engaged by private firms specialized in arms production: four engineers at Chuo Industry, one at Dainippon Arms and one at Hitachi Arms Works. Actually, as the entire industry was engaged in war production at the time, the distinction between military and civilian industry in 1942 is not absolute. Some DAP graduates working in machine, metalworking or electrical appliance companies may have been employed to supervise and organize war production within these companies. For example, Mitsubishi Heavy Industries, the biggest private employer of DAP graduates in 1942 (see tab. 6), obviously hired these engineers for the production of war material: one served at Nagasaki Munitions Works and seven at Tokyo Machine Works, a plant specialized in tank production.[61] The other engineers were dispersed between the Nagoya Aircraft Works (2), the shipyards of Nagasaki (1), Kobe (1) and Yokohama (1), and the headquarters (1). The case of Japan Steel Works is very similar. This steelmaking company involved in weapons production was founded in 1907 as a joint venture company between Hokkaido Colliery & Steamship Co. and two British arms manufacturers, Vickers Sons and Armstrong, Whitworth & Co.[62] The actual work carried out by the five DAP engineers is unknown, but they may have been engaged in the production of weapons. Three of them are not mentioned any longer in the 1955 *Gakushikai* directory, perhaps due to their death in the 1945 bombing of the main plant which killed some 200 employees. Also, Japan Optical Industry (Nikon since 1988), the second biggest private employer of DAP graduates in 1942, was a firm founded in 1917 to carry out R&D and produce optical instruments for the Navy.[63] As for the Army, it sourced these apparatuses from the company Tokyo Optical Industry (Topcon), founded in 1932 by the watchmaker Hattori.[64] It employed three DAP-trained engineers in 1942. Finally, one should mention the presence of Tokyo Aircraft Instruments within these main employers. This firm began by producing measuring instruments for the aircrafts and then participated directly in the war effort. Nothing is known about the actual work carried out by the DAP graduates within the other main firms mentioned in table 6.

Tab. 6: Private companies employing more than two DAP graduates, 1942

Name	Industry	Number of DAP graduates
Mitsubishi Heavy Industries	Machine	14
Japan Optical Industry (Nikon)	Optical instrument	9
Japan Steel Works	Steel	5
Toyo Precision	Testing instrument	5
Japan Special Steel	Steel	4
Tokyo Aircraft Instruments	Measuring instrument	4
Chuo Industry	Weapon	4
Sumitomo Metal Industries	Metal	4
Riken Industry	General	3
Kawasaki Heavy Industry	Machine	3
Hitachi Works	Electrical appliance	3
Tokyo Optical Industry (Topcon)	Optical instruments	3
Toshiba	Electrical appliance	3

Source: see tab. 4.

[61] *Mitsubishi jukogyo kabushiki kaisha shi*, Tokyo: Mitsubishi jukogyo, 1956, pp. 299-304.
[62] *Nihon seikojo hyakunenshi*, Tokyo: Nihon seikojo, 2008.
[63] *40 nenshi*, Tokyo: Nihon kogaku kogyo kabushikikaisha, 1960.
[64] *Tokyo kogaku 50 nenshi*, Tokyo: Topcon, 1982.

Apart from these firms which engaged more than two DAP graduates in 1942, there was also a huge number of companies which employed one or two of them. Among the 123 engineers working in private firms in 1942, nearly half of them (63) were in such a case. Here, a special mention should be made of the precision machine industry (9.1%) and the machine tool industry (7.0%). In both sectors, DAP was carrying out R&D to support their technological development since the end of the 1920s. There was thus a link with the industry prior to the war. Among the 17 engineers engaged in the precision industry, the majority worked on manufacturing optical instruments for the Army and the Navy. Nine were employed at Nippon Optical Industry (Nikon). Finally, the last five engineers active at the time in the precision machine industry were working at the watch and clock companies Seikosha (2) and Tokyo Clock (1), as well as at the scientific and measuring instruments manufacturers Shimadzu (1) and Tanaka Instruments (1). All these firms produced weapons and munitions during the war, and these engineers were probably in charge of this production.

Finally, in 1942, there were also 28 DAP graduates working outside the military and the industry. Thirteen worked at universities and schools, especially at the University of Tokyo (five, including four at DAP) and Tokyo Institute of Technology (two), while the others primarily served at engineering faculties (one at Osaka University; one at Keijo University, Seoul) or at industry high schools (one at Yamanashi Industry High School and one at Ube Industry High School). Accordingly, their role was to train the new generation of engineers, to support the war effort, and subsequently the technological development of the industry after 1945.[65] Eight of them were indeed still engaged at universities in 1955. The administration was a source of employment for 10 DAP graduates in 1942, in particular five in some agencies of the Ministry of Commerce and Industry (Patent Office and Machine Experiment Station) and one in the Scientific Division of the Cabinet Planning Agency (*Kikakuin*). Finally, six DAP graduates were engaged by research centers, namely at the Aircraft Research Center, the Riken Research Center and the Railway Research Center.

After 1945, there was no major shift except for the engineers employed by the Army and the Navy during the war. In 1955, 198 of the 242 engineers listed in 1942 were still present and 176 were professionally active. The persons employed in the industry and the administration in 1942 did not redirect their career, with the exception of a few cases of change from the industry towards academic positions or in the administration, as well as from the administration to the industry. It is however difficult to ascertain how many engineers remained within the same company or group, due to the dissolution of the *zaibatsu* and the restructuring of many industrial groups after the war. Yet the demilitarization of Japan impacted on the employment of the 86 engineers who were working for the Army and the Navy in 1942. Thirteen years later, the fate of 70 of them is known. 61 were still active, most of them in industrial firms (53), careers in universities (2), the administration (1) the Army (1), or, exceptionally, as independents (3). One out of five engineers who redirected his career towards industry was engaged in the precision machine sector (watches, sewing machines, measuring instruments, cameras), as illustrated by the examples mentioned above. Together with the machine

[65] Sawai, Minoru, "Senchu – sengo Osaka no shinsetsu koto kogyo gakko – kogyo senmon gakko", *Osaka Economic Papers*, vol. 57 no. 4, March 2008, pp. 278-296.

tool industry, which employed 21 of the pre-1942 DAP graduates in 1955 against only 17 in 1955, the precision machine industry (33 pre-1942 DAP graduates in 1955 against 22 in 1942) was the sector which benefited most from the post-war shift, while metalworking and electrical appliance industries were not especially prone to engaging former DAP graduates after 1945.

Tab.7: Place of employment of the 1946-1955 DEP graduates, 1955

	1955	
Function	Number	%
Army, Navy	-	-
University, school	5	11.6
Administration	4	9.3
Research centers	-	-
Industry: various	11	35.8
Industry: metalworking	2	4.7
Industry: electrical appliances	6	14.0
Industry: machine-tools	6	14.0
Industry: precision machine	5	11.6
Independent / other	-	-
Total	43	100

Source: see table 4.

One should also ask what are the characteristics of the employment of the engineers who graduated the Department of Precision Engineering (DPE), as DAP was renamed in 1945. An analysis of its structure and organization reveals a continuity of the teaching staff and a reorientation towards the needs of the civil industry, especially in the precision machine industry. As shown in table 7, an overwhelming majority of postwar DEP graduates who were members of the *Gakushikai* (1946-1955) entered private firms (79.1%), most of them in machine tool (14.0%), in precision machine (11.6%) and in electrical appliance (14.0%) companies.[66] As was the case in 1942, DPE graduates did not mainly flow towards a few big enterprises but rather were engaged by a wide number of firms. In the machine tool industry, Tsugami Precision employed two new graduates, while Ikegai, Okamoto, Shibaura Industry and Mitsui Precision each engaged only one new graduate. The situation was similar in the precision machine industry, where six companies each hired one DPE graduate: the camera makers Nihon Optical Industry (Nikon) and Canon; the watch maker Daini Seikosha; the scientific instruments and machine producer Shimadzu Works; and the producer of measuring instruments Tokyo Aircraft Instruments. The relative small number of engineers hired by enterprises

[66] In 1946-1955, these 43 members represented about 25% of all the DEP graduates for this period.

in these both sectors can be explained by the fact that they had already employed some of them during the war and usually did not sack them after 1945. If one considers the cumulated number of DAP / DPE graduates active in 1955, that is, the engineers who stayed since the war and these engaged after 1945, the machine tool and the precision machine industries are preponderant. Among the 15 biggest employers in 1955, there were 3 camera makers (Nikon, Canon, Topcon), 2 instrument/tool makers (Tokyo Aircraft Instruments, Nippei Machine) and 1 machine tool maker (Tsugami Works).

Nevertheless, these two sectors were not the only job opportunity for DAP / DPE graduates after the war. Indeed, they were trained in not only producing precision machinery, but also in introducing it within the production system in general. This is probably what explains the large number of these engineers who entered electrical appliance companies after the war. While this sector employed only 5.4% of the graduates in 1942, this proportion rose to 14.0% for the period 1946-1955. Some companies such as Toshiba, Oki Electric and Hitachi were organizing the mass production system during these years.[67] They obviously needed the DAP / DPE graduates for its implementation.

As for the other sectors of the industry, they appear to be a major employer of DPE graduates after the war, as nearly one-third of these graduates took employment in private firms active in other sectors than machine tools, precision instruments and electrical appliance makers. Yet, as in 1942, there were no sectors or companies which were predominantly hiring these engineers, the only exception being the steel and general machine industries. Indeed, among the biggest employers of DAP / DPE graduates in 1955 were two steelmaking companies (Japan Steel Works; Japan Special Steel) and Mitsubishi Japan Heavy Industry. Nevertheless, the presence of these companies within the 1955 ranking for main employers is due to from different employment strategies. In the case of Japan Steel Works, virtually all of the 11 engineers were hired after the war. The only person already in charge in 1942 who was still working in 1955 was Shintani Tetsuji. After graduating from DAP in 1924, he entered Japan Steel and was an engineer at the Hiroshima plant during WWII. He became a member of the Board of Directors in 1946 and Chairman the following year.[68] As for the other engineers, they had worked during the war for various Army or Navy arsenals (7), for the arms manufacturing company Hitachi Weapon Co. (1) and for Riken Machine Tool Co. (1). Only one postwar graduate was hired, in 1946. Some other companies, such as Oki Electric, employed only postwar DPE graduates. Thus, the war experience was not a necessity for all companies. In other firms, however, the large number of DAP / DPE graduates in 1955 is mainly due to their pre-1945 employment. Among the six engineers of Mitsubishi Japan Heavy Industries, as was renamed in 1952 one of the three companies resulting from the dissolution of Mitsubishi Heavy Industries, four were former engineers of Tokyo Machine Works, while two others graduated from Tokyo University, in 1944 and 1951, respectively.

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[67] Wakabayashi, Naoki, *Kaden sangyo seicho no kiseki*, Tokyo: Denpa shuppan, 1992.
[68] *Nihon tekkojo hyakunenshi*, Tokyo: Nihon Tekkojo, 2008, pp. 720 and 723.

Tab. 8: Enterprises employing more than two DAP / DPE graduates, 1955

Name	Industry	Number of DAP graduates
Japan Optical Industry (Nikon)	Optical instruments	12
Japan Steel Works	Steel	11
Mitsubishi Japan Heavy Industries	General machines	6
Canon Camera	Optical instruments	5
Oki Electric	Electrical appliances	5
Sumitomo Metal Industries	Metalworking	5
Tokyo Aircraft Instruments	Measuring instruments	5
Tsugami Works	Machine tools	5
Hitachi Works	Electrical appliances	3
Ishikawajima Heavy Industry	Jet engines	3
Japan Special Steel	Steel	3
Nippei kiki	Tools	3
Nisshin Machine Industry	Machines	3
Tokyo Optical Industry (Topcon)	Optical instruments	3
Toshiba	Electrical appliances	3

Source: Kaiin shimeiroku, *Tokyo: Gakushikai, 1955*.

In addition, some graduates entered universities and other schools. In 1955, a total of 38 DAP / DPE graduates worked in such institutions, of whom only 5 had graduated after 1945. Education did not become an obviously important job opportunity after the war. Unsurprisingly, the biggest employer in education was the Faculty of Engineering of the University of Tokyo (11), followed by Chuo University (5), a private university specialized in law and business which opened in 1944 a faculty of engineering with two departments of mechanics and aeronautics,[69] the Tokyo Institute of Technology (2) and Yokohama National University (2). The last 18 professors taught in other various universities and high schools, usually in the faculties of engineering.

Finally, the administration was still a place of employment after the war. Some 24 DAP / DPE engineers were there in 1955, of whom 3 had graduated after the war. Nearly half of them worked in some agencies and departments of the Ministry of International Trade and Industry (10): six at the Machine Experiment Station – two of whom conducting research for the watch industry[70] - directed by DPE professor Okoshi since 1946, two in the aeronautic industry division, one in the patent office and one in the central office. Accordingly, they were working to support the technological development their fellow graduates were undertaking in private firms. Most of the other DAP / DPE engineers

[69] *Chuo daigaku hyakunenshi*, Tokyo: Chuo University, 2 vol., 2001-2003.
[70] *Nihon tokei kyokai 30 nenshi*, Tokyo: Nihon tokei kyokai, 1980, pp. 16–17.

working as civil servants were in charge in some prefectural institutions engaged in R&D activities to back the development of local enterprises (Aichi, Hyogo, Kanagawa, Osaka).

Conclusion

The objective of this paper was to highlight the contribution of universities, and mainly of engineering faculties, to the development of the Japanese precision machine industry between 1930 and 1960. The Department for Arms Production (DAP) of the University of Tokyo, which after the war became the Department of Precision Engineering (DPE), was tackled as an example, with a special focus on the activities of two professors, Aoki Tamotsu and Okoshi Makoto, and on the career of the engineers who graduated from this department. In conclusion, I would like to emphasize two points.

Firstly, this case study contributes to an understanding of the process of redirecting the war industry towards civilian industry after 1945 (*gunmin tenkan*). The contribution of the war to civilian industry is not a new topic.[71] In the case of Japan, it gave rise to a wide literature highlighting the role of engineers in this process.[72] However, their actions in terms of product innovation have been largely emphasized in these works, showing the use of knowledge acquired while producing arms to developing new industries (automobile, bullet train, ball bearing, radio, etc.). Yet the example of the DAP engineers reveal that their action was also decisive for process innovation. The introduction of new technologies enabling the introduction of mass production, as they were studied at the DAP and tested in the naval shipyards and armories during the war, appears as a key element in the shift of precision machine enterprises towards competitive firms in the 1950s.

Secondly, the role of the State and of industrial policy must be recalled here. In the international literature, special emphasis is placed on both the support of exports and the protection of the domestic market as elements explaining the growth of a competitive industry in Japan. Yet, in some industries, the State also intervened at another level ever since the interwar period, one certainly less visible from abroad as it did not lead to international commercial frictions, that is, the organization of collective R&D in collaboration with universities and industry (*sankangaku renkei*).[73] Firms wishing to boost their technological level have a choice between in-house R&D and collaboration with external partners, such as foreign companies, through licensing agreement or joint ventures. Collaboration

[71] See for example Roland, Alex, "Technology and War: A Bibliographical Essay", in Smith, Merritt Roe (ed.), *Military Enterprise and Technological Change: Perspectives on the American Experience,* Cambridge: MIT Press, 1985, pp. 347-379 and Ndiaye, Pap, *Nylon and Bombs: DuPont and the March of Modern America*, The Johns Hopkins University Press, 2006.

[72] Takashi, Nishiyama, *Swords into plowshares: civilian application of wartime military technology in modern Japan, 1945–1964*, The Ohio State University, dissertation, 2005, Sawai, Minoru, "Sengo fukkoki nihon no kenkyu kaihatsu taisei: gunmin tenkan to kenkyu kaihatsu no saikochiku", in Nakamura, Tetsu (ed.), *1930 nendai no higashi ajia keizai*, Tokyo: Nihon hyoronsha, 2006, pp. 135–163, Sawai, Minoru, "Gijutsusha no gunmin tankan to tetsudo gijutsu kenkyujo", *Osaka Economic Papers*, Vol. 59 No. 1 (2009), pp. 1-18, Ueda Hirofumi, "Sengo fukkoki no bearing sangyo", in Hara, Akira (ed.), *Fukkoki no nihon keizai*, Tokyo: Tokyo University Press, 2002, pp. 225–252.

[73] For the period 1960–1980, it has been analyzed by Okimoto, Daniel I., *Between MITI and the Market. Japanese Industrial Policy for High Technology*, Stanford: Stanford University Press, 1989 and the efficiency of this model was called into question by Scott, Callon, *Divided Sun. MITI and the Breakdown of Japanese High-Tech Industrial Policy, 1975–1993*, Stanford: Stanford University Press, 1995.

with domestic research institutions and universities appears to have played a key role in the case of the Japanese precision industry after the war. In order to become a competitive industry on the world market, it had to take up the key challenge of its technological improvement. This industrial sector benefited notably from the support of DAP, whose second chair, occupied by Aoki, was redirected towards the needs of precision machine makers in the late 1920s. The development of machine tools during World War II offered yet another opportunity to organize cooperation between bureaucrats, academics and industrialists. After 1945, it was pursued in the precision machine industry through several bodies, mainly the Machine Experiment Station, directed by Okoshi from 1946 onwards. Although it was a success in the precision machine industry, this public policy had no impact in other sectors of the industry, where technological development relied on cooperation with Western multinational enterprises and in-firm innovation. Moreover, its impact was time-bound: the Machine Experiment Station carried out R&D on cameras, sewing machines and watches only until the beginning of the 1950s. Once they had reached a sufficient level of technological development, companies began to carry out their own R&D, driven by a climate of keen competition.[74] The technology and R&D policy of the State can therefore be understood as a strategy to support infant industries in their take-off phase. Thus, the actions taken by the State in the interwar period to promote the training of engineers and the development of collective R&D directly supported the restructuring of the precision machine industry into a competitive industry after 1945.

Finally, the influence and role of military engineers in postwar Japan should be discussed. It may be attractive to consider the technological development of Japanese industry after 1945 as the result of their massive influx into civilian industry. By bringing with them knowledge acquired in top-universities – especially the Faculty of Engineering of the University of Tokyo – and experience gained in war production, they made advanced technological know-how available to many private companies whose technical level was low at that time. Yet technological knowledge is only a part of the process of growth. The military engineers had to face new challenges in private firms, these of budget constraints, market-oriented management and negotiation with technicians on the shop floor level.[75] Technology gave DAP / DEP graduates a strengthened position within the firm but this was not an unlimited power.

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[74] For the example of the camera industry, see Sawai, Minoru, "Kogaku kogyo ni okeru kyodo kenkyu no tenkai: kogaku kogyo gijutsu kenkyu kumiai no katsudo wo chushin to shite", *Osaka Economic Papers*, Vol. 59 No.3 (2009), pp. 281-297.

[75] Lazonick, William, *Competitive Advantage of the Shop Floor*, Cambridge: Harvard University Press, 1990.