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The role of patents and standards in shaping the punched card systems of the Bull Company from 1918 to 1952

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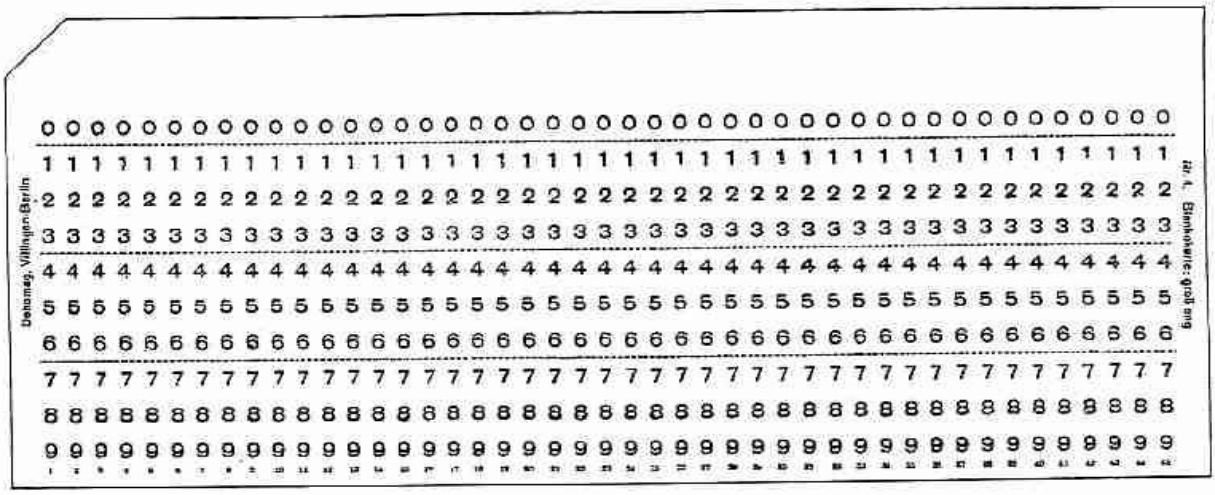
Patents and standards played important roles in shaping the Bull company and its punched card systems.

An industry standard was established as early as 1907 by Herman Hollerith, then the sole punched card producer, condensed in his 45 column punched card containing numbers only.[1] It was well suited for processing various kinds of statistics, then constituting the applications. This universal standard was adopted, first by James Powers, and later by Fredrik Rosing Bull, as they entered the field. For a quarter of a century the 45 column punched card containing numbers rendered the framework to the development of applications, as well as machines.

Also patents contributed to the shaping of the industry. During the reign of this universal standard, hundreds of punched card system patents were issued to various inventors in the United States, as well as in other counties. A few were basic patents; most were on minor machine improvements. As a first mover, Hollerith and his company got several basic patents. As time went by, patents expired, but at any time this company held a few, that could complicate life to any competitor. This was the reason, why the first competitor, James Powers, in 1914 entered into a licence agreement with the Hollerith company.

From the start in Norway in 1918, Fredrik Rosing Bull adopted this universal standard. Then the crucial patent was the Hollerith automatic group control feature, patented in the United States and in several European countries, but not in Scandinavia and Switzerland. These countries made up the market of the Bull machines in the 1920s. Bull and his successors only encountered the brunt of the patent system, as they tried to move outside these countries.

At the same time the Powers and Hollerith companies started to expand the punched card's application fields, which made visible two of the universal standard's shortcomings: the lack of letters, and the limited size of a record - the 45 columns on a card. The outcome was several exclusive standards, one from each member of the industry. In 1931 Bull machine development and production moved to Paris. At that time, the Hollerith company - then IBM - introduced a new and exclusive 80 column punched card. The Bull company developed their own alphanumeric standard, but in 1938 they adopted this 80 column card. IBM filed a patent infringement suit,



The 45 column punched card (8.3 by 18.7 cm) made a standard by Herman Hollerith in 1907.

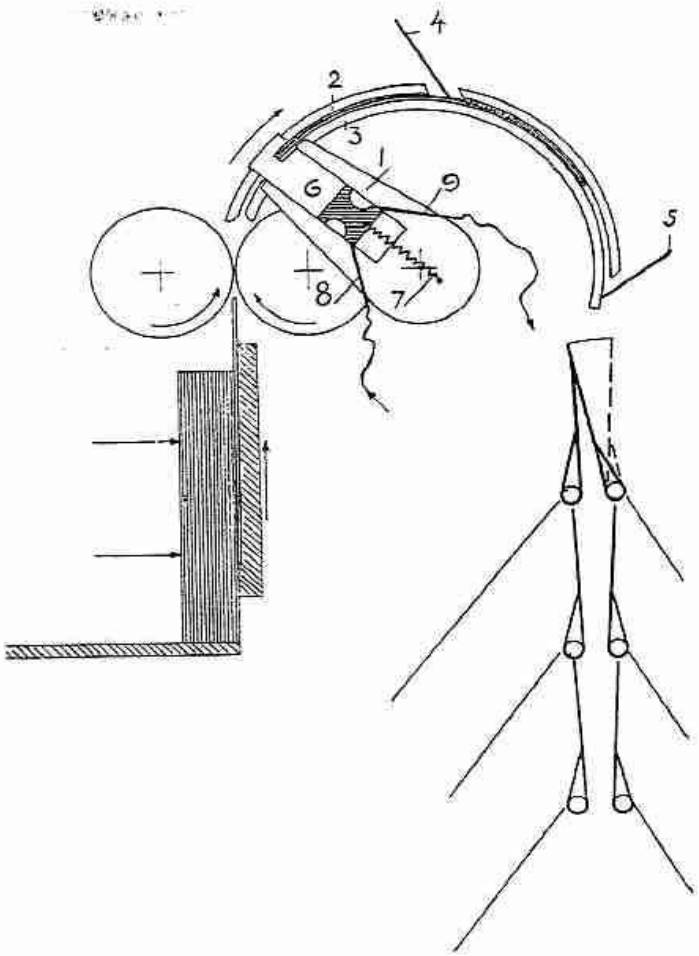
which they lost, in 1947.

This paper analyzes the importance of patents and standards in the shaping the Bull punched card systems and the Bull company. In the conclusion this punched card history is compared to the introduction of the IBM System 360 in 1964 and its consequences for the competitors.

Fredrik Rosing Bull's Statistics Machines

Fredrik Rosing Bull's punched card innovations took place within statistics processing. This application field constituted the foundation of Herman Hollerith's 1907 standard, condensed in his 45 column punched card with sole numeric representation, which allowed storage of 45 digits, one in each of the columns. As there were 12 punching positions in each column, only 10 of the 4095 possible combinations - 0.02% - were used. This was not impressive, but Herman Hollerith and others proved able to construct machines, which could read and process the punched information.

Hollerith's original system had been invented to process the United States 1890 census and then additionally shaped until 1907. The original system was an *ad hoc* system to solve a special statistical assignment. This system was subsequently shaped by commercial statistical applications, mainly railway statistics and cost accounting. The outcome by 1907 was a standardized system based on the 45 column card with numerical representation. Herman Hollerith marketed punches, sorters and a tabulator, a machine with separate adding machines, which allowed various conditioned additions from punched cards. The outcomes were not printed, but displayed visually to be copied by hand. This was sufficient for making statistics tables based on a large number of



The basic mode of operation in Fredrik Rrosing Bull's original punched card machine. Source: F. R. Bull, Norsk Patent, No.34,630 (1924, filed 1919).

data, like basic actuarial statistics. Alternative processing tools were written index cards and adding machines.[2]

Bull's 1918 starting point was a report by a colleague at the Norwegian non-life insurance company *Storebrand* on the punched card installation in a Swedish insurance company - and probably some trade literature.[3] Bull found that he could build such machines as well, and he offered to construct a machine for the *Storebrand* company. This was agreed, and the first Bull machine was supplied in 1921, which was based on Hollerith's 1907 standard, as the rest of the machines build under Bull's supervision. This standard both supplied a framework to Bull's work, and enabled users the option to compose their installation of machines from several suppliers. For example, in the 1920s this was the case at the Danish State Railways and at the Statistical Office in Copenhagen.[4] If Bull had chosen not to join this standard, he would have had from the outset to supply a full set of machines for statistics processing. This would provide a high threshold, that might have ended the Bull punched card story.[5]

Hollerith's company protected their punched card systems through a large number of patents. You had to patent in each country to achieve protection, and the Hollerith company had patents in most major European countries, France, Germany, and Great Britain, but they had refrained from patenting in small European countries, like Scandinavia. In addition, by 1920, most of the early basic patents had expired. Only the crucial automatic group control patent was in force. Automatic group control enabled the tabulator to stop for manual reading or later automatic printing of a

subtotal, for example when all successive cards in an income group punched on the card ended, and the next started. Automatic group control was the first major method to control the processing through information punched on the cards. It was originally filed in the United States in 1914, but only issued in 1931, which made it valid until 1948.[6] In the major European countries it was valid throughout the 1920s and early 1930s.

In the United States the patents was probably a major reason that only two punched card producers emerged, Herman Hollerith and James Powers. Several independent inventors are known from their patents, but only one - John Royden Peirce - nearly became a competitor. He worked outside the 1907 Hollerith standard but was not able to produce well functioning machines.

In Scandinavia the lacking patents supplied Bull a free scope, but Continental and British patents restricted exports.

Patents Guide from Oslo to Paris

Fredrik Rosing Bull developed and produced his machines in Norway working within a Scandinavian insurance network. Only a few machines went slightly outside this network, to the Norwegian Statistical Office and the Danish Statistical Office. The scale of production was limited. The machines were artisan build by an Oslo precision maker, Christian Ormestad.

Bull wanted to turn to an industrial scale production.[7] Bigger scale could yield more revenues. The machines required innovation to run more efficiently, and his production never became profitable. Of the Scandinavian countries, only Sweden had an industrial scale office machine production, but all had factories producing telephone and telegraph equipment, in addition to scores of precision makers. The Scandinavian countries held the technological capability for an industrial production of punched card machines, but Bull and his successors never appears to have considered this possibility. One reason was, that the engineer Reidar Knutsen, who financed and marketed the Bull machines in Norway, was a graduate from the *Technische Hochschule Berlin-Charlottenburg*. Therefore, he knew the opportunities in a big country, and he had contacts in Germany. Another reason was, that Bull's wish for a foreign production probably was the result of a foreign initiative. These reasons made Bull and his successors go for industrial production in a country with a large home market.

In 1922 Bull was approached by Reidar Knutsen's brother in law, Robert Thelen, who wanted to produce punched card machines in Berlin. Thelen also was a graduate from the *Technische Hochschule Berlin-Charlottenburg*, and he was director of the German Albatros company.[8] This company was established in Berlin in 1910 to build airplane fuselages, which they equipped with

motors from diverse producers.[9] After the First World War, German airplane production was forbidden by the Versailles Treaty, and German airplane producers moved production abroad or reoriented. Then Bull had no German patents, but quickly he filed patent applications on his sorter and his tabulator.[10] The Hollerith company's German sorter patents had expired, but their automatic group control patent would remain valid until 1932.[11] This severely restricted the scope of a German production of Bull punched card machines, as only sorters could be built or marketed in Germany. Therefore, it was agreed that Albatros should build three sorters, produced 1923-1924. All were failures mainly because of low quality craftsmanship, but also due to deficiencies in the design, and this production was terminated. Albatros never build engines; they only produced fuselages.

During the years from 1924 to 1927 the American Powers company and the German Powers agency considered establishing a production of Bull machines in Germany or in the United States. The reason was the priority of the Powers and Hollerith automatic group control patents in the two counties. Both filed patent applications in the United States in 1914, first Hollerith and then Powers, both only issued in 1931.[12] Also in Germany, both patents were issued, Powers' in 1921 and Hollerith's in 1924,[13] but the Hollerith company contested the validity of Powers' patent in court. The dispute was only solved in 1929 by a supreme court ruling.[14] Therefore, for several years buying the Bull tabulator for the Powers agency could be a way to get around the Hollerith automatic group control patent. They had no basic interest in the electromechanical Bull machines as an alternative to their own mechanical punched card machines.

In 1925 Fredrik Rosing Bull died. He had no heir, and his estate wanted to capitalize his inventions. For two years they, in vain, pursued the German track. Then a Swiss option emerged, which originated within an extension of the Scandinavian insurance network. In 1922, an employee at the insurance company *Schweizerische Lebens Versicherung und Rentenanstalt* (Swiss Life) read about the first Bull machine in a Scandinavian insurance periodical. *Rentenanstalt* considered acquiring punched cards for making their statistics. In late 1925, they ordered a sorter and a tabulator, which were supplied in boxes the next year. The electrical engineer Knut Andreas Knutsen, who succeed Bull for technical support, travelled to Zürich and assembled the machines, which worked to the company's absolute satisfaction.[15] There was no patent problem in Switzerland, as IBM had no patents there.[16]

The satisfied *Rentenanstalt* director Emile Marchand promoted a contact to a Swiss-Belgian group of business machine producers and sellers, who in 1927 bought the rights from the Bull estate to produce and sell his machines. A Swiss production started at a mechanical adding machine factory in Zürich in 1928, but it ran into three problems: First, during the 1920s, the competitors machines had improved, which made the Bull sorter and tabulator obsolete. Second, it

proved difficult to produce well functioning punched card machines in Zürich. Third, though Switzerland had about the double population than Norway, they still had to rely on export to get a profitable production of punched card machines.

Solutions to the first two problems existed in Norway. Since Bull's death Knut Andreas Knutsen proved able to manage production of well functioning machines. In addition, an improved sorter had been constructed, and a new numerical printing tabulator designed (see below). Remaining was the need for a large home market.

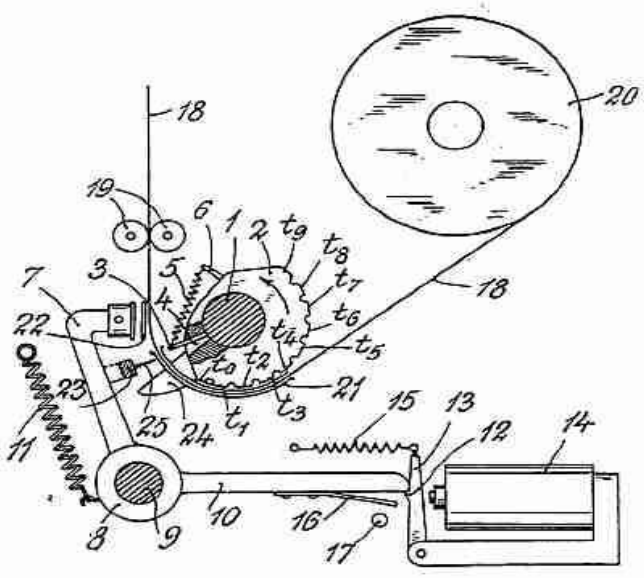
In 1930, the Swiss-Belgian group producing Bull machines in Zürich learned of the improved sorter and tabulator in Norway, which they wanted to produce as well. In order to improve the quality of the machines produced, they offered Knut Andreas Knutsen the position as technical director. The third problem was the home market size. The possibility of moving the production to France was raised. A member of the Swiss-Belgian group had a machine shop in Paris producing parts to mechanical adding machines, but the Hollerith company - from 1924 IBM - had several French patents, amongst them an automatic group control patent valid until 1933. But the French patent law required the patented device to be produced in the country within three years, and IBM only had a repair shop in France.[17]

In 1931, a French company was formed and the production was transferred to Paris, where Knut Andreas Knutsen became technical director. The new company took over the Belgian owned machine shop for production and in 1933 got the name *Compagnie des Machines Bull*. IBM tried, in vain, to contest the originality of the basic Bull patents in various French courts,[18] but these court cases did not delay the establishment of French punched card machine production.

The wish to earn money - to get a greater market and bigger production - was the basic incentive on the Bull machines' road from Oslo via Berlin and Zürich to Paris. But they were guided - or the road was shaped - by the patents in the various European countries and their patent laws.

Numeric Printing

For statistical applications, tabulators printing the outcome was a pleasure, not a necessity. The advantages of printing grew with the raising number of outputs. A numeric printing tabulator was introduced in 1907 in the United States as a major achievement by the Census Bureau's own tabulating machine production, and since 1914 the Powers company had a numeric printing tabulator as a cardinal marketing feature. The Hollerith company only got a printing tabulator in 1921, though the company's revenues grew each year from 1914-1920. The real importance of a



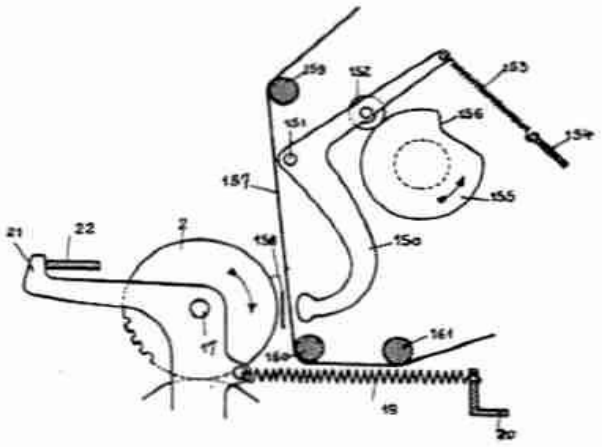
Fredrik Rosing Bull's wheel printing device for tabulators, 1924. 5 is the spring returning the wheel to the starting position for each processed punched card. t_0, t_1, ..., t_9 are the numeric types. Source: F. R. Bull, U.S. Patent, No.1,675,969 (1928, filed 1926).

printing tabulator only emerged with the rise of punched card based bookkeeping. In bookkeeping all entries are important, and generally speaking a written record of each entry is required. In addition, bookkeeping brought punched cards in tough competition with adding machines, which could print figures since the turn of the century. Printing became requisite.

The introduction of numeric printing only constituted an improvement of machine capability within the framework of Hollerith's numeric punched card standard from 1907, but Bull's and Knutsen's constructions offers an insights on patents shaping role.

In 1924, Bull started to construct a numeric printing tabulator, probably triggered by comments from Henrik Hartzner, who as general agent for the Bull machines in Denmark believed the lack of a printing tabulator was a competitive disadvantage. He was looking for bookkeeping application customers.[19] Two basic ideas appeared. First, Bull proposed to use printing wheels, one for each printing position. Then, Hartzner proposed to use type bars, but Bull declined this idea, as it would be an infringement of an existing patent form the Dalton adding machine company.[20] Thus, the printing wheels were introduced to circumvent existing printing patents. For each card Bull's printing wheels were turned to the designated position, all digits were printed simultaneously, and then the printing wheels returned to a starting position by use of springs. This was a simple construction, but it only functioned as long as the springs functioned, and returning the wheels to the starting position used time.

Knut Andreas Knutsen only took up the construction of a printing tabulator in early 1929, based on Bull's construction. Knutsen invented an improved design of a numerical printing mechanism for the tabulator and filed a patent application in the Summer of 1930.[21] His printing wheels turned all the time in the same direction and a hammer struck, when the designated digit was in the right position. This was a brilliant construction which enabled a high processing speed, and later proved a good basis to the construction of an alphanumeric system. The disadvantage was



Knut Andreas Knutsen's wheel printing device for tabulators, 1930. 2 is the type wheel turning all the time in the same direction. 150 is the hammer striking the wheel, when the designated digit is in the right position. Source: K. A. Knutsen, Norsk Patent, No.53,545 (1934, filed 1930).

high requirements to maintenance; else the printing line grew wavy, and it became difficult to discern which digits constituted a figure. The technicians learned their job, and wheel printing became a major success.

Thus patents guided once more. This time they made Bull and Knutsen choose wheels instead of bars for printing.

Exclusive Alphanumeric Standards

The need for alphanumeric punch card printing and the resulting requirement for an alphanumeric hole representation resulted from bookkeeping. Within bookkeeping alphanumeric printing was particulary crucial in billing. When you wrote a bill, it was highly desirous in the same operation to write the recipient's name and address. Another need was to be able to specify entries by using not just numbers, but letters as well. By 1930, both numerical and alphabetical information could be put on a bill by use of a billing machine, a combined typewriter and calculating machine; but billing machines were slow to use, as the operator had to type the full name and address on each bill. Alternatively, when a bill was written by use of a numerical system, a bookkeeping machine or a punched card system, specification, name, and address could be added in several ways. It could be handwritten or typed. It could be added by use of an addressing system, which consisted of an address plate for each recipient and a machine to print the information on the address plates. Address plates were made of zinc in which the recipient's name and address were stamped, but they held several disadvantages. The zinc addressing plates were heavy to handle, selection of the plates to be used was elaborate, and correcting an address was detailed. The main disadvantage was that billing was performed in two separate operations. First, the amounts were written on one machine. Then, the bill was taken to an addressing machine.

Using punched cards for the full billing process was tempting. The idea was first proposed by the punched card inventor, John Royden Peirce, in 1913, but he never completed a functioning punched card machine that performed this. In 1921, the British Powers company introduced the first functioning punched card based alphabet printing system, and in 1931 IBM followed.

Little is known of the Bull company's reasons in 1931 to start developing an alphabetical capability. Plans to introduce punched cards for insurance policy administration could be a reason,[22] another could be arguments on new customer groups from the Swiss-Belgian office machine group. Alphanumeric systems opened new large application fields. A prime example is the punched card mobilization register developed from 1940 to 1944 by René Carmille within the Vichy government.[23]

A precondition to print letters from punched-cards was to have a punch code for letters which the machines were able to read. This required a decisive expansion of the existing numerical standard. Powers introduced their own exclusive standard, which they patented. IBM followed suit.

At a first glance, all letter systems were similar, as they were based on the representation of each letter by a combination of two or three holes in the same column. Two holes in a column enabled 78 combinations and made use of 1.9% of all possible combinations. Three holes enabled 298 combinations and made use of 7.3% of all combinations. But the stumbling block was the machines' ability to distinguish different hole combinations. For punched card machines, no producer ever exceeded about 40 characters, of which 10 were reserved for digits. Though the systems could look similar, no producer supplied a punched card machine that could translate from one alphanumeric system to another.[24] This tied the costumer to his producer. If he changed producer, he would have manually to repunch all his punched cards. And he could have millions of punched cards.

The problems of implementing alphanumeric systems were so great, that all producers first introduced a letter printing system incompatible with the numeric system used so far. This meant that punching a house's number in a street was different from punching the number of Francs to be payed, which complicated the key punch operators' work. Knut Andreas Knutsen's development of an alphanumeric system from 1931 to 1934 exemplifies this. He first devised a system for printing letters and figures, that required different representation of figures for printing with letters and figures for calculations.[25] In 1934, this was developed to an alphanumeric system which allowed the same letter representation to be used for both purposes.[26]

The Knutsen alphabetic and alphanumeric printing systems were based on his printing wheels. The numerical printing wheels were small, as they contained only 11 characters (10 digits and a minus indicating a negative number or credit). The alphabetic and alphanumeric wheels were

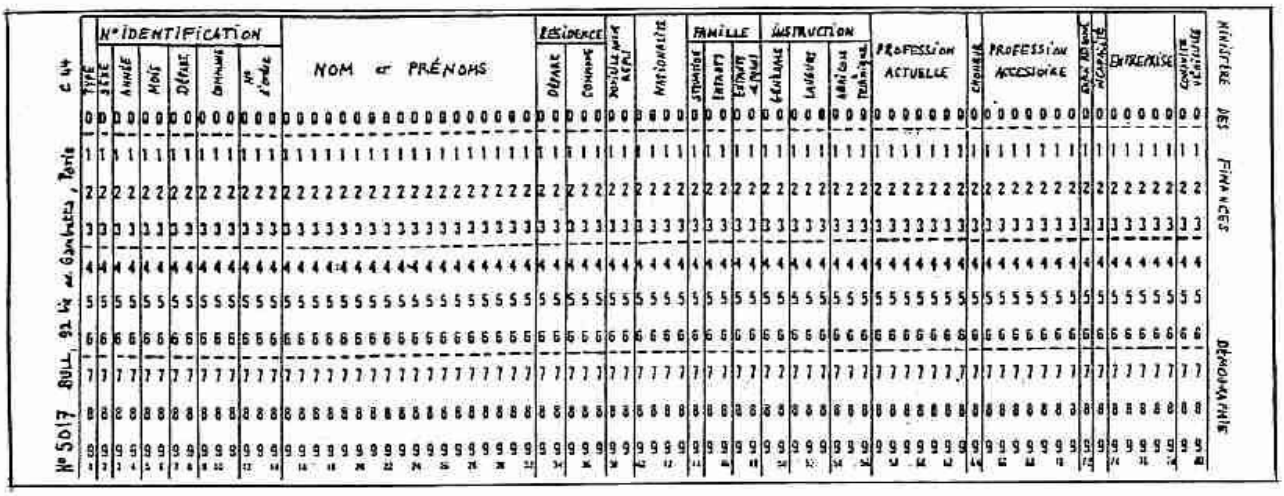
larger, as they contained 35 characters (10 digits, 24 letters, and a minus). Using printing wheels, the writing mechanism came into the writing position with a very small movement, during which all the printing wheels were turned into the right position. Then the printing wheels were struck against the paper. This only used a fraction of a machine cycle, compared to three in the IBM tabulators, which used type bars to be raised to the relevant printing position and then resat. The outcome was a much higher printing speed in the Bull machines.

In fact, the IBM research department in New York developed on wheel printing as well, but their work was discontinued due to the Knutsen patents.[27] Eventually, in 1949, IBM marketed a wheel printing tabulator. The printing mechanism was identical to the Bull tabulator, but by that time the Knutsen patents had expired.[28]

The introduction of alphabetical printing enabled a significant extension of punched card application fields, but the previous universal punched card standard perished. The low number of industry members and their geographic dispersion were probably major reasons that a new universal standard did not emerge.[29] One consequence of the exclusive standards was that the user became closer tied to his supplier. In addition, after the Second World War this lack of common standard became a prejudice in the emerging computer industry against establishing industry standards.

The 80 Column Card

Alphanumeric punched card systems opened new application fields, but the storing capability on a 45 column card was a severe limitation. In most cases it was impossible to hold even an identification number, a full name, and a full address on one 45 column card, a problem that deteriorated if the card also held some information to be mailed. This problems could be solved either by putting more columns on a card or by dividing the information on several cards. Using more than one card required control to ensure that the all information on a bill related to the same recipient. The users always preferred to use as few cards as possible. To ease the the 45 column card's limitations, in 1928, IBM introduced an exclusive and patented 80 column card with rectangular holes instead of the round holes used so far.[30] This exclusive standard enabled a continuation of the existing punching system, and the rectangular holes were well suited to IBM's electrical brush reading of cards. Even, the 80 column card machines could be adjusted to run 45 column cards, which offered the customers a smooth transition. The rectangular hole was no advantage to the Powers companies, who used mechanical pin-reading. They developed their own standards, one in the United States, and another in Great Britain. In 1932, the American Powers company (Reming-



The lay-out of the 80 column Bull punched card used for the mobilization register in Vichy-France 1940-1944. Source: R. Ligonnière, *Préhistoire et histoire des ordinateurs*, Paris 1987, p.181.

ton Rand) started to use the old 45 column card as a 90 column card. This was achieved by use of a new hole code based on 6 rows or positions, which enabled each of the old columns to be used twice. The British Powers company chose to squeeze 35 additional columns with 12 position onto the card, which they only achieved in 1954. Whereas the British hole code remained unaffected by the growing number of columns, the American Powers company introduced a completely new hole code.

In the mid 1930s Bull needed an increased punched card to compete with IBM on the market of punched card applications, that required information of more than 45 characters per unit, like insurance policy administration. Bull had three possibilities: they could choose a longer punched card; they could choose a more compact punched card code as did the American Powers company; they could squeeze more columns on the existing card as did IBM. A longer punched card, for example twice as long as the existing to get 90 columns, would be awkward to handle and require bigger and more expensive machines. A more compact punched card code would require total redesign of Bull's alphanumeric machines, only introduced in 1934. Squeezing more columns on the existing card would require the adoption of oblong holes, patented by IBM. Therefore, it made no difference, whether they chose 70, 80 or 90 columns. In 1938, Bull introduced the same 80 column card, as IBM marketed. The 80 column card added to the Bull system's capability, and for example enabled the punched card based mobilization system in Vichy-France 1940-1944. But IBM considered it an infringement of their patent and filed a patent infringement case, which Bull lost in 1941. In 1947, Bull took this judgment to the *Cour d'Appel*, as they had learned, that IBM's American patent had been judged null and void. The reason was, that the company used its

invention before a patent was filed.[31] Only new inventions were patentable. Now, the 80 column card was no longer exclusive.

After the Second World War the 80 column card approached universality, as computer input and output tool. It even found its way into the computer development at the successor companies to the American and British Powers companies.

This story reminds that of the IBM PC. Soon after its introduction in 1981, it became a standard, which IBM in the long run proved unable to control. The current anti-trust case against Microsoft in the United States originates from a similar position. Through DOS and Windows Microsoft gained a position of nearly total control of the market of PC operating systems. This position is based on intellectual property right, having longer duration than patents, but this does not imply that Microsoft will prove able to keep their monopoly for the duration of the intellectual property rights on the existing software products. IBM no longer market 80 column punched cards, and they no longer control the PC market.

The Importance of Patents and Standards

This paper demonstrated how patents provided frames for the development of the Bull punched card systems. Punched card patents and national patent laws guided this production from Oslo via Berlin and Zürich to Paris. Patents shaped the Bull-Knutsen construction of a wheel printing tabulator by baring the alternative bar printing approach. The French IBM 80 column card patent disclosed this exclusive standard, which Bull introduced, though they knew this required a licence. It only became a free standard in 1947, as a French court judged the patent null and void. Thus the 80 column card patent demonstrates another aspect of the patent system: The patents were printed and became an important source to the competitors' ideas and constructions, and they were used to locate independent inventors of interest.

This paper also analyzed the crucial transition of the punched card systems from the numeric 45 column universal standard punched card from 1907 to alphanumeric standards with extended punched cards. The industry failed to establish a universal alphanumeric standard, probably due to the low number of industry members and their geographic dispersion. Eventually, the 80 column punched card, marketed by IBM in 1928, emerged as the successor standard to the 45 column card.

But how important were these shifts of standards, for example compared to the introduction of the IBM System 360 in 1964? Both transitions involved a transformation of data standard, and of programs. The shift in data format in the Interwar Years included the introduction of letter

representation and new lager records. In 1964, the news was small letters in addition to the capital letter from the previous shift. The Interwar Years shift was fundamental, while the 1964 shift just enlarged the scope of letter printing. In both cases most programs had to be rewritten. Punched card machine programs were represented either as pin boxes or as pugboard wirings, which totally had to be changed. In the 1960s, computer programs were composed of lines of characters, which had to be corrected or rewritten for the new computers. In 1964, program changes was the main problem to the users.[32]

Probably the major difference between the two changes was their introduction. The transition from numeric to alphanumeric representation and the extension of the 45 column card happened little by little and lasted several years. The IBM System 360 was introduced with great fanfare in presence of the press. In the Interwar Years, IBM innovated their systems little by little as did simultaneously the competitors. In 1964, the suddenness, the technological force, and the effective publicity of the introduction of the IBM System 360 compelled the rest of the industry to react.

References:

1. Hollerith's original basic patents covered the process of producing statistics by use of punched strips or punched cards and mechanical or electro mechanical counting of the various hole combinations. (H. Hollerith, "Art of Compiling Statistics", *U.S. Patent*, No.395.781 (1889) and "Art of Compiling Statistics", *U.S. Patent*, No.395.782 (1889)). Storing information as holes on strips or cards was not patentable as it was known from the Jacquard loom and the telegraph transmitters. Hollerith's 45 column card did not differentiate sufficiently from his previous cards to be patentable.

2. L . Heide, "Shaping a Technology: American Punched Card Systems 1880-1914", *IEEE Annals of the History of Computing*, vol.19 (1997), p.28-41.

3. K. Lyche to R. Knutsen, 10 June 1949; interview with K. A. Knutsen, January 1973 (Bull Interview No. 8), both in Bull Archives, Paris.

4. L. Heide, *Hulkort og EDB i Danmark 1911-1971*, Århus: Systime, 1996. p.36.

5. A Bull punch was only supplied in 1926. L. Heide, "From Invention To Production: The Development of Punched-Card Machines by F. R. Bull and K. A. Knutsen, 1918-1930", *Annals of the History of Computing*, Vol.13 (1991), p.268.

6. H. Hollerith, "Automatic Group Control for Tabulating Machines", *U.S. Patent*, No.1,830,699 (1931).

7. This reason is only mentioned in a letter from F. R. Bull to H. Hartzner, 7 June 1924, that is after the conclusion of the Albatros contract.

8. K. A. Knutsen interviewed by D. Pagel, typescripts, 1978, p.4.

9. *All the World's Aircrafts*, 1926, p.167b-170b.

10. H. Hartzner to F. R. Bull, 4 January 1923; F. R. Bull to H. Hartzner, 14 November 1923.

11. H. Hollerith, German Patent, No.406.744 (1924, valid from 1914). Patents were valid 18 years in Germany. (*Das Reichspatentamt 1877-1927*, Berlin 1927, p.8)

12. Hollerith (1931); J. Powers, "Self starting automatic total taking mechanism", *U.S. Patent*, No. 1,836,039 (1931).

13. J. Powers, German Patent, No.333.413 (1921); H. Hollerith, German Patent, No.406,744 (1924).

14. Knutsen (1978), p.4.

15. R. Knutsen, *Oversigt*, typescript, 1927, p.7, in Bull Archives; Knutsen (1978), p.32, 37-48.

16. Knutsen (1978), p.43.

17. Knutsen (1978), p.84-85.

18. J. Vernay, *Chroniques de la Compagnie IBM France*, Paris: IBM France, 1988, p.24; D. Pagel, K. A. Knutsen biography, typescript 1976, in Bull Archives, Paris.

19. Hartzner Diaries, May-June 1924.

20. F. R. Bull to H. Hartzner, 27 August 1924; H. Hartzner, "Forslag til Skriveapparat til Bulls Maskine", 25 November 1924 (Date from Hartzner Diaries, 25 November 1924); F. R. Bull to H. Hartzner, 27 November 1924 (2), all in correspondence between H. Hartzner and F. R. Bull, 1921-1925; F. R. Bull, "Automatic printing machine", *U.S. Patent*, No.1,675,969 (1928, filed 1926).

21. K. A. Knutsen, "Trykkeværk, særlig i forbindelse med tabelleringsmaskin for gjennemhullede registerkort," *Norsk Patent*, No.53,545 (1934, filed 1930);
K. A. Knutsen, "Printing device for tabulating", *U.S. Patent*, No.1,969,082 (1934).

22. Indicated in Hartzner Diaries, 1 February 1931.

23. R. Carmille, *La mécanographie dans les administration*, Paris: Sirey, 1942; R. Ligonnière, "Petite histoire des statistique", Part 4, "Mécanographie et banques de données, le régne de R. Carmille", *Ordinateurs*, part 4: 25 November 1985, p.44-46, 48.

24. Such a machine could have been build. One possible construction was a machine that read the cards one column at a time, that is from one en of a card to the other, instead of the usual reading from bottom to top (or from top to bottom). Translating one column or character at a time was feasible.

25. K. A. Knutsen, "Printing device for statistical, calculating, and tabulating machines", *U.S. Patent*, No. 2,046,464 (1936, filed 1933).

26. K. A. Knutsen, "Printing device, particularly for tabulating machines controlled by record cards or bands", *U.S. Patent*, No. 2,175,530 (1939, filed 1936).

27. W. W. McDowell to F. M. Carroll, 10 July 1936, In IBM Archives, box: A-22-3 (Endicott Engineering).

28. *IBM's Early Computers*, by C. J. Bashe, L. R. Johnson, J. H. Palmer, and E. W. Pugh, Press, Cambridge, MA: MIT Press, 1986, p.481-482.

29. M. J. Enright in a recent study offered three examples of coordination in three geographically concentrated industries, M. J. Enright, "Organization and Coordination in Geographically Concentrated Industries", in N. R. Lamoreaux and D. M. G. Raff (eds.), *Coordination and Information. Historical Perspectives on the Organization of Enterprises*, Chicago: University of Chicago Press, 1995, p.103-146.

30. C. D. Lake, "Record Sheet for Tabulating Machines", *U.S. Patent*, No.1,772,492 (1930, filed 1928), which equates his French Patent, No. 677,427. Only the oblong or rectangular holes were patented. Using rectangular holes was a way to enable electrical card reading and at the same time avoid weakening a card, which contained more perforations than a similar card having similarly arranged and spaced circular perforations.

31. Cour d'Appel de Paris, Greffe Civil, No. H-1440 (23 April 1947), in Archives de Paris.

32. IBM supplied "emulators" which enabled the new computers to run programs from old computers, though slowly.