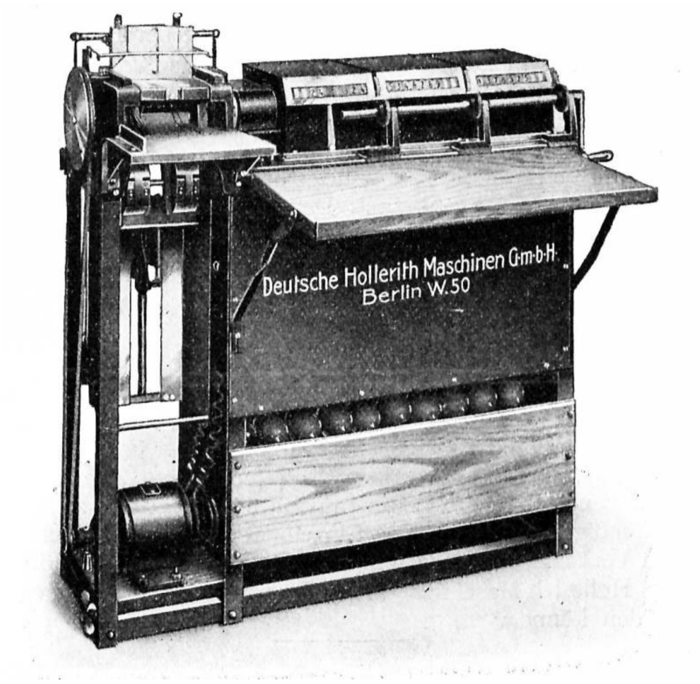
The First Informationexplosion

The Role of Punch Card Technology in the Office Rationalization in Germany, 1910-1939



A Dehomag tabulating machine with a wooden board as a writing drawer and three counters from 1912. (source: Hans Görlitz, Die Hollerith-Sortier- und Tabelliermaschinen und ihre Anwendungen für Verkehrszählungen, in: Elektrische Kraftbetriebe und Bahnen 11, 1913, Heft 3, p. 55)

Working Paper on the History of Computing No. 1/2017

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Published with the Open Access Server KOBRA of University of Kassel,
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An abbreviated version was published in German in Zeitschrift für Technikgeschichte, vol. 84, 2017, Issue 3, pp. 3-36.

Status: 20 June 2022

Content

1 Summary

The paper places punch card technology in the context of the office machine industry in Germany and discusses the exciting relationship between the two competitors on the market for punch card technology, Dehomag and Powers, in Germany. The question is whether the leading role of the United States in the use of office machines frequently cited by Anglo-American authors really applies. How punch card technology in Germany has advanced from its beginnings is discussed under the heading of rationalisation strategies. The technologies of the punching machine, the sorting machine and the tabulating machine are shown and an example of tabulating a sales table is given. At the example of a chocolate producer a punch card is discussed of how the various products of the chocolate plant are organized on the card. The punch card could use only one thousandth of the information content available in the binary number system. The buzzword of the information explosion, which was introduced into the debate by Lars Heide, will be filled in here. Many examples are given how the use of punch card technology expands the demand for information. The paper gives evidence for the suggestion of Theo Pirker that formalization of information induces the growth of the information department in enterprises so that the rationalization is absorbed by expansion. This process is labeled as informationexplosion and the paper portrays the first informationexplosion in history. The article concludes with an overview of how punch card technology fits into the broader debate about the feminisation of the office. The research in the eBook is based on various archives: The Federal Archive Berlin, the State Archive Berlin, the Economic Archive Baden–Württemberg in Hohenheim, the corporate archive of Bayer AG in Leverkusen, the archive of Deutsche Museum Munic, the archive auf Technikmuseum Berlin, and the Municipial Archive Nuremberg. This paper is an extended version of my paper „Die erste Informationsexplosion – Die Rolle der Lochkartentechnik bei der Bürorationalisierung in Deutschland 1910 bis 1939“, in: Technikgeschichte, vol. 84, 2017, issue 3, pp. 209-242.

2 Introduction

This paper is intended to give an overview of the development of the mechanisation of administrative work using punch card (also punched card) technology in Germany in the period 1910 - 1939. So far, only little research has been published on this topic. Most investigations deal with the history of the computer and are very strongly focused on the USA and England. Topics there are the technical development towards the tube-based electronic computer, the dominance of IBM and questions of the priority of inventions. In Germany, works have been published that focus primarily on the life's work of Konrad Zuse, the inventor of the digital computer in Germany. While studies on the spread of punch card technology in US businesses and administrations and as a step towards electronic data processing have appeared in the US, this is not the case in Germany. The importance of punch cards extended beyond the period from 1910 to 1939 to well into the 1970s, as they served as a medium for entering programs and data in computer data centres of industry and public authorities before they were replaced by floppy disks. IBM Germany even produced the tabulating machine D11, introduced in 1935, until 1960.[1] In computer data centres also were used the punching machine and the sorting machine.

This study also aims to place punch card technology in the context of a broader movement to rationalise office work in the period before the Second World War. The new machines in the office included not only punch card equipment but also typewriters, calculators, address machines and booking machines. The mechanization of the office can in turn be classified in the rationalization movement of the 1920s, for which numerous studies have already appeared, but which mostly focus on the production area, but omit the administration.[2] So far, the topic of office technology has received little attention in the history of technology. It is missing in the standard works of the history of technology.[3] Even the biography of Carl Duisberg recently presented by Werner Plumpe does not deal with Duisburg's leading role in the introduction of punch card technology in Germany. The recently published survey essay on the digital history of Germany in the journal Technikgeschichte also omits the punch card technique.[4]

The aim of this paper is to make this aspect of the history of technology, which has so far received little attention, accessible to research and also to make visible the former industrial clusters of office machine technology in Thuringia and Saxony, which disappeared with the entry of microelectronics into office technology. The keyword of the information explosion brought into the debate by Lars Heide will be filled in here. Also, the dominance of IBM historians in the depiction of punch card technology should be balanced with the IBM competitor Powers.

The following terms and concepts are covered in this paper. Rationalisation means the splitting of related work processes into individual sub-steps, the execution of which is strongly standardised and possibly supported or even completely taken over by machines. In this understanding, rationalisation is only possible in larger companies in order to arrive at a large number of cases of similar work processes. According to this rationalisation concept, no rationalisation occurs when a company replaces male workers with low-paid female workers at certain workplaces. For more information on the concept of rationalization, please refer to the standard literature on the history of rationalization in the 20th century. Economic history, antitrust law and microeconomic theory distinguish between different market forms, which are spanned in a continuous band between the two extremes of full competition and the monopoly in ascending degrees of concentration. A monopoly is a dominant company that holds at least 80% of the total market volume. The case of the duopoly is similar, where two companies account for 80 % of the total market volume. The explosion of information is understood here as the sudden increase in formalised information as a result of the use of information technologies, which are either printed as texts on paper or printed out as tabular overviews on paper or made available on screens.

3 State of the literature

In contrast to the hitherto little-noticed importance of office technology, research in German library systems reveals a surprisingly rich collection of German-language publications on office rationalisation and punch card technology before the year 1940. German-language company journals by the German branches of the two leading manufacturers of punch card technology worldwide up to 1960, namely Powers and IBM, are also among the rich publication activities.[5]

In the past, numerous presentations have appeared on the topics of typewriters, calculating machines and booking machines. Also a multiplicity of collector and lover literature is to be found. The individual presentations by Herbert Waize on calculating machines (1999) and typewriters (1998) as well as the dissertation by Hartmut Petzold (1985) on calculating machines and punch card technology are worth mentioning.[6] About the calculating machine Brunsviga the representations of Peter Faulstich (1992) and the dissertation of Jasmin Ramm-Ernst (2015) were published.[7] The dissertation by Verena Pleitgen (2005) uses three case studies to investigate how the use of office machines is changing accounting. The work of Günther Schulz (2001) provides information on the use of booking machines at the savings banks.[8]

In the publication "IBM and the Holocaust" published in 2000, Edwin Black examines the cooperation of the German IBM subsidiary "Deutsche Hollerith Maschinen Gesellschaft" (in the following: Dehomag) with the Nazi regime.[9] Based on the study by Black, Dehomag can be regarded as partially researched from 1933. Blacks study focuses on the conflicts between the IBM headquarters in New York and Dehomag, as well as on Dehomag's cooperation with the administrations and concentration camps of the Nazi state. However, it is not a study on office technology in the narrower sense.

The publication by Götz Aly and Heinz Roth (1984) deals with the gradual collection of personal data on the population by the Reichsamt für Statistik during the National Socialist era, which ranged from the work book (1935), the Gesundheitsstammbuch (1936), the Meldepflicht (1938), the Volkskartei (1939) to the Personenkennziffer (1944).[10] In addition, the SS kept records of the pedigrees of its members. All these data were stored on index cards, but not on punch cards. Only the censuses of 1933 and 1939 used the punch card technique, as the authors emphasize. In the censuses, Jewish citizens could only be identified as a statistical group due to the indication of religion in column 21 of the punch card, but not individually, since punch cards could not contain any address components.[11]

A massive use of punch card technology in the National Socialist state first took place in Speer's Ministry of Armaments, which from 1942 set up a "Machineal Reporting" (MB) department for economic planning, as the authors describe in detail and for which extensive file stocks are also available in the Federal Archive.[12]

4 Office machines in the context of punch card technology

This section describes the various segments of office technology, such as typewriters, calculators, address machines and booking machines. It shows how similar structures in technology, production and sales have developed in these segments, which have been transferred to the punch card technology sector.

The emergence of large corporations at the end of the 19th century created a new need for internal communication and control. The individual departments had to communicate with higher-level supervisory units and be accountable. The business results of the individual parts had to be consolidated into a consolidated result on a monthly basis.[13] These procedures were strongly schematized and led to always new entries into the account books according to the same scheme. They were therefore suitable for the rationalisation processes of work decomposition and machinisation through the introduction of typewriters, calculating machines, booking machines and punch card technology.

5 The office machinery industry in Germany

Since 1890, the office machine industry in Germany has also developed in small villages with loyal skilled workers in remote mountain valleys of Thuringia and the Erzgebirge. The villages of Sömmerda and Zella-Mehlis in Thuringia and Glashütte in the Erzgebirge mountains are worth mentioning, where three companies for calculating machines settled. The Wanderer plants in Siegmar-Schönau near Chemnitz and Seidel&Naumann in Dresden each produced 1.2 million typewriters until 1939, the Mercedes plants in Zella-Mehlis and AEG-Olympia in Erfurt 700,000 each. The last two plants were initially located in Berlin and were then outsourced for mass production from 1907. As a conversion project after the First World War, the armaments company Rheinmetall manufactured typewriters and calculating machines in its factory in Sömmerda - later the headquarters of the GDR computer company Robotron. The Adler factories in Frankfurt a.M. alone produced 70,000 typewriters from 1898 to 1911.[14]

The rapid industrialisation of Germany at the end of the 19th century created a need for control and billing facilities in the rapidly growing companies. In addition to the calculator cluster in Glashütte, the Braunschweig-based company Grimme, Natalis & Co. produced almost half a million Brunsviga calculators between 1892 and 1959 and became the market leader in the field of calculators. The basis for this success was a tightly organized distribution system with numerous sales offices, which made the company present in all major cities and at the same time offered a service for training and repair. This was accompanied by intensive advertising measures, which in Germany made the term Brunsviga synonymous with calculating machines.[14A] Under the conditions of hyperinflation in 1923, the banks experienced a strong increase in personnel, which was followed by a reduction in personnel and increased use of calculating machines after the stabilization of the Mark. The criticism of office mechanisation, which led to staff reductions, seemed to be conclusive in the banking sector.[15]

In addition to their use in business and administration, the calculators were also used for scientific and technical computing. In her study on the Brunsviga calculating machine, Ulrike Ramm-Ernst names the fields of actuarial mathematics, official statistics, geodesy, engineering sciences and applied mathematics as fields of application for calculating machines.[16] These fields of technical-scientific computing became the exclusive drivers for the development of digital computers in the United States from 1944 onwards, with the US military in particular focusing on them. In contrast, punched card technology was concentrated on business and administration (also referred to as "commercial data processing"), and applications for scientific-technical computing remained an exception.[17]

The advertising slogan for the Brunsviga since 1909 has been: "Brain of steel". tWhile in the 19th century allegorical man-machine connections regarded the human body as a machine, Brunsviga's copywriters reversed this connection. The machine was now imagined as something alive, as a brain, as Ulricke Ernst-Ramm had worked out[18]. It is noteworthy that the brain metaphor, which in the 1950s was associated with the computer as the "electronic brain", already appeared in 1909 in the context of calculating machines. Dehomag used this metaphor again in 1935 to characterize the tabulating machines (see below). Leslie Comrie published 1946 on the application of commercial calculating machines to scientific computing discussing the calculating machines Brunsviga, Burroughs and Marchant. He considered multiregisters for sums of products ab+cd+ef+..., which frequently occur in scientific calculations.[19]

The machines of writing and calculating grew together. The trade fairs for office machine technology presented special departments for calculating typewriters and typewriter booking machines. The typewriters were equipped with additional calculators and the calculators with wide rollers for holding paper sheets for writing numbers in columns. In his study, Günther Schulz showed how special booking machines enabled savings banks to book items in different departments. The typewriter carried out the horizontal and vertical additions and printed texts.[20] The office machinery industry found a platform at the office exhibitions held in Berlin since 1907. After the restrictions on international trade imposed by the Treaty of Versailles had ceased to apply in the 1920s, foreign manufacturers could also exhibit in Germany. The office exhibitions held in Berlin were therefore renamed "Internationale Büro-Ausstellung Berlin" in 1928.[21]

The spread of punched card technology was able to record numbers, but not customer address components. A different type of office rationalization machine from the 1920s, the address machine, was used for this purpose. The Berlin company "Adrema Maschinenbau GmbH" became the market leader. Addresses of persons could be printed on small aluminium plates as pressure stamps. Stacked up in a magazine with a capacity of 250 pieces, the addresses could then be inserted into prefabricated serial letters. This process was particularly important for invoicing companies with numerous customers, such as municipal utilities for gas, water and electricity. The Deutsche Reichsbahn also used this method to create consignment notes more quickly. The payroll office of the Berlin-based company Osram alone stored 32,000 addresses of its employees. In his speech to the meeting of 100 branch managers and representatives of the Adrema in Berlin in 1927, Jakob Goldschmidt, chairman of the Adrema supervisory board, placed the use of Adrema machines in the general rationalisation movement of the 1920s.[22] In 1934, the German Association of Municipalities conducted a survey on the widespread use of address machines in municipal administrations since 1928. The Berlin district of Kreuzberg alone had 290,000 address plates of its inhabitants over 14 years of age.[23]

It was not until 1936 that IBM (USA) was able to develop a punched card technology to print one line of text for the purpose of printing addresses, due to the requirements of the social insurance institutions in the USA. In order to print the three address components name, street and city, three punched cards had to be used one after the other.[24]

6 The liquefaction of information with the typewriter

The increased intensity of internal communication affected the rapidly growing industrial conglomerations in the chemical, steel and electrical engineering sectors more than the old trading houses.[25] The classic business letter addressed to external business partners was handwritten, so that the training of office clerks in calligraphy was an essential part of their job description. While the handwritten business letter expressed respectability and tradition of the company, reading handwritten texts with individual writing styles was annoying and time-consuming for internal communication. Typewritten texts, on the other hand, promised to be able to grasp the content quickly. With the control procedures in the large corporations, typewriters now also penetrated the offices, and letter communication increased.[26] The considerable administrative effort can be seen at the Reich Office for Vegetables and Fruit in Berlin for the supply of the population during the First World War. In 1918, 2000 letters a day were dictated, stenographed, typewritten and prepared for dispatch there.[27]

Before the Internet made the liquefaction of information universal, the typewriter was the first approach to liquefying texts, since typewriters could also be used to make carbon copies by inserting "carbon paper", which could now be sent to other places.[28] In addition, the typewriter could be used to produce wax matrices that could be copied in any number of copies. The typewriter thus initiated the first information explosion. Observers spoke of a flood of paper overrunning the offices. In 1962 Theo Pirker put forward the thesis that a formalization and machinization of information in the office leads to its multiplication and thus questions partial advantages of rationalization. He thus provided the decisive theoretical foundation for the phenomenon of the explosion of information through office technology.[29] Polemically, he classified the use of typewriters as a sham rationalization.

7 Sales systems for office machines

Although the office machines were divided into different divisions, the sales systems, each characterised by branch offices in the major German cities, were similar. In 1905, the Brunsviga calculating machine factory already owned 40 of them.[30] These offices established contact with customers in the region and offered training programs for the operation of the machines, such as typewriter training, which required several days of training. There was also advice on the use of the machines in the respective administrations, where, for example, the rational use of calculating machines in booking costs and sales could be planned together with the customer. The representatives for office machines were trained in the handling of the machines in the parent plants, e.g. in 14-day courses in the Brunsviga works in Braunschweig. Brunsviga has developed sample solutions for special industries such as insurance, construction and dairy companies.[31] For customer loyalty Brunsviga published the "Brunsviga-Monatszeitschrift", which was discontinued during the world economic crisis in 1931. In addition to the advisory function, the respective branch offices also provided repair services for machines that did not function properly. With advertising campaigns in the local media, the branch offices also built up a brand image in the public eye, as Peter Faulstich demonstrated with the example of the Brunsviga. The advertising slogan for the Brunsviga was: Brain of steel.[32] It is noteworthy that the brain metaphor, which was associated with the computer as the "electronic brain" in the 1950s, already appeared in 1905 in the context of calculating machines. Dehomag used this metaphor again in 1935 to characterize the tabulating machines (see below). In order to become known in the professional world, the office machine manufacturers used the Association of German Engineers, in which they gave lectures and published articles.[33]

The special conditions in the production and distribution of office machine technology can also be found among the manufacturers of punch card technology. The career of later IBM boss Thomas Watson can be used as a model to study how he transferred the tightly managed sales system from National Cash Registers (NCR) to CTR or IBM. The German branches of Powers and IBM also typically had well-organised sales systems with branch offices in large cities. The German branches of Powers and IBM also use their own in-house magazines, the evaluation of which offers a rich pool of case studies, in order to strengthen customer loyalty and as an advertising medium for the dissemination of practiced solutions for the use of their tabulating machines.[34]

8 Office machines as precision mechanics

Office machines belong to the technical field of precision mechanics and flourished at the beginning of the 20th century. She promised to relieve people of "mentally tiring, mentally killing work" in their working lives, after large-scale mechanical engineering had made heavy physical work in factory work easier, as was formulated on the occasion of the 8th International Office Exhibition in Berlin in 1934.[35] Office machines were made up of hundreds of individual parts, each of which had to be manufactured with high precision so that the mechanical movements could interlock smoothly. The design also had to be designed for continuous operation without failure. For this purpose, high-quality materials had to be selected and special care had to be taken during assembly.[36] An advertising text from the Archimedes works in Glashütte in 1915 summarised these requirements as follows: "The material used for the machine is hard drawn and rolled brass and the best quality steel. The individual parts of the Archimedes are manufactured in the factory itself by special machines, mostly automatic and accurate to 1/10 mm".[37] The standard model of the Brunsviga RK calculating machine produced in the 1920s had 985 parts, with drill holes having to be made with a precision of 0.015 mm, as Joseph Platen points out. Other authors speak of calculating machines with up to 3000 individual parts.[38]

The punch card technology of the Hollerith machines extends beyond the purely mechanical dimension of the above-mentioned office machines by incorporating electromechanical aggregates into the machines which, from the technical point of view, originate as "low-voltage technology" from the machines and systems of telephone and telegraph technology, such as cabling boards, relays and electrically driven counters and transport and sorting systems for punch cards.[39] The engineering field of precision engineering expressly included "electromechanics" among its tasks, as Paul Schlichting emphasizes in his 1929 standard work on precision engineering with sections on telephony and telegraphy.[40] A report on the production of tabulating machines at the Dehomag plant in Berlin distinguishes mechanical production from the subsequent electrical equipment of the machines, in which, as in a clinic, "doctors in white gowns insert the brain", cf. following figure.

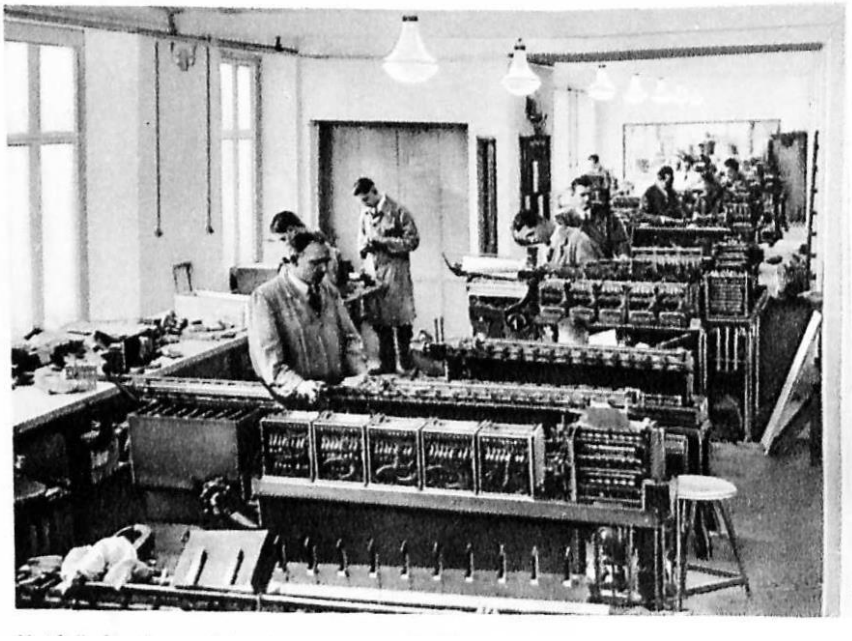

Figure 1: Assembly of Tabulators in Dehomag Works Berlin (Source: Denkschrift, p. 8)

The electrical aggregates were electrically connected by ready prepared cable harnesses with up to 2000 connection points. A total of 5000 m of cable were contained in one machine.[41] The detailed presentation of the electrical aggregates in the Hollerith tabulating machines was also a top against the competitor Powers, whose machines had no electrical aggregates except for the transport of the cards in the machine, and only functioned purely mechanically.

9 Did the United States have a leading role in office machines?

Anglo-American research often puts forward the thesis that the United States has a special leading role in the use of office machines and punched card technology. The Americans would even have a "love affair" with office machines, as Martin Campbell-Kelly and William Aspray formulated exuberantly.[42] On closer examination, however, the thesis of the leading role of the USA for Germany can be rejected. If one takes the benchmark of concerns, where there was a need for internal control with office machines, then groups such as Siemens, AEG, Krupp and IG Farben emerged in Germany as early as in the USA. After the beginnings at the end of the 19th century, Wright Mills estimates that office machines did not spread widely in the USA until the 1920s - similar to Germany.[43] The production of office machines started in Germany before 1900, for example with calculators in the factories in Glashütte and Braunschweig and with the Remington Standard No. 7 - the most advanced type lever typewriter in the USA - which had been building the Glogowski company under licence in Berlin since 1896. Typewriters constructed in Germany followed from 1898 at the Adler factories in Frankfurt a.M.[44] The leading role of the USA is that the production of punch card machines initially began in the USA. However, there were branches of licensed production in Great Britain and later also in Germany.

The institutionalisation of the office machinery industry, which can be seen in the founding of magazines, trade associations and office fairs, took place in Germany at a similarly early stage as in the USA. The first issue of the office economics magazine "Organisation" dates back to 1898, while the first office trade fair in Berlin was held in 1907 with 173 exhibitors, where office machines were also exhibited. The following fairs took place in Berlin in 1908, 1911, 1923, 1925, 1928, 1931 and 1934. The following illustration shows the Dehomag stand at the International Office Exhibition Berlin 1934.

Figure 1A: Dehomag exhibition stand at the International Office Exhibition Berlin 1934 (Stiftung Deutsches Technikmuseum, Historisches Archiv, holdings: I.2.007.002, photo: Max Missmann).

The typewriter industry has been attracting attention at trade fairs since 1908 with typewriter typing competitions. At the 1911 trade fair, the German office machine industry was characterised as "young and vibrantly forward-looking".[45] In 1908, the actors founded the community of interests of the office machinery industry, which served the purpose of protecting common interests when participating in exhibitions. In 1909, a preparatory committee of the office sector was formed in Berlin with a view to expanding its tasks. It included representatives of the typewriter industry, the seating furniture industry, the chemical office supplies industry, and office machine importers and traders. These activities led to the founding of the German Association of the Office Industry, which held its first meeting in 1911. Members of this association were the manufacturers of typewriters, calculators, copying machines and chemical office supplies. His tasks included representing the office industry at the Chamber of Industry and Commerce and participating in specialist office exhibitions.[46] The Committee for Economic Production, founded in 1918 as part of the war economy, was joined by the Committee for Office Organisation, founded in 1919, which was renamed the Committee for Economic Administration in 1924. The foundation of the National Association of Office Managers in the USA, which also aimed at office rationalisation, dates back to 1919.[47]

According to James Cortada, the breakthrough of punched card technology in the US economy did not take place until the 1920s, as he notices from the rising level of magazine publications. In the same way, the rise of publications on punched card technology can be demonstrated in Germany in the 1920s, thus suggesting a breakthrough in punched card technology. If one takes the bibliography of the book by Robert Feindler (1929) as a reference, only 2 to 5 articles of the 90 journal articles listed there appeared between 1910 and 1925.[48] In contrast, the number of articles rose sharply between 1926 and 1928. The breakthrough of punch card technology is also reflected in the growing interest in this topic in the German steel industry. To the 11 German smelting works, which used the punch card technique in 1928, eight were added in 1927 alone. In 1928, the number of members of the punched card subcommittee of the Steel Industry Business Management Committee rose from five to 30.[49] The Osram plant in Berlin, a large company with 20 to 30 thousand employees, only introduced punched card technology in 1925 and 1926.[50]

he claim of the leading role of the US in office machinery stems from the British scholar Martin Campbell-Kelly. He observed that in Great Britain the industry for office calculators developed as late as the end of the 1910s. This low grade of development was even an obstacle in founding a British manufacturer for punched card technology because there was no supplier of calculation technology. The first exhibition of office machinery in Great Britain took place in 1920 as Business Efficieny Exhibition.[51]

At this point, the technical basics of punched card technology will be explained to the reader. The actual punch card, the mode of operation of the tabulating machine, the sorting machine and adding units are addressed.

10 The punched card

The decisive technological innovation of punched card technology was to understand the punched card as a mobile carrier of information and to machine information processing. The innovation consisted in the mechanical documentation of numbers on the punch card by means of manually operated punching machines, which were also referred to as punchers, and secondly in the mechanical reading of the documented numbers with the tabulating machine, which could later be used again and again in changing contexts. The following illustration shows a Hollerith hole punch from 1910. In the context of later computer science, punching can be interpreted as a "writing process" and the use of punched cards in a tabulating machine as a "reading process" of information.

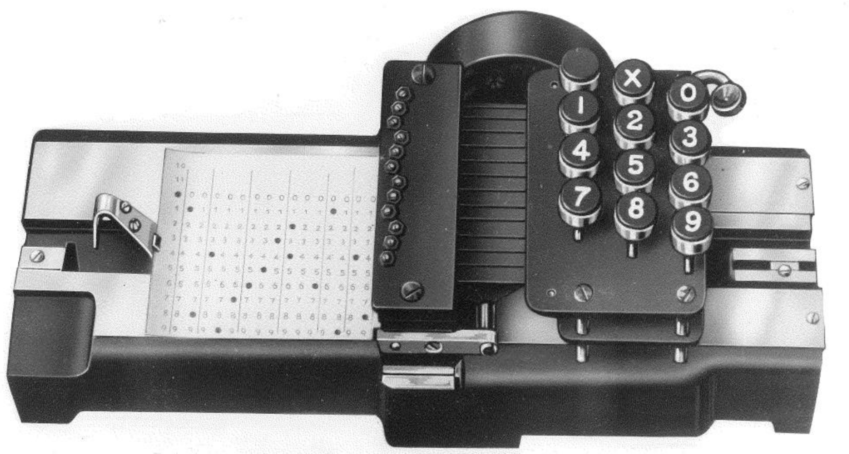

Figure 2: Puncher of Hollerith from the year 1910 (IBM press photo, released by the press office of IBM Germany). Archive of the German Museum of Technology Berlin, inventory : I.2.007/002, released by the archive).

The mobility of the punched card as a data carrier was the basis for the liquefaction of information, which led to the first information explosion. Until 1914, the standard size of a cardboard punched card was 5 3/8 inches by 7 3/8 inches (corresponding to 142.9 mm by 187.3 mm) and a thickness of 0.18 mm, which was retained in computer technology until the 1970s.[52] The punched card was made up of ten lines representing the numbers 0-9 and numerous columns. Until 1940 punch cards with 45 columns were common. In 1928 IBM additionally introduced a punched card with 80 columns and the same outer dimensions, to which Powers replied with a card with 90 columns. For the 1933 census in Prussia, punched cards with 60 columns were used. The punched card represented numbers in the decimal system. Single-digit numbers were documented by perforating a column in the relevant row, multi-digit numbers by perforating the sequence of numbers in several adjacent columns.

The use of the decimal system to represent numbers implies that the information content of the punch card was only marginally exploited. Only one hole could be made in each column, i.e. only one of the ten possibilities was used. The low utilization led to the concept of the "compound punch card", on which fields were kept free for handwritten documentation of elementary economic services, such as a material withdrawal slip (see Figure 3), an expense account, the writing down of a refa time study[53], the driving report of a locomotive driver, etc. The fields were then used for the documentation of the basic economic services. These were collected as original receipts in the accounting department and thus called into question the traditional model of bound account books. If necessary, it was also possible to perforate the free fields with compound punch cards.[54]

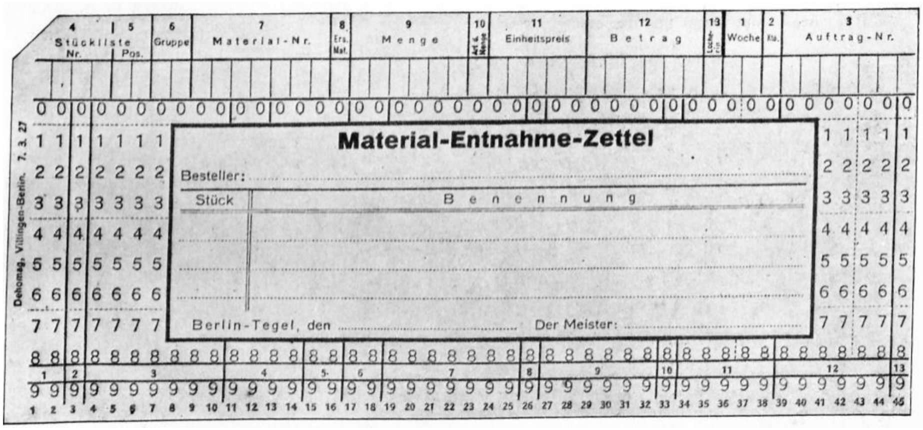

Figure 3: A material withdrawal slip as a composite punch card.[55]

If the punched card is interpreted in the context of the binary system, the 1024 (corresponding to 2^{10}) different numbers from zero to 1023 could be represented binary in a column by hole patterns. From the point of view of the binary system, the punched card thus uses less than one thousandth of the information content. The fact that the punched card did not also introduce the binary system, which was later used in digital computer technology, into machine data processing is due to the fact that punching the numbers in the binary system would have been too labor-intensive. Nevertheless, the punch card has very strongly connected the engineers' thinking with the decimal system, so that for example the first digital tube computer in the USA, the ENIAC, calculated internally with the decimal system.

In contrast to main frame computers of the 1970s when data and programs were loaded by standard punch cards of 80 columns, the use of tabulating machines in public authorities, banks and industry required the adaptation of punched cards to the given questions.

So there existed no standard punch cards. This is explained in the following Figure 4. It shows how a punched card was to be constructed in a project of Dehomag in the chocolate industry in 1932.[56]

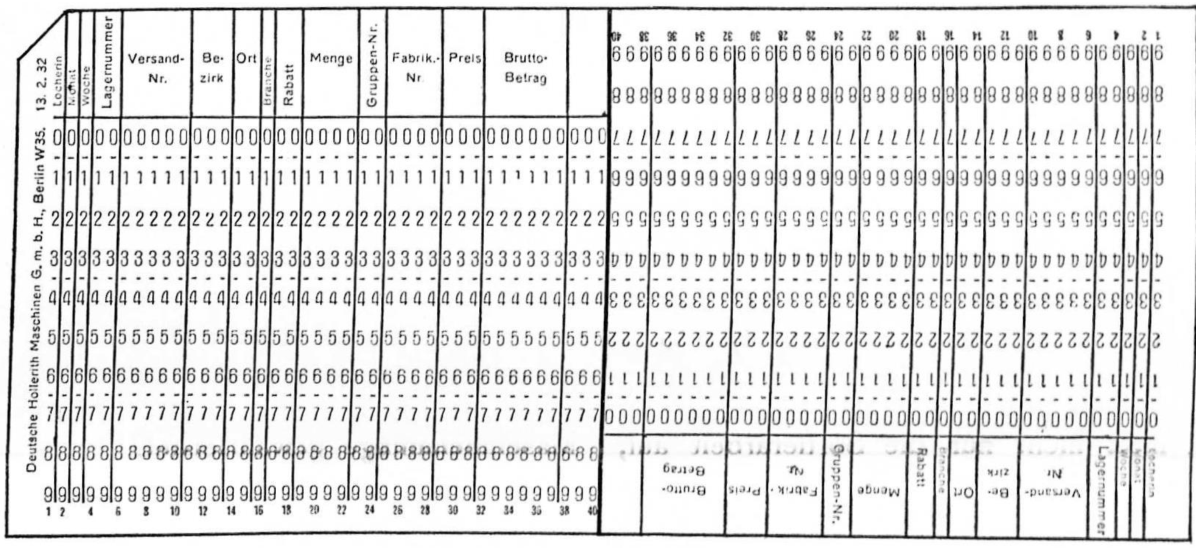

Figure 4: The design of a punched card for the chocolate industry.

In the project, the sales structures of a chocolate factory were to be mapped via various regional warehouses and the respective sales in the various representative districts and branch locations were to be recorded. To realise this project, the requirements had to be discussed with Dehomag's consultants and translated into a concept for the design of the punched cards. Dehomag therefore printed the punched cards supplied with the column headings visible in Figure 4 on a project-specific basis. This meant that Dehomag had to print specific punched cards for each project and deliver them in the long term. The punch card company Dehomag (as well as Powers) had a large paper processing department where punch cards were cut from cardboard rolls and finally printed to customer specifications.[57] In Germany alone in the 1930s, billions of printed punched cards were delivered to customers every year. The punched card of the chocolate industry project in question had ten lines assigned to the numbers 0...9. For the representation of a single-digit number, one column of the punched card was sufficient, where a hole was made in the line corresponding to the numerical value. For multi-digit numbers, a corresponding number of columns had to be reserved. Figure 4 shows the column headings District, City, Industry sector, Group number and Factory number. The chocolate factory produced approximately 2000 to 3000 different articles, which were identified by the factory number, for which four columns - corresponding to a four-digit number - were reserved. In order to simplify the evaluation of the sales by different articles, the countless articles were concentrated on only a few different groups, as for example cocoa in packs, cocoa loose, melting chocolates, milk chocolates, cream chocolates. The deliveries could then be evaluated group-specifically.

Two columns for the group number were provided on the punch card, so that two-digit numbers could be assigned to the group numbers and punched there. The column "Branch" distinguished different branches of customers with a perforation in lines 1 to 8: 1. colonial goods and delicatessen retailers, 2. jam retailers, 3. bakeries and confectioneries, 4. colonial goods and delicatessen wholesalers, 5. jam wholesalers, 6. station taverns, 7. canteens, hotels, cafés, restaurants, shopping cooperatives, 8. miscellaneous. This example clearly shows that a company had to convert its information system to numbering keys in order to use punched card technology. Material types, product types, wage types, posting accounts, personnel, customers and suppliers had to be numbered. In 1925, for example, the railway organization Reichsbahn numbered its stations, offices and track sections for punched card technology.[58]

11 The tabulating machine

The evaluation of the punched cards was done with the help of two machine types, the tabulating machine and the sorting machine, the functional principles of which are now presented here. The term tabulating was coined in management science to present turnover data according to various principles: time (January to December), region (North, West, South, East) and product groups.[59] In order to display the evaluations of a tabulating machine according to various criteria here, a simple, fictitious sales table is used to illustrate the evaluation options. The table shown in Table 1 provides the daily sales of porcelain goods in the various branches of a retailer for household goods in different regions in the form of raw data; in real applications, however, data of hundreds or even thousands of products, branches or employees are collected.

Date	Items	Colour	Number	Price per piece RM	Turnover RM	Branch	Region
06/20/1925	Cup	blue	22	5	110	1	north
06/21/1925	Plate	blue	8	7	56	2	north
06/22/1925	Pot	blue	18	9	162	3	north
06/23/1925	Cup	yellow	7	5	35	1	north
06/24/1925	Plate	yellow	3	7	21	4	south
06/25/1925	Pot	yellow	9	9	81	2	north
06/26/1925	Cup	red	13	5	65	3	north
06/27/1925	Plate	red	6	7	42	4	south
06/28/1925	Pot	red	2	9	18	1	north

Table 1: Sales of branches by articles, number, colours, turnover, branches and regions (RM = Reichsmark).

The raw data, if transferred to punched cards, can be evaluated according to various criteria with the aid of a tabulating machine. Questions can be asked on the basis of the available data: Where do you sell more, in the region North or in the region South? Which colour is most in demand? What sales are available, broken down according to the products plate, cup, pot? For each of these questions, the complete set of punched cards had to be reworked by the tabulating machine. Cards which meet the selected criterion (region, colour, product, branch) have a hole for the criterion and trigger a corresponding electrical pulse during scanning, which causes the counter of the tabulating machine to count as many units as the numerical value on the card indicates.

The result of a tabulating run, in which all cards pass through the machine from a stock magazine, was then the sum of the selected criteria (number or turnover), which had to be read off the counter and transferred in handwriting to a journal lying on an unfolded wooden board of the machine (see Figure 5). In this case we speak of a group sum. In order to achieve a group sum, the tabulating machine had to be wired on the back according to the selected criteria, where cable connections are made between two sockets each, as in a telephone exchange.[60]

The following table 2 shows the group totals of table 1 for the turnover on the three articles pot, cup and plate. In Table 2, the rows of Table 1 appear ordered by articles: pot, cup, plate. It can be seen that the turnover for pots was 261 RM, for cups 210 RM and for plates 119 RM. Total sales reached 590 RM.

Date	Items	Colour	Number	Price per piece RM	Turnover RM	Branch	Region
06/22/1925	Pot	blue	18	9	162	3	north
06/25/1925	Pot	yellow	9	9	81	2	north
06/28/1925	Pot	red	2	9	18	1	north
	Pot result				**261**		
06/20/1925	Cup	blue	22	5	110	1	north
06/23/1925	Cup	yellow	7	5	35	1	north
06/26/1925	Cup	red	13	5	65	3	north
	Cup result				**210**		
06/21/1925	Plate	blue	8	7	56	2	north
06/24/1925	Plate	yellow	3	7	21	4	south
06/27/1925	Plate	red	6	7	42	4	south
	Plate result				**119**		
	overall result				**590**		

Table 2: Result of the tabulation run for three articles with group totals on turnover (displayed in Excel style).

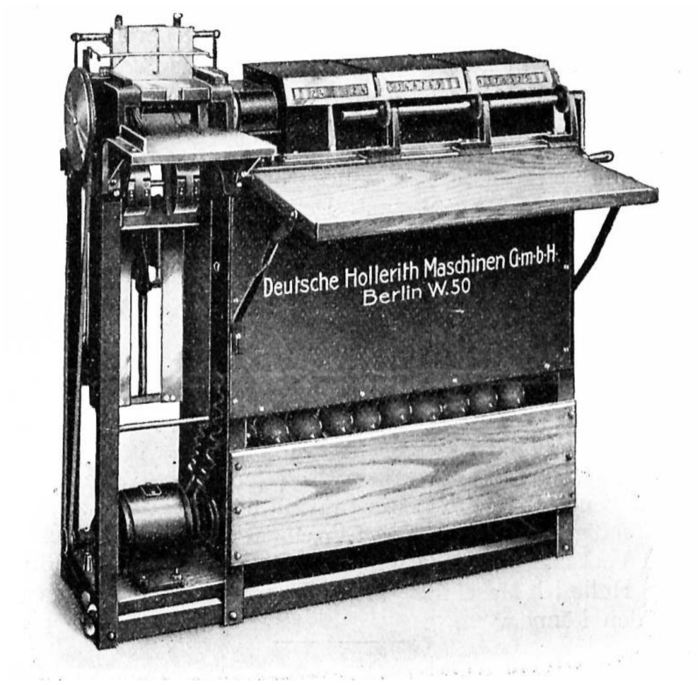

Figure 5: A Dehomag tabulating machine with a wooden board as a writing drawer and three counters from 1912.[61]

This was a "programming" of the tabulating machine, which required a special know-how, which had to be acquired in training courses. The publication by Robert Feindler (1929) shows some wiring diagrams for the cabling.[62] The programming can also make a combination of criteria: How many yellow cups were sold in the northern region? At the programming level, this is a logical "AND" linking the cup, yellow and north criteria. If you wanted to distinguish the sales (quantity or turnover) of the three products pot, cup and plate and extract these as group totals from the raw data, you had to program three registers. However, the result could then be achieved with a "run" of the tabulating machine, in which all punched cards from a magazine passed through the machine and were evaluated one after the other. This means that you could only distinguish as many products or group totals in a run as totalizers were installed. In 1913 the tabulating machines contained up to five counters for seven-digit numbers.[63]

With the introduction of digital computers in administration, IBM transferred the tabulation technique of tabulating machines on computers. The great success of IBM's punch-card oriented software product "Report Program Generator" (RPG), which lasted until the 1980s, with the sum[63A] of a turnover list or similar lists being drawn over various criteria and printed out as reports on paper, on the IBM S/360 in the 1960s demonstrates this policy of continuing the old tabulating machine approaches of administrative data processing, which certainly also explains IBM's market success in part.[63B]. Today the tabulating technique is preserved in the table software Excel where one can use the pivot technique.

12 The sorting machine

During the survey of agricultural statistics in the USA in 1900, Hollerith recognized the limitations of the tabulating machine. It could not be used to map size classes of farms that were important for statistics. The tabulating machine could not link queries of different criteria with the logical "OR" nor could it link queries referring to a minimum size. To solve this problem, Hollerith invented the sorting machine. Fed with punched cards from a magazine, the machine searched the holes in a preset column of the punched card and sent the card into one of the prepared compartments corresponding to the numbers 0 to 9. The result of a sorting run was the physical separation of the cards into compartments according to one criterion. In order to sort multi-digit numbers, the cards had to be sorted several times one after the other.[64] The machine was positioned vertically to save space in the office. Powers later appeared with a horizontally arranged sorter that was easier to operate and also had a counter for each tray that showed how many cards had fallen into the tray. The sorter could also be used to pre-sort large stocks of punched cards by criteria and physically separate these stocks of punched cards. In the personnel administration, for example, the punched cards of all employees could be separated according to the categories single and married. When in the 1920s CTR equipped the tabulating machines with printing units in order to be able to print the group totals in competition with Powers, the cards first had to be sorted in the sorting machine according to the group criterion for the tabulating run. The sorting machines were also important for this process. As Barbara Anderson reports, the use of sorting machines were common in data centres until the 1970s to keep the stack of program cards in the proper order.[65]

13 The Adders

The tabulating machine used by Hollerith for the census in 1890 could only count people, but not add numbers in the narrower sense. As a simple counter, the tabulating machine achieved the fantastic speed of being able to count 12,000 cards per hour, i.e. 3 cards per second. Hollerith first used an "analog" display in the form of a clock face to display the counted values for each digit, see Figure 6.

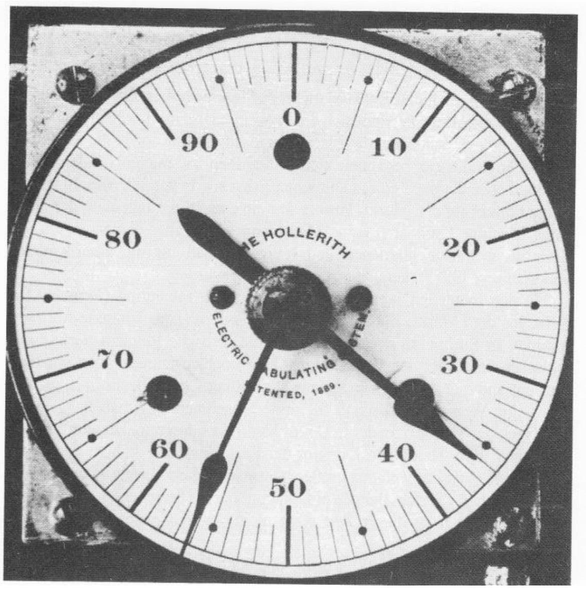

Figure 6: Analog display of a totalizer.[66]

For subsequent applications in the economy, where the addition of multi-digit variables such as quantity, costs or turnover was involved, Hollerith built complete adders for seven-digit numbers into the machines, which represented the numbers as "digital" counters on small wheels with the digits 0...9 (see Figure 5). Depending on the sampled values, the machine sent up to 9 current pulses to the motor driving the counting wheel.[67] Apparently Hollerith added the different digits of a number in parallel for each digit and not sequentially. How he realized the transfer of 10, which was also a problem with mechanical calculating machines, is unknown from a technical-historical point of view.[68] Lucas notes the fantastic performance of adding 10,000 punched cards with up to seven-digit numbers per hour.[69] The architecture of the counting wheel, which represented the numbers of digits 0...9, was very influential for the construction of computers in the U.S. from 1940 onwards. The computer ENIAC was given an electronic analogue of the counting wheel in the form of a ring counter, designed in 10 steps of flip-flops.[70]

The fixation on the decimal system instead of the dual system was also a barrier to later computer development, which could only be overcome by the von Neumann concept. In Germany, however, Konrad Zuse had designed the memory for the binary system from the outset.

The counters on the tabulating machine were mere counters, but could not compute arithmetic expressions. So, to compute the interest on an account in a savings bank was impossible with a tabulating machine. IBM extended the computation ability of the tabulating machine in 1948 with the device IBM 604 comprising 1200 electronic tubes. The French computer firm Bull offered in the 1950s a computation device Bull Gamma 3 with 400 electronic tubes which was used in savings banks.[70A]

Tables of the type in Table 1 represent the data basis of the relational databases used with the development of large computers from the 1970s onwards, after IBM had pursued a hierarchical approach to databases in the 1960s.[71] In the context of these databases, the group totals represent only certain "views" of the raw data. Since the advent of spreadsheets on personal computers in the 1980s, group totals of tables can be easily generated using the functionality of pivot tables. Evaluations of tables with different group totals were also referred to as reports and can be directly traced back to evaluations with tabulating machines of punch card technology. IBM successfully distributed a software product called "Report Generator" (RPG) for their small computer 1401 and for their large computers 360 and 370 until the 1980s, and from 1969 for the smaller variant System/3, which had 8K main memory. With the report generator, IBM imitated many of the peculiarities of cabling on the tabulating machine and was thus able to make the transition from punch card technology to computers easier for users.[72]

14 The Duopoly of Hollerith and Powers

The history of punch card technology is one in which there was fierce competition between the two market leaders Hollerith and Powers, who as a duopoly dominated punch card technology for 50 years.[73] Herman Hollerith achieved fame when he was able to organise the 1890 census in the USA with his system of punched cards and tabulating machines. While punch cards have been used to control Jacquard looms for 100 years, the census can be seen as the first use of punch card technology in administrative tasks.[74] Hollerith's invention of the tabulating machine is to be judged in the context of the "electric age" at the end of the 19th century. Electricity was considered a new, exciting technology that captivated many. Electric power plants and networks were built in the United States and Europe, and there was an electricity fever in the public.[75] Examples for the electrical aggregates in Hollerith's tabulating machine included the relay stations in the telegraph network for the forwarding of telegrams, where paper strips with punched out patterns of dots and strokes were electrically scanned on a metal roller in order to forward the telegram to a new branch of the line network. Hollerith had also applied for numerous patents to improve the Westinghouse air brake for freight trains, which concerned the electrical control of the valves for compressed air during the braking process.[76] Hollerith was able to exploit the above-mentioned possibilities of electricity for his tabulating machine, whose "intelligence" was based on electrical circuits with which the patterns of the perforations on the punch cards were scanned and transferred to counters.

The American census authority proved to be a site from which numerous impulses for the spread of punched card technology in the USA and Europe emanated. The head of the census authority, Robert Porter, strongly supported Hollerith in his efforts to finish developing the tabulating machines for the 1890 census. In 1902 Porter promoted a British subsidiary of Hollerith's tabulating machine company and became a partner in the British company.[77] The tabulating machine (see Figure 5) made it possible to evaluate the data stored on punched cards from authorities or companies according to various criteria as "group totals", e.g. on turnover or quantity. Later, from 1910, the sorting machine was added, which served to sort punch cards in ascending order according to a criterion (e.g. quantity or turnover).

James Powers, Hollerith's competitor, also emerged from the American census authority in 1910. After conflicts with the Census Office, Hollerith could no longer carry out the 1910 census after 1900 with his system, as the office now operated its own workshops where it built its own tabulating machine.

One of the leading employees of the workshops of the Census Office, James Powers, set up his own tabulating machine business in 1911 and founded the Powers Accounting and Tabulating Company with capital from venture capitalists. Powers used Hollerith's patents and paid him a royalty. In 1910, when Powers appeared with his tabulating machine, 20 years had already passed since the 1890 census. In the context of innovation theory, Powers' tabulating machine can thus be regarded as a "late follower" of Hollerith. In this position Powers was able to study the deficits in the operation of the Hollerith machine in detail and use these for further development and improvement of his machine. The decisive improvement on his machines was a printing unit that printed the group totals on paper, while the Hollerith machines had no printing unit and the group totals had to be read manually from the counter and written into a journal, which was also a source of transmission errors. Hollerith's successor company, CTR, reacted very late to Powers' innovation and did not launch devices with printing units until the early 1920s.

Unlike Hollerith, however, Powers remained at the mechanical level and did not use electrical controls. As a trained mechanic, he invented purely mechanical solutions for scanning punched cards and controlling counters using moving pins and Bowden cables. However, the cards were moved through the machine with the power of an electric motor. By doing without electrical controls, however, Powers could not achieve the freedom in mechanical design that Hollerith could exploit by laying electrical cables in his machine.[78] In spite of Powers' regressive approach, which seemed to have been achieved by dispensing with electrical controls, its tabulating and sorting machines were almost as fast as the Hollerith machines. The Hollerith company (or its successors CTR and IBM) and Powers remained fierce competitors until 1960, when the computer replaced punch card technology, dividing the market among themselves, including internationally in England, Germany and Europe. In the 1930s, the dominance of IBM in the USA became clear, where IBM achieved a market share of 85 percent in punch card technology, as became apparent in an anti-trust case of the US government.[79] The duopoly between Powers and IBM was only disturbed by the French punch card company Bull, founded in 1931, which also had some installations in Germany.[80] Even after the takeover of Powers by the typewriter company Remington - the leading typewriter manufacturer in the USA - and the merger into the Remington Rand group in 1927, the Powers brand remained unchanged. Until the 1950s, Powers insisted on the purely mechanical control of its tabulating machines by a "control chamber" (pin box), as publications such as the Powers house magazine prove. The control chambers were mechanical programming instruments that had to be replaced depending on the problem.[81] Despite purely mechanical, i.e. non-electrical, control, the Powers sorting machine achieved a fantastic output of 24,000 cards per hour in 1934, while the tabulating machine processed at least 6,000 cards per hour with additions.[82] There is hardly any research on Powers.

The study by Lars Heide is the only one on James Powers, who was otherwise completely neglected by research and stood in the shadow of Hollerith. In the magazine Annals of the History of Computing, which has been published for 37 years, there is not a single entry about Powers in its search mask.

15 The Duopoly of Dehomag and Powers in Germany

If the story of Dehomag and Powers in Germany is to be told at this point, it should be remembered that the history of computing technology is dominated by IBM historians. The house historian of IBM Germany, Friedrich Kistermann, has alone published seven articles in the journal Annals of the History of Computing, where there is not a single article on Powers machines. Nor does the catalogue for the exhibition "Office Machines in Berlin" at the Museum für Verkehr und Technik Berlin in 1988 address the Powers Society in Germany, which operated a production plant in Berlin and had 450 employees throughout Germany.[83] The Deutsche Hollerith Maschinengesellschaft, founded in 1910, has provided Dehomag with a certain image of history through numerous publications.

The history of Powers in Germany, on the other hand, is only known in fragments, like data from the catalogue of the International Office Exhibition 1934 and the Powers house magazine. The history of the Powers-Vertriebsgesellschaft in Germany is the sole subject of a study by IBM historian James Connolly (1968), based on a book published by Hans Görlitz[84] on the history of the Powers machine in 1934, which, according to the Karlsruhe Virtual Catalogue, cannot be traced worldwide. Also, it is not in the stock of the files to IBM of the Baden-Württembergischen Wirtschaftsarchivs in Hohenheim, where in the stock B 95 the files of the IBM are archived since the year 2000.

Although in Germany there was also an in-house magazine of the Powers Society, "Die Lochkarte", which had been published since 1929, but which provided hardly any information about the structure and organization of the Powers Society, except for a depiction of the Berlin production plant for equipment for the punch card system with numerous photos, where initially only additional equipment was produced, but not the main equipment - such as the tabulating machine and the sorting machine. In the article on the Berlin production plant, the number of 450 employees of Powers Germany is mentioned - a number which corresponds in the order of magnitude to the number of employees of Dehomag, which indicated the number of 300 employees for 1930.[85]

Dehomag was founded by Willy Heidinger in 1910 as the "Deutsche Hollerith Maschinen Gesellschaft" in Berlin, inspired by a demonstration of a Hollerith machine by Hollerith's European representative Neil Williams in Berlin in 1910. Williams' goal was actually to oblige enough investors in Germany to set up a production facility for Hollerith machines in Germany.

After a trip to the USA, Carl Duisberg, director of Farbenfabriken Bayer, had already ordered a Hollerith machine for his plant in 1910. In a circular to his department heads, he asked whether Hollerith machines could be used in the departments. In November 1910 the first tabulating machine arrived at the company headquarters in Elberfeld.[86] Duisberg can thus be regarded as the first user of punch card technology in German industry and as a promoter in the companies of IG Farben who has so far received little recognition. According to Frederic Steinfeld's study, accounting had a high priority in the IG Farben Verbund in order to be able to delimit the interests of the members of the Verbund. Therefore, the procurement of a Hollerite machine by Duisberg is only logical.[86A]

Neil Williams first asked Carl Duisberg as Hollerith's first customer in Germany whether he would like to support the founding of Dehomag financially with a shareholding, but was rejected because of the poor market prospects, as Hartmut Petzold was able to ascertain in the archive of Bayer AG.[87] The Berlin electrical industry (AEG and Siemens), which grew up at the end of the 19th century, also failed to seize the opportunity to enter the punch card machine business, although it had an affinity for Hollerith machines in low-voltage technology (telephone and telegraphy) and AEG had even been producing typewriters in Berlin and Erfurt since 1903. Heidinger's offer to participate in founding the company was rejected by the Berlin electrical industry.[88] Heidinger could only raise enough capital for a distribution company, but not the larger sum for a production plant. In Germany, he sold Hollerith machines imported from the USA, which he initially purchased from Hollerith's "Tabulating Machine Company", which financial investor Charles Flint merged in 1911 into CTR, which was then renamed International Business Machines (IBM) by Thomas Watson as President of CTR in 1924.[89] In the inflation period of 1922, Dehomag ran into a financial bottleneck and Watson took over 90 % of Dehomag's shares, while Heidinger held only 10 % and remained managing director. Dehomag thus became a subsidiary of CTR and IBM respectively.[90]

Dehomag applied marketing strategies similar to those already used in the office equipment industry. In addition to the tightly organized system of representatives, lectures in specialist committees ensured the dissemination of Hollerith's ideas. In 1913, one of their project partners from the Hagen accumulator factory gave a lecture at the Association of German Engineers.[91] Between 1912 and 1914, Dehomag published a house magazine "Hollerith Mitteilungen" to popularise its products, where it published case studies on the application of the Hollerith system. In contrast to Carl Duisberg's negative assessment, Dehomag achieved a fantastic market success right from the start. In his study, Petzold reports on censuses in Württemberg and Baden in 1910 and on applications in numerous industrial plants and at the Imperial Statistical Office, where export statistics were kept. Heidinger demonstrated the tabulating machine to members of the Reichstag and representatives of the authorities in 1911.[92]

Dehomag published a list of users of its system in large-scale industry and even reported a tripling of its turnover between 1911 and 1914.[93] How Dehomag managed so many projects for a product requiring explanation between 1910 and 1914 with its few employees is unknown.

The articles in the issues of Hollerith Mitteilungen of the years 1912-1914 show the enormous processing speed of the tabulating and sorting machines that processed up to 12,000 punched cards per hour, i.e. more than three cards per second.[94] This also shows how important the robustness of the cardboard as a data carrier for the punched cards is, so that the cards can survive several runs of these machines undamaged. Apart from the printing industry and the textile industry, there were probably no other machines with such high processing speeds. Furthermore, the modernity of the concept of information, which underlies the texts of these booklets, is striking. All economic or social variables, be it a sales volume, a turnover figure, an account balance, a wage payment, the age, gender and religious affiliation of persons, all these were recorded on a punched card to the abstract of "information". Thus, the concept of information used by information science (computer science) in the 1960s and 1970s can be traced back to the concepts of punch card technology before 1914.

Powers visited Germany in 1913 with the aim of establishing a production and distribution company for his machines in Germany, which would be financed with the American capital of his venture capitalists. In the Hotel Esplanade in Berlin he organized a demonstration of his machines and won Mannesmann Röhrenwerke in Düsseldorf as his first customer. Heidinger tried to prevent the founding of a Powers company in Germany by filing patent infringement suits. Only when the highest German court, decided that Heidinger had to grant Powers a compulsory license was Powers able to found the "Deutsche Gesellschaft für Addier- und Sortiermaschinen GmbH" at the beginning of 1914 with the capital of US venture capitalists. War and inflation in 1923 prevented the Powers company from continuing its business activities, which was newly founded in Germany in 1924 and then expanded strongly. Connolly states that in the mid-1920s about 250 IBM and Powers punch card machines were installed in Europe.[95]

Founded before 1914, Dehomag entered the war economy of the First World War and supported numerous organizations of central economic planning with the use of tabulating machines. Dehomag mentioned an impressive list of 16 economic planning organisations.[96] Since it was no longer possible to import Hollerith machines from the USA during the war, the War Ministry withdrew the original Hollerith machines available in Germany from the private sector and used them to plan the production of weapons and food in the above-mentioned organizations. The government in Vienna did the same for Austria. Dehomag reported a doubling of its turnover during the war.[97]

How this became possible without importing machines from the USA and with the withdrawal of personnel for military service remains unclear. In a factory in Villingen, Dehomag initially produced spare parts and punch cards and later also tabulating machines and sorting machines. In 1927, Dehomag separated from the Villingen site and relocated production to the Optima plant in Sindelfingen, where IBM Germany's headquarters were located during the Berlin blockade in 1948. In 1934 Dehomag merged with Optima.[98]

Furthermore, the problem arose that the punched cards as carriers of information on specially produced cardboard could no longer be supplied from the USA during the war period 1914 to 1918. Here Dehomag had to have suitable cardboard produced by itself after lengthy trials. It is known from IBM's history that the company jealously watched over its foreign subsidiaries to ensure that they only imported original IBM punched cards from the USA. For IBM, supplying its customers with punched cards was an important source of long-term sales, which flowed steadily even in years of crisis. In its review of history in 1935, Dehomag assured the National Socialist public that it would only use "German cardboard".[99]

In the 1920s, IBM CEO Thomas Watson visited his European offices annually. Willy Heidinger travelled to the USA in 1931, 1933 and 1936 to discuss technical developments and licensing issues with Watson. After all, Dehomag had to pay 25 % of its rental income to the USA as a licence fee. As his correspondence shows, Heidinger surprisingly did not conduct Dehomag from Berlin but from his country house in Pöcking on Lake Starnberg.[100] Dehomag won the Reichsbahn as a major customer. Since, according to the provisions of the Dawes Plan for the Stabilization of the Reichsmark, the Reichsbahn was subject to the supervision of the reparation commissioners and had to pay 600 million Reichsmarks annually in reparations, it was subject to special rationalization pressure and in 1925 introduced the Hollerith procedure for determining the operating performance (train kilometers, locomotive kilometers) in all Reichsbahn directorates and extended the procedure to other areas of accounting (distribution of service coal, administration of superstructure material). In 1931, the Reichsbahn operated 89 tabulating machines and 96 sorting machines and processed 100 million punched cards annually. Since Powers was also able to win the Reichsbahn as a customer - in this case the Eisenbahnzentralamt - the Reichsbahn used both systems from Hollerith and Powers in parallel.[101]

During the Nazi period, the construction of a minority holding by Heidinger in Dehomag proved to be favorable, since Heidinger could now issue Dehomag as a German company that only transferred license fees to IBM, as Heidinger trustfully assured the representatives of the Nazi regime.

In April 1933, after four years of negotiations, Dehomag purchased a building complex in Berlin-Lichterfelde with a low-cost rail connection on the Berlin-Potsdam line, where it began producing tabulating machines in January 1934.

Figure 7: The Dehomag Factory in Berlin–Lichterfelde (Source: Dehomag (ed.): Denkschrift 1934)

Dehomag was now less dependent on imports from the USA. Watson made this investment possible with one million US dollars (corresponding to 4 million Reichsmarks).[102] With this plant, Dehomag was able to catch up with the Powers-Gesellschaft, which already operated a production plant in Berlin and which, in the June 1933 issue of its in-house magazine, drew the attention of the Nazi rulers to "German" production and the "German" designs in its plant. Dehomag responded with a pompous memorandum on the occasion of the opening of its new work on January 8, 1934, which was thickly printed with Nazi ideology and contained photos of the opening with local Nazi figures and SA trellises.[103]

As is usual with fiercely competing duopolies, Dehomag and Powers copied each other's actions in Germany. From August 1929 Powers and September 1931 Dehomag published a company magazine in which they documented successful applications of their systems in public authorities, administrations and production plants. A comparison of both house magazines shows a similar style in structure and style. Powers may have been just as successful in Germany as Dehomag in its market presence. The special issue of the Powers house magazine on the occasion of the 7th International Office Exhibition in Berlin 1931 documents an impressive list of users of the Powers System in Berlin and in Germany.[104]

From 1934 Powers, with the participation of Siemens, traded as "Siemens-Powers" in Germany. In a division of labor, Siemens produced sorting machines and Powers tabulating machines.[105] When ten patent infringement cases were pending between Powers and Dehomag in 1936, both parties surprisingly withdrew their claims and granted each other rights to use the patent.[106] Whether this contract came about under pressure from the Reich Economic Ministry remains to be investigated. In 1941, the Rheinmetall armaments group acquired a majority stake in Powers and changed its name to "Rheinmetall Lochkarten Maschinen GmbH" with the aim of becoming independent of US patents.[107]

In June 1933, Powers GmbH published an address of loyalty to the Hitler government on the prominent first page of its House Notices No. 47, where it quoted the text of the government declaration of May 5, 1933, after the "trade union action" - meaning the smashing of the trade unions on May 2, 1933 - the entrepreneurs were now to refrain from nervousness and confidently plan their investments. Maybe Powers was speculating on the big census job.[108]

However, Dehomag also served the new rulers not only with its 1934 memorandum. She wrote in her commemorative publication for the 25th anniversary in 1935: "The reorganization of our Wehrmacht will continue to require a large number of mass observations and investigations.... A gigantic field of mass observation is opened up by the great framework conditions of our national body: the German Labour Front, the Reichsnährstand, the Organisation of Trade and Industry, the Reichsbund deutscher Beamten, the Reichskulturkammer, and the Bund Nationalsozialistischer Deutscher Juristen.... Your problem area has immense dimensions and will in many cases be dependent on the use of the punched card method in view of the mass investigations, because many other questions remain unsolved. Likewise, the NSDAP will make extensive observations in its large administrative apparatus about the existence and movement of the party members, their separation according to age, gender and occupation, as well as about the personnel relationships of the SA, SS, JH, Jungvolk, BDM, Frauenschaft, Studentenschaft, NSV, etc.".[109] However, this speculation on a mass market for punch card technology remained unfulfilled in the organizations of the National Socialist state until 1940, since mostly mere card indexes were created, as the study by Aly and Roth showed.[110] In the US, on the other hand, from 1935 IBM was able to collect large orders from public insurance companies on the basis of President Roosevelt's legislation on social security.

Because of the Prussian government's bid to carry out the census in Prussia in 1933, which was actually planned for 1930, Dehomag developed extremely successfully and gained a great reputation in Germany with this major order. In its in-house magazine Hollerith Nachrichten, Dehomag published a report on the conduct of the census in an open-plan office of 2000 square metres in the Karstadt administration building on Alexanderplatz, with numerous flow diagrams, as well as a picture report in its memorandum.[111] At Alexanderplatz, the census sheets of 41 million citizens of Prussia were transferred to punched cards. Dehomag employed 900 temporary workers for this purpose, who had previously been trained in two-week courses with the Berlin-Mitte employment office.

The company history published by Dehomag shows the growth of the branches in the major German cities. For customer contacts in important sales segments, she hired special sales managers, such as one for contacts with authorities, one for the textile industry, one for banks and insurance companies and one for the consumer goods industry. This division into sales segments shows the special importance of these branches of the economy for sales of tabulating machines.[112] In 1930 its workforce reached the strength of 300 employees, then in 1933 it grew to over a thousand, which was connected with the census and the beginning of the production of tabulating machines at the beginning of 1934.

16 Rationalization strategies and the information explosion

As shown above, it was not until the 1920s that punched card technology became widespread among large companies. An evaluation of the book series "Musterbetriebe der Deutschen Wirtschaft", which had grown to 38 volumes by 1937, could provide a picture of the application of the punch card system, since the volumes also describe the administrations of the companies in detail. Random samples showed that Rhenania-Ossag Mineralölwerke in Düsseldorf used the Powers system, but until 1937 there was no application of punch card technology at the Mercedes office machine plant in Zella-Mehlis. Production, but not administration, was rationalised there.[113]

When asked how punched card technology was integrated into the debate on office rationalization in the period 1910 to 1939, many contributions can be found that refer to the analogy "office equals factory" and state that similar processes of work fragmentation and machinization take place in the office as in production. In fact, in the 1920s, the work of the employees was concentrated in large, factory-like halls filled with machine noise, where they worked on the machines functionally isolated under supervision. The expert for banking operations, Wilhelm Kalveram, spoke of a "de-soiling" of the work.[114] The transfer of flow work from production to the office was regarded as an ideal. Some authors became enthusiastic and spoke of punched card technology as a realization of the ideal of flow work in the office.[115] It is striking that the Committee for Economic Administration in the Reich Board of Trustees for Economic Efficiency assessed punched card technology very cautiously. Both its contribution and the corresponding bibliography in the Handbook of Rationalization, which was widely published with the second edition in March 1930 immediately after the first edition in January 1930, deal only marginally with this topic. Probably the committee was not convinced enough by the efficiency of the punched card method.[116] Also, the specialized knowledge of punch card technology represented a high barrier to entry into the knowledge market of consultants. One had to work for about a year in the sales organization of Powers or IBM to understand the functions of the machines for tabulating sales tables. Simple rules from management manuals did not help. Therefore, Taylor and the Taylorism movement were excluded from consulting on punch card technology.

The advertising emphasized that adding machines, calculating machines and booking machines were distinguished by the speed and precision of their operations and thus followed the general rationalization discussion of the 1920s, as Ursula Ramm-Ernst emphasized. The speed meant that the accounts for the day were already available in the evening, while in the "pre-machine" time the day's closing had required a lot of overtime work.[117]

The properties of speed and precision could also be found in punch card technology. This was not so much a matter of daily closing of accounts as of the monthly closing of accounts for the numerous sub-companies in groups, the creation of which had caused a lot of overtime work. The newly formed companies in the steel, chemical and electrical engineering sectors therefore began using punched card technology early in 1910 to absorb the peak workload at the end of the month by machine automation and to obtain financial statements that were corrected for calculation errors.[118] In his letter to Hoechst on February 16, 1912, Heinrich Cassel, the head of Bayer AG's accounting department, emphasized that the benefits of Hollerith's technology were not in a cost savings, since the rental costs were very high. On the contrary, the accounts could be drawn up in the short term, and "further desirable statistics" could be made with these cards.[119] A second monthly peak was the monthly pay slips, which were made in Germany, where wages were paid weekly only as an advance. For the calculation of net wages, numerous taxes, insurances, rent payments for company flats and the consumption of gas and electricity there had to be taken into account. The house news from Powers and Dehomag offer numerous articles on this subject.

While at first the reduction of overtime peaks at the turn of the month was the motivation for the big industry to enter punch card technology, this singular use of technology did not stop there. It was recognised that the use of technology was very expensive - which was not really a major factor in large industry - and that the machines therefore had to be continuously used to capacity in accordance with profitability criteria. The requirement was to send a steady stream of receipts to the punch card department in order to ensure that the machines were working at full capacity. The authors of the office rationalization admitted that many additional evaluations would not have been carried out by the punch card technology if this technology had not offered free capacities.[120] One can study the extension of the tasks at a metallurgical plant as a model. In addition to the work peaks in payroll accounting, the punched card department took over the analysis of the company health insurance fund as - as the author put it - "filling work" and extended the criteria for the evaluation from two to ten. Potential cost reductions for doctors and hospitals were identified and the contribution rate could be reduced.[121] The punch card technology extends its field of application from finance and personnel management to materials management, sales and other operational functional areas.

It is remarkable how the argumentation of the two major manufacturers of punch card technology, Powers and Dehomag, changed during the Great Depression of 1929-1933. While they had previously placed punched card technology in the context of a general rationalisation effort, they now saw the economic crisis as a particularly compelling reason to thoroughly examine the business in order to identify hidden sources of loss.

On the occasion of the 7th and 8th International Office Exhibition in Berlin in 1931 and 1934, the criticism of punched card technology, which led to large staff layoffs, was countered by the argument that staff layoffs were not the aim of punched card technology, but rather to make companies fit for competition.[122] Powers responded to the economic crisis by launching a smaller, cheaper machine that could also be used by large companies if sales slumps meant that the large machines could no longer be used to capacity.[123]

On the basis of the sources, it can be demonstrated in this book that the use of punch card technology gave rise to more and more fields of application in the field of commercial data processing. This expansive behaviour of information technology can be described by the term information explosion. Just as in the fission of the uranium atom 235, a splitting neutron leads to the emission of two more neutrons, triggering a chain reaction with explosion, the introduction of punch card technology in one field creates a hunger for formalized information in neighbouring fields and a further expansion of punch card-based analysis. It is interesting to note that the first information explosion in history occurred in the field of commercial data processing, not in the field of scientific technical data processing. Moreover, punch card technology in the first half of the 20th century was characterized by merely slow technical progress, so that the benefits of information processing had not increased through rapid technical progress, as was seen in the second half of the 20th century with microelectronics. The first information explosion was based on the liquefaction of information by punch cards as a decisive technological advance in punch card technology. Until now, the information was stored on index cards as well as in the posting journals. Also, in the office machines the information was fixed, as one can prove exemplarily by the advertising slogan of the Brunsviga Rechenmaschinenfabrik, which spoke of a "brain made of steel".[124] The liquefaction of information by punch card technology was already observed by engineers in the U.S. in 1905. Morell Gaines wrote in the Engineering Magazine: “Cost-keeping by hand, with its hard-and-fast entries in ink, is at best but stiffly adaptable to the many-sided interrogations whose answer it is its function to provide. Limitation by rigidity of form, which makes it represent as absolute conclusions that are only conditional, is its great defect. Cost-accounting by tabulating machine, offers, on the other hand, the utmost flexibility, or, rather, fluidity, in mode of expression. Without the necessity of transcribing, its records permit the application of re-classification after re-classification to the same set of facts. They are, accordingly, for all analytical purposes infinitely to be preferred to the fixed-form, ink-entry records.”[124A]

The liquefaction of information is a major topic in the Internet age, where a worldwide exchange of data and files is smoothly possible. But liquefaction already began with punched card technology, since the punched cards were movable and tabulating machines made it possible to evaluate the same punched cards again and again according to different criteria.

The sorting machines were also able to sort the punched cards in ascending order according to various numerical sizes once and again. The liquefaction already before 1914 reveals a fundamental paradox of the approaching information age: the liquefaction led to an information explosion, as evaluations and analyses according to new, previously unforeseen criteria became easily possible. The information explosion is a fine example of Theo Pirker's thesis that the machinization of information leads to its rapid multiplication.[125] The thesis of the information explosion will be substantiated by two quotations from the Hollerith Mitteilungen. Issue 3 of 1913 refers to the "infinite" analyses and interprets the use of Hollerith machines at Pennsylvania Steel-Company in the U.S. as follows:

"We have often been asked how the costs of obtaining information with tabulating machines compare with previous methods. It's hard to say, because the ease with which information can now be obtained gives us such an infinitely greater analysis than we would have required in the past."[126]

Issue 4 of 1914 shows the "enormous extension" of the analyses and makes the following programmatic remarks "On the exploitation of Hollerith machines":

"Of particular importance for assessing the value of the system is the fact that many public authorities and commercial bodies, which had initially limited the use of the system to carrying out the necessary work, have often made a huge expansion in the field of statistics of all kinds, payroll accounting, calculation, etc.".[127]

It is striking and underlines the high barrier to entry into the consulting market for punch card technology, that Frederic Winslow Taylor who work for Bethlehem Steel – a leading steel mill in the United Sates, located at Bethlehem Pennsylvania – around 1900 did not mention the punch card technology at all in his book “Principles of Scientific Management” which appeared in 1911 – although his consulting effort at Beethlehem Steel works was only 90 miles distant to Steelton, the location of the Pennsylvania Steel-Company where punch card technology was applied. Also, in the Bethlehem Steel mill the punch card technology was applied, as Lars Heide revealed in his archive–based research on Herman Hollerith.[127A] While Taylor investigated the unloading of ore wagons with the low tech instrument of a shovel at the Bethlehem steel mill, Bethlehem was already a Hollerith customer applying the high tech tabulating machine, which indicates the backwardness in Taylor's thinking. During 1900 to 1914, the popular Engineering Magazine was an important voice in the efficiency movement in the U.S. and published many papers on the use of the tabulating machine (compare endnotes 124A and 133A). So, the engineer Taylor must have known about this technology.[127B]

The information explosion had also left its mark on the household of the German Reich. In 1911 the Reichstag approved 10,000 Marks for a model project of Dehomag to introduce the Hollerith system at the main customs office in Aachen. The project was so successful that in 1913 the Reichstag approved a supplementary budget of 200,000 marks to create 33 new jobs for the Hollerith system at customs.[128]

Rationalisation strategies with punch cards in Germany have two special features compared to those abroad. The method first introduced by Stadtwerke Amsterdam in the 1920s of sending invoices as a punched card to its many thousands of customers was copied by numerous municipal utilities worldwide - but not in Germany.[129] Furthermore, the punched card system was not introduced in Germany for small life insurances (death benefit insurances), where the administrative costs were unfavourable in relation to the low contribution payments and it was therefore obvious to rationalise administration with the punched card system. This happened - as Joanne Yates investigated - at Prudential Insurance in the USA and Prudential Insurance in England. The British Prudential even became a partner in the British subsidiary of Powers.[130]

17 The feminization of the office and the work of the perforators

In the literature on the social history of the 20th century, the "feminisation of offices" associated with the mechanisation of the office is often described.[131] What is meant here is that office technology has created a large number of specialised workstations on typewriters, calculators and booking machines, where personnel could only be deployed on the machines after long training phases, without, however, having any prospect of advancement in the hierarchy of office organisation. Despite a high degree of specialisation, these jobs were low-paid and filled by women. Feminization began with the spread of the typewriter. Young women filled the typewriter positions, as the male office clerks initially refused to carry out this activity. Young girls were also considered to be particularly agile in operating the typewriter. Günther Schulz emphasized that the combination of dictation, shorthand and typewriting created the professional image of the stenotypist. Although in Germany in 1912 more than 100,000 people were organized in stenography clubs, which offered about 10 different stenography systems, there was a shortage of stenotypists before 1914. As Siegfried Kracauer described in his reports on the number of employees in the 1920s, entire classes of girls switched to training courses to learn typewriter writing and shorthand after leaving school.[132]

Feminization can also be observed in the field of punch card technology. When punching card technology was first introduced in Germany by Bayer AG in 1910, the job of punching was initially assigned to male workers. But soon the work of punching was transferred to female workers, who were referred to as "punchers" in other companies as well.[133] In US sources before 1910 also “punch boys” were mentioned.[133A]

Almost from the beginning, the work of punching was assigned to female workers also in other works, who were referred to as "punchers". They were concentrated in one room and trained in the work of punching for ten days, with the structure of the punch card depending on the project.

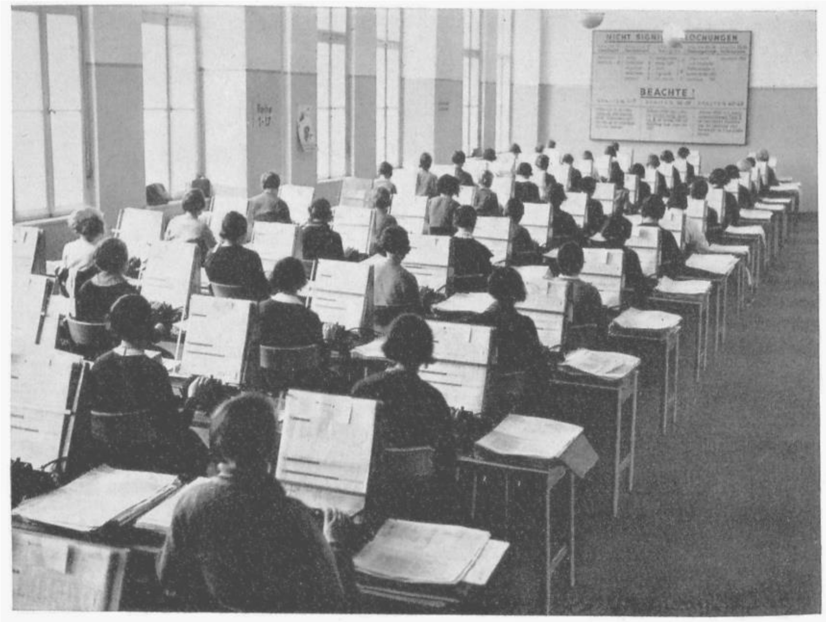

Figure 8: Punching room (Source: Hollerith Mitteilungen, issue 36, 1934, p. 454)

One puncher achieved an output of 200-300 cards per hour. According to Kollatz, 900 Marks annual wage was paid for a perforator in 1916, but for the male operators of tabulating machines 2400 Marks.[134] Numerous publications have reported on the results of psychotechnical studies on the selection and suitability of workers for punching. It was observed that interruptions and breaks increased work performance on average. Powers therefore set up three three-hour shifts a day for the 1933 Hungarian census.[135] The gender relations when punching and operating the tabulating machines were explicitly surveyed by the German Association of Municipalities in 1937 on the use of punched card technology. At hole workstations in the Berlin water works, zero male workers were recorded, at operator workstations zero female workers.[136]

In her study on the mechanization of the Krupp Group's headquarters, Verena Pleitgen showed that after the introduction of the Hollerith system in 1927, 800,000 cards were punched there every month Two examiners were assigned to each three hole punchers in order to minimize errors during punching. The examiners had to expect a deduction of 50 Pfennig per overlooked error. Seven months after its introduction in September 1927, the best female examiner achieved an hourly output of 400 cards (containing about 16,000 holes) and the best female punch 290 cards (containing 11,000 holes). The 800,000 cards that were punched each month passed through the sorting machine on average 30 times a month and the tabulating machine four times a month. The operation of the tabulating machine was reserved for younger male personnel.

Female personnel aged 16-21 were hired for the perforators. Assuming a punching capacity of 200 cards per hour, there was a requirement of approx. 21 punchers and 14 examiners for punching 800,000 cards per month. The fact that Krupp hired such young staff for the work of the perforators probably has to do with the low wage costs for this group of employment.

After punch card technology was introduced, administrative expenses for central accounting at Krupp rose from 25,000 Reichsmarks in 1925 to 1.5 million Reichsmarks in 1930 - a fine example of the information explosion at Krupp.

18 Outlook

The concept of information explosion can be used as a heuristic principle to detect other peculiarities in the history of data processing. One example is the introduction of the IBM 1403 high-speed printer in 1959, which had a capacity of 600 lines per minute. As a result of the printing possibilities, it can be assumed that the offices are flooded with paper printouts. In addition, the introduction of municipal computer centres in the federal states of Hesse and North Rhine-Westphalia, which Julia Fleischhack has worked on, can be examined to see whether this has led to a further information explosion. After all, the author notes that the data centres did not lead to the expected cost-effectiveness of centralized processing, but without elaborating further on this point.[139] Barbara Anderson (2022) reports on some examples of how the development digital computers induces the growth of research in demographic analysis.[140] In her study "Productivity Machines. German Appropriations of American Technology from Mass Production to Computer Automation", Corinna Schlombs (2019) portrays the digital computer as a productivity machine without regard of how the computer expands the demand for information.[141]

19 Endnotes

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56 Das Hollerithverfahren in der Umsatz- und Lagerkontrolle der Schokoladenindustrie, in: Hollerith Nachrichten, issue 11, 1932, pp. 108 – 118, here p. 109.

57 In „Die Lochkarte und das Powers System“, issue 47, 1933, p. 501 is a photo of the paper processing at Powers. In 1933, the Reichsbahn bought 90 million cards a year from Dehomag and 20 million from

Powers, letter on 8 March 1933 der Dehomag an Willy Heidinger, Wirtschaftsarchiv Baden-Württemberg, file IBM, B95/101.

58 Landesarchiv Berlin, Akte 7059, A Rep 080.

59 Business statistics by John R. Riggleman and Ira N. Frisbee, second edition, New York 1938.

60 Placing the wiring board at the front was an improvement of the Dehomag, siehe James Connolly, History of Computing in Europe, IBM World Trade Corp., 1968, p. 18.

61 The foto is from Hans Görlitz, Die Hollerith-Sortier- und Tabelliermaschinen und ihre Anwendungen für Verkehrszählungen, in: Elektrische Kraftbetriebe und Bahnen 11, 1913, issue 3, p. 55.

62 Robert Feindler, Das Hollerith-Lochkartenverfahren, Berlin 1929, pp. 265-269.

63 Lucas, Sortier-Maschinen (cf. note 39), p. 11.

63A Other statistical functions could also be programmed, such as mean, minimum and maximum of the values in question. With the sorter the minimum or maximum of values could be computed. For calculating the mean by a tabulating machine see Feindler (cf. note 62), p. 309. The function maximum was important for utilities. In industry electric power was rated according to the daily maximum use, see Festschrift 50 Jahre Siemens Schuckert, Berlin 1953, p. 595. For the use of tabulating machines at Berliner Elektrizitätswerke to calculate the bills for the 70.000 customers see L. Lucas: Selbsttätig arbeitende Sortier– und Addiermaschinen für Kalkulation und Statistik, in: Wirtschaft und Technik, vol. 6, April 1913, issue 4, p. 225.

63B Campbell-Kelly, Martin und William Aspray: Computers – A History of the Information Machine, New York 1996, p. 133. Rottmann, Hans: IBM/360 Modell 20: Programmieren leicht gemacht mit RPG, München 1966. Heger, Hans: 100 Jahre Datenverarbeitung, vol. 1, edited by IBM, Stuttgart 1990, pp. 140–144.

64 Feindler, Hollerith (cf. note 62), p. 126.

65 Ibidem, p. 250. For Anderson cf. note 1.

66 Dorsch, Büromaschinen (cf. note 14), p. 57 (with permission of IBM Deutschland).

67 Kistermann: Als die Daten, (cf. note 51), p. 28.

68 By tens carry is meant that the next higher digit counts on by one unit when the previous digit reaches zero, so for example 69 plus 1 equals 70. Here the tens carry of 6 jumps to 7.

69 Lucas, Sortier-Maschinen (cf. note 39), p. 11.

70 Herman Goldstine: The Computer from Pascal to von Neumann, Princeton UP 1972, p. 158. Thomas Haigh, Mark Priestley and Crispin Rope, ENIAC in Action, (Cambridge, Mass., 2016).

70A Schmitt, Martin: Die Digitalisierung der Kreditwirtschaft: Computereinsatz in den Sparkassen der Bundesrepublik und der DDR 1957-1991 (Medien und Gesellschaftswandel im 20. Jahrhundert), Göttingen 2021.

71 Heger, 100 Jahre (cf. note 1), Band 2, p. 67.

72 Siehe z.B. Hans Hubert Rottmann, IBM/360 Modell 20: Programmieren leicht gemacht mit RPG. Mit 3 Anwendungsbeispielen, München 1966. Campbell-Kelly und Aspray, Computer (cf. note 42), p. 133.

73 To limit its scope, this eBook largely hides the level of patent litigation at which the competition between Powers and Hollerith or IBM played out. For this subject see the book of Lars Heide (cf. note 24).

74 Birgit Schneider, Kleider für Automaten. Muster und Karten in der Lochkartenweberei des 18. Jahrhunderts unter spezieller Berücksichtigung des Webstuhls von Vaucanson, in: Technikgeschichte 70, 2003, issue 3, p. 185 – 206. James Essinger, Jacquard's Web: How a Hand-Loom Led to the Birth of the Information Age, New York 2004. For the bridge from weaving to number theory see Ellen Harlizius–Klück et al.: Conflicting Threads. Technological Innovation and the socio–technical ensemble of weaving, in: Z. f. Technikgeschichte, 1/2022, pp. 35–62. The literature on Hollerith's invention of the tabulating machine is not very extensive, see Geoffrey Austrian, Herman Hollerith Herman: forgotten giant of information processing, New York 1982.

75 Thomas Hughes, Networks of power: Electrification in Western Society, 1880 – 1930, Baltimore 1983. Thorsten Dame, Elektropolis Berlin: die Energie der Großstadt, Berlin 2011. Günther Luxbacher, Massenproduktion im globalen Kartell: Glühlampen, Radioröhren und die Rationalisierung der Elektroindustrie bis 1945, Berlin 2003. Anker, Peder: The Power of the Periphery. How Norway Became an Environmental Pioneer for the World. Cambridge 2020.

76 Geoffrey Austrian, Herman Hollerith Herman: forgotten giant of information processing, New York 1982, p. 13, Chapter 4. For the relay-stations in telegraphy see Campbell-Kelly, Computer (cf. note 42), p. 19.

77 Martin Campbell-Kelly, ICL – The official History on Britain's leading information systems company, Oxford 1989, p. 9.

78 Lars Heide, in his study of Powers, surprisingly does not see a technological regression from electrics to mechanics when he argues that in 1910 the electricity grid was still too heterogeneous and unstable to be relied upon, Heide, Punched Card (cf. note 24), p. 73-89.

79 Cortada, Computer (cf. note 48), p. 116.

80 Pierre Mounier-Kuhn, Bull: A World-Wide Company Born in Europe, Annals of the History of Computing 11, 1989, issue 4, p. 279-287.

81 Die Lochkarte und das Powers System, issue 98, Juli 1937, p. 1061-1068, and issue 119, Juni 1939, p. 1363-1365. Wilhelm Lind, Büromaschinen, 2. edition, Füssen 1954, p. 274. Cortada, Before the Computer (cf. note 48), points to Remington Rand's low spending on research and development, p. 219, which may explain its insistence on purely mechanical solutions.

82 Die Lochkarte und das Powers System, issue 36, Juli 1932. Heinz Henking, Das Siemens-Powers-Lochkarten-Verfahren im Industriellen Rechnungswesen, Sonderdruck von Siemens-Powers, Berlin 1936, p. 3.

83 Dorsch, Büromaschine (cf. note 14).

84 In the trade journals there are some publications to punch card technology by Hans Görlitz, e.g.: Die Hollerith-Sortier- und Tabelliermaschinen und ihre Anwendungen für Verkehrszählungen, in: Elektrische Kraftbetriebe und Bahnen 11, 1913, issue 3, p. 53-56.

85 Die Lochkarte und das Powers System, issue 47, 1933.

86 Letter on April 1910 in: Wirtschaftsarchiv Baden Württemberg, Bestand IBM, B95/88. 100 Jahre Datenverarbeitung bei Bayer. Eine Zeitreise, in: Compact 2010, Nr. 38, p. 14s. I would like to thank the archives of Schering Berlin for providing me with the employee newspaper Compact.

86A Frederic Steinfeld: Das quantifizierte Unternehmen. Rechnungswesen, Bilanzierungen und Entscheidungen in der deutschen Chemischen Industrie, 1863 – 1916, Berlin 2021.

87 Petzold (cf. note 12), p. 198.

88 Eberhard Lippmann, AEG-Olympia-Optima. Büromaschinen aus Erfurt 1924-2004, Erfurt 2010, p. 9. Aus der Geschichte der Deutschen Hollerith Maschinen Gesellschaft, in: Hollerith Nachrichten 1935, pp. 729-738, here p. 729. Siemens did not enter into a joint venture with Powers for a production and distribution company of Powers machines in Germany until 1934.

89 Emerson Pugh, Building IBM. Shaping an Industry and its Technology, Cambridge (Mass.) 1995, p. 18, p. 27.

90 Black (cf. note 9), p. 55. Black even claims that Watson loaned Heidinger the money for his 10% shares without interest, so that Heidinger was merely a pro forma shareholder. Aus der Geschichte der Deutschen Hollerith Maschinen Gesellschaft, in: Hollerith Nachrichten 1935, pp. 729-738.

91 Lucas, Selbsttätig (cf. note 39). This paper was published in April 1913 in the monthly journal of the Association of German Engineers "Technik und Wirtschaft".

92 Petzold, Maschinen (cf. note 6), p. 200. An overview of the use of the tabulating machine in censuses in Europe is provided by Kistermann, Locating (cf. note 10), p. 36.

93 Farbenwerke Bayer, Leverkusen, Farbenwerke Frankfurt (Main)-Höchst, Badische Anilin- und Sodafabrik, Ludwigshafen, AEG Kabelwerk Oberspree, Berlin, AEG, Friedrich-Karls-Ufer, Berlin, Siemens-Schuckertwerke, Berlin-Siemensstadt, Osram, Charlottenburg, Brown Boverie & Cie, Mannheim-Käfertal, Festschrift (cf. note 41), p. 69, p. 8.

94 Lucas, Sortier-Maschinen (cf. note 39), p. 11.

95 James Connolly, History of Computing in Europe, IBM World Trade Corp., 1968, p. 13, 21. Promotion of firm Powers, Katalog der 8. Internationalen Büro-Ausstellung Berlin 1934, p. 120 (Archiv des Deutschen Museums, München).

96 Die Reisgetreidestelle Berlin, die Zentraleinkaufsgesellschaft Berlin, Kriegsmetall AG Berlin, Kriegsbekleidungstelle Berlin, Kriegswollbedarf AG Berlin, Kriegsausschuss für Kaffee, Tee und deren Ersatzmittel GmbH Berlin, Reichsstelle für Gemüse und Obst Berlin, Reichshülsenfruchtstelle Berlin, Gartenbau Verwertungsgesellschaft Berlin, Deutsche Papiergarn GmbH Berlin, königlich preußisches Kriegsministerium Kriegsrohstoffabteilung Sektion Berlin, Sanitäts-Statistik-Abteilung bei der Kaiser-Wilhelm-Akademie Berlin, die KuK Artilleriezeugs-Fabrik in Wien, der Vollzugsausschuss der drei Getreidezentralen Wien, Baumwollzentrale AG in Wien, KuK Waffenbeschaffungsamt, Wien. Aus der Geschichte der Deutschen Hollerith Maschinen Gesellschaft, in: Hollerith Nachrichten 1935, p. 729-738.

97 Festschrift (cf. note 41), p. 10.

98 Wirtschaftsarchiv Baden-Württemberg, Bestand IBM, B95/93.

99 Festschrift (cf. note 41), p. 9.

100 James Connolly, History of Computing in Europe, IBM World Trade Corp., 1968, p. 19, Wirtschaftsarchiv Baden Württemberg, Bestand IBM, B95.

101 Ruser, Ursula, Die Reichsbahn als Reparationsobjekt, Diss. Freiburg 1980. Jan Peters, Personalpolitik und Rationalisierung der Reichsbahn, Frankfurt 1996. (without prename) Küchler, Statistik und Büromaschinen der Reichsbahn, in: Der Eisenbahnfachmann 7, 1931, p. 549. R. Schneider, Maschinelle Aufstellung der Selbstkosten eines Lochkartenbetriebs, in: Hollerith-Nachrichten, issue 13, 1932, p. 142. Zentrale Stoffeinkäufe beim Reichsbahn-Zentralamt, in: Die Lochkarte und das Powers-System, issue 28, 1931, p. 290-296. Julius Dorpmüller, Rationalisierung bei der Reichsbahn, in: Verkehrstechnische Woche 22, 1928, issue 1, p. 4.

102 For the inauguration of the new production facility, see „Denkschrift zur Einweihung der neuen Arbeitsstätte der Hollerith Maschinen Gesellschaft in Berlin-Lichterfelde“ am 8. Januar 1934, Berlin 1934.

Black (as Note 9), p. 74. The buildings at Lankwitzer Strasse 13 in Berlin can still be viewed from the outside today.

103 „Denkschrift zur Einweihung der neuen Arbeitsstätte der Hollerith Maschinen Gesellschaft in Berlin-Lichterfelde am 8. Januar 1934", Berlin 1934. In his speech, Dehomag Chief Heidinger spoke the terrible words about the role of statistics, which dissects the body of the people and corrects pathological conditions by interventions, ibid, p. 39. What the intentions of his remarks were remains unclear. The ousting of Jewish citizens from leadership functions in state and society already took place in 1933 completely without statistics and punch card technology., see the Gesetz zur Wiederherstellung des Berufsbeamtentums on 7 April 1933.

104 Die Lochkarte und das Powers System, issue 25, September 1931 claims as users oft he Power system: Die AEG Zählerfabrik Berlin, Magistrat Berlin, Amt für Stadtreinigung, Verband öffentlicher Lebensversicherungsanstalten Berlin, die Commerz- und Privatbank Berlin, Städtische Elektrizitätswerke Berlin, Reichsbahnzentralamt Berlin. Curt Piorkowski also names the oil refinery Rhenania-Ossag as a user of the Powers system, see Curt Piorkowski, Die Benzin- und Ölversorgung durch die Rhenania-Ossag Mineralölwerke Düsseldorf (Musterbetriebe der Deutschen Wirtschaft vol. 7), Berlin 1928, p. 31, where the administrative procedures are described in detail.

105 Aus der Gemeinschaftsarbeit Siemens-Powers, in: Die Lochkarte und das Powers System, issue 99, Oktober 1937, p. 1083. For the Cooperation of Siemens with Powers see Petzold, Maschinen (cf. note 6), p. 239s.

106 Wirtschaftsarchiv Baden-Württemberg, file B 95/107. For a patent lawsuit see Die Lochkarte und das Powers-System, issue 1, 1929, p. 1.

107 Petzold, Maschinen (cf. note 12), p. 260.

108 Die Lochkarte und das Powers-System. Zeitschrift für neuzeitliches Rechnungswesen, issue 47, Juni 1933, p. 1. Powers got a great commission for the census in Hungary, see Die Lochkarte und das Powers-System. Zeitschrift für neuzeitliches Rechnungswesen, issue 42, Januar 1933, pp. 457-459.

109 Festschrift (cf. note 41), p. 74.

110 Aly und Roth, Die restlose Erfassung (cf. note 10). In the search mask Invenio of the Federal Archives, only one hit is found for the search word Hollerith in the organizations of the NSDAP, namely at the Labor Science Institute of the German Labor Front.

111 Ludwig Hümmer, die Aufbereitung der Volks-und Zählung 1933 im Hollerith Lochkartenverfahren, in: Hollerith Nachrichten, issue 28, 1933, p. 343-369. Black, IBM (cf. note 9), p. 69-75. The economic crisis of

1929 to 1933 left many office spaces in Berlin empty, which Dehomag was now able to rent at short notice even in Berlin-Mitte at Alexanderplatz.

112 Aus der Geschichte der Deutschen Hollerith Maschinen Gesellschaft, in: Hollerith Nachrichten 1935, p. 735.

113 Julius Schmitt, Mercedes Büromaschinenwerke (Musterbetriebe der Deutschen Wirtschaft Band 14), Leipzig 1937. Piorkowski, Benzinversorgung (cf. note 104).

114 Kalveram, Rationalisierung (cf. note 15), p. 154. Hans-Jochen Fritz, Der Weg zum modernen Büro, in: Rolf Stümpel, Vom Sekretär zur Sekretärin, Berlin 1985, p. 52. See also Siegfried Kracauer's reportage, Die Angestellten, Frankfurt 1971. Jürgen Bönig, Die Einführung von Fließbandarbeit in Deutschland bis 1933 – Zur Geschichte einer Sozialinnovation, 2 volumes, Frankfurt 1993. Siegfried Kracauer's reportages tell of the noise of machines (cf. note 114), p. 28.

115 Remington-Powers Lochkarten-Maschinen GmbH (Hg.), Powers Lochkarten-Maschinen, Berlin 1930, p. 1 (Archiv Deutsches Technikmuseum Berlin). Lehmann, Lochkartenverfahren (cf. note 45), p. 795. Siegfried Kracauer's reportages tell of the noise of machines (cf. note 114), p. 28.

116 Reichkuratorium für Wirtschaftlichkeit (ed.), Handbuch der Rationalisierung, Berlin 1930. Fort he foundation of Reichskuratoriums 1921 see Bönig, Fließbandarbeit (cf. note 114), p. 102.

117 Ramm-Ernst, Stahlgehirne (cf. note 7), p. 230. E. Gobbers, Die mechanischen Hilfsmittel der Verwaltung, in: Hollerith Nachrichten, issue 43, 1934, p. 563.

118 For the large companies, see Hollerith's customer list (cf. note 112). The first Powers customer in Germany in 1913 was Mannesmann Röhrenwerke Düsseldorf, which cited the end-of-month peak workload as the reason for procuring the Powers machine, see Connolly, History (cf. note 100), p. 13. For the peak of workload wage accounting see ibidem, p. 26.

119 Archive Bayer AG, file 399-009.

120 Georg Brandl, Das Lochkartenverfahren im Rechnungswesen der Eisenindustrie, in: Technik und Wirtschaft 27, 1929, issue 10, p. 281s. According to C. Kollatz, Das automatische Kartotheksystem von Hollerith, in: Organisation 19, 1917, issue 1, p. 7, in 1916 the annual rent for a sorting machine was 1000 marks and for a tabulating machine 3300 marks. The sum of 4300 marks corresponded approximately to the annual wages of two operators on the tabulating machine. Dehomag stated the production costs for a type 4 tabulating machine at 25,000 Reichsmark in 1933, see Wirtschaftsarchiv Baden-Württemberg, Bestand B 95/67.

121 G. Lehmann, Die Mechanisierung des Bürobetriebs, in: Technik und Wirtschaft 27, 1929, issue 2, p. 32s.

122 Die Lochkarte und das Powers System, issue 25, 1931, p. 236. Hollerith Nachrichten, issue 41, 1934. Die Büro-Ausstellung 1931 konnte wegen der tiefen Wirtschaftskrise nur unter größten Schwierigkeiten überhaupt veranstaltet werden.

123 Die Lochkarte und das Powers System, issue 31, 1932, p. 348.

124 Ramm-Ernst: Stahlgehirne (cf. note 7).

124A Morell Gaines: Tabulating-Machine Cost-Accounting for Factories of Diversified Products, in: Engineering Magazine, vol. 30, 1905, pp. 364–372, here p. 364s.

125 Pirker, Büro (cf. note 28). The term "information explosion" was introduced by Lars Heide in his study on punch card technology (see note 24). However, this term remained confined to the title of the book without any interpretation of its content in the text.

126 issue 3, 1913 der Hollerith Mitteilungen, p. 25.

127 issue 4, 1914 der Hollerith Mitteilungen, p. 1. Further hints to informationexplosion one can find in: Hümmer, Volkszählung (cf. note 114), p. 369 und Peter Schausten, Die Netto-Lohnabrechnung bei Vereinigte Stahlwerke AG Bochumer Verein, in: Hollerith Nachrichten, issue 24, 1933, p. 294.

127A Lars Heide: Herman Hollerith (cf note 10), there note 31.

127B For a critique on Taylor see Richard Vahrenkamp: Taylor and Taylorisms. Public Debate and Decline in the U.S. and Europe, 1900–1930, eBook 2023 by Tolino Media.

128 Wirtschaftsarchiv Baden-Württemberg, Bestand IBM, B95/88.

129 Connolly, History (cf. note 100), p. 20. Surprisingly this leading role was not mentioned by Onno de Wit, Jan van den Ende, Johan Schot und Ellen van Oost in their paper Innovation Junctions. Office Technologies in the Netherlands 1880 – 1980, in: Technology and Culture 43, 2002, issue 1, p. 50-72.

130 Joanne Yates, Structuring the Information Age. Life Insurance and Technology in the Twentieth Century, Baltimore 2005.

131 Wolfgang Winkler, Soziologische, organisationstheoretische und arbeitsmarktpolitische Aspekte der Büroautomatisierung, Berlin 1979, p. 142. Statistical data on the feminization of the office are missing for the first half of the 20th century, since data on employment were collected by economic sector but not yet by the category "office, see Günther Schulz, Die weiblichen Angestellten vom 19. Jahrhundert bis 1945, in: Hans Pohl and Wilhelm Treue (ed.), Die Frauen in der Wirtschaft, Stuttgart 1985, p. 179-226. Zu weiblichen Beschäftigten in der Fertigungsindustrie bei AEG und Siemens see Bönig, Fließbandarbeit (cf. note 114), vol. 1, p. 289-301.

132 Ursula Nienhaus, Innovationen (cf. note 44), p. 315. Günther Schulz, Correferat to Ursula Nienhaus, in: Rolf Walter (ed.), Innovationsgeschichte, Stuttgart 2007, p. 329-332, here p. 330. Organisation 10, 1913, issue 2, p. 37. Ursula Nienhaus, Weibliche Angestellte in Deutschland 1880 - 1945, Hagen 1987, p. 34. Kracauer, Angestellten (cf. note 114), p. 30.

133 Letter from the head of Bayer AG's Group Accounting Department, Heinrich Cassel, to Gruschwitzer Textilwerke on February 25, 1913, stating that "young ladies" are now doing the punching work, punching up to 2000 cards in eight hours, Archiv Bayer AG, Akte 399-009.

133A Gerskon Smith: Distribution of indirect Costs by the Machine–Hour–Methode, in: Engineering Magazine, vol. 30, 1905, pp. 383–395, here 392. A.W. Buel: Cost Keeping in General Construction and Contract Work, part III, in: Engineering Magazine, vol. 29, 1905, pp. 707–718, here 717.

134 Kollatz, Kartotheksystem (cf. note 120), p. 7.

135 Steigerung der Lochleistung durch Abwechslung, in: Die Lochkarte und das Powers-System, issue 53, 1933, p. 550-555. Volkszählung in Ungarn, in: Die Lochkarte und das Powers-System, issue 42, Januar 1933, p. 457-459. Erwin Gehrts, Der Mensch im Lochkartensystem, Hollerith Nachrichten, issue 32, 1933, p. 394-396.

136 Landesarchiv Berlin, file A Pr. Br. Rep 057/2208.

137 Pleitgen, Rechnungswesen (cf. note 8), p. 205-208.

138 It is also known of the Bata shoe factories with worldwide locations that they hired primarily young personnel for cost reasons In her study "The Shoe in National Socialism," Anne Sudrow showed that Bata had repeatedly disregarded the youth protection regulations for its workers in its U.S. production plant, see Anne Sudrow, Der Schuh im Nationalsozialismus: Eine Produktgeschichte im deutsch-britisch-amerikanischen Vergleich, Göttingen 2010, p. 143.

139 Julia Fleischhack, Eine Welt im Datenrausch: Computeranlagen und Datenmengen als gesellschaftliche Herausforderung in der Bundesrepublik Deutschland (1965-1975), Zurich 2016, p. 43.

140 Anderson, cf. note1.

141 Schlombs, cf. note2.