Innovations in Production Technology in the German Electrical Industry 1873 – 1904

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I

It is the main concern of this article to make clear features of innovations in production technology in the German electrical industry from 1873 to 1904 based on some cases of major enterprises.

During the last quarter of the nineteenth century the electrical industry developed into one of the key industries in Germany, while electrical enterprises were involved each other in severe price competition which resulted in the establishment of "monopoly" by the two giant concerns — Siemens (Siemens & Halske A.-G./Siemens-Schuckerwerke GmbH) and AEG (Allgemeine Elektricitäts-Gesellschaft) — at the beginning of the twentieth century. Until today, a considerable amount of study on this development of the electrical industry has accumulated centering around studies of its financial system as a unique mechanism under which required capital could be provided and accumulated and products could find their buyer.[1)] Despite of the significance of such mechanism, the basic driving forces for the development of the electrical industry cannot be, however, comprehended without analysing the changes of production process especially occurred in the factories. The reasons are as follows: the power to establish the financial system, which provided companies with a part of competitiveness, was backed itself by the creditability of parent enterprises, and their creditability

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This paper is written based on the following papers already published in Japanese, revising some of their contents.

"19 Seikimatsu Doitsu Denki-Kogyo ni okeru Keiei-Rohmu-Seisaku (Die Arbeitsverwaltung in der deutschen elektrotechnischen Industrie 1873 – 1903/04)" (5) – (6), *Saga University Economic Review,* Vol.21, No.2,3, 1988.

1) See on this above all Max Jörgens, *Finanzielle Trustgesellschaften,* Stuttgart/Berlin 1902; Friedrich Fasolt, *Die sieben größten deutschen Elektrizitätsgesellschaften, ihre Entwicklung und Unternehmertätigkeit,* Borna-Leipzig 1904; Robert Liefmann, *Beteiligungs- und Finanzierungsgesellschaften,* Jena 1909; R. Riesser, *Die deutschen Großbanken und ihre Konzentration in Zusammenhange mit der Entwicklung der Gesamtwirtschaft in Deutschland,* Jena 1912; Toshiharu Fuzisawa, "Daiichiji Taisenzen ni okeru Doitsu Denki-Konzern no Shihon-Chikuseki to Kinyu Kaisha (Die deutschen Elektro-Konzern und ihre Finanzierungs-Gesellschaften vor dem 1. Weltkrieg)" (I)(II), *Kinyu Keizai* (The Jounal of Financial Economics), No. 178, 179, 1979. The papers and books titled in parenthesis in English or in German are all written in Japanese originally, except for any special notification.

was ultimately based on the productivity development and resultant reduction of production costs at their factories. In other words, the competitiveness of electrical enterprises at that time was sustained by innovations in production technology, namely, the introduction of mass production, which notably made great stride during the turn of the century, being accompanied by product innovations in both areas of heavy current and low-voltage electricity. Nevertheless, full-scale analysis has been scarcely made on the production process except for rather fragmental indications.[2] This paper is an attempt to fill up the vacuum in studies by analyzing significant changes of production process in major electrical enterprises.

With the introduction of mass production in the electrical industry the perspective was also opened for conversion to the mass production system in German economy as a whole. Industrial sectors can be classified thereby into three types according to the production method: the "mechanical process industry" such as cotton-spinning industry; the "chemical process industry" such as iron processing industry; and the "assembly industry" such as machine or automobile industry. Of which, major sectors which belong to both mechanical process and chemical process industry had successed, in Germany, a step earlier to introduce the mass production system by the last decades of the nineteenth century. The mass production in the assembly industry, however, had not still been achieved at that time, as the relatively complex processes of machining and assembly of diversified parts and components in this sectors made it difficult to achieve even in this country. In other words, the productivity leap of overall German economy could be epochally achieved not only with the introduction of mass production in both process industries, but rather with its achievement in the assembly industry. In this regard, the last quarter of the nineteenth century was the very period that the introduction of mass production in the assembly industry with such significant meanings became an important subject.

On the other hand, realization of the mass production system was, combined with huge amount of investment on fixed manufacturing assets through which one of high barriers to entry was formed, to be the most powerful productivity base for gaining dominance of huge capital enterprises and for forming monopolistic structure in the industry.

The electrical industry in the late nineteenth century was a pioneering sector which achieved the mass production in the assembly industry as such. And the power plants and electric motors in various sizes and standards, both being a part of its products, with their resultant influences for the innovation of the power transmission system in factories and handicraft workshops in various sectors, promptly facilitated innovations in machine tools or equipments, rationalization and elaboration of their arrangement to the machinery system and to various processes. The changes of production process in this industry, therefore, had a strategic implication for the perspective of the establishment of phased and epochal productivity improvement of German economy as a whole. Therefore, this paper

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2) For this see Emil Kreller, *Die Entwicklung der deutschen elektrotechnischen Industrie und ihre Aussichten auf dem Weltmarkt*, Leipzig 1903; Hermann Hasse, *Die Allgemeine Elektrizitäts-Gesellschaft und ihre wirtschaftliche Bedeutung*, Heidelberg 1902; Hiromu Ishiro,"Doitsu Denki-Kogyo no Dokusen-Keisei-Katei (Eine Betrachtung über die deutsche elektrotechnische Industrie im Monopolbildungsperiode)" (I) (II), *Keizaigaku Kenkyu* (Economic Studies) (Hokkaido University), Vol. 20, No. 4, 1971, Vol. 21, No. 4, 1972.

will mainly concentrate on the introduction of mass production in the electrical industry at that time.

In order to grasp the changes of production technology (the process of introduction of mass production) in this industry, the period from 1873 to 1904 has to be divided into following three subperiods, each of which was based on the corresponding production method and workshop organization provided by production equipments and their arrangement:[3)]

1. From the 1870s to the middle of the 1880s: a phase in which the individual, multi-variety and small amount production by universal machine tools under the multi-purpose plant system was predominant, while the machine tool type workshop system was only recognized in its initial appearance.

2. From the middle of the 1880s to that of the 1890s: a phase of the relatively wide-variety, medium amount, and serial production under the machine tool type workshop system (the "gang system") which was based on the "developing division of labor and introduction of specialized machine tools".

3. From the middle of the 1890s to the beginning of the 1900s: a phase of "transition to the mass production of limited-variety products" under the product-type work group system which was based on the major changes in machinery system following to the introduction of electric motors, and on the interchangeable components and product standardization.[4)]

The changes of production technology will be, thereby, traced as the progressive processes from the first phase through the second to the third.[5)]

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3) Concerning these three sub-divisions see Shigetaka Mohri, *Keiei-Kanri-Sohron* (The General Theories of Management), 2. ed., Chikura-Shobo 1965, pp. 146-167; Hideichi Horie, "Factory, Past and Present" *Keizai-Ronso* (The Economic Review) (Kyoto University), Vol. 115, No. 3, 1975, pp. 137-161.

4) Kreller, *op. cit.*, p.8; Wolfgang Ruppert, *Die Fabrik. Geschichte von Arbeit und Industrialisierung in Deutschland*, München 1983, pp. 242-243.

5) In this regard, Kreller divided nearly the same period only into two stages with the middle of the 1880s as watershed. And he held the second period as that of shifting into "mass production" by the developing division of labor and the introduction of specialized machine tools after the 1880s, not referring to more epochal changes which were realized by introduction of electric motors after the middle of the 1890s. *Ibid.* Shifting into mass production could not have been realized, if the innovations in production processes by introduction of electric motors would not have been achieved in the 1890s. In other words, one may not be possible to grasp the characteristics of the innovations in production technology in this period if he ignores the meanings of appearance of electric motors as epoch-making means of power driving to the innovations in production technology, even though the changes of production process under the factory system depend first of all on the innovations of working machines. Hans von Soethen, *Die Wirtschaftspolitik der Allgemeinen Elektrizitäts-Gesellschaft*, Freiburg i. Br. 1915, p. 18 has similar problem as Kreller, when the former describes the same innovations of production technology only as the "mass production system of a small number of components by specialized machine tools and very wide range of the division of labor". Ishiro, *op. cit.* (I), pp. 122-127 emphasises the period after the 1880s as that of "implementation of mass production system" through " 'specialized operation machines' by each category of products". But the period of the 1880s is too early for such characterization. On the other hand, Ruppert describes the period after the 1870s as the stage of series production through the development of process mechanization and product standardization, while he puts the period after the 1890s as that of the big industry-style mass production (Ruppert, *op. cit.*, pp. 242-243). However, it can not be said that the series production had been consistently dominant until the 1880s. One should rather recognize

II

In the German electrical industry from the 1870s to the middle of the 1880s, the system of individual manufacturing of multi-variety and small amount products was still dominant as it had been in the mid-nineteenth century, which was based on the multi-purpose plant system using universal machine tools.

Firstly, at the beginning of the 1870s Siemens & Halske (established in 1847, abbreviated hereafter as S & H), the largest and most advanced firm in the electrical industry at that time, introduced different kinds of American machine tools into the newly-established "American workshop", in which a part of machining processes was included.[6] However, as shown in table 1, at the middle of the 1870s, universal machines were used in the greater portion of the company's machining processes, while the number of machine tools placed on other processes were a few. The working machines were generally lower in process accuracy and required more skill for their operation. The precision tools being used were little and the assembly process demanded skillful manual finishing and fitting.[7] While, at that time, the "normal inker" had been manufactured as the standardized product in S & H, the degree of the firm's product standardization was generally at very low level which was incomparable to the later periods.

Secondly, in 1875, the Berlin works, the main factory of S & H was given the framework of "a real machinery system" in which, as shown in table 1, 40HP steam engine transmitted its power uniformly through mechanical transmissions to different working machines operating on the principle of the "division of labor".[8] However, limited number of working machines which could be connectable

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that the "individual production" was dominant up to the middle of the 1880s and full scale shifting to the series (lot) production only came after that. Ruppert does not also mention the meanings of electric motors. Although Kocka supposedly recognizes the period after the 1880s virtually as that of the mass production, he only uses the term "Serien (an-) fertigung" instead of the normal term of the "Massenfabrikation". Therefore, his conceptual distinction between series production and mass production may be ambiguous, or he may underestimate the shifting into the (semi-assembly-line production type) mass production by the system of product-type work group (Jürgen Kocka, *Unternehmensverwaltung und Angestelltenschaft am Beispiel Siemens 1847-1914*, Stuttgart 1969, p. 337, 372). In addition, one should distinguish between various types of mass production, especially the mass production by the system of product-type work group should be differentiated by that of assembly-line production or automation. There can be found almost no suggestion, however, about this point under the above mentioned literature.

6) Georg Siemens, *Der Weg der Elektrotechnik*, Bd. 1, München 1961, p.76. The firm, initially established as Telegraphen-Bau-Anstalt von Siemens & Halske, Offene Handelsgesellschaft, Berlin (1847-1889), was renamed Siemens & Halske Kommanditgesellschaft, Berlin (1890-1897), and later Siemens & Halske Aktiengesellschaft, Berlin (1897-1966). But in this paper these are all abbreviated to S & H.

7) Alois Riedler, *Emil Rathenau und das Werden der Großwirtschaft*, Berlin 1916, p. 62.

8) The cable factory of S & H in 1876 was also equipped with a machinery system. Although the machinery in this factory was arranged basically on the principle of the machine-type workshop system, its arrangement seems to have only become possible by so early stage because the features of cable manufacturing which were very close to that of the mechanical process industry allowed relatively rational setting of machines in this product section. Hans Borchardt/Siegfrid von Weiher, *75 Jahre Kabelwerk Berlin 100 Jahre Siemens-Kabel*, 1951, pp. 11-12.

Table 1: Machine Tools at S & H in the End of 1875

Machine Type	Number
Steam with 1 boiler, stationary machine (with 40 HP)	1 (–)
Circular saw	5 (4)
Band-saw	1 (1)
Wood milling machine	1 (1)
Zinc cutting machine	1 (0)
Wood lathe	2 (1)
Crucible furnace	4 (2)
Cupola-furnace	2 (1)
Drawing band for wire	2 (1)
"Scharen"-punching machine	1 (1)
Milling machine	22 (20)
Grind stone	12 (12)
Planing machine	8 (4)
Drilling or boring machine	20 (15)
Lathe	270 (220)
Stone-steel-press	1 (1)

Number in parentheses indicate annual average.

Source: *Abschrift des ausgefüllten Fragebogens über Gewerbebetriebe zur Volks- und Gewerbezählung am 1. 12. 1875*, SAA 68/Li 180.

with such relatively low power steam engine probably restricted the reasonable arrangement of machines and processes, and the scale of the factory and its workshops.

As for the whole electrical industry, there were few workshops equipped even with such small scale machinery system. The company of Sigmund Schuckert in Nuremberg was equipped with only a small type foot-driven lathe and a vise in 1873 when it was established. Accordingly it was at most a manufacture where tools were main "instruments of labor" while a manpowered, primitive universal machine was still of subordinate importance. In 1874, although the firm moved into a new hydro-powered workshop, the restriction of power supply caused by natural conditions could not eventually be avoided.[9)]

Thirdly, at this time, the first step for shifting toward series production through the division of machining and assembly into each workshop as well as through the system of machine type workshop (or in part already that of product-type work group) was seen in advanced factories, as the fact of the establishment of the "American workshop" in the Berlin works of S & H at the beginning of the 1870s and that of the start of the series production of dynamo electric machine by the company in 1878 indicate[10)]. However, the division of labor was on the whole still not thoroughgoing and the

9) *Entwicklung der Elektrizitäts-A.-G. vorm. Schuckert* & Co., Nürnberg (EAGvS), Siemens-Archiv-Akte (SAA) 28/Lp 268, p. 1.

10) *Wichtige Daten zur Geschichte des Hauses Siemens*, Berlin-München-Erlangen 1962, p. 13.

series production was anything but a dominant production system. The fact that even this Berlin works "was not the factory by quite normal meaning but rather, until the 1890s, was a large scale workshop for the precision machining with fitting process"[11], virtually indicates the predominance of the system of multi-purpose plant among electrical industry at that time. This was because in the factory "production was originally carried out as the manufacturing of diversified and complicated individual products (mainly by manual labor)[12], and, being accompanied with "resistance toward new production system by senior workers who held artistical proud", "the transition period continued until the middle of the 1880s and the new as well as the old manufacturing method coexisted" during the period.[13]

The situation depended also on the market as the share of order production from government, municipal offices and public service corporations was at that time much higher than at the later period, while prospective production toward private demand was not yet developed.

III

Following to the expansion of markets and the increase of prospective production during the middle of the 1880s and the early 1890s based on the widely-opened application area of products with low-voltage current and (especially) heavy current technologies, the "transtion into factory operation"[14] in the electrical industry began to have more substancial meaning.

In the first place, Felten & Guilleaume Carlswerk Co., Ltd., the cable and wire maker, which had already diversified its production by taking part in the electrical sector in the 1870s, comprised, in the end of 1887, various producing divisions such as a cable factory, a gutta-percha core factory, a wire rope mill, a wire drawing mill, a fine wire drawing mill along with a scratch wire factory and a hardening mill, a wire ware factory, a zincing mill with a tinning and a leading mill, copper-works, a measurement room, gas works and water works. The Carlswerk realized considerable specialization by product group and by function as compared with the time of 1874/75, expanding its factory scale and production capacity into the employment of 1,450 workers and 28,000 ton annual production (in 1875 the number of workers was still 160 in average with 3,500 ton annual production).[15] However, while the pretreatment processes showed progress toward subdivision by function and partly by machine-type, each division had not become independent workshop.

Secondly, in 1888, a five-storied building of the S & H's incandescent lamp division was consisted of workshops with respective machines or equipments as follows: two Siemens-generative anneal-

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11) E. Waller, *Studien zur Finanzgeschichte des Hauses Siemens*, 3. Teil, 1960/61, p. 3.

12) *Kurze Geschichte des Wernerwerkes seit dem Jahre 1896*, SAA 68/Li 181, pp. 1-2. Cf. Hans Dominik, *Das Wernerwerk von S & H A.-G. Berlin-Nonnendamm*, 1906, p. 44.

13) *Wie der Siemens-Konzern entstand*, 1914, SAA 33/Lh 292, p. 10.

14) "Das Nürnberger Werk der SSW", *Deutsche Industrie Deutsche Kultur*, 1910, SAA 68/Li 269.

15) While the company originated in a handicraft workshop of wire master in Cologne in the late 18th century, Carlswerk itself was established in 1874 and was reorganized into a stock company in the end of 1899. W. Jutzi, *50 Jahre Carlswerk 1874-1924*, Köln 1926, p. 20 and 32.

ing furnaces, a steam boiler, and steame engines in the basement; a machine room and dynamo-machines on the ground floor; bureaus, a physico-chemical laboratory, a small mechanical workshop, and later a socket shop on the first floor; a filament drawing shop, an inpregnating shop, and a store room on the second floor; a lamp-base building shop, a filament mounting shop, galvanic baths, a photometor, and a store on the third floor; a glass-blowing shop and pumps on the fourth floor.[16] Therefore, it was a more progressed building based on the principle of functional and probably machiny-type work-shop. Since this division of workshop, however, was accompanied by decentralization of workshops into each floor, and the arrangement of working machines or equippments was essentially restricted due to traditional mechanical transmissions, it seems to have been inevitable that the work flow included detour and reverse movement in both vertical and horizontal directions.

Nevertheless, at the end of 1893, the "transition into factory operation" could typically be observed in the Berlin works of S & H. It seems that the works converted into the system of medium lot series production with a framework of machine-type worksplace in which working machines were arranged by machine-type to each workshop. Namely, at first, as shown in table 2, the number of major machine tools markedly increased as the works expanded its scale. Above all, not only the growth of specialized machine tools as a whole was conspicuous but also the number of their categories had significantly increased as follows: 392 large and small lathes, 75 milling machines, 60 drilling or boring machines with different diameters, 26 "Drehstühle", 18 presses & balancers, and 27 sander disks & grind stones. And especially, an increase in category and in the number of specialized machines in each process for individual sort of product was conspicuous: 11 electric wire-spinning machines, 31 wire coil & winding machines, and 48 incandescent lamp pumps. In consideration of the large number of these machines, it may not be inadequate to understand that the machine-type workshop had been individually formed there. On the other hand, however, there could be found no evidence of the formation of production line for each product-type.

Secondly, at the Berlin works, sixteen steam engines were utilized, which consisted of three 100 HP-type, one 50 HP-type, one 45 HP type, six 25 HP-type, one 15 HP-type, one 12 HP-type, two 10 HP-type, and one 5 HP-type.[17] This indicates that the plural number of medium and small scale machinery systems was formed in the factory, in each of which different kinds of machines were integrated, being combined with medium and small powered steam engines and with mechanical transmissions. So far as this case is concerned, it meant the expansion of factory scale, and it also indicates that some systems of machine-type machinery workshop appeared themselves on the principle of "co-operation based on the division of labor".

These systems indicated that the expansion of factory scale in this time was accompanied by sub-division of processes from the first step of the system of machine-type workshop to that of full-scale one. It could be estimated from these facts that the specialization of machining processes toward machine-type workshops and the division of the whole processes into rough shaping, machining and assembly progressed greatly from the late 1880s to the middle of the 1890s. The various processes of rough shaping and parts-machining were thereby reorganized in separate workshops, each of

16) *Schreiben über die Entwicklung des Glühlampenwerks*, SAA 68/Li 188, p.1.

17) *Ausgefüllter Fragebogen von der Berufsgenossenschaft*, 27, 12. 1893, SAA 29/Le 932.

Table 2: Machine Tools in the Berlin Works of S & H

Machine Type	Number	Number of Employee in Each Power	
		Hand or Foot	Motor
Drilling or boring machine up to 3mm hole	20		4
〃 〃 over 3 -25mm hole	18		10
〃 〃 over 25mm hole	22		16
Centrifuge	2		1
Wire-spinning machine	11		6
Wire-adjusting machine	12	5	
Wire-coil & winding machine	31	16	
Lathe up to 200mm Sp: H	64	10	216
over 200mm Sp: H	28		23
"Drehstühle"	26	1	25
Drop hammer	1		1
Paint mill	1		1
Milling machine	75		29
Gas blower	09	85	
Planing machine 1 meter	8	1	3
〃 over 1 meter	1		1
Band-saw	2		1
Forming lathe	1		
Wood milling machine	2		1
Wood planing machine	1		1
Zinc-machine	1		1
Circular saw (wood)	6		3
〃 〃 (metal)	2		1
Press & balancer	2		1
〃 〃	16	8	
Lever shears	4	1	
Table shears	1	1	
Sander disk & grind stone	27		3
Rolling mill	2	1	
Draw-bench	3		2
Incandescent lamp pump	48		25
Crane keeper	2	1	
Lithographer	1	1	
Keeper	8		10
Total		131	385

Source: *Ausgefüllter Fragebogen von der Berufsgenossenschaft der Feinmechanik behufs Einschätzung zu den Klassen des Gefahrentarifs gültig für das Jahr 1893 und folgende*, 27. 12. 1893, SAA 29/Le 932.

which was distincted between the types of working machins or between functions. A series of these reforms contributed, partly due to the concentration of similar machines to each workshop, to the productivity improvement in saving the necessary equipment per unit labor, in making machine control easier, and in increasing machine operation rates.

However, in this phase when electric motors were not yet came into wide use, various restrictions caused by "fully-developed machinery" equipped with steam engines and mechanical transmissions could not be avoided. In other words, working machines had to be arranged along with transmissions, which made it impossible to make a reasonable process arrangement following to the work flow.[18] Thus, they caused idleness in process arrangement such as the requirement of extra storing space, and the complication of work flow due to the extension and detour or reverse movement of transportation was also unavoidable.[19] Although the pluralized machinery system combined with medium and small scale steam engines could partly exclude such weak points, another defect had conversely emerged, i.e. it leaded to the increase of the needed space and equipment and that of the operation costs due to the pluralization of steam engines and transmissions. And, added by the problem of coordination among machinery systems, it could become a cause to increase complexity and confusion of production process. Furthermore, it was not yet free from the restriction caused by the mechanical transmissions themselves. Manually powered machines were still left in no small number, and the division and co-operation among machines as well as among machinery systems had been restricted also by this situation.

In S & H, some efforts toward standardization of a part of products and normalization of parts were made in the early 1890s including the establishment of a norm bureau at Charlottenburg works in 1890.[20] And, as it could be seen in the work regulations of Schuckert & Co. in 1892,[21] the use of precision support tools had gradually increased which made possible to promote standardization and normalization in those days. Nevertheless, the full-scale development of normalization of parts and standardization of products, including S & H, were not seen yet, and the precision measuring instruments for the purpose did not come into common use either.

As for the above outlined situation, although the productivity leap was seen compared to the phase of the multi-purpose plant system, the mass production system could not be organized yet, and the medium lot (series) production was at most possible, sustained by the extension of market and that of factory scales.

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18) Hennig Rogge, *Fabrikwelt um die Jahrhundertwende am Beispiel der AEG Maschinenfabrik in Berlin-Wedding*, Köln 1893, p. 17.

19) Kisou Tasugi/Shunji Mori, *Sintei-Seisan-Karri-Kenkyu* (a Study of Production Management, revised version), 1960, pp.164-166; Kiyoshi Yamamoto, "Kodo Seichoki no Rodo Mondai—"Gijutu Kakushin" to Sagyo-Shokuba-Soshiki wo megutte (Technological Change and Labor Problems in Japan", *Shakai Kagaku Kenkyu* (The Journal of Social Science) (Tokyo University), Vol. 38, No. 6, 1987, pp. 202-204.

20) Kocka, *op. cit.*, p. 373.

21) *Arbeitsordnung für die Werkstätten der EAGvS*, 15. 3. 1892, SAA 32/Li 382, pp. 8-9.

IV

In the electrical industry during the period of the middle of the 1890s and the early 1900s, the area of heavy current products such as power generation and transmission system, electric railway, lighting facilities and electric powered machines rapidly expanded by the success of high-tension power transmission technology in 1891, while the competition within expanding product market became keener among the actors inclusive with growing entries of new companies. Under such new technical and market situations a fundamental change occurred in production process, i.e. a shifting to the limited-variety mass production through the reform of machinery system by introducing electric motors and through the making of the system of product-type work group.

(1) Among reforms of machinery system, changes of working machines should, first of all, be noticed.

i. Firstly, in case of the Berlin works of S & H in 1896, table 3 shows that the special machine tools took predominant part of whole working machines, which was realised through remarkable diversification and increase of them in use. Also table 4, which shows details of newly procured working machines so far as mentioned in the annual reports of the Berlin works from 1898/99 FY to 1902/03 FY, indicates that the diversification and increase of the specialized machines for parts-machining, which could further improve the precision of processing, advanced during the last phase of prosperous period with its peak in 1899/1900 FY. In the small-type electric motor factory of AEG which started its operation in 1897/98 and in the mechanical workshop of its cable works established in 1897, diversified special machine tools were equipped which "produce the single part or limited-variety of parts in mass and can be operated even by non-skilled workers".[22] There were no less than 422 electric motor-driven working machines installed in the works hall of the big electric machine factory of AEG in 1899, of which specialized working machines for processing heavy and large size objects were also not a few.[23] In short, the highly precise machining by specialized machine tools, prerequisite to the mass production, was realized extensively among the factories of the general (diversified) makers, and the degree of precision work and productivity of the large size and/or heavy objects were also significantly improved by extensive mechanization in parts machining.

Secondly, an appearance of electric motors brought about the rise of two type working machines with new functions. One of them was the "self-acting machine". In 1897 it was expressed about a specialized manufacturer in Berlin, Gebrüder Naglo (established in 1872), that "these equipments (the sheet metal cutting machines) were also full automatic similar to the majority of working machines which were utilized here".[24]. Two years later it was also remarked that the "self-acting machines" such as self-acting gear-milling machines or automatic-shift milling machines installed in AEG were

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22) "Beiträge der AEG zur Entwicklung der Antriebstechnik", *Aktensammlung: Rationalisierung, Fließarbeit, Wandertisch und Normung*, oO. oJ., AEG-Archiv. p. 3.

23) "Bau und Einrichtung der neuen Maschinen-Werkstätten der AEG", *AEG-Zeitung*, No. 7, 1899, p.33; Rogge, *op. cit.*, pp. 108-109. AEG was established in 1883 originally as Deutsche Edison Gesellschaft für angewandte Elektricität. And the firm changed its name to AEG in 1887.

24) Paul Hirschfeld, *Berlins Groß-Industrie*, Berlin 1897, p. 125.

Table 3: Machine Tools, Number of Employee in the Berlin works of S & H (1896)

Workshop	Number of Employee	Floor	Machine tool	Power
a				
1 Telegraph & telephone-instruments	309	2,3,4	Small & middle-size lathes, drilling machines, sander and grind stone, presses, balancers, lever shears	m*
2 Instruments for railway securing system	240	1,2,3	Middle & big-size lathes, milling machines, drilling machines, planing machines	m
3 Precision measuring instruments for heavy & weak current	100	3,4	Small & middle-size lathes, milling machines, storage, batterie	m
4 Galvanic cells	10	1	Presses	–
5 Water meter	75	Basement, 1	Small & big-size lathes, lead screw cutting lathe	m
b Wire spinning-mill; painting shop	30	2,3,5	Wire spinning machines, paint mill	m
c Milling shop & planing shop	70	1,2	Small & big-sized milling machines 〃 〃 planing machines, 〃 〃 drilling machines, milling cutter-grind machines	m
d Box fabrication and forwarding department	30	Basement, yard	Circular saws, cranes & winches	m/h**
e Power & hand-smith	16	Basement	2 (Small & middle-sized) Drop hammer	m
f Machine & hand-joinery	45	2	All of the commonly used wood processing machines, small & big-size of screw-cutting lathes, cicrular saws	m
g Metal screw-cutting & shaping mill, combined with drawing & rolling mills	125	1,2,3 4,5	Draw-benchs, rolling mills, straightening machines, centrifuges	75%m 25%h

1. 4 boilers with steam engines were equipped in the workshop "a" for the supply of power, lighting and heating.

2. In the column of power "m" means machine power, while "h" means hand or foot power.

Source: *Fragebogen von der Berufsgenossenschaft der Feinmechanik zur Aufstellung einer Statistik für einen Gefahrentarif nach Industriezweigen*, August 1896, SAA 29/Le 932.

Table 4: Newly-equipped Machine Tools in the Berlin works of S & H

Machine Type	1898/99	1899/1900	1900/01	1901/02	1902/03
Lathe	17	36	14	3	9
Precision lathe			5		4
Backing-off lathe		1			
Spindle press	1		1		
Pillar spindle press					1
Pillar press			1		1
Press		4			
Excenter press	1				1
Turret lathe	4	6	8	10	1
Facing-turret-lathe				2	
Automatic turret lathe	2				
Face lathe	1				
"Kugel"-lathe	1				1
Universal-milling machine	1				
Milling machine		21	3		4
Shaping maschine	2	1			
Shaping lathe		13			
Planing lathe	2	2			
Cutter with reduction gears					1
Cleveland-automatic lathe					1
Gear cutting machine	1			2	
"Patronenbank"				1	
"Tafelscheere"	1				
"Theil"-machine		1			
Screw machine			1		
Screw-lathe		10	7		
Screw slit maschine			1		
Automatic screw lathe		3			2
Threading lathe		3	1		
Drilling machine		43	7		1
Quick drilling machine	6				
Pillar-quick drilling machine				1	
Grinding machine					1
Facing-granding machine	1				
Tool-grinding machine			1		
Grinding machine for drill		2			
Polishing lathe	7	4			
Polishing and grinding machine				5	
Paint roller				1	
Iron-cold saw			1		
Lever-cold saw			1		
Wood-planung machine		1			
Wood-milling machine		1			
Wood-circular saw		1	1		1
Saw scharpener	1				
Sheet metal-adjusting machine		1			
Balancer	1	4			
Engraving machine		1	2	1	1
Belt-binding machine		1			
Casting machine		1			1

Source: *Geschäftsberichte des Berliner Werks für die Geschäftsjahre von 1898/99 bis 1902/03*, SAA 15/Le 822.

also "widely utilized".[25] At the Berlin works of S & H, various types of "automatic lathes" were utilized as well. In case of these self-acting machines, judging from the technical standard of the time, it seems appropriate to understand from the word "self-acting" or "automatic" as mentioned here that probably two operation factors of forwarding and stopping among whole processes of setting → starting → forwarding → stopping → dismounting were incorporated into the mechanism of machines. The "widely-utilized self-acting" machines in both general makers and the specialist firms played the role of technical base on which industry-wide permeation of mass production became possible because of the simplification and increased speed of production.

Another one was the transportable machine tool. The electric-powered drive, especially individual drive, about which we will see later, brougt about not only the basic change in the system of fixed working machine and mobile work piece-type operation, but it also made the system of mobile machine tool and fixed work piece-type machining (operation) for not-easily-movable work pieces possible or easier with the innovations of transportable machine tool. This development specifically made it possible, on the one hand, to mechanize the manual processing work for the large size, special profile and heavy weight pieces or materials (on which mechanization had scarcely been possible), to increase the direct processing time due to the significant reduction of transportation and setting time, and to improve accuracy and continuity of operation as well as "operating density" and "operating speed" by means of synchronized co-operation of similar or different kinds of machine tools.[26] On the other hand, it brought about the improvement of investment efficiency (by means of investment saving for jigs and fixed working machines as well as by the increased number of transportable machine tools in use) and the saving of labor costs mainly in the indirect non-clerical sections.[27] It must be, therefore, payed attention to the fact that the notable change on the working machines of the time had occured not only for the mass-produced products but also for the single and/or large sized products. At the same time, since the transportable working machines had even an effect partly on machining of the mass-produced products, they might have brought about greater benefit to the general makers which subsumed both small-lot production of large size products and mass production of small size products. While about 50 transportable machine tools were utilized in the machinery hall of the AEG's big electric machine factory in 1899,[28] presumably the other large scale general makers also introduced them to get such benefit.

ii. Precision tools or precision measuring instruments such as various gauges were also used which were essential to secure process accuracy of mass-produced parts (mostly down to 0.005 mm). In the big electric machine factory and the instrument factory of AEG in the turn of the century, they were extensively utilized in the production of all kinds of interchangeable and standardized parts which led to the situation that no subsequent revising work was necessary for assembly and "screw driver is the one and only tool in assembly shops".[29] In the mechanical workshop of the company's

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25) "Bau und Einrichtung", pp. 33-41.

26) Hasse, *op. cit.*, p. 76.

27) "Transportable Werkzeuge", *AEG-Zeitung*, No. 8, 1899, pp.17-29; "Bau und Einrichtung", pp. 33-42.

28) "Bau und Einrichtung", p. 33.

29) *Ibid.*, p.35; Soethen, *op. cit.*, p. 20.

cable works the tools for lead-coating press such as dies and counter-dies, which were essential for securing uniformity of many and diversified steel forms and cable-lead coats for manufacturing insulation material, were manufactured together with other various kinds of tools.[30] In S & H, the similar situation could be observed: establishment of a special tool workshop and the manufacturing of special tools in it for mass production in 1896/97; establishment of grindry for both milling machine operator and drilling machine operator in the Berlin works in 1903/04 FY as well as that of polishing mill in 1900/01; extension of mass production area to telefone and instruments sustained by use of many special tools in 1903/04 FY; and utilization of many special tools for the production of microphone, magnet ignition coil, line selector and land mine detonator in the same years.[31] Utilization of precision auxiliary tools contributed to the simplification of work and the improvement of working speed by securing process preciseness.

iii. Electrification of the factories through the utilization of electric motors changed not only machinery system but also its arrangement.

In the conventional factory, overall machinery system and equipment arrangement were the "slave of mechanical transmission", and "not the manufacturing process of products" but the "power transmission" formed the leading thread. Mechanical transmission required plenty of space as well as the arrangement capable for maintenance and lubrication, the costs of which amounted to significant proportion among operation costs, and the time of operational suspension caused by transmission trouble could not be also ignored.[32]

These disadvantages were liquidated through the utilization of electric motors, especially by removal of mechanical transmission consequent upon the introduction of electric powered individual drive. In the machinery hall of the AEG's big electric machine factory in 1899, "except for a few manually-operated machines, all other machines were individually driven by the three-phase electric motors with the power ranging from 0.25 HP to 20 HP".[33] By this innovation, the installation and operation costs for mechanical transmissions became unnecessary, and it became possible to use power more effectively. Moreover, the "mutual position of workshops and the arrangement of working machines in them depend not any more on the power to be supplied, but on the work to be done", and "the working machines are not needed to be all arranged mutually in juxtaposition or in a straight line. One will carry out rather more rational arrangement of working machines (in sequence of product formation), with which workpieces can most optimally be processed on each machine tools and intermediate transportation is avoided, so that process movement in the workshop itself continued without interruption".[34]

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30) *Das Kabelwerk der AEG Berlin*, 1904, pp. 45-66.

31) *Geschäftsberichte des Berliner Werks für die Geschäftsjahre von 1896/97 bis 1903/04*, SAA 15/Lc 822; *Arbeitsordnung für das Berliner Werk der S & H A.-G. vom 1. 3. 1903*, SAA 32/Li 382, p.9; Kocka, *op. cit.*, pp. 337-338 and 373-374.

32) Oskar Lasche, "Die elektrische Kraftverteilung in den Maschinenbauwerkstätten der AEG", *AEG-Zeitung*, No. 7, pp.5-9; "Allgemeines über electrischen Betrieb in Neuanlagen", *AEG-Zeitung*, No. 7, pp. 14-18.

33) "Bau und Einrichtung", p. 33.

34) "Allgemeines über elektr. Betr.", pp. 14-19.

Furthermore, the similar or different kinds of working machines could be arranged in the same operation space by higher density and by increased number, so that the "Mehrbanksystem" in which each operater took in charge of more than two machine tools also appeard or spreaded among machining processes.[35] In other words, remarkable improvement of productivity was brought about as a result of further deepening of the co-operation of machines as well as their co-operation based on the "division of labor".[36] Also, by means of electric powered individual drive, installation of working machines even in finishing or assembly process became possible where mechanical transmission had not been equipped due to few machines to be utilized and under higher rate of machine idleness. Consequently, the deepning of machinery system in the meaning of the mechanization of production process as a whole could be brought about.[37]

Arrangement of machinery system in the factories was largely changed by above mentioned factors. In the AEG's big electric machine factory in 1899, 422 heterogenious, individually-driven and fixed-type working machines and 50 transportable working machines were systematically arranged by clearly classified 7 product-type machining and assembly fields (see Fig. 1). It was the very machinery system for mass production by means of semi-assembly-line operation which will be explaind later.

iv. Electrification of factories brought about further mechanization and systematization of transportation directly by the electrification of transportation means themselves. At the factory sites of AEG and other companies, various transportation movements were set up in almost every required directions: horizontally by utilizing the trolly type electric locomotives, accumulator locomotives and large or small size freight cars and trucks by laying out specific railroad from the nearest national railway freight stations, while horse-drawn carriages and hand carts were supplementary used for small-scale transportation; vertically or in horizontal-vertical directions, different types of electric power cranes and winches as well as electric freight elevators were thoroughly used. Sweeping out of the mechanical transmission allowed full use of the electric power cranes, and the effectiveness of laid out rails were further heightened as accumulator locomotives were used here, which required no electric cable stretched in midair where they otherwise could have interfared with crane transportation.[38] These indicate the significance of the electrification of transportation means for the rationalization of both transportation and processing.

The AEG's instrument factory in Ackerstraße and its factories in Humboldthain (which comprised of the big electric machine factory, the small-type electric motor factory, an assembly hall of electric locomotives and freight cars, and a foundry) were connected with electrified subways. Streetcar motors fabricated at field 14 of the big electrical machinery factory were carried to the assembly hall of electric locomotives and freight cars by railways (layed in the factories) for setting up the streetcars, and finished streetcars were then delivered by railways in the yard which also connected

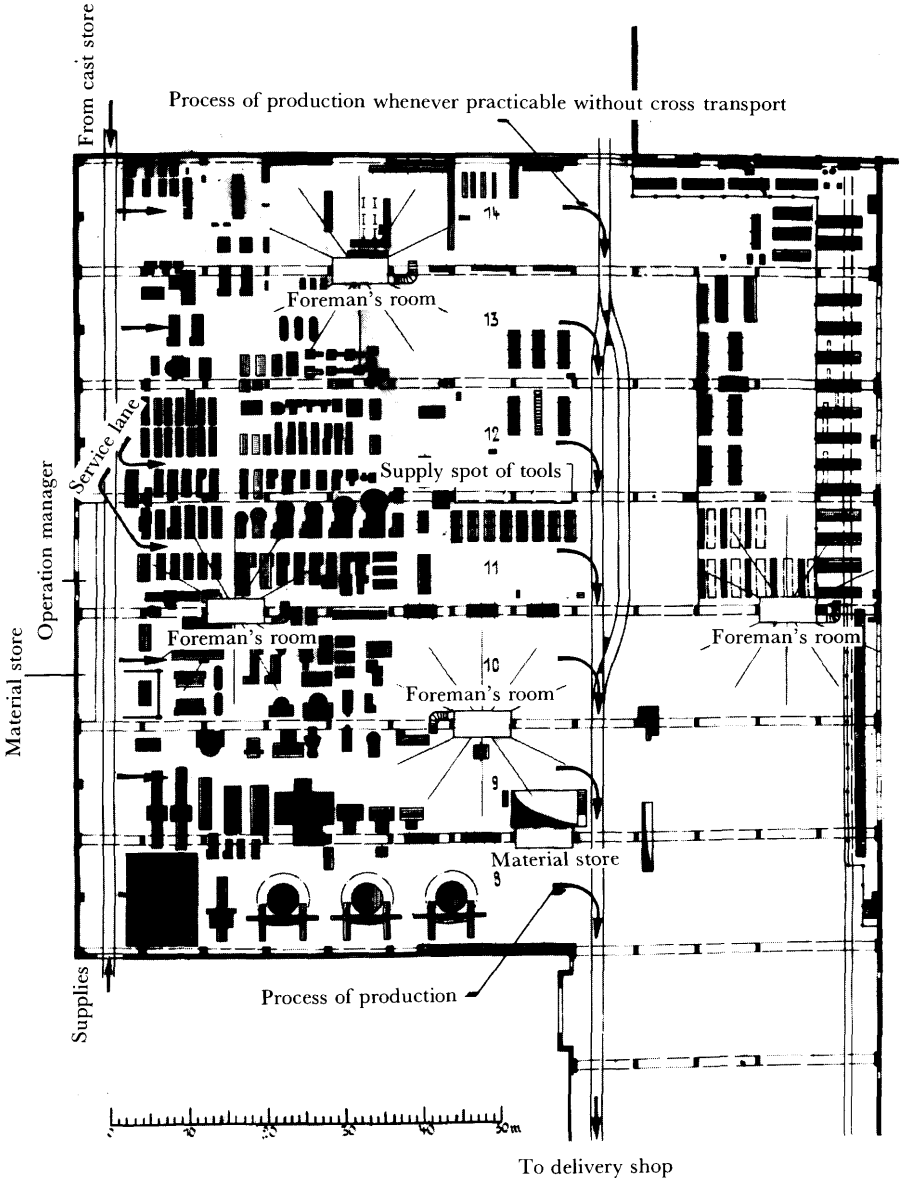
35) *Die Arbeitsverhältnisse der Eisen-, Metall-, Modell-, Werkzeug-, Revolver- und Automaten-Dreher Deutschlands*, festgestellt vom Vorstand des Deutschen Metallarbeiter-Verbandes, Stuttgart 1912, pp. 101-102.

36) "Bau und Einrichtung", pp. 38-41.

37) *Ibid.*

38) "Allgemeines über elektr. Betr.", pp. 14-20.

Fig.1: Arrangement of Work places in the AEG Big Electric Machine Factory (1990)



Source: Hennig Rogge, *Fabrikwelt um die Jahrhundertwende am Beispiel der AEG Maschinenfabrik in Berlin-Wedding*, Köln 1983, p. 110.

with another railways in each factory. Both factories, almost all transportation processes including those mentioned above were systematized and mutually connected through electrified mechanization: for example, between factories where transport operation might occur and outside; between factories; between outside and inside of factory buildings; among each floor of the factory and among divisions and workshops on the same surface for up and down and all other possible directions. Moreover, the system was arranged divisionally and systematically in accordance to the weight and size of the objects to be transported and was made flexible for switching of equipment as the need arose. The transportation equippments thus contributed for the rationalization of transportation (the rapid improvement of the density and speed of transportation) and facilitated, at the same time, the systematization of production at each processing stage.

It was more important that the system of product-type operation itself brought about the rationalization of transportation indirectly because it lessened the necessity of transportation within processes. In the AEG's big electric machine factory, "production was so arranged that transportations within workshop were restricted as little as possible",[39] and "production process was progressed within each field avoiding side cross transportation.[40] In brief, the product-type work group was arranged there to shorten transportation distance of large-size and heavy weight products, so that the burden of overall transportation, especially between divisions or work groups, was reduced. Also within each product-type division or work group, transportation between work places was scaled down and was partly incorporated into each production process by means of the arrangement of different kinds of working machines and workers according to the process flow, so that transportation could be realised basically with one way and minimum distance.

Thus, "overall transportation is carried out with minimum time and power consumption". It conversely led to further heightening of organic connection of the system of product-type work group, which contributed to realize the "fine and speedy operation process and low cost production", i.e. to increase productivity by accelerating of operational continuity.

(2) The next to be noticed is a change in workshop organization. The arrangement of machinery system by product type according to process flow and the electrification of transportation, both of which became possible by introduction of electric drive system, coupled with product standardization and parts normalization as described later, brought about the shifting from the system of machine-type workshop operation to that of product-type operation.

i. The AEG's big electric machine factory in 1899 was a typical example of the change. The aforecited fig. 1 demonstrates that the factory organized the system of product-type work group (under the clear division between mass-produced products and single produced products), which integrated a series of successive product-type work group from rough shaping through machining to assembly (each of which included the system of machine type workshop) with successive, process oriented and functional work places which similarly followed work flow from post-assembly to delivery. This system brought about a qualitative jump of productivity as compared with traditional sys-

39) "Bau und Einrichtung", pp. 31-33.

40) Rogge, *op. cit.*, p. 110.

tem of the machine type workshop. This was because the typical "semi-assembly-line system" was nearly realized, in which "operational continuity is enhanced on the whole as the delay of process flow due to the crossing of various kinds of operation lines at one working point is avoided, and detour or reverse flow of work can be also eliminated at each workshop", and furthermore, "the function of work place and work sequence planning (process planning) is incorporated into the operational mechanism".[41)]

ii. In the factory, the "intermediate stores" were also equipped. These were, in the system of product-type work group, to work as the "buffer" for continuous and steady supply of work in order to avoid suspension and congestion of work flow owing to supply fault of processing objects, and at the same time, they were to provide supplemental time and space for the manufacturing workshop, which could not otherwise be possible to use for the "direct work".[42)]

In the system of machine type workshop the intermediate stores had to be placed by each machine type workshop and carried out the function of supplying work objects to each workshop and that of storing them from each workshop. Many storing warehouses, however, reduced space for the "direct work" and the positions of warehouses themselves caused process restriction. Moreover, the intermediate store arranged by each workshop had to be a package type (universal) store for multi-product processing objects, with which the suppliability of storing objects by each product type was considerably restricted. In short, it could not create the rational work flow. It became rather a factor which impede the rational process formation of the operation system.

Due to the formation of the product-type operation system, production processes could be arranged according to work flow so that defects of the stores were significantly eliminated. The intermediate stores could basically be placed between each product-type process which was combined each other organically, so that the scale of the intermediate stores per unit as well as total cubage of entire warehouse could be reduced, and the composition of stocks in the intermediate stores could be also rationally divided. The intermediate store became the product-type exclusive style warehouse.

The intermediate store was assigned a farther function to avoid interruption of process flow and to facilitate it. In other words, it was assigned the function to serve as a mediating ring to combine machining and assembly more organically and systematically, as well as to serve as a "buffer" of processes to maintain and promote regularity and continuity of operation by coordinating work flow. The product-type exclusive style warehouses, which were arranged being mediated by the successively organized processes, conversely integrated the processes organically, so that the mutually promoting effect on the smooth flow of processes could be expected.[43)]

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41) Kazuhito Siomi, *Gendai-Tairyoseisan-Taisei-Ron* (The Modern Mass Production System), Moriyama-Shoten, 1978, p. 96.

42) Artur Fürst, *Emil Rathenau. Der Mann und sein Werk*, Berlin-Charlottenburg 1915, p. 98; "Bau und Einrichtung", p.98.

43) Since a huge casting storage space of the AEG's big electric machine factory collected, stored and supplied parts etc. according to the arrangement order by product types, it can be also seen as a kind of gathering place of intermediate stores for the product-type special parts, which at the same time had functions of process integration and adjustment.

iii. Innovations in the machinery system and formation of the system of product-type operation brought about also rationalization in the controlling of labor force at workshop level. These were revealed in the shape of factory buildings with a fine prospect over non-partitioned machining and assembly or finishing hall as well as in the form of forman's rooms which were set at a step higher level (being covered with glass walls on all sides) and located at important positions inside of factory buildings.

"From here, works engineers and foremen can overlook and supervise all area assigned to them through unobstructed view", and "all workers on their part feel that they are always being supervised. Taking a whole view at a glance with no considerable time loss, it is possible especially for the operation manager to confirm the operation always for himself. There may be no need of redundant words for how much this system influences on workers' moral, and how much of this effect is converted to their will to work and enhanced profitability".[44] "Well-lighted environment is another important benefit of the non-divided style hall buildings. The more the wall are reduced, the more dark corners and nooks are reduced where workers apt to stroll and to waste time lazily".[45]

It seems that the setting of foremen's rooms became possible as a part of their former functions of production and labor management was integrated into the newly formed system of product-type operation itself at the non-partitioned style operation hall so that the stationing of foremen at each workshop became partly unnecessary. In any case, the non-partitioned organization of the factory, including foreman's rooms placed at key points allowed further efficiency and concentration of labor management (i.e. "production encouragement", improvement of "will to work" and production accuracy by workers).

On the other hand, in the factories there were also management issues on the industrial relations. The forbidden clauses of working rules stipulated as "No worker is allowed to leave the assigned workshop to himself or move to other workshop divisions, when it is not necessitated by his work", "Visit of relatives and friends or any other persons is not allowed to be received in the workshops and generally during the working time", and "Any transaction by workers in the factory is strictly prohibited"[46] were in fact also designed to regulate social and political contact among workers and labor movement. The factories and foreman's rooms with good perspective held a structure which enabled to control even such behavior of workers.

(3) Standardization of products, normalization and making interchangeability of parts or components, each of which was prerequisite for the low-cost mass production, also advanced notably. In the 1890s AEG "had already made an effort to normalize quantitatively the most important individual parts with the aim to reduce stocks of raw materials and semi-finished products on the one hand, and to shorten delivery times of the specified products on the other". In addition, "the Verband Deutscher Elektrotechniker (VDE) had made itself the body responsible for an effort of normalization and patternization for the whole electrical industry directly after its establishment (in 1892)". And "Emil

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44) "Bau und Einrichtung", p.30; "Allgemeines über elektr. Betr.", p.20. Vgl. Hasse, *op. cit.*, S. 68.

45) "Allgemeines über elektr. Betr.", p. 22.

46) *Arbeitsordnung für die Werkstätten der FAGvS*, 15. 3. 1892, SAA 32/Li 382. See also *Arbeitsordnung für das Berliner Werk vom 1. 3. 1903*, SAA 32/Li 382.

Rathenau (the head of AEG) had taken a leading part in all activities of the federation relevant to the tasks".[47] The representative factories of mass-produced standardized products based on interchangeable and normalized parts were the small-type electric motor factory (established in 1897) and the instrument factory of AEG. While repeatable (interchangeable) components of electric motors and the smallest-type motors as standard model were mass-produced in the former factory, the mass production system of repeatable components was "promoted with highest possible perfection, and up to about 10,000 price-list items (various types of electric supply meters, breakers, change-over switches etc.) were mass-produced in the latter".[48]

Also in S & H, under the recognition that the rapid price cutting of heavy current electrical products was forcing inter-factory unification and integration of products and manufacturing designs, it became an important issue to unify the simplification and normalization of the products and parts construction among business establishments and group enterprises in European countries, especially in connection with increased competition among companies after the middle of the 1890s. Thus, after 1899, a course aimed at unification of product technology in the whole enterprise group was worked out. Namely, the Technical Central-Bureau (abbreviated hereafter as the TCB) was established in the same year. According to the draft of the initial establishment plan:

1. While the TCB belongs to the Central Department in the head office, it constitutes the common body for group enterprises.
2. Its main tasks are to unify on cost accounting and especially to reduce construction failures by comparing and observing products and designs which were made under the same purpose but with different manufacturing method among group companies.
3. Each company in the group has to provide information to the TCB when required, and the head of the TCB is authorized to know constructions and production methods, and is allowed to enter anytime into any workshop and bureau.[49]

The following measures were taken to reform product strategy among international S & H-group companies, among factories as operational divisions, and among divisions within each factory, being accompanied with the establishment of the TCB: integration of electro-chemistry divisions in both the Berlin and Vienna works in April 1900; co-operative control of the new division by managing directors of both works; taking all areas of electro-chemistry in charge of the new division, including pure chemistry business in the Berlin works and the Charlottenburg works, but exclusive of the same division in the Vienna works; putting the new division under the direct control of the board of directors in S & H; maintaining close contact with both Siemens subsidiaries in Russia and in London

47) *50 Jahre AEG 1883-1933*, Berlin-Grunewald 1956, p.146.

48) "Beiträge der AEG zur Entwicklung der Antriebstechnik", AEG-Archiv, pp. 1-2; Soethen, *op. cit.*, pp. 18-19, cf. *50 Jahre AEG*, p. 146.

49) *Entwurf des Programms für Errichtung einer technischen Centralstelle vom 16. 9. 1899*, 35/63/Lp 758; *Geschäftsordnung für Herren Richter*, Juli 1899, SAA 35/63/Lp 758; *Chronik der Zentral-Werksverwaltung (ZW)*, 1. Teil, ed. by Siemens-Schuckertwerke AG, München 1965, pp. 1-5.

by this new division;[50] an adjustment plan of production facilities proposed by Ernst Richter, the head of the TCB, in January 1901, based on the viewpoint that under the existing conditions of competition it was impossible to equip all factories for the manufacturing of all kinds of products, and the company could only lead a step forward by specializing of its products in each factory as well as by reducing operational dispersion through concentrating lesser products for each factory, saying, "since it seems that the product items suitable for transfer from the Charlottenburg works to Vienna are particularly high-tension breakers and high-tension fuses, while the item fitting for transfer from the Vienna works to Charlottenburg is over load breaker, the Charlottenburg works is recommended, 'under consideration of business policy', to endeavor in improving production of high tension breakers, fuses and transformers, by entrusting the production of over load breaker to the Vienna works";[51] and an instruction of the Berlin works in August 1901, which provided that "to make it possible to introduce our standards and to utilize existing parts on a larger scale than before, every sketch appointed for workshop or every production model is transmitted to the construction bureau for inspection before it reachs the workshop. The workshop is instructed to produce no equipment based on sketchs or models for which no assent by the construction bureau is attached; moreover, whenever the production order is issued, the construction bureau has to be informed of it to be able to controll over the drawings".[52] As pointed out above, these measures indicated that the group policy for unification of constructions and products was clearly established.

Furthermore, the Technical Commission was established in December 1901 to assist activities of the TCB, and it was renamed and reorganized as the Unity Commission (the chairmen were Emil Budde, the executive director, and Ernst Richter, the chief of the TCB) in February 1902. The latter held supervisory authority for constructions of heavy current products of both works in Charlottenburg and Vienna, while the approval of the Commission was required for construction and experimentation of the standardalized product series.[53]

The processes explained above show that the unification of construction and standard was thoroughly pushed forward across the whole company. As a result, normalization of parts and standardization of products were promoted in each factory of S & H, which are suggested by the fact that at the Berlin works already in 1898/99 FY, "after a part of products was designed easier than before and suitable to the mass production, a significant change was arisen on the production equipment".[54]

Meanwhile, the efforts to establish the measurement standard for normalization and standardization had been also made on the industry level since the 1890s. This movement had been in parallel with activities of industry-wide unification for parts design, being started in that of wiring technology and installation material, and had overlapped with the movement to set up the safety standards for the handling of electrical equipments. The publishment of the first safety standard handbook by the VDE in 1904 can be seen as an indication for the establishment of unified interests in the

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50) *Neuorganisation der Elektro-Chemischen Abteilung*, 30. 4. 1900,SAA 35/63/Lp 758.

51) *Richter (TCB, Centralabt.) an das Charlottenburger (Dynamo-) Wk. vom 1. 11. 1901*, SAA 25/Ln 400.

52) *Verfügung des Berliner Werks vom 9. 8. 1901*, SAA 32/Lo 601.

53) *Chronik der ZW*, p.1-8; *Verfügung betr.: Befugnisse der Einheits-Kommission vom 26. 2. 1902*, SAA 68/Li 71; *Brief der Centralabteilung der S & H A.-G. an R. Fellinger in Wien vom 27. 2. 1902*, SAA 68/Li 71.

54) *Geschäftsbericht des Berliner Werks pro 1898/99*, SAA 15/Lc 822, p.15.

industry on this point.[55]

(4) Thus, the system of mass production gradually appeared and spreaded in the electrical industry following to the formation of the system of product-type operation and the advancement of specialization and standardization of parts and products.

Especially, AEG firstly shifted its manufacturing of electric bulbs, installation materials and small-type electric motors into mass production in 1895, and set about full-scale mass production of electric motors at the newly-established factory for small-type electric motor in 1897/98. This factory mass-produced, as the first factory specialized for mass production in Europe, "repeatable components of electric motors and the smallest-type motors as standard models". In the instrument factory, about 10,000 price-list items, such as various types of electric supply meters, breakers and change-over switches, were mass-produced and "limited varieties of grips, sockets and axes, catwhiskers, connector types etc. were applied for breakers of many hundreds of types and varieties which amounted to 3 million pieces per year, and the latter could often be mass-produced by self-acting machine tools operated by female workers. Each part was then assembled in special assembly shops and was combined into various types of products".[56] At the field 14 in the big electric machine factory electric generators for electric railway and presumably the parts and components of many other large size and/or heavy weight products were also mass-produced.

These meant that production in the large-scale advanced factories began, on the whole, to orient itself basically toward mass production through the semi-assembly-line operation. This was the very content which formed a technological base for the rapid rise of the electrical industry being accompanied with severe price-cutting competition among companies in the last quarter of the nineteenth century, and which at the same time indicated the productivity base which allowed for major enterprises to put foward the "concentration movement" in this industry. Riedler wrote properly on the situation as follows: "Adequate, planned, and very profitable production of the low cost mass-produced products in the electrical engeneering was, from the beginning, one of the reasons of Rathenau's success", and "enormous profit" obtained by mass production "and Rathenau's financial policy made it possible to execute extremely large scale depreciation, which led to further reduction of the production costs, and selling price could be cut down more intensively, so that competition was almost impossible".[57]

(5) By the turn of the century, nevertheless, there were still some limitations for the transition to the system of product-type work group, so that the mass production based on this system did not fully established in the electrical industry.

i. There were differentials among companies in forming the system of product-type work group operation. The AEG's big electric machine factory at that time was undoubtedly the most advanced one. Many other factories did not reach to its level. Even the S & H's Dynamo works, which belonged to the most advanced factories except for the above mentioned factory of AEG, was still in the

55) Kurt Janczikowski, "Normung in der Elektro-Technik", *Aktensammlung; Rationalisierung* ..., AEG-Archiv, p. 2.

56) Soethen, *op. cit.*, pp. 18-20.

57) Riedler, *op. cit.*, pp. 127-130.

shifting stage, because in 1901 it was a production unit which combinated some divisions for different kinds of products such as divisions of electric generator and motor as well as those of apparatus and small-type products. In this case, the system of product-type operation of the Dynamo works was combined with the traditional system of machine-type workshop operation. On the other hand, in AEG each division was specialized into the independent production unit such as the big electric machine factory, the small-type electric motor factory and the instrument factory. Furthermore, each unit was organized according to the system of product-type operation. In the S & H's Dynamo works, on the contrary, the rational arrangement of the processes was restricted and work flow was apt to be detoured and complicated because of its multi-product-type production system added with its constructive restrictions of the multi-floor building.

For the production process in the electrical industry as a whole, the period from the middle of the 1890s to 1904 should not be deemed therefore as the establishment period of the system of product-type work group operation but as the transition period to it.

In regard to the electric motor which could arrange working machines parallel with work flow, prerequisite to the formation of the system of product-type work group operation, its industrial use did not widely spreaded until 1904, and the introduction of electric power individual drive was not permeated even in the electrical industry, although the mass production of electric motors had started in the late 1890s.

Normalization of parts and standardization of products which were indispensable to the mass production did not smoothly progressed, since they were restricted by industry wide conflict of interests as well as, in case of the multi-national and multi-divisional enterprise such as S & H, by that among group-companies located in each country, among operational divisions, and among sub-divisions within a factory as an operational division.

The TCB's establishment in 1898 itself was, as a matter of fact, a result of compromise made under the explicit or tacit resistances. Namely, to the original draft of the establishment programm of the TCB, the chairman of the board of directors, Tonio Bödiker, submitted the following restrictive comments on September 19, 1899: "The original draft detaches the technical central office entirely from every relation with parent firm (in Berlin), and puts it as somewhat completely independent organization in the midst among companies in Berlin, Vienna, Petersburg and London ..... Although it takes its meals from the parent firm in Berlin and operates basically with employees of the latter, the technical central office can carry out the change of front-line against the parent firm at any time ..... A new organ will come into being, which will not be controlled by anybody else, and will be left only to its own resources, entirely free and independent ..... The programm is just an evidence of the centrifugal tendency which is arising in our company so frequently". The comments intended to regulate the TCB's autonomy and the possibility of its rivarly with the (head of fice of) parent firm as stipulated in the draft, recognizing that these had the same nature as the "centrifugal tendency" being arisen in the subsidiaries in different countries as well as in the different divisions, and so to secure the parent firm's authority over the TCB through measures for example to bear the TCB's expences up to about a half by the head office.[58)]

The draft for the establishment programm of the TCB submitted to the board of directors in September 27, 1899 was virtually based on his comments, and was approved under the condition that

it would have to be also approved by subsidiaries in foreign countries.

However, their approval could not be obtained immediately, and the draft caused especially criticism of Hermann Görz, the president of Russian S & H. Görz wrote:

a. The name of the TCB is not suitable as it can imply organizationally higher position than each works, so that it should be renamed. The rule that provides the TCB with responsibility to supervise production activities of each works should be deleted.

b. Repartition of the TCB's costs beared by group companies should be determined before the establishment of the TCB, based on the scale of invested capital etc.

c. The TCB's participation in cost accounting of group companies should be limited to the determination of raw materials and labor costs for concerned products. All other business factors should belong under the authority of the commercial division or the direction office of each works. Since the whole rules of participation to cost accounting as described is overextended and it intervenes too much to the authorities of the works directions and apt to induce disputes, it is desirable to delete this item totally.

d. Acceptance of the TCB in each works should be done by the level of direction office of works, and the visiting business is to be finished as far as possible in the acceptance room by the chief of the TCB or at least by its senior clerks. Necessary information about matters and personnel can only be obtained by this way.[59]

In brief, while Görz was originally a positivist about the TCB's establishment for the purpose of company wide unification of product constructions, he was critical to the point that it might restrict the autonomy of subsidiaries in foreign countries and that of operational divisions (works), since the TCB could function as a supervisory organ of the head office against them.

On the other hand, Görz took positive position to centralize the authority within each com-pany or each works, expressing concern about the possibility that the authorized activities of collecting informations about the works by the TCB might cause the supervisory confusion within company and works. According to the letter from Petersburg (Görz) to the Central Division of the head office in Berlin on December 18, 1899, Görz requested the information whether Charlottenburg works approved its bureaus to contact directly with the TCB. Petersburg itself, however, expressed not to venture into it. Because "we see in it a decentralization which would possibly be accompanied by troublesome results".[60] These indicate that the management policy for normalization of parts and standardization of products gave rise to a break of the concerted steps within enterprise and works, or there were situations in which such policy was impeded by that break. These dissonances existed, presumably, not only between production site and technical staff division, which was paradoxically in-

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58) *Votum zu den von Herrn E. Richter vorgelegten Programm für Errichtung einer technischen Centralstelle*, gez. v. Bödiker am 19. 9. 1899, SAA 35/63/Lp 758; *Vorläufige Bestimmungen über das Technische Central-Büro vom 27. 9. 1899*, SAA 68/Li 122.

59) *Vorschläge St. Petersburg (Görz): "Technische Vermittlungsstelle" oder "Technische Vermittlungsamt"*, 22. 9. 1899, SAA 35/63/Lp 758; *Görz an Bödiker vom 22. 9. 1899* (Eingang 7. 10. 1899), SAA 35/63/Lp 758.

60) *Görz an die S & H A.-G. Central-Abteilung vom 18. 12. 1899* (Eingang 2. 1. 1900), SAA 68/Li 122.

dicated in the fact that the establishment plan of the TCB boldly adopted as an important issue to open the road for reasonable co-operation between construction and production, as well as in the instruction concerning about the controll of workshops by construction bureau, but they exsisted also among various divisions and various management levels.

The draft for the establishment of the TCB in September 27, 1899 which had revised according to Bödiker's suggestion as mentioned previously, was basically recognized in the meeting of the board of directors held on November 4, being co-ordinated by or added with Görz's amendment suggestion.[61] However, doubts about the TCB's organizational form had smoldered even after its establishment. One of them was revealed in a suggestion made by the Charlottenburg works to the Central Division of the head office on September 13, 1990, in which it stressed the principle of equal sharing of the TCB's expenses basically among related six companies or works. This may be deemed that the works was more cautious than the Russian subsidiary against intervention on the autonomy of each works (as operational division) by the head office through the TCB[62]. All these make clear that, on regard to the issues of concrete procedure and organization activities by the TCB for the unification of constructions, there existed strong "centrifugal tendencies" among companies and works based on respective interests.

Activities of the TCB and the Unity-Commission did not, at least, advanced easily, being faced with resistance from the factory side. A correspondence addressed to Wilhelm von Siemens, the head of S & H, in July 12, 1901 said that, although both Charlottenburg and Vienna works had tried to realize fullscale factory-base production of resistors and broken down them into various simple elements, their methods to accomplish the same purpose had been different, as Vienna had adopted band turns or wire turns by discontinuing utilization of traditional Maeander-resistances, while Charlottenburg works had changed arrangement and structure of existing Maeander-strips to make these applicable for mass production[63]. Although it is not clear how this proposal was treated, this correspondence at least indicates that the object to discontinue the duplicate production of the same product by the different method among works, which had been planned with the establishment of the TCB, was not yet achieved even after two years of the TCB's start.

On this point, the proposal addressed to the Charlottenburg works from Richter in January 1901 and that of Görz in October 29, 1901 (in Russian calendar) and in April 3, 1903, as previously mentioned, indicate the similar situation. Although they show efforts of chief executives toward changing diversification strategy on the international level as well as on the level of operational division through the unification of product construction, the fact that the similar proposals were repeatedly made even after the establishment of the TCB and the Unity-Commission meant that the com-

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61) According to the minutes of the 68th meating of board of directors held on November 4, 1899 an information was given that Bödiker's suggestion to establish the TCB was not accepted by each company, and agreements were made on obtaining oral understanding (of each company) for another revisional suggestion by S & H Petersburg (*Auszug aus der Protokolle der Directorums-Sitzungen vom 27. 9. und 4. 11. 1899*, SAA 68/Li 122). Effectuation and inauguration of the TCB were also made under these understandings.

62) *Charlottenburger Werk an die Central-Abt. vom 13. 9. 1900*, SAA 35/63/Lp 758.

63) *Brief an W. v. Siemens vom 12. 6. 1901*, SAA 35/63/Lp 758.

pany-wide issue to unify the products and designs through the TCB and the Unity-Commission could not be solved without conflicts.

Furthermore, an industry-wide attempt of normalization as well as that of unification of construction and safety standards also did not necessarily advance smoothly because they were restricted basically by severe competition among electrical firms.[64]

Therefore the German electrical companies by 1904, generally speaking, still had not obtained the technological capability to establish so to speak the disposal of the alternative of mechanical equipment under the system of product-type work group or human labor (in other words, the alternative of equipment costs or labor costs). They had to wait for obtaining such alternative until the subsequnt phases of innovations in production technology in the twentieth century.

ii. Despites of using "advanced" machine tools in the German electrical industry, it had problems of the comparative disadvantage of productivity and costs. There were many American special machine tools at that time, on this point, the performance of which was "an almost phenomenal one". For example, according to the related report by Otto Feuerlein, the director of the S & H's incandescent lamp factory, in 1903:

a. The quantitative productivity of the American carbon filament melting and handling machines which were used by GE for manufacturing incandescent lamps exceeded 50 — 100% than that of prevailing manufacturing method of his factory.

b. The performance of combined working machine for bulb drawing and cutting manufactured by York Electric and Machine Co., York Pa., the maker of special machine tools for GE's incandescent lamps, was about 50% higher than that of existing equipment in his factory, and the productivity of its electrode press machine was also 80% higher, while that of the "Teller-Maschine" was 100% higher.

c. In case of the fixing of contact socket with glass shades, American method only required that lampbases were set on lamps in a special kiln at 150℃ being used of a newly-developed putty. This methode was less complicated than prevailing one, so that its quantitative productivity amounted to about two times more than present puttying method. The main advantage were that lamps could be kept clean and, with this, existing troublesome after-treatment falled away, and that the delivery became possible immediately after puttying of bases. The latter meant that the space for warehouse could be remarkably saved etc.[65]

Feuerlein gave advise to Wilhelm von Siemens that the latter decided to know American incandescent lamp factories through personal study on the spot, as the permeation of American new production methodes into Europe seemed, in his eyes, to be a question of time in consideration of the

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64) *Wilhelm v. Siemens an Richard Ehrenberg vom 25. 6. 1913*, SAA 4/Lc 600.

65) *Bericht von Otto Feuerlein über die letzten Neuerungen der amerikanischen Glühlampentechnik*, 17. 3. 1903, SAA 4/Lk 84; *Aktennotiz von Feuerlein betr.; Amerikanischen Glühlampentechnik*, 17. 3. 1903, SAA 4/Lk 84; *Aktennotiz von Feuerlein betr.; Amerikanische Spezialmaschinen*, 5. 11. 1903, SAA 4/Lk 84.

activities of other European competing companies for studying or introducing those methods.[66] The report makes clear that the American electrical industry had threatened the European companies and factories by its remarkable man-hour reduction and higher productivity which were probably possible by the product-type and machine-type division of work for mass-produced products, using of product-type special machines and equipments, and that an introduction of American style production system could be a matter of life or death for the European electrical industry. It means at the same time that the machinery system and production process of the German electrical industry had not yet reached the most advanced level of the same age.

iii. Finally, the advanced cases themselves held their inherent limits.

The innovations in production technology followed with the appearance of electric motors did not mean that they gave possibility to realize the objective "compulsory progression of work" directly. Even at the most advanced big electric machine factory of AEG, where the combination and coordination between workshops or manufacturing processes advanced a great deal, the work-tact synchronization between different processes were still not realized. Each work within each process as well as between processes was, therefore, not fully set in the mechanical continuity, as those which could be observed in case of the assembly-line work system at later stages.[67] The mass production by the system of product-type workshop (semi-assembly-line) operation had a historical limitation in such sence. There were still many technological conditions on which working moral of workers could have significant influence.

In formation of the system of product-type work group operation, not all divisions of the factory were organized for the mass production. Such areas as fabrication of large size and heavy weight individual products, tool manufacturing, machining and assembly of precision-measuring instruments were still depended either on the system of machine-type workshop operation or even on that of the multi-purpose plant. Also on the product-type operation system the "division of labor" among different types of working machines which were set along work flow in machining was still on the way to be formed, and the degree of self-action of working machines was largely limited.

While electrification and rationalization of transportation heightend the degree of working succession in the system of product-type operation markedly, the processing was still not combined with transportation organically, so that the objective "compulsory progression of work" was not yet realized. The technological innovations which would make transportation mechanism the means of organic integration (such as conveyer system) for the realization of synchronized work flow among various processes was still out of range.

In regard to the intermediate stores to which the function of adjustment and buffer of work flow were assigned, it can not be denied that their existence itself expressed discontinuity and asynchronism of processes (a lack of the objective "compulsory progression of work") and, at the same time, they could change into additional cost factors.

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66) *Feuerlein's Bericht*, SAA 4/Lk 84.

67) Mohri, *op. cit.*, pp.144-162; Siomi, *op. cit.*, p. 237.

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Innovations in production technology in the German electrical industry during the period in question were finally took place as changes from the multi-product, small lot, and manual-individual production under the system of multi-purpose plant up to the middle of the 1880s through the medium-lot (series) production under the system of machine-type workshop operation during the middle of 1880s and that of the 1890s to the mass production system of limited-variety products under the system of product-type (semi-assembly-line) operation after the middle of the 1890s.

Such innovations were implemented as unavoidable means to secure competitive advantage by leading general enterprises and specialist firms forced by severe low-price competition among them. But it became, after all, the most essential factors which contributed to develop the electrical industry into one of the key industries and which made the establishment of "monopoly" by the two giants possible. They were the most advanced innovations in the assembly industry and they brought about a model effect to the other sectors. They were therefore, at the same time, strategic innovations in terms of guiding whole German economy toward productivity leap with shifting to the mass production system.

However, although the shifting innovations to the mass production under the system of product-type work group (semi-assembly-line) operation after the late 1890s meant undoubtedly a qualitative leap in productivity level compared with that of previous stages, they held still limitations because they were not completely achieved smoothly and totally compared with the full-scale mass production system by means of the assembly-line system after the 1920s. Especially, the innovations of production system during the turn of the century were still characterized as so to speak the "human wave tactics", so that their productivity was much more largely regulated by the quantity and quality of labor force than that of assembly-line system. It was therefore unavoidable,for the companies or factories to come to grip with the following additional issues such as: reform of management organization to co-ordinate it with production technological innovations; implementation of efficiency management for the purpose of securing the rationalization effects of technological innovations; and training of labor power which could be suitable for production technological innovations, all of which can no more be discussed here because of limitation of given space.[68)]

Furthermore, before even such production technological innovations were fully spreaded out, the "monopoly" by the two giant electrical concerns had already been established at the beginning of the twentieth century. Although this was established being sustained by the transition into the system of product-type operation, the latter did not permeate widely among the industry as a whole

68) See on this Sachio Imakubo, "19 Seikimatsu Doitsu Denki-Kogyo ni okeru keiei-Rohmu-Seisaku (Die Arbeitsverwaltung in der deutschen elektrotechnischen Industrie 1873-1903/04)" (7)-(10), *Saga University Economic Review*, Vol. 1. 22, No. 2, 3 and 4, 1989; *ditto*. Vol. 22, No. 5, 1990, Imakubo, "19 Seikimatsu Doitsu Denki-Kogyo ni okeru Rodo-Nouritsu-Zoushin-Saku (Das Management der Leistungsförderung in der deutschen elektrotechnischen Industrie 1873-1903/4)" (1)-(4), *Keizai-Ronso* (Kyoto University), Vol. 146, No. 3 and 4, 1990; *ditto*., Vol. 147, No. 1・2・3; *ditto*., Vol. 148, No. 4・5・6, 1991; Imakubo, "Labor recruitment and vocational training in the German Electrical Industry 1873-1895", *Keizai-Ronso* (Hiroshima University), Vol. 17, No. 1, 1993.

during a decade before World War I except for major enterprises and factories, as under the "monopoly" by the two giants a new leaping innovation of the production technology (espe-cially the implementation of the assembly-line operation) was, as suggested previously, compelled to wait until the period of the rationalization movement in the 1920s, when severe competition with American firms etc. in the world market started all over again.[69)]

69) See Thomas von Freyberg, *Industrielle Rationalisierung in der Weimarer Republik: Untersucht an Beispielen aus dem Maschinenbau und der Elektroindustrie*, Frankfurt am Main/New York 1989; Heidrun Homburg, *Rationalisierung und Industriearbeit; Arbeitsmarkt — Management — Arbeiterschaft im Siemens-Konzern Berlin 1900-1939, Berlin 1991.*