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# FACILITATING A CHALLENGER

## Industry Standards in the Development of the Bull-Knutsen Punched Card System 1919 – 1931

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*This paper argues that industry standards played a crucial role in the history of the Bull punched card system in Norway in the 1920s, which would become a challenger of IBM's monopoly after its development was moved to France in 1930. While a variety of national patents were of course also important determinants of business opportunities for Bull in the Inter-War Years, the foundation for the confrontation with IBM was laid by adherence to available technical standards.*

In the autumn of 1930, Norwegian Engineer Knut Andreas Knutsen was offered a position as chief engineer at the H.W. Egli factory in Zürich. His task would be to improve production of a punched card system that the Egli Company had acquired the rights to in 1927. Knutsen accepted the offer on the condition that production was relocated to France, gambling on an opportunity he saw in this important European market. French patent law required the patented device to be produced in France within two years of the filing of the patent application[1] and this clause had rendered a key IBM patent void already in 1920. In the absence of hostile patents, France was now largest home market available to new developers of punched card systems. I have dealt with the crucial legal battles about these patents elsewhere[2]; suffice it to say that Knutsen's intuition was vindicated and this relocation became an essential component in attaining the success of Compagnies de machines Bull,

[1] Loi du 5-8 juillet 1844, sur les brevets d'invention. This law was valid until 1959, Chavanne, and Burst, *Droit de la propriété industrielle*, 25-26.

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predecessor to today's French computer producer Groupe Bull. In this paper, I want to turn my attention to the period leading up to Knutzen's decision to move production to France.

Patents and standards were both essential elements in shaping business in the international punched card industry, simultaneously facilitating all producers' business by limiting challenging companies' opportunities in several countries of Europe. Interestingly, however, patents and standards are not a key element in the publications on history of the information technology industry.[3] Indeed, the punched card systems of the later nineteenth and early twentieth centuries can be seen as harbingers of the more recent legal and technical battles on the personal computer markets. Here the tension between technical standards, which can be freely adhered to, and patents, which of course determine the rights of producers to market technologies, has become decisive. Bull developed his punched card technology in an area of the world where he faced few patent restrictions, but he did not proceed in a technological vacuum. I will argue that this early stage in the development of a competitive punched card system had more to do with standards than with patents. After all, the importance of patent issues depends on the existence of a similar product. And Fredrik Rosing Bull, the originator of this punched card system, had indeed taken great pains to develop his system so as to render it as compatible and competitive with existing punched card technologies as legally possible. Although he was largely free to do as he chose, Bull always had an eye on the industry leader, the Tabulating Machine Company, which would later come to be known as IBM. It was only on the background of this development process that Knutzen's gamble made sense and it is the story of that process that I want to tell here. The case of the Bull punched card seems to be an early case of an 'IBM compatible' system, with all its attendant legal and technical difficulties.

**The punched card industry**

Engineer Herman Hollerith built the first punched card system to process the United States' census in 1890. Punched card systems were based on the storing of information as combinations of perforations on single cards, to be machine-processed by several stand-alone machines, of which the most important were punches, sorters and tabulators. Each job required the punched cards to be processed on an established succession of the different machines. For example, one card was needed for each individual in a census. The cards were

[2] Heide, *From Detail to Data*, forthcoming.
[3] For example, Campbell-Kelly, *ICL;* Cortada, *Before the Computer;* Yates, *Structuring the Information Age*.

punched on a key punch, and an operator sorted them into a specific succession for the subsequent tabulation on a tabulator. This was a combined calculating machine and printer that could perform the additions (and for advanced versions subtractions) needed in each case to reach the total amount and print the outcome. The success of Hollerith's processing of the 1890 census in the United States enabled him to incorporate his activities as the Tabulating Machine Company. In the years up to 1907, he improved the initial punched card system into a general statistics processing-tool that found widespread success in the processing of operational statistics for business. The 45 column card was its most conspicuous characteristic.

Back in 1889, Hollerith had attained patent protection of his original punched card system that expired in 1906. Patent protection in the United States at the time started when a patent application was filed and expired 17 years after the patent was granted.[4] He also obtained several patents on subsequent improvements, including a sorting function that proved difficult for challengers to avoid infringing in the 1910s.[5] The 45 column card itself, however, did not differentiate sufficiently from previous cards to be patentable.

As big American companies grew in size and hierarchical organisations were established, monitoring their internal business became essential to secure advantages of scale. Statistics about operations within a big company, such as cost-accounting, for example, was a key to achieve this.[6] In the processing of operating statistics by use of punched cards, each record was entered onto a separate punched card to be machine-processed. This made it much easier to verify a set of outcomes than by manual means. The machines applied repeated processing of the same punched cards, which also facilitated the production of other statistics on the same information once it had been punched. The proliferation of punched-card-based statistics production brought soaring revenues to Hollerith's company. In 1911, he reaped the benefits of his success by selling his company to investors who turned it into a conglomerate. In 1924, this conglomerate was named the International Business Machines Corporation (IBM). The growth of the punched card trade in the early 1910s, however, also stimulated the emergence of the Powers Accounting Company in the United States, which challenged the Tabulating Machine Company's first mover position.

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An exception is Heide, *From Detail to Data* which complements the analysis in this paper.

[4] U.S. Patent Act of 8 July 1870, 16 Statutes at Large, 198, section 32.

[5] Herman Hollerith, "Art of Compiling Statistics", [US] *Patent*, No 395.781 (1889, filed 1887), "Art of Compiling Statistics", [US] *Patent*, No 395.782 (1889, filed 1887) and "Tabulating apparatus", [US] *Patent*, No 685,608 (1901, filed 1901); Heide, *From Detail to Data.*

[6] Yates, *Control through Communication*; Johnson, and Kaplan, *Relevance Lost*, 19-46.

## Patents and standards in business

Patents and standards provided frames for business, but they were negotiated in very different settings. Patents were based on national legislation and litigation and their basic national objective was to encourage innovation. An inventor or his company filed a petition and gained a monopoly for a number of years on the condition that the patent was published and became public domain at its expiration.

In contrast, technical standards like the design of a punched card was decided either by the producer or the industry in order to facilitate the interchangeability of machines and cards, essential in any punched card installation. Strictly observed standards of punched card size and location of perforations were essential to facilitate the processing of a large number of cards on several individual machines. As Hollerith improved his original system for general statistics processing, he redesigned his punched card and settled on the standard of the 45-column card in 1907. Once established, the standard gained momentum. It was essential for the design of a large number of machines and a new standard should provide substantial business advantages to justify the costs of producing and marketing new equipment.

When James Powers emerged in the United States as the first challenger to the Tabulating Machine Company's monopoly, he accepted Hollerith's punched card standard (which cost him nothing) and made it an industry standard. Similarly, Fredrik Rosing Bull accepted this industry standard at the outset, and he and his successors' copied machine facilities that they found essential to meet the industry's standards, i.e., those of IBM and the Powers company.

## Fredrik Rosing Bull's Statistical Machines

In Norway, the *Storebrand* insurance company had been established in 1847 in Kristiania (renamed Oslo in 1925; "Storebrand" means Great Fire in Norwegian). In 1918, this company discussed improving its statistics production by introducing punched cards. For this end, an individual from Storebrand studied statistics production at the Svea insurance company in Gothenburg, Sweden, which used punched card equipment from the Tabulating Machine Company.[7] The Norwegian national statistics (*Statistisk Centralbureau*) had

[7] Letter, Kai Lyche, to Reidar Knutsen, 10 June 1949 [SIC!], Archives Bull, Paris, 92HIST-DGE07, folder: F. R. Bull.

established early punched card installations in 1894. However, by 1918 no up-to-date punched card installation existed in Norway, and IBM and Powers did not establish operations in Norway until the 1920s.[8]

Engineer Fredrik Rosing Bull of Storebrand read the report describing the punched card installations at the Svea insurance company in Gothenburg. This motivated him to find that the Hollerith machines were too expensive, and he suggested that he should build such machines.[9] This offer gave Storebrand an alternative to leasing equipment from the Tabulating Machine Company and it chose Bull's proposal.[10]

Bull was trained as a constructional engineer at *Kristiania tekniske Skole* (the Technical School of Kristiania) and he graduated in 1907.[11] Subsequently, he was in construction and insurance jobs, and Storebrand hired him to inspect factories in 1916.[12] He would resign in 1922 and start his own insurance company. While insurance work remained his main occupation, he always worked on technical designs, made several inventions, and received two patents outside the field of punched cards.[13]

Back at the start of Bull's punched card endeavour in 1919, he needed to chose standards but did not encounter problems with granted patents. He made three basic decisions based upon established standards. First, he selected Hollerith's 45 column numeric punched card instead of designing a new, proprietary card. The choice was not surprising, as Bull's knowledge of punched card systems was based upon a Tabulating Machine Company installation. The choice of Hollerith's established standard enabled his customers to install machines from several suppliers. For example, in the 1920s this was the case at two installations in neighbouring Denmark.[14] If Bull had rejected this standard, he would have had to supply a full set of machines for statistics processing from the outset. This would provide a high threshold that might have ended his punched card story, as he did not produce a working punch machine until 1926. Second, Bull also adopted the Tabulating Machine Company's dynamic, electrical brush-reading of cards.[15] Third, his machines also applied

[8] Nerheim, and Nordvik, *'Ikke bare maskiner'*, 26-27.
[9] Letter from Kai Lyche, Storebrand, to Reidar Knutsen, 10 June 1949.
[10] The British Powers company appears not to have been known in Norway by this time.
[11] Bassøe, *Ingeniørmatrikkelen*, 71.
[12] Bull's personnel file at Storebrand, Archives Bull, Paris, 92HIST-DGE07, folder: F. R. Bull.
[13] Fredrik Rosing Bull, "Automat for Spareur," *Norsk Patent*, No 28,732, (1918, filed 1917); A. T. Bull and Fredrik Rosing Bull, "Anordning ved Automobiler eller andre kjøretøier for at tilkjendegi til hvilken side kjøretøiet skal svinge," *Norsk Patent*, No 33,428, (1921, filed 1921); Bull, *Den trønderske slekt*, 145-146.
[14] Heide, *Hulkort og EDB*, 36.
[15] Herman Hollerith, "Registering Apparatus", [US] *Patent*, No 777,209 (filed 1903, issued 1904); Herman Hollerith, "Apparatus for Use in Tabulating Systems", [US] *Patent, Reissue*, No 12,523 (1906).

visual reading of results, as the tabulators from the Tabulating Machine Company did until 1921. In contrast James Powers from the outset chose to design and build machines that printed results.

No Norwegian punched card patent existed to bar Bull from building punched card machines.[16] The Tabulating Machine Company filed its first Norwegian application in 1919.[17] This eased his initial attempts to build punched card machines, but Norway's small population (2.5 million) also hampered his punched card machine production. The Norwegian market for punched cards for statistics processing was in fact further limited because it was predominantly an agricultural nation and had few industrial concerns of a size calling for extensive production of operating statistics.[18]

To reduce the purchase price, Bull's first punched card machine was a combined sorter and adding tabulator. Compared to the machines from the Tabulating Machine Company and the Powers company, his original design was unique and he was granted a patent.[19] Bull's machine had a selector with ten or twelve rows of buttons. Each row had one button for each punching position. For example, if you turned button 7 in column 1 and button 3 in column 2, the machine would only beat cards having 7 punched in column 1, and 3 punched in column 2. All the other cards would be ignored. If one had to make a statistical statement of a certain occupation, say, characterized by 73, the machine could, for example, sum the incomes of that occupation, ignoring all other cards. And when the cards had passed they were still in order. In comparison, to sum the income of occupation number 73 in a Hollerith or a Powers installation, one first had to sort all cards having 73 in the said field on a sorter. Then the cards were moved to a tabulator in order to sum the incomes. Finally, they were taken back to the sorter in order to sort them back in order. Which column the sorter and counter facilities should apply to was decided by wiring a plug-board, a technique Hollerith had used since 1895. Bull's strategy, then, was based upon adherence to technical standards established by the industry's first movers combined with two competitive advantages: the selector and a low price.

However, it proved difficult to convert Bull's ideas into reliable machines. Bull was

[16] Annual lists of patents granted in Norway.
[17] The first Norwegian punched card patent: "En tællemekanisme for tabelleringsmaskiner", filed by the Tabulating Machne Company, *Norsk Patent*, No 33,168 (1921, filed 1919).
[18] Statistics for 1918 in *Annuaire statistique de la Norvège, 1920* (Kristiania: Aschehoug, 1921), 56-62.
[19] Fredrik Rosing Bull, "Automatisk registreringsmaskin for statistiske og lignede øiemed," *Norsk Patent*, No 34,630 (1924, filed 1919), letter, Henrik Hartzner to OKA, 19 June 1923, Archives Bull, 92HIST-DGE07, box 2. The punched-card example in *Norsk Patent*, No 34,630.

trained as a construction engineer and he had no mechanical and electrical training. He designed the machines, which were built at *Kristian Ormestad Aktieselskap* (Ormestad Limited), a precision engineering shop in Kristiania. This work provided no profit to Ormestad, who joined the project with an assumption of getting additional orders.[20]

Bull started to build his first punched card machines in 1919, but it was not delivered to Storebrand before 1921. Further, the machines had serious operating problems, forcing Bull, and later Engineer Knut Andreas Knutsen, to travel around to the customers to repair and develop modifications. These travels expanded as Bull won customers in Denmark (1922) and Finland (1924) and the last mechanical problem was not solved before 1927.[21]

In 1921, Bull consolidated his business through a contract with the company *Aktieselskap OKA*[22] (OKA limited) of Kristiania financing development, production and marketing of his machines in Norway, Denmark, Finland and Sweden. OKA was a small company that sold Dutch diesel motors for Norwegian fishing boats and consulting engineering services. It was headed by Bull's schoolmate, Mechanical Engineer Reidar Knutsen.[23] Bull's delivery of his original punched card machine to Storebrand in 1921 triggered several Norwegian news articles. Henrik Hartzner read one. He was insurance clerk and managed the statistical office at the Danish life insurance company Hafnia in Copenhagen.[24] By then, Hafnia had leased punched card machines from the Tabulating Machine Company, but the management was dissatisfied with this arrangement. The Tabulating Machine Company exclusively leased machines out while Hafnia demanded buying. Hafnia therefore ordered a combined tabulator and sorter machine from Bull, which was delivered in 1922. However, even this machine did not work efficiently and Hartzner proposed to divide it into two separate machines, a sorter and a tabulator, which Hafnia received in 1923. Subsequently, Bull built only separate sorters and tabulators.

While Bull was striving to produce reliable statistics production machines, the Tabulating Machine Company in the United States changed standards for tabulator facilities by introducing automatic group control and number printing on a new tabulator in 1921.

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[20] Letter, Kr. Ormestad to Dir. Diesen(?), 23 July 1925, Archives Bull, 92HIST-DG07, box 1, folder: F. R. Bull - Kr. Ormestad.
[21] Correspondence between H. Hartzner and F. R. Bull, 1921-1925, Archives Bull, 92HIST-DGE07, box 2; Hartzner Diaries, 1921-1927; Reidar Knutsen, *Oversigt*, typescript, 1927, Archives Bull, 92HIST-DGE07, box 1.
[22] Originally *Otto Kahrs Kommanditistselskap*.
[23] Dominique Pagel, Interview with K. A. Knutsen, 1978, Archives Bull, 92HIST-DGE07, box 3.
[24] Thorgny Haaness, "Maskiner for statistik etc.", *Aftenposten*, 19 November 1921; *Forsikringstidende*, 1921, 317; Hartzner Diaries, 7 November 1921.

Automatic group control was based on two successive readings of every card and significantly eased the processing of punched cards. The Tabulating Machine Company had filed a petition for this facility in 1914 in the United States, but the patent was only granted in 1931 making it valid until 1948.[25]

Bull was in an excellent technical position to answer the challenge of automatic group control, as his tabulators held two readings, one for the selector and the other for the adding units. Henrik Hartzner in Copenhagen, who had been appointed general agent for the Bull machines in Denmark, proposed to use the two readings as a basis for automatic group control. This started a common development process that produced a reliable design in 1923.[26] This group control design was implemented and Bull once more followed the standards established by the industry leader. However, this technical facility was not free due to the Tabulating Machine Company's patents in several countries, as Bull's original design was subsequent to Herman Hollerith's automatic group control petition in 1914. Therefore, while the absence of patents in the Nordic countries gave Bull free reign, Continental and British patents restricted exports.

Bull also engaged in answering the challenge of the number printing tabulator, and he started designing a printing tabulator in 1924, possibly based on a suggestion from Hartzner. He believed that the lack of a printing tabulator was a competitive disadvantage.[27] Two basic designs were considered. First, Bull proposed to use printing wheels, one for each printing position.[28] Then Hartzner proposed to use type bars, but Bull declined this idea, as it would be an infringement of a patent from the Dalton adding machine producer.[29] This shows that Bull was aware of the restrictions posed by patents and avoided them. While he originally had acted in a patent vacuum in his field, patents started to limit his prospects as the Tabulating Machine Company started to file patents and as Bull started to work on facilities developed in neighbouring industries. Bull nonetheless managed to design a number printing

[25] Herman Hollerith, "Automatic control for tabulating machines", [US] *Patent*, No 1,830,699 (1931).
[26] Henrik Hartzner, "Report", 21 November 1921; letters, Bull to Hartzner, n.d. (November) 1921, 15 December 1921, 17 October 1922, 17 March 1923, 8 October 1923; Hartzner to Bull, 30 September 1923; concepts of two letters from Hartzner to K. A. Knutsen, October-November, 1927, Archives Bull, 92HIST-DGE07, box 2, folder: Correspondance between Hartzner and Bull; Hartzner Diaries, 22 March 1923, 22 November 1927, 5-8 March 1933.
[27] Hartzner Diaries, 3 June 1924.
[28] Letter, Bull to Hartzner, 27 August 1924.
[29] Henrik Hartzner, "Forslag til Skriveapparat til Bulls Maskine", n.d. (25 November 1924, date from Hartzner Diaries, 25 November 1924); letter, Bull to Hartzner, 27 November 1924; Fredrik Rosing Bull, "Automatic printing machine", [US] *Patent*, No 1,675,969 (1928, filed 1926). Dalton did not have any Norwegian patent.

unit in early 1925, though it was not implemented.[30]

**Attempts to establish Bull machine production abroad**

Back in 1922 Bull was approached by Robert Thelen, who was director of the Albatros company in Berlin and wanted to produce punched card machines. The Albatros company had been established in Berlin in 1910 and built aeroplane fuselages, which they equipped with motors from diverse producers. After the First World War, German aircraft production was forbidden by the Versailles Treaty and German producers moved production abroad or reoriented. Thelen's initiative was not a coincidence, as it passed through the director of OKA, Reidar Knutsen. Both he and Robert Thelen were graduates from the Technical University of Berlin (*Technische Hochschule Berlin*) and Thelen was married to Reidar Knutsen's sister.[31]

Two years later, Fredrik Rosing Bull explained a similar agreement with reference to his aspiration for an industrial scale production.[32] Indeed, greater scale could yield more revenues, his machines needed innovation to operate more efficiently, and his production in Norway never became profitable. Only Sweden among the Nordic countries had an industrial scale production of office machines, but all of them held the technical capability needed for an industrial production of punched card machines, as they all had works producing telephone equipment, in addition to many precision engineering shops. Therefore, it is noteworthy that neither Bull nor his successors appear to have considered this possibility. The reason was no doubt the lack of demand.

Thelen's approach brought Bull into the realm of the Tabulating Machine Company's patents, but he had already considered the German market and had filed a German patent application on his punched card machine in 1921.[33] The Tabulating Machine Company's sorter patents in Germany had expired, but their automatic group control patent would remain valid until 1932.[34] Therefore, Bull's sorter could be built and marketed in Germany while a

[30] Letters, R. Bull to Hartzner, 27 August 1924, 27 November 1924 (1), n.d. (probably March 1925), Archives Bull.
[31] *All the World's Aircrafts*, 1926, p.167b-170b; Bassøe, *Ingeniørmatrikkelen*, 282; Pagel, interview with K. A. Knutsen 1978. The archives of the Technische Hochschule Berlin were destroyed during the Second World War. Letter, TU Berlin to Lars Heide, 18 March 1998.
[32] Letter, F. R. Bull to H. Hartzner, 7 June 1924.
[33] Fredrik Rosing Bull, "Selbständige Registriermachine für statistische Zwecke", [German] *Patentschrift*, No 398,634 (1924, filed 1921).
[34] "Selbsttätige Tabelliervorrichtung für Zählkarten", (filed by the Tabulating Machine Company of Washington, DC.) [German] *Patentschrift* No 406.744 (1924, valid since 1914). German patents were valid for 18. (*Das Reichspatentamt*, 8).

production of his tabulator could cause patent litigation. This explains the agreement for Albatros to build three sorters, which they did in 1923 and 1924. However, all were failures due to low quality craftsmanship and this production was terminated.[35] Albatros' experience from producing aeroplane fuselages did not provide the precision engineering expertise needed to build punched card machines.

On the other hand, Bull's contract with the Albatros company and the filing of patents in Germany made his machines internationally known. 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. However, neither of these projects was implemented.[36]

The problem of priority between the Hollerith and Powers automatic group control patents in the United States and Germany was the main reason for approaches by the two Powers companies. Hollerith had filed patent applications on this facility in the United States in 1914, and Powers had filed a competing application in the United States in 1915. Powers' patent was granted in 1917, while Hollerith's superior patent was granted in 1931.[37] Also both patents were issued in Germany, but the German agency of the Tabulating Machine Company, contested the validity of Powers' patent in German courts. This dispute was only solved in 1929 by a Supreme Court ruling that the Powers patent was valid.[38] Bull's automatic group control design differentiated from Hollerith's and Power's designs. For several years, therefore, the rights to produce Bull's tabulator could have been a way for the Powers company to get around Hollerith's automatic group control patent. However, this was never tested in a law court, probably because Albatros and were advised against pursuing it. Further, the Powers companies had little basic interest in the electromechanical Bull machines as an alternative to their own mechanical punched card machines. Producing electromechanical equipment differed fundamentally from producing mechanical equipment, as illustrated by the Egli company's subsequent experiences of this change.

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[35] Letter, Bull to OKA, 25 July 1923, Reidar Knutsen, "Oversigt", 1927, Archives Bull, 92HIST-DGE07, box 1; Pagel interview with Knutsen 1978.
[36] Letters, Bull to Hartzner, 7 June 1924, 16 June 1924; Hartzner Diaries, 2 June 1924, 4 October 1924.
[37] Heide, *From Detail to Data*.
[38] James Powers, "Statistische Tabelliermaschine, bei welcher die nach verschiedenen Gruppen gelochten Karten nur innerhalb der aufeinanderfolgenden Gruppen zur Tabellierung und Summierung gelangen", [German] *Patentschrift* No 333.413 (1921, valid from 1915); The Tabulating Machine Company, "Selbsttätige Tabelliervorrichtung für Zählkarten", [German] *Patentschrift* No 406,744 (1924, valid from 1914); *Blatt für Patent-, Muster- und Zeichenwessens*, 1930, 6-7.

**Selling Bull's patents**

Bull fell ill in 1924 and underwent an operation for cancer. He resumed work, but was soon taken ill again and died in the summer of 1925.[39] This made it indispensable for OKA to engage an engineer to install and maintain the Bull machines. Starting at the beginning of 1925, Engineer Knut Andreas Knutsen took care of this. A large part of his work consisted in travelling to the customers in order to install, repair and improve machines. Knut Andreas Knutsen was a younger brother of Reidar Knutsen and also trained at the Technical University of Berlin.[40] After his graduation as a construction engineer in 1913, he had returned to Norway and had worked on the construction of hydro-electrical power plants. Unlike Bull, Knut Andres Knutsen now worked full-time with punched card machines, and though he was neither trained in electrical nor in mechanical engineering, he managed to get the Bull punched card machines to work properly by 1927. He improved the reliability of the machines produced before his arrival, and the new machines produced under his supervision only held minor errors.[41]

Bull's death raised the issue of selling his patent rights in order to complete his estate. The contacts with the American Powers company and the German Powers agency had been unsuccessful, and the German Albatros contract had fizzled out. Reidar Knutsen was not keen to stay in the punched card business. He had a business selling machines to Norwegian ships that probably went well because the number of Norwegian ships rose and many got diesel motors in the 1920s.[42] At the same time, building the Bull machines ran at a deficit, and the prospect of selling the patent rights was dim, due to the perennial problems with getting the machines to run properly. However, Reidar Knutsen's brother became hooked on the possibilities of Bull's punched card machines and remained in the business.

In 1926, Knut Andreas Knutsen organized a group of Oslo townsmen that bought Bull's patent rights for all but the Nordic countries, which remained with Reidar Knutsen. During the next few years Knut Andreas Knutsen laboured to sell Bull's patent rights. He pursued similar paths as those of Fredrik Rosing Bull had explored between 1922 and 1925. The alternative approach to a production of statistics machines on the European continent would have been to extend the scope of their machines' applications to attract more customers in the Nordic countries, which would have required extensive development of the

[39] Bull's wife died in November 1925. They did not have any children, Bull, *Den trønderske*, 145-146.
[40] Bassøe, Ingeniørmatrikkelen 282.
[41] Hartzner Diaries; Pagel, interview with Knutsen, 1978.
[42] Hodne, *Norges økonomiske historie*, 487, 498-502.

punched card machines. The Tabulating Machine Company and the Powers company pursued this approach as they developed punched card based bookkeeping during the 1920s. This approach was hardly available to Knutsen, who had to concentrate on the urgent need to get the existing non-printing machines to work properly and improve the Bull machines' capacity to live up to the standards of the equipment from the Tabulating Machine Company and the Powers company. There were not many industrial companies or big public institutions in Norway in the 1920s that could act as market basis for the substantial development of Bull's punched card machines needed to make them fit for bookkeeping tasks. In addition, the failure to establish a production of Bull punched card machines in the early 1920s did not encourage establishing machine production on the European continent. Here too, the prospects were dim.

However, in 1926, a Swiss alternative emerged, originating within an extension of the Nordic insurance network. Back in 1922, an employee at the insurance company *Schweizerische Lebens Versicherung und Rentenanstalt* (today Swiss Life) in Zürich had read about the original Bull machine in a Scandinavian insurance journal. Rentenanstalt Zürich considered acquiring punched cards to process their insurance statistics. To choose a supplier, the company's deputy director, Emile Marchand, studied installations from the Tabulating Machine Company (IBM in 1924) and the Powers company in the Netherlands and Bull installations in Denmark and Norway. Marchand recommended Rentenanstalt buying Bull machines, as they were the cheapest and as Rentenanstalt only planed to use punched cards to compile statistics with a limited number of outputs that did not require a printing tabulator.[43] In addition, IBM did not have any essential patent in Switzerland restricting the possibilities of acquiring Bull punched card machines, resembling the situation in the Nordic countries.[44] Rentenanstalt ordered a sorter and a tabulator, which were supplied in 1926. Knut Andreas Knutsen travelled to Zürich to assemble the machines, which worked to the company's satisfaction.[45]

Further, in 1926 Emile Marchand suggested establishing a Swiss production of Bull

[43] "Anschaffung der elektrischen Sortier- und Additions-Machine von Frederik Rosing Bull ...", recommendation for Rentenanstalt's board of directors (signature illegible, hardly Marchand), 20 November 1924, Archives Bull, 92VEN08, box: 5, Folder: Rentenanstalt. Letter, Bull to Rentenanstalt, 16 March 1922; "Vorstellung der RA", 1973, copies kindly supplied from Swiss Life; "In memorraim Prof.Dr. Emile Marchand".
[44] Swiss annual lists of granted patents; Pagel interview with Knutsen 1978.
[45] Letter, Hartzner to Bull, 4 January 1923; letter, Bull to Hartzner, 13 September 1923; Hartzner Diaries, 15-16 October 1923.

machines in order to promote Swiss industry.[46] Marchand approached several Swiss companies for this end, including the H. W. Egli company of Zürich, which produced the non-printing "Millionaire" and "Madas" mechanical multiplying machines. They hesitated, as the Bull tabulator could not print. IBM and Powers supplied printing tabulators and the competitive advantage of printing numbers was growing even for key multiplying machines. Also, Marchand approached Emile Genon, who was a Belgian businessman selling American Elliott-Fisher mechanical adding machines that could print in Switzerland, France and Belgium. Genon sold a large number of these adding machines, but he expected that the market soon would be saturated and saw the Bull machines as a way of getting beyond that problem.[47] Genon did not have a production facility in Switzerland and he tried to get the H. W. Egli company to produce the Bull machines, but it continued hesitating. Therefore, Genon went to Oslo in 1927 and bought the rights for Europe outside the Nordic countries to the Bull patents. The following year, Genon surrendered the rights to produce these machines to the H. W. Egli company of Zürich, which they started to produce, while Genon established a marketing company, the *Bull Machinen Handels Aktiengesellschaft* of Zürich.

The Genon contract held the decisive advantage of supplying much-needed money to the Oslo consortium that owned the Bull patent rights, but the Swiss production ran into three problems. First, during the 1920s, the machines from the competitors had improved significantly. Second, the Bull machine producers still needed export to become profitable. Third, it proved difficult to establish an industrial production of reliable punched card machines in Zürich.

**Catching up with the competitors' improved machine standards**

By the mid 1920s, the Powers company and IBM had improved its punched card machines significantly.[48] Now, both companies supplied horizontal sorters and number printing tabulators that differed from Bull's vertical sorter and non-printing tabulator. The vertical sorter had been introduced by the Tabulating Machine Company in 1907, but it was rather inconvenient to use. It had very small card pockets, as they had to be placed one over the other and as a consequence could not be very high. Consequently, the operator very often had to stop the machine in order to empty the pockets, which kept him rather busy. When the

[46] Enright, "Organization in Geographically Concentrated Industries", 130.
[47] Pagel interview with Knutsen 1978; Chase, "History of Mechanical", 214, 218.
[48] Heide, *From Detail to Data*.

Powers company emerged as a competitor in 1914, it marketed a horizontal sorter that was more convenient to use and a number printing tabulator. These facilities provided the Powers company with competitive advantages and changed the industry's standards of facilities, as the Tabulating Machine Company marketed a vertical sorter (1917) and a number printing tabulator (1921).

Emile Genon and the Egli people in Switzerland knew the demand for a number printing tabulator and a horizontal sorter from marketing key office machines. Also, Henrik Hartzner, Bull's general agent in Copenhagen, recorded this demand form his sales activities. In 1924 Hartzner triggered Bull's development of a printing tabulator based on a sales visit to the Danish state railways (Statsbanerne), but Bull did not built a reliable printing tabulator before he died in 1925.[49]

In 1928, Henrik Hartzner designed a horizontal sorter, which Ormestad's precision engineering shop built in 1929.[50] Though Henrik Hartzner was the inventor, patents on this sorter was filed by Knut Andreas Knutsen. Hartzner had no reasons to hold the patent himself, and an agreement was concluded between the two. Knutsen managed the patent in several countries and paid Hartzner handsome amounts.[51]

As soon as the building of the first horizontal sorter had started at Ormestad's precision engineering shop, Knut Andreas Knutsen started to build a printing tabulator based on Bull's printing wheel design, which had an independent printing wheel for every printing position. In every printing operation, the printing wheels were turned to the designated position, all digits were printed simultaneously and the printing wheels were returned to their starting position by use of springs. This was a simple design, but it only functioned as long as the springs behaved, and it took time to return the wheels to their starting positions.

Knutsen improved the design of the numerical printing mechanism in 1930 and designed a version for alphanumeric printing the next year.[52] His printing wheels turned all

[49] Hartzner Diaries, 3 June 1924.
[50] Hartzner Diaries, 29 September 1927 - 25 July 1928; concept of a letter, Hartzner to Knutsen, 29 October 1927.
[51] Knut Andreas Knutsen, "Sorteringsmaskin for gjennemhullede registerkort," *Norsk Patent*, No 53,950 (1934, filed 1929); Knut Andreas Knutsen, "Maschine zum Sortieren von gelochten Registrierkarten", [German] *Patentschrift*, No 554,168 (1932, filed 1929); Knut Andreas Knutsen, "Machine à trier les cartes perforée" [French] *Brevette d'invention*, No 685,038 (1930, filed 1929); Knut Andreas Knutsen, "Machine for sorting perforated cards", [US] *Patent*, No 1,916,801 (1933, filed 1929); Hartzner Diaries, September 1928, 15 November 1928, 23 Marts 1931; Hartzner's private accounts 1932-1937.
[52] Knut Andreas Knutsen, "Trykkeværk, særlig i forbindelse med tabelleringsmaskin for gjennemhullede registerkort," *Norsk Patent*, No 53,545 (1934, filed 1930); Knut Andreas Knutsen, "Trykkeværk, særlig i forbindelse med tabelleringsmaskin for gjennemhullede registerkort," *Norsk Patent*, No 55,409 (1935, filed 1931); Hartzner Diaries, 31 March 1929 - 1 May 1930.

the time in the same direction and a hammer struck, when the designated digit was in the right position. This was a brilliant design which enabled a high processing speed and later proved a good basis for designing an alphanumeric system, as the extension was simple of a numerical printing wheel with 11 characters (10 digits and a minus indicating a negative number, credit) into a larger alphanumeric wheels with 35 characters (10 digits, 24 letters and a minus). The disadvantage of a wheel printer was 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.

In contrast, the Powers and Hollerith tabulators used type-bars, one tall type bar for every printing position holding about 35 characters. During the writing operation these bars were raised to get the types into the writing position, then a hammer struck against each of the bars and they hit the paper. This process was rather time consuming due to the type bars' length, much slower than Knutsen's wheel printer. For this reason, IBM also developed a wheel printing tabulator in the early 1930s, but their work was discontinued due to Knutsen's patents.[53]

**From Zürich to Paris**

The problem of the home market was not solved by establishing production in Switzerland. Though it had twice the population of Norway and a much larger industry, Bull machine production still needed export to become profitable. 10 of the 21 Bull machines produced in Norway from 1921 to 1927 were exported. Large reliance on foreign markets made import duties a problem, as they increased the price on the imported machines. This problem was smaller in one of the large European countries.

In Zürich, the Egli Company started to produce Bull machines in 1928, but they ran into problems that were different from those encountered by Albatros from 1922 to 1925. Egli was an experienced producer of precision machines and the Norwegian blueprints had been improved after the Albatros problems. In Oslo, Knutsen had managed the building of reliable machines, and Egli's expertise should have been able to handle the transition from craftsman-like building to industrial production. However, Egli encountered problems in the production of the electromechanical Bull machines, as their expertise was in the production of mechanical calculating machines. Further, the Swiss producer shared the problem with Knut Andreas Knutsen of outdated machine design and of a production in a small country.

The problem of the outdated machines could be remedied through the new sorter and the new printing tabulator that were developed in Copenhagen and Oslo by Hartzner and Knutsen from 1928 to 1930.

In the autumn of 1930, Egli and Genon learned of Knut Andreas Knutsen's horizontal sorter and the printing mechanism, which they wanted to buy. They offered Knutsen a position as chief engineer at the Egli factory in Zürich in order to improve production. Knutsen embarked on a gamble and accepted the offer on the condition that the production was transferred to France. Emile Genon was partner in a machine shop in Paris that produced parts to the Elliott-Fisher and Sundstrand mechanical calculating machines, and experienced declining production.[54] But the choice of France for the production of the Bull machines was based on a shrewd assessment of IBM patents in France. French patent law required the patented device to be produced in France within two years of the filing of the patent application.[55] This clause had made IBM's automatic group control patent void by 1920, as IBM filed the petition in 1917 and the company only established production facilities in France in 1924.[56] Consequently, IBM could not claim Bull violating their group control patent. In fact, IBM tried in vain to contest the originality of the basic Bull patents in various French courts.[57] A serious challenger to IBM's global dominance of the data processing market had been born.

However, this position was only attained through extensive development of the existing punched card machines producing equipment that equalled the technical capabilities of equipment from IBM and the French Powers subsidiary, which extended the scope of Bull's strategy from statistics processing to encompass bookkeeping applications. In this process, Bull distinguished by shaping its own path to bookkeeping with punched cards. In addition, though the Bull machines were based on the same basic electro-mechanical technology as IBM, the Bull people chose separate designs.

The French Bull company had the choice of focussing on the development of several facilities for their equipment to extend the scope of punched card applications to encompass

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[53] Note, W. W. McDowell to F. M. Carroll, 10 July 1936, box A-22-3, IBM Corporate Archives, New York.
[54] Hartzner Diaries, 26 June 1930, 16 August 1930, 6 - 10 October 1930: Pagel interview with Knutsen 1978.
[55] Loi du 5-8 juillet 1844, sur les brevets d'invention. This law was valid until 1959, Chavanne, and Burst, *Droit de la propriété industrielle*, 25-26.
[56] [Tabulating Machine Company] "Dispotif contrôlant automatiquement les appareils enregistreurs d'un tabualteur", [French] *Brevette d'invention,* No 487,667 (1918, filed 1917); Heide, *From Detail to Data*, forthcoming.
[57] Vernay, *Chroniques*, 24; Dominique Pagel, K. A. Knutsen biography, typescript 1976, Archives Bull, 92HIST-DGE07, box 3.

bookkeeping, alphanumeric capability, an extension of the 45-column card, and improved calculation capacity. First, influenced by considerations by insurance companies to introduce punched cards for insurance policy administration, they focussed on alphanumeric punch card printing.[58]

A precondition to print letters from punched-cards was a punch code for letters which the machines were able to read. This required a decisive expansion of the existing numerical industry standard. IBM only decided on an exclusive standard for alphanumeric representation in 1933. Knut Andreas Knutsen therefore designed his separate standard in parallel and found a different design completed in 1934, because the Bull punched card machines read cards starting at bottom of a card, while the IBM machines read them top-down. A tabulator based upon Knutsen's improved design was produced in 1935 and continued to be manufactured without major modifications until 1968.[59]

Extending the standard 45-column card was the second basic feature of the Bull punched card system to be improved. 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 worsened if the card also held some mailing information. This problem could be solved either by putting more columns on a card or by spreading the information over several cards. Using more than one card required control to ensure that the all information on a bill related to the same recipient. Customers always preferred to use as few cards as possible. To circumvent the 45 column card's limitations IBM introduced an exclusive and patented 80 column card in 1928, with rectangular holes instead of the round holes that had been used so far.[60] 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. In contrast to earlier Hollerith and IBM patents, the new card was soon produced in France which made the French patent valid. In spite of this, the Bull company

[58] Hartzner Diaries, 1 February 1931.
[59] Knut Andreas Knutsen, "Dispositif imprimeur, spécialement pour machines contrôles par cartes enregistreuses" [French] *Brevet d'invention*, No 795,586 (1936, filed 1935); Knut Andreas Knutsen, "Printing device, particularly for tabulating machines controlled by record cards or bands", [US] *Patent*, No 2,175,530 (1939); Dominique Pagel, *Histoire de Compagnie des machines Bull*, manuscript 1979, Archives Bull.
[60] 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.

prepared their machines to be built for 80-column cards from 1931.[61]

Bull first applied 80-column cards for the machines used by the French army to test a new conscription administration system in 1935. For this application, the extension from 45 to 80 columns facilitated additional information about the conscript to be stored on the card, avoiding the use of a second card for every conscript and making the processing more complex. The French army probably required 80-column cards for this application, as the extra capacity was needed and as IBM had alphanumeric machines for 80-column cards. Subsequently, the French army made 80-column cards a prerequisite for orders, and the Bull company marketed the 80-column machines in 1938.[62] This caused IBM to instigate legal proceedings. Bull lost this lawsuit in 1941 in the lower courts, but they later won the appeal in 1947.[63] Not until the appeal was it disclosed that this patent had been dissolved in the United States in 1933, as the design had been disclosed in the United States prior to the filing of the patent application.[64] Thus, IBM's suit had been based upon a dissolved patent.

**Conclusion**

When Fredrik Rosing Bull started to build punched card equipment in 1919, his objective was to produce machines compatible with the Tabulating Machine Company's equipment. Therefore, his strategy was based upon a combination of adherence to technical standards established by the industry's first mover, and leveraging technical advantages and selling cheaper machines than existing producers. His alternative was to design and produce a proprietary system based on a different technical standard than those designed by Hollerith and the Tabulating Machine Company. Such strategies were pursued by Lucien March, John Royden Peirce and several other challengers. Lucien March built *classi-compteurs* in France in the years around 1900 that were used to process French census returns. The *classi-compteur* applied a different principle than punched cards. Between 1906 and 1926, John Royden Peirce designed and built punched card systems that were based upon different punched card standards in the United States. However, no challenger to the Tabulating Machine Company and IBM based upon a different technical standard than those established

[61] Minutes from Conférence technique, 28-29 April, Archives Bull, 93DJFG-DDS02, box 1.
[62] Letter, Bureau de Recrutement de Versailles to CMB, May 30, 1936, Archives Bull, box 92VEN08, box 4, folder Ministère de la Guerre.
[63] Cour d'Appel de Paris, Greffe Civil, No H-1440 (23 April 1947), Compagnie Machines Bull contre Compagnies Electro Comptable, Archives de Paris. More explicit argumentation in previous, parallel case, Cour d'Appel de Paris, Greffe Civil, No H-1441 (23 April 1947), Compagnie Piles Wonder contre Compagnies Electro Comptable, Archives de Paris.

by the first mover accomplished to gain but a few customers.

While you could copy standards at no cost, patent privileges were regulated by law and infringements were prosecuted, though this proved difficult to implement due to variations in national patent laws and litigation cultures. Fredrik Rosing Bull started building punched card machines in a small country, Norway, outside the realm of valid Tabulating Machine Company patents.

The potentials and limitations of the patent systems became conspicuous, as Bull and his successors tried to expand their business to include large European economies, where the Tabulating Machine Company and IBM held patents and the German legal tradition held that a claim for patent infringement caused a sale based upon the patent to be upheld until the claim proved unfounded.[65] First, the endeavour to establish production of punched card equipment in Germany from 1922 to 1924 ran into problems caused by the Tabulating Machine Company's German patents. In addition, this endeavour suffered from the German company's lack of expertise in fine mechanical engineering. However, no additional attempt emerged in the 1920s or 1930s to establish production of Bull equipment in Germany.

The story of establishing production and sales of Bull equipment in France contrasted with the German story, as a different national patent legislation facilitated this effort. France required a domestic production of a patented device, which restricted the business opportunities of a company in United States with a strategy of producing equipment in the United State for marketing abroad.

Simultaneously with the endeavour broadening the geographic basis of Bull's business, the various companies in the industry worked to enlarge the basis for punched card applications from statistics processing to comprise book-keeping assignments. The main IBM patent from this process was the patent on the rectangular perforations on the 80-column card. Early production in France of this card fulfilled the French patent law requirement, but the patent was never valid, as the original United States patent had been disclosed before the application was filed. Though, the IBM suit for patent infringement against Bull eventually failed, the suit demonstrated the potential of patent protection of a monopoly.

The Bull company's adoption of the 80-column card was a key element in their strategy to establish book-keeping capability for its equipment. This extension brought the industry beyond the established numeric industry standard of the 45-column punched card

[64] National Archives, Washington, DC, RG-241, Entry 9A, Interference in Patent Case File No 1,772,492.
[65] Heide, *From Detail to Data*.

which Herman Hollerith had established for his own punched card machine production in 1907. Both James Powers and Fredrik Rosing Bull had accepted this standard, as they established their production. Now all producers wanted cards holding more information, letters and alphanumerical characters. All producers made the simple choice of developing their own proprietary standards for the representation of letters. There were so few companies and small variations that the companies might have been able to agree on a new industry standard, but none of the producers saw any sufficient reason. The only exception was the Bull company's adoption of IBM's 80-column card. Technical standards in industry can be universal, either if one company decides on a standard that all other companies subsequently accepts, or through a consensus.

Bull could copy the technical standards of the industry's first mover at no cost to establish his competing product of statistics machines because the established companies' patent protection did not apply in Norway. This freedom disappeared as Bull and his successors extended their business to bigger countries where the established producers had patents and as focus in the companies' marketing strategies was extend beyond statistics processing to bookkeeping where they diverged as to their punched card systems basic technical capabilities.

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